ASTRONOMY FOR·ALL

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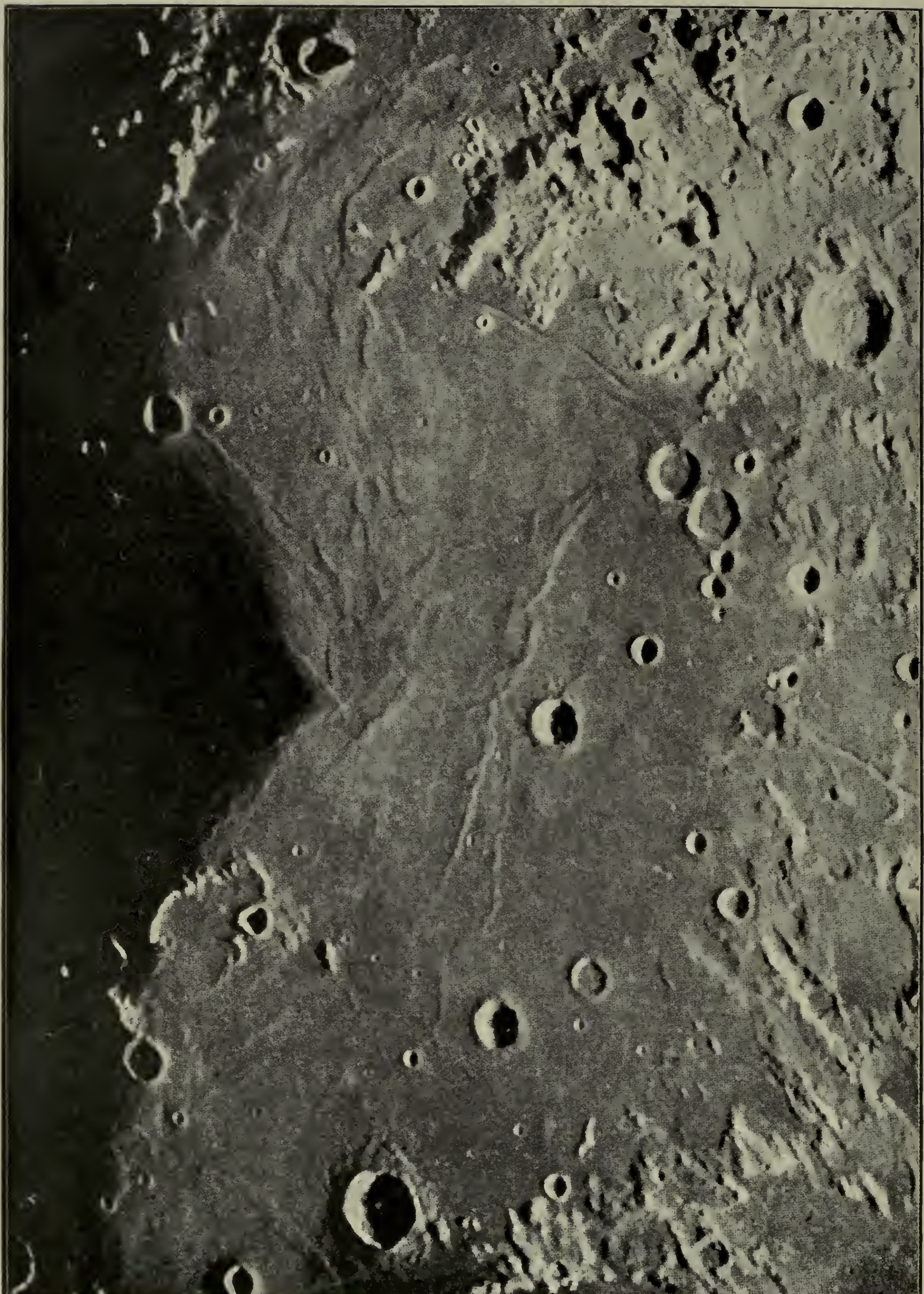

The Sea of Calm (Mare Tranquillitatis) on the Moon.

(From a photograph taken at the Paris Observatory.) *See p. 181.*

Frontispiece.

ASTRONOMY FOR ALL

BY

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TRANSLATED FROM THE GERMAN
BY
STELLA BLOCH

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ASTRONOMY FOR ALL

CHAPTER I

A GLIMPSE INTO INFINITY

THE waves lap monotonously against the shore, crooning a melancholy cradle-song. A belated sailing-boat heads towards the little fishing-village from which the evening wind carries the sound of a dog's bark across to me sitting alone in the gloaming. The last golden tints are dying in the west; tiny clouds float in a roseate sea which dims gradually as the sun travels rapidly away to the countries far westward, where the long night is almost past. The wind whistles gently in the reeds and grasses, which nod dreamily and sway softly as though they were telling each other wondrous tales—like children before "the dustman" comes.

The Evening Hour.—This is the hour when the stars awake. The ruddiness in the west has paled, the fiery lines that glowed across the horizon like streams of molten gold have vanished, and night approaches on its raven-hued wings. The silvery horn of the moon hangs over the village, where the lights begin to gleam, and in the mirroring surface of the waters hundredfold reflections dance unceasingly. We stand in solemn silence and gaze at the eternal lights overhead. They appear in stately measure, one after the other—first the large bright ones, and then the smaller; and now that the moon prepares to set, the starry robe of the goddess of the skies is spread out wide above us, sparkling as though millions of diamonds had been lavishly scattered all over it.

" Look now toward heaven and tell the stars, if thou be able to number them." We suddenly remember the old Bible words we learnt as children, and the days come back to us when we stood and vainly tried to count the stars in the firmament. Many years have passed since then; but they have kept their mysteriousness for us. The eye loses itself in this sea of light, this world of worlds. Man, an atom, a parasite on the grain of sand we call the earth, whirling through the universe, is confronted by the infinite, where, since times eternal, a never-ceasing play of myriads of spheres has taken place. The deeper he tries to penetrate into its mystery the more inexplicable, the more majestic it grows.

Ancient Beliefs and Copernicus.—There was a time when the earth was believed to be the centre, the very heart of the world, even the world itself in the widest sense of the word (Fig. 1). It was believed that the stars floated in the aerial regions of the earth, and mankind thought them to be the heads of golden nails driven deep into the crystal of the heavenly dome—a view held by the Greek scholar Anaximander 2,500 years ago. Enlightened minds in ancient days seemed to admit a possibility of the insignificance of the earth and its lack of importance in the universe, and surmised that the celestial lights above were worlds great distances away; yet it needed thousands of years for the human mind totally to divest itself of the delusion that the earth, the crown of the *all*, rested firmly in the centre of the world with the stars grouped around it. It was Nicholas Copernicus who cast the earth from its central pivot and reduced it to but a star among stars, to an infinitesimal drop in the ocean of the worlds, whose glistening waves play on the shoreless infinite.

The Life of the Stars.—And the atom called man, tied down to this speck of dust, the earth, conquered it by the force of his brain alone. He recognised slowly, but surely, that the stars, which had once appeared eternal and unchangeable to him, came up and died away like the flowers of the field; that they had a birth and a death-hour like himself. His own fast-rolling wheel of life does not permit him to follow their growth and death to a finish; the thread of their existence unwinds itself with almost incomprehensible slowness. Thousands of generations pass before even tiny alterations are noticeable in those shining formations of the heavens; but if we could turn millions of years into seconds we should see the stars suddenly gleam out like glow-worms at night, watch them grow brighter and brighter and then darken, sparkle and die away like the ruddy coal on the hearth, sinking into utter blackness. They come and go

Fig. 1.—Medieval representation of the Universe.

like ourselves. There millions of years, here a few decades only; but millions and seconds are one in the tide of eternity.

Movements of the Constellations.—The waves beat against the shore in everlasting sameness, throbbing out the same melodies down through the ages. Men may have gazed up to the stars in the quiet of night thousands of centuries ago as we do to-day. Their traces have vanished. No songs, no stones are left to tell of their deeds; but the old stars still twinkle up above, and, on the whole, we see the heavens in much the same condition as they did. Over yonder the Great Bear preserves nearly the same shape, the Dragon spreads out its chain of small stars as of yore, and bright Vega emits the same blue rays to us as to them. There they stood when, thousands of years back, the cave-men of the Stone Age represented the flower of mankind, and there they stood when 1,300 years before Christ, Egypt's great king Ramses II., whose dried-up mummy curiosity has so rudely torn from its many centuries' repose, marshalled his huge forces in war against the Syrians. Columbus saw them when he peered out anxiously for the desired land at dead of night; Napoleon saw them in the great steppes of Russia; and Nansen watched them sparkle in the ice and snow regions of the Pole, far away from all civilisation. And yet we know that these stars dart hither and thither with great velocity; that the stars which apparently group themselves together in certain figures—constellations—are in reality divided by huge distances, and that their nearness to each other is due only to an accidental perspective. Measurements have convinced us that some stars move through the universe at a speed of many thousand miles a minute; some members of a constellation may approach and recede from each other, whilst others wander away together through the infinite (Fig. 2). Although this takes place at a tremendous speed, some thousand times faster than an express train can travel, yet they appear to us for thousands of years in their old shape, as though the stars forming these constellations stood immovably still.

A railway train, if watched from close by, passes so quickly that the eye can hardly follow it, whilst, if seen from a long way off, it appears to crawl; it is the same with the stars. They are such immense distances away that, in spite of the speed of their movements, they apparently remain motionless, and, seen from earth, most of them take thousands of years to travel a full moon's-breadth onward. But if we could press solar distances into inches, turn eras into seconds, we should see the stars play about like gnats in the sun and dance up and down in the depths of space like specks of dust in a sunbeam. The rigid peace of the heavens is but an apparent one, apparent its eternity, so far as its separate members are concerned. A constant coming and

Fig. 2.—The Great Bear as it is now (A), as it was 10,000 years ago (B), and as it will be 10,000 years hence (C).

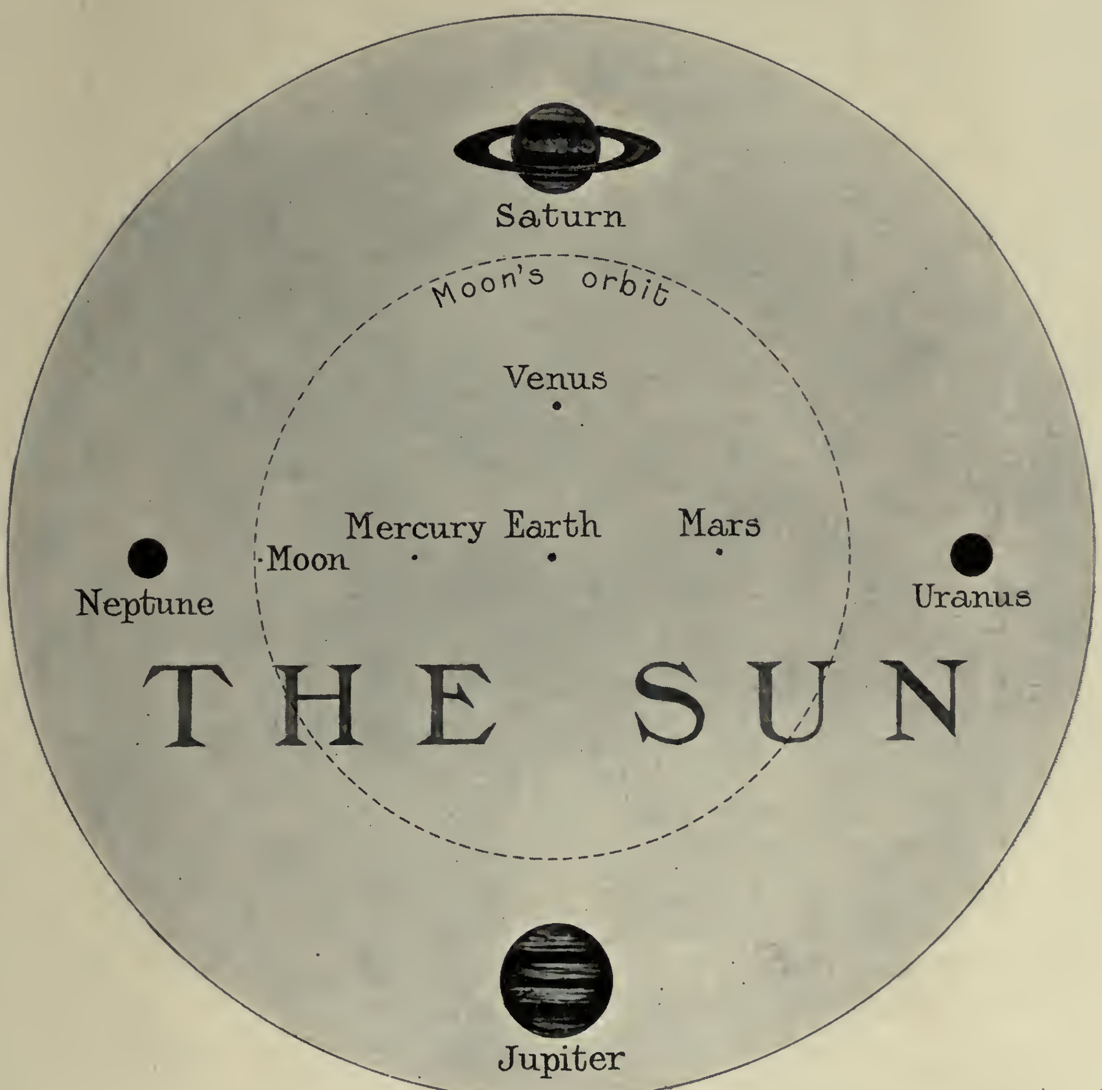


Fig. 3.—Proportions of the Sun and the Planets.

Fig. 4.—Part of the Milky Way in the Constellation Cygnus.
After a photograph by E. E. Barnard, Lick Observatory.)

going, floating to and fro, rising and sinking take place there too, as everywhere else in Nature's great realm; the scale alone differs. Does not a human being, however, live a thousand times as long as a May-fly? And do not the giant trees of California, whose leaves rustle in the winds for tens of centuries, far surpass the human life in length? Flowers and men, stars and mountains, may pass away, but the stream of eternity rolls on for ever.

The Minuteness of the Earth.—The wan moon has gone to rest behind the cottages; a thin silvery light remains to point its path. The fishermen's houses show up in black silhouettes against the sky, and the massive tower of the old church is thrown out in bold relief. Every now and again a signal fire is seen in the distance, and suddenly a red and white light flares up—the lamps of a homebound ocean steamer. How small the earth is! Yonder vessel, that will reach its native port within a very few hours, has wandered around a third of the globe in the lapse of a few days—a third of this earth-clod in the universe which, a few centuries back, was regarded as the very beginning and end of the world. How small the earth is! Ever since man has learnt how to harness Nature's forces to his chariot it has been considered good sport to encircle the planet in an ever shorter time, and the world has in very truth almost become a village. Old Mother Earth's girdle spans 25,000 miles, a distance which an express travelling night and day could cover in a period of twenty days. How can the earth, the residence of nearly 1,500 million people, even be compared with the sun, in whose gigantic body more than 1¼ million earths could find a home? (Fig. 3.) And the universe is filled with such suns, as our room is with dancing particles of dust. Millions of such suns form the glittering belt of the Milky Way—millions of suns, and in all likelihood millions of earths too (Fig. 4).

How tiny this earth is, for whose possession blood has been so liberally shed ever since the beginning of the human race! Had it been possible for man to leave this island in the ocean of space he would long since have carried war and death to other worlds, just as in modern days, starting from Europe, the continent of culture, he gradually mastered the other continents of our planet. But there is no bridge to span infinity, from which light's rays alone bring news of the other earths on the far side of the dim vapours to the restless inhabitants of that lost star, the earth.

Distances of the Moon and Planets.—Could one but get up there! How close the moon is, our nearest station to infinity! Astronomically reckoned it is but a step, as it runs its course only 240,000 miles away. Thirty terrestrial globes laid in single file would bridge the distance dividing us, and an express would need but six months, and a wireless telegram little more than a second to travel to the dreary mountain ranges of our neighbouring world. The moon may almost be termed a portion of the earth itself, a trusty vassal, a small island situate in front of the earth's fastnesses.

Distances grow, however, if we desire to visit the earth's sisters and brothers, the stars we call planets, which, like us, move around the sun, collect around it like chickens about the mother-hen. Over yonder, where the sun set, the luminous evening star Venus still glows like a pure flame in the dip of the horizon. Of all the earth's kin it comes nearest to us, being at times only 25,000,000 miles away—figures easily written, but so difficult to realise. Think of it, one hundred and four times the distance that divides the earth and the moon; a continuous journey of fifty-two years by train; while a cannon-ball capable of flying 1,100 yards in two seconds would at an equal rate of speed be two and a half years on the way. Another two and a half years of life for the man who, if such a thing were possible, were marked down by a shot fired from the planet Venus! But a wireless telegram would reach him in two and a quarter minutes, for the electric waves spread themselves out at a speed of some 186,400 miles per second.

How remote it all seems! And yet beautiful Venus is our nearest neighbour, our nearest city in the kingdom of the sun, and the sun itself is almost four times farther off, or a train journey of 190 years; nine and a half years for the cannon-ball, and eight and a third minutes for the electric waves.

The sun, too, is still within the regions nearest the earth, for so long as we wander through the planetary system we are still at home in the universe. Earth's big brother Jupiter is five and a fifth times as far from the sun as we are; Saturn and its rings almost twice as far as Jupiter, and Uranus, which moves majestically on the other side of Saturn, is at twice his distance. One thousand six hundred million miles divide this star from the earth even when it is nearest to us; the train journey would take almost 3,300 years to accomplish, travelling day and night; a cannon-ball would speed on for 160 years, and even a marconigram would need two and a half hours to connect the earth and Uranus. But even then the borders of the solar system have not been reached, great empty spaces, only traversed by comets and shooting stars, stretch out endlessly in those regions far away from the sun. Our fantasy carries us on farther and farther through the voids, until we at last reach the border-stone of the huge empire in its most extreme planet, Neptune, 2,788 million miles away from the sun's fiery ball, reduced here to a very bright star-like point. Our tiny earth has long ere this faded from sight; the immeasurable distance that separated it from the sun has, seen from here, dwindled into a speck, and the little star that shelters 1,500 million people has sunk away in the glow shed by the ball of fire. And if we were desirous of returning straight home from this most remote of the earth's "ain folk," we would have to travel for 5,700 years by train, or fly through space for 285 years perched on a cannon-ball! The electric waves, which travel seven times round the earth at the equator in a single second, would need four hours and more to transmit a message from the earth to Neptune. What do these figures convey to us? We can no longer grasp their meaning; they bewilder and confuse us in their dazzling unintelligibility. And yet we have not left our home in space, for even at this distance the gloom is pierced by the rays—greatly weakened—of the same sun that ripens the corn on the far-off invisible earth and pours fire into the grape; we can still see the constellations in their old shape, for, despite our changed point of view, the perspective is very slightly altered.

Neighbouring Suns.—We are at the border of the solar system; but the universe is simply thronged with such solar systems. We take wing once more and fly towards the distant stars, which once upon a time appeared to us to lie within the air-zones of the earth. A long interval elapses before we encounter another sun. Tremendous distances divide the different provinces of the universe. Only very few stars are close enough to our solar system for us to determine their distance with anything like precision, and the nearest of these, Alpha Centauri (Fig. 5), shining brightly in the Southern hemisphere, in the constellation Centaurus, and the nearest neighbour of our sun, is 9,000 Neptune-distances away from our solar system! (Fig. 6.) Our train would have to journey fifty-two million years, the cannon-ball to fly two and a half million years to traverse the twenty-five and a half billion miles that separate us! Even the electric waves would be 4.3 years on the road to convey a message to this neighbouring sun from our own sun or earth! These figures are totally meaningless for us; let us try another method. Suppose the sun were not farther away from the earth than our eyes are apart from each other, we should yet find, reckoning on the same scale, that the star in the Centaurus group was a little more than ten miles away. Yet it is our sun's neighbour!

Years of Light.—Even the astronomer accustomed to deal with immense figures has to turn to special measurements to help him on; he reckons the distances of the fixed stars according to "years of light." A light suddenly gleaming out will be visible a thousand miles away at the very second it flares up, for the rays of light travel through the ether with a speed practically infinite for terrestrial distances. This speed has been measured, and it was found that the light-waves travel 186,400 miles, or almost eight times around the globe, per second. Their speed-rate is equal to that of the electrical waves. An easy sum proves to us that light only needs one and a quarter second to come to earth from the moon, and eight and a third minutes to span the distance between earth and sun. The distance the light needs a full year to traverse is called a year of light. As a year has 31,536,000 seconds, and as light travels at a rate of 186,400 miles a second, a year of light represents the enormous distance of 5,883,000,000,000 miles—a journey of about twelve million years for the express.

Fig. 5.—The Constellation Centaurus, with our nearest Fixed Star Alpha Centauri and the Southern Cross.

Fig. 6.—Cluster of Stars in the Constellation Centaurus.

Fig. 7.—Elliptic Nebulæ.

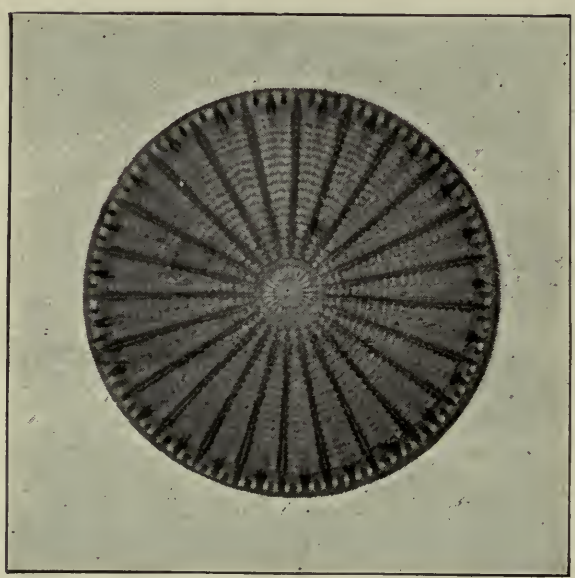


Fig. 8.—Photograph of a Diatom. × 250.

Fig. 9.—Snowflakes. (*Highly magnified.*)

Remoteness of Some Stars.—Alpha Centauri, our nearest fixed star, is 4.3 years of light away, nearly four and a half years before the light it gives reaches our solar system! If a mighty hand were to take the star down from the skies at this very second, we should still see its sparkle for nearly four and a half years in the old place, as it would take this time for the last rays it emitted before its disappearance to reach us. And this is our next-door neighbour! Other fixed stars are ten, nay, a hundred times farther away than Alpha Centauri. We can no longer measure their distances, we can only draw conclusions according to their magnitude and rate of motion. The Pole Star is sixty years of light away, Capella, the radiant star in the Auriga cluster, about seventy such years distant. Stars that we are just able to recognise with the naked eye, which we call stars of the sixth magnitude, are at a distance of about 330 years of light; the remoteness of the eighth-magnitude stars is put at 780 years, and those tiny specks which in their entirety form the soft radiance of the Milky Way are estimated to be about 4,000 years of light away from us. It is useless to ponder such immensities, to try to materialise them, for they are altogether beyond our finite minds.

The Milky Way.—But if we really had penetrated as far as the stars of the galaxy, we would once again have reached the frontier of a mighty complex, similar to that of the vastly smaller solar system. Look up above. The Milky Way extends in a mellow arch and continues its course in the Southern hemisphere, proving to us that it is a gigantic ring encircling the whole of the heavens and enclosing the mighty army of stars and constellations within its zone. This tremendous girdle belting the skies consists of millions of stars, millions of suns, and within its confines, which are estimated at 8,000 years of light in breadth, lie countless new suns, lie our own sun with the earth and all the other planets. The Milky Way is the border, the edge of the huge stellar army to which we gaze up, and is a constellation consisting of millions of solar systems. The whole of these swarms of suns is dubbed the Milky Way System; and if we were able to fly through space and cross the border of the Milky Way we should find that this whole immense structure of suns swims in the universe like a tremendous solitary gleaming island, and that its shape resembles that of a lentil (Fig. 7). A lentil consisting of nearly three hundred million suns, each divided from the rest by vast distances, and in the middle of the mass our own sun, the fixed star about which we revolve! There are, however, good reasons for thinking that the Milky Way is not a mere continuation of the star-system immediately around us, but that it is a definite zone or belt in which the stars are probably much more crowded than elsewhere.

Beyond the Milky Way.—But even now we are not at the end, for this starry group, 8,000 years of light in diameter, represents but a part of the whole. The earth and the moon form a system of their own, the sun and its planets are another larger system, and the Milky Way, as such, is but a single body in space. There are earths innumerable, suns innumerable in these depths, why not Milky Ways as well? Our telescopes have shown us pearly-tinted clouds called nebulæ, which were formerly supposed to be external universes; this view is still held by some (at least as regards those that appear to be stellar, not gaseous), but it is by no means established, and it is quite likely that they are subordinate systems within our own universe. In any case, the existence of external systems far outside the Milky Way is probable by analogy, even if human eye has never seen them. We still see the stars of the most extreme parts of our own Milky Way in the light they shed 3,500 years ago, at a time when Babylon was the centre of culture on earth and Hammurabi wrote down his laws. Perhaps many of these stars had already perished when the great Man of Nazareth preached His beautiful sermon on brotherly love —an exhortation that mankind even to-day has not entirely comprehended in all its simple grandeur—suns that died thousands of years ago and whose beams still travel through space to be beheld by modern man, whose own electric suns render the stars above as pale as will-o'-the-wisps at dawn.

Man and the Universe.—We are unable to comprehend such space, and figures only bring home to us the feeling of our own infinite littleness; it makes us recognise the more fully how lost in the universe is the speck which represents all in all to us, as it has done to endless generations. It is like a tiny flake of snow the storm drives past our eyes, together with millions of others, which is lost and melted in the following instant. Is it not as though all our work and battling were in vain? The eternal wear and tear, the everlasting tussle with our brethren for trifling strips of this tiny sphere, a madness that wears us down and fills the short span of our existence with paltry, transient phantoms? Think it over, and you will find how little mankind has learnt to enjoy the fleeting hospitality afforded us by our all-embracing mother Nature on this star in general peace and friendship; but you will also find that man, earth's tiny parasite, has conquered this sphere by the force of his brain alone, and that one of these days, in centuries to come, he will have entered into the state so aptly expressed by Kant's aphorism, "The starry heavens above us and the moral law within us." Which is the more marvellous of the two—the vast canopy of stars, the hosts of suns and planets vanishing in the depths of the infinite, or the brain of man, which rendered him able so decidedly to define his position amid Nature's tremendous machinery and to study and measure the cosmos as a whole?

Atom Worlds.—The morn breaks in the east. The stars fade gradually, and the new day rapidly approaches the lonely shore. A slight southerly breeze blows across the silent country-side and grey mists rise up from the waters. The restless ocean flings wave upon wave against the shore, and all around me are incessant motion and change like to those in the army of worlds overhead, through whose glittering members our winged fantasy bore us at dead of night. Is not this world around us just as wonderful and puzzling as that above? Are not the tiniest plant (Fig. 8), the delicate star-shaped snowflake (Fig. 9) that rests on our sleeve for a moment in its white purity before it melts, just as much a riddle to us as the stars of the universe? Is it not their colossal scale of construction that renders those flaming worlds so imposing to our sight?

We know that even the smallest formation on earth consists of innumerable millions of those minute bodies we call atoms or molecules, and that these bodies are in incessant motion even in the stones that lie apparently motionless at our feet. Natural science and chemistry have shown us that in every body, be it ever so tiny and composed of what it may, there are so-called atom-suns and atom-planets of almost incredible minuteness which constitute the whole. If we look at a pebble or even a grain of salt with this fact in our mind, and fancy ourselves the size of a germ, or even thousands of times smaller, and then imagine ourselves existing on an atom-planet in our pebble, it is quite possible that we should perceive the millions of atoms, divided from each other by considerable distances, in the guise of a sea of stars similar to the one in the heavens of man. The whole of the atoms forming the stone would represent a Milky Way system to the stone inhabitant; and great men have frequently expressed the idea that the inhabitants of an atom may take their atom-universe to be the only existing world, just as we believe the mass of suns and solar systems above to be the universe, beyond which there is but a void.

Verily, an odd, a bizarre idea! And yet where is there a final measure for Nature's great handiwork—what is really "great" and what "small"? It is just as easy to imagine a world on a scale as vast as the atom-world is tiny, to whose inhabitants our Milky Way system with its millions of suns would be naught but a small body and its suns but atoms. Singular thoughts! It is almost as though we were sinking into bottomless space, into a shadowy realm of misty fantasy, where all our philosophy, work and strife, our whole being, energy and desires fade into ashen grey immeasurabilities.

But behold! the first early sunbeams struggle victoriously through the clouds, and as the grey mists dissolve into nothingness, the strange dream that oppressed our senses accompanies them. The world whose existence we had almost argued away lies before us in all its pristine freshness, the foundation of our toil, our development, our being.

CHAPTER II

ASTRONOMY AND ASTRONOMERS

The Public and Astronomy.—Mankind in general has but a very vague idea of astronomy, the science of the glittering stars in the heavens, and of astronomers, the representatives of this science, as well. Opinions on the work and profession of an astronomer vary greatly, and it all depends whether the speaker has a practical or poetical turn of mind for a kind or disdainful view to be taken. An astronomer, who is probably better informed of the happenings on the moon than other folk are of what goes on around them, surely *must* be an odd mortal! Why do we need to trouble about the stars floating up there at a perfectly impossible distance away; they look pretty enough, but really have little or no importance for us! Most extraordinary persons these star-gazers must be, who night after night watch the starry hosts, and try to count every one of the "Almighty's candles" and see that none get lost! They sit in their observatories at dead of night, when everybody possessing a grain of sense is fast asleep, and simply stare up at the moon—decidedly a crazy hobby! That is about the gist of the views held by the majority of people regarding astronomers and their work.

There are others owning a slightly different opinion, and who regard an astronomer with a certain amount of awe and admiration. They, in turn, imagine him far more interesting than he really is, as he is so well primed on the occurrences in the universe, knows the paths followed by celestial objects, calculates their movements almost to a second, and even describes what happens on their surfaces. How very elevating it must be to have to deal daily with subjects so inconceivably grand and lofty! How can a person whose eyes constantly contemplate an infinity in which the earth is but a speck, care to lower himself to the level of the trivialities which make up life here below? Can there be anything grander, more sublime and more poetical, than to trace those distant worlds in the depths of space; to behold the rigid, tranquil mountain world of the moon, with its pointed crags and deep gorges, over which the sunlight flits; to see the planets, encircled by their moons, floating in the universe; to travel in thought to the starry regions where the suns huddle together in their thousands to one nebulous cloud of world-systems, to distances which it takes a lightning-winged ray of light thousands of years to traverse?

The Actuality of Astronomical Work.—The working astronomer himself (Fig. 10) hardly takes so poetical a view of the matter. It is midnight; the thermometer rapidly sinks to 15 degrees (Celsius) below zero (17 degrees Fahrenheit). Silence reigns everywhere; Nature and mankind are at rest. The astronomer stands expectantly at his telescope in the icy, cold hall (for observatories may not be heated, since this would cause currents of warm air, which would make the objects appear tremulous and indistinct in the telescope), and the iron levers and cylinders of his telescope are like bars of ice to his touch. The wind blows in through the aperture in the roof, and eyebrows and beard are soon frosted over. There he stands in all his loneliness, tied to his telescope for many hours at a stretch, perhaps from 10 P.M. to 3 A.M. He does not, however, indulge in dreamy admiration of the stilly lunar world, the planet surfaces with their clouds and seas, or the glittering patches of stars, but is widely alert, endeavouring to watch the movement of a

Fig. 10.—Camille Flammarion, the popular French Astronomer, in his Observatory at Juvisy, near Paris.

Fig. 11.—An Observatory for the People: the Urania, in Berlin.

tiny innocent satellite, hardly recognisable even in his giant telescope, whilst his eyes smart and ache from the continuous strain. Each swing of the pendulum clock has to be carefully noted, as it tells him whether that distant dot of light is keeping true to the path set it, and in the dark he has to jot down the readings of the micrometer and the second beats of the clock, whilst the stars shine down into the open observatory chamber; the clockwork which keeps the telescope revolving buzzes softly, the mercury in the thermometer continues to fall, and the very blood in his veins freezes, despite fur coat, thick felt boots, and all the beauties of the starry skies.

And yet a feeling of contentment reigns over all; only one more reading is lacking, and then it is enough for to-day. But, look! A cloud has suddenly arisen, and spreads over that very part of the sky under observation. Nothing is left but a thick, grey mist, which no telescope is able to pierce. The star vanishes behind the scenes of the theatre of the worlds, and possibly the long watch has borne little fruit owing to cloud at a critical juncture. Another attempt has to be made to-morrow.

And, now, a different scene. The sun beams down cheerfully. Our astronomer is seated at his desk with a pile of mathematical formulæ in front of him—long strips of paper covered with telegraphic time-determinations gained from nightly watches at the telescope. A wearisome intricate calculation has to be made, a thousand values to be skilfully connected to decide finally the star's orbit and time of revolution out of all this labyrinth of algebraical markings, time and place determinations. He sits there, a man of figures, a living arithmetical machine; he himself has not caught even the slightest glimpse of the star concerned in his calculations, as a colleague was stationed at the instrument, but his is the mind that carries out the calculations. The work is parcelled out just as it is in a large factory.

The Grandeur of Astronomy.—Nevertheless, there is justification for calling astronomy "the queen of all the sciences," and the person who has once gazed deeply into the mystic orbs of the goddess Urania can never again free himself from her toils, and remains her faithful vassal to his death, even though external circumstances may not permit his worshipping her in practice. "There are two things," said Immanuel Kant, in words already quoted, "that ever fill me with new and growing admiration, the moral law within me and the starry heavens above me." One of the greatest pedagogues of all times, Diesterweg, held the opinion that nothing was so calculated to purify and elevate the mind of man, and, above all, of budding man, as astronomical studies. According to him, "astronomy is an elevated, because an elevating science. It should, therefore, be rendered attainable to all—aye, to everybody."

Astronomy is not a Means of Livelihood.—The very circumstance that it is not exactly a bread-earning art, able to support its disciples in comfort, has secured for astronomy the ardent devotion of lovers of Nature whose minds are raised far above the material needs of this earth. The prospects of an astronomer, even after a course of studies extending over many years, are extremely poor, and the salaries paid at the observatories are only very moderate. That is the reason why so many former devotees, not being unduly blessed by riches, have had to forsake their career with aching hearts, and seek to employ their knowledge as mathematicians, teachers or surveyors.

The Number of Observatories and Astronomers.—There are not many observatories; according to the latest census there are only 479 in the whole world, of which number a third are privately owned and no assistance is employed. There may be about five hundred professional astronomers all told, and an astronomer is as yet a *rara avis*. Observatories are few and far between in Europe (Figs. 11, 12), and sparsely manned. The generosity extended to astronomy which is so pleasant a feature of the United States, is unfortunately lacking in Europe. A feeling of envy very naturally seizes us when we read that millionaires in the country of unlimited possibilities have over and over again given thousands of dollars for the erection of huge observatories and the purchase of giant telescopes. The Mount Hamilton Observatory in California (Fig. 13), the

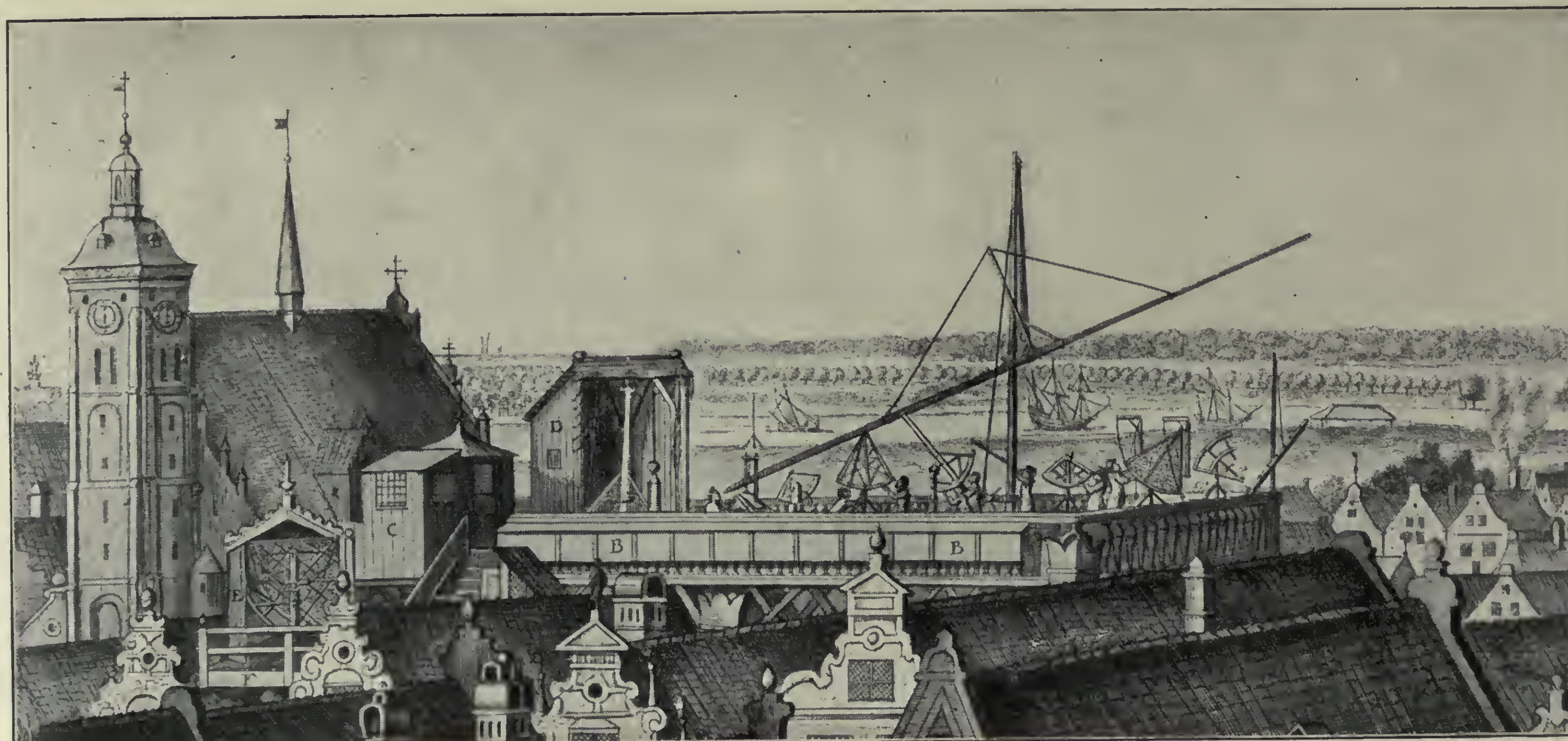


Fig. 12. - Hevel's Observatory in Danzig in 1640.
From Hevel's "Machina Cœlestis."

Fig. 13.—The Lick Observatory on Mount Hamilton, California.

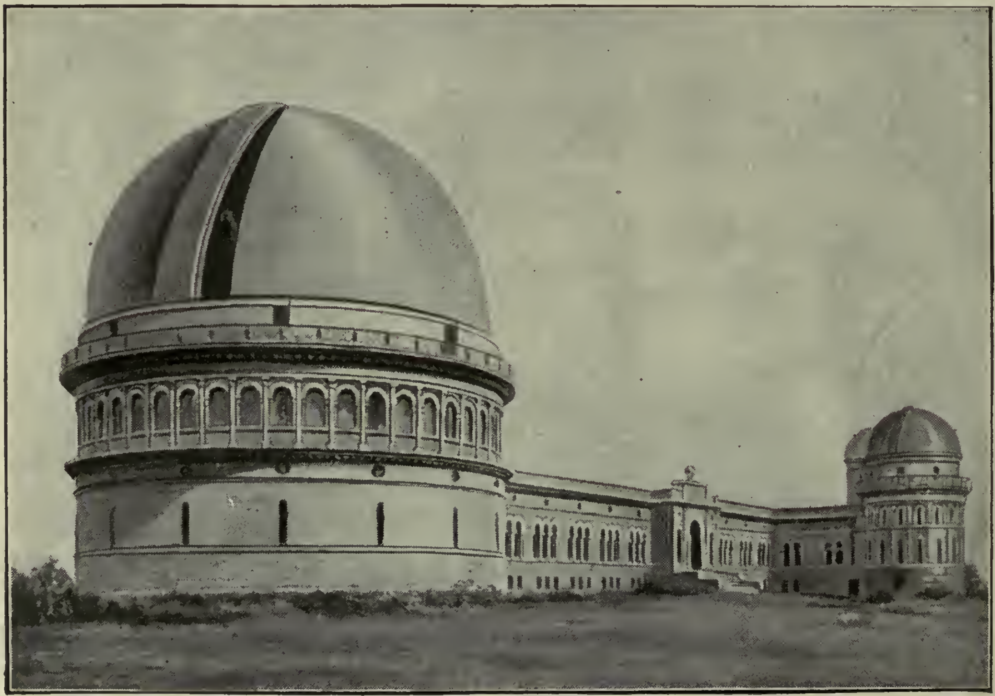


Fig. 14.—The Yerkes Observatory, near Chicago.

second largest in the world, was presented by James Lick, organ-builder, and cost one and a quarter million dollars to erect, whilst the wonderful observatory at Lake Geneva, in Wisconsin, was the gift of the railway king, Charles Yerkes, and was built at a cost of two million dollars (Fig. 14). Presentations of instruments costing five thousand pounds are not uncommon in the United States, and one wealthy lady, Miss Bruce, who has most liberally supported astronomy in her native country, presented the observatory at Heidelberg with a fine telescope.

Development of Astronomy.—Astronomy is as old as mankind. Even in the very earliest ages the stars above attracted the eyes of man and gave his brain occupation. They were the sign-manual of the untutored child of Nature then, as they are to-day. Although in ancient times star-observations were only made for practical reasons, such as the determination of time and place—astronomy being a calendar science only—yet it is from these humble beginnings that its present development sprang. According to old Chinese chronicles, the stars were carefully studied in the reign of the Emperor Fu-Hi, 3000 B.C.; Babylonians, Egyptians, Greeks, all in turn attempted to solve the riddles of the universe. Aristyllus made out a list of the positions of the chief stars about 300 B.C., and some decades later Aristarchus attempted to compute the distance of the sun and moon; and so far back as 550 B.C., or so, Pythagoras and his pupils spread the teaching that the earth was not a disc surrounded by water (Fig. 16), as had once been believed, but a globe instead. They slowly but surely combated the old views held by Thales of Milètus and his disciples that heaven was a huge crystal bell set over the earth, and that the stars were gilt-headed nails driven deep into it. The penetrating mind of Aristarchus also recognised that the earth turned on its axis and wandered around the sun in the course of a year; but mankind as a whole was not yet ripe enough for this great truth, and the earth remained the stationary "centre of the world," around which the stars carried out their revolutions. The size of the earth was determined in the year 230 B.C. for the first time by Eratosthenes; and the greatest astronomer of ancient times, Hipparchus, compiled the first really important star catalogue about this period, which is still referred to when questions arise concerning alterations in

Fig. 15.—An Ancient Astronomer engaged in Observation.
(From a book published early in the seventeenth century.)

the brightness of the stars (Fig. 17). One hundred and fifty years after the beginning of the Christian era Ptolemy wrote his comprehensive work on star-lore as then known, including very accurate calculations of solar and lunar eclipses, and set up his definition of the universal system. (*See* Chap. X., p. 111.)

During the decline of arts and letters in Greece the grand old schools of savants were blotted out in the political and

Fig. 16.—The Earth as a disc floating on the Water.
(*After an Oriental Cosmograph of the twelfth century.*)

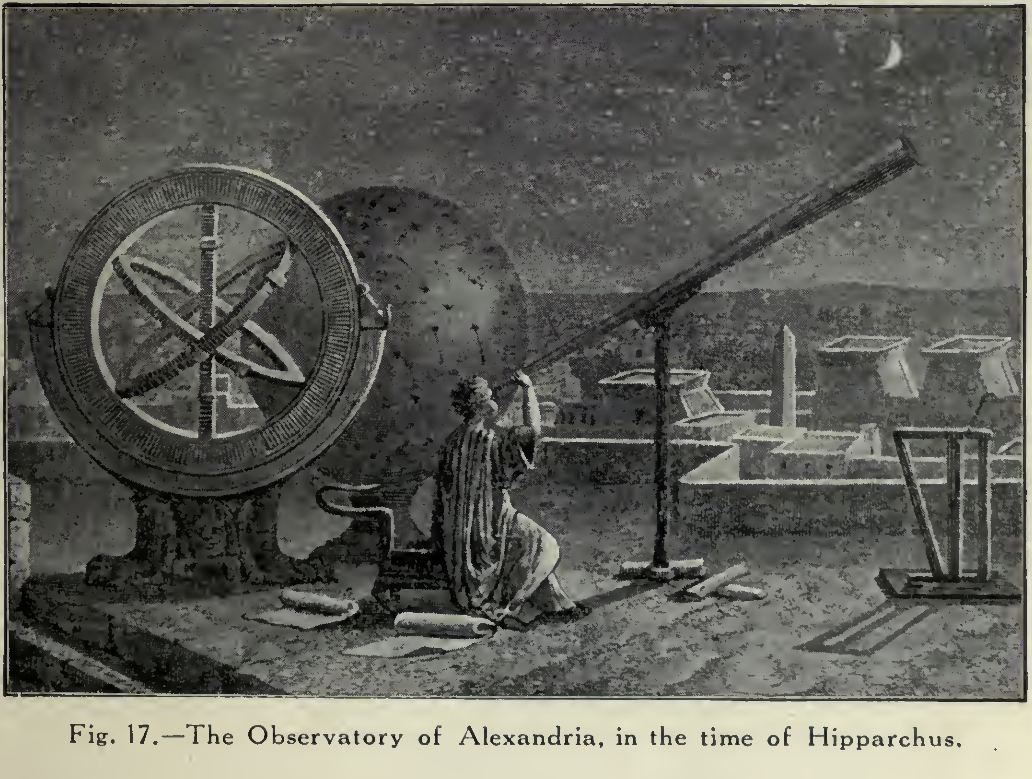


Fig. 17.—The Observatory of Alexandria, in the time of Hipparchus.

Fig. 18.—Tycho Brahe.

religious upheavals, and war devastated the country. Astronomy was swamped by astrology and superstition (Fig. 17), but it found a home from the eighth to the eleventh century with the Arabians, then at the zenith of their power.

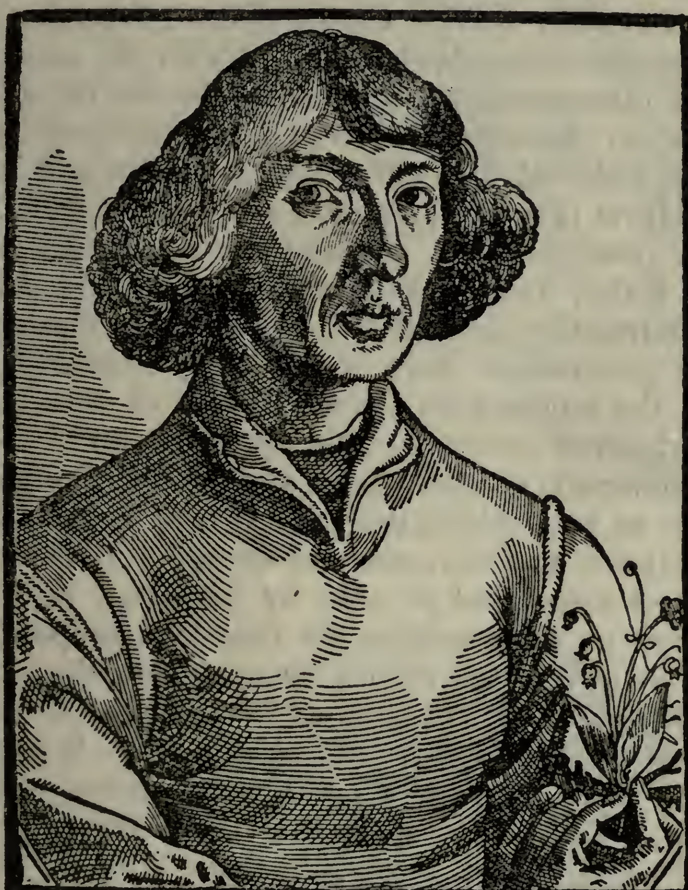


Fig. 18.—Nicholas Copernicus.

Several observatories were erected in Persia by Mongolian princes during the thirteenth century, whilst the first German observatory was founded in 1471 by Regiomontanus and Walter at Nuremberg.

Two years later a man was born at Thorn in Germany who was destined to become the reformer of astronomy, who cast the earth out of its central position in the universe, who recognised the real motion of the earth and the other solar planets—Nicholas Copernicus. He was followed by Tycho Brahe, the great Danish observer, who was born in

1546, and worked at his magnificent observatory, Uranienborg, from which he diligently searched the skies (Figs. 20, 21). He had a follower in Kepler (Fig. 22), who helped to spread the teachings of Copernicus, and who set up his epochal laws of planetary motion. The telescope was invented in 1608; Galileo Galilei (Fig. 23) promptly made astounding discoveries by its aid, and with the advent of this wonderful instrument, which brought the distant stars much nearer to us, astronomy entered on a perfectly new era. Discovery followed discovery. Astronomers and observers such as Hevel (Figs. 12, 24, 30), Halley, Bradley, Cassini, Herschel, mathematical geniuses and theorists such as Newton, Euler, Gauss (Fig. 25), Laplace and Lagrange, laid the foundations of that wondrous structure at which the following generations have so faithfully laboured, greatly aided by the stupendous onward march of natural science in the eighteenth century. This, again, brought inventions and improvements in instruments and methods, widening our outlook to an astonishing degree. Where would astronomy or astrophysics be to-day without spectrum analysis? This method was discovered in 1859 by Kirchhoff and Bunsen, and enables us to determine the chemical composition and constitution of celestial bodies by analysing the light they shed. (*See* Chap. VI.) Photography is also of enormous importance to the science. (*See* Chap. V.) It is futile to attempt to trace astronomy's victorious career with a few strokes of the pen, and even if all our knowledge be but piecework, and all our joining and patching do not bring us a hair's-breadth nearer to the solution of Nature's great problems, yet it affords us a glorious vista; and who would not be an Ahasuerus to live on for centuries and follow the progress of knowledge down to futurity?

Characteristics of a Good Astronomer.—Artists cannot be made; great painters, musicians and actors are born with the gifts that distinguish them, and I am bold enough to aver that a really eminent natural scientist is no exception to the rule, if rule it be. It is a mistake to believe, as is generally supposed, that much learning will supply this want; where the necessary talent is lacking, a mediocre worker only will result, and our age surely has more than

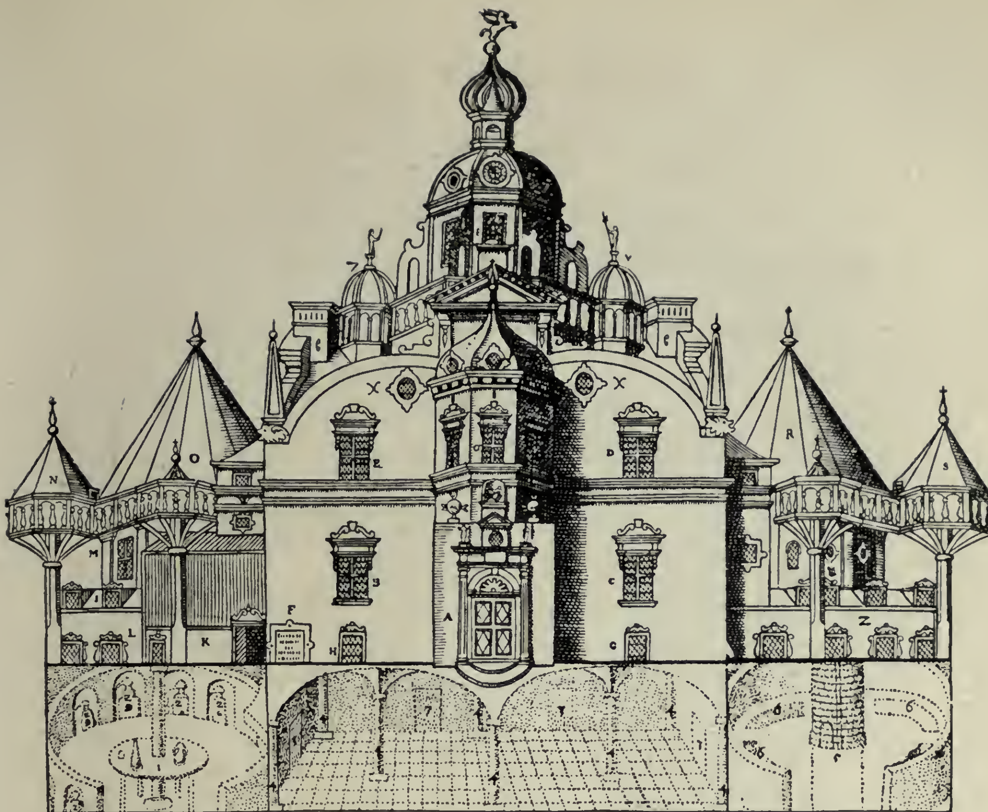


Fig. 20.—Tycho Brahe's Observatory, Uranienborg, in the Island of Hven, in 1576.

Fig. 21.—Celestial Globe made by Tycho Brahe.

Fig. 22. John Kepler.

Fig. 23.—Galileo Galilei.

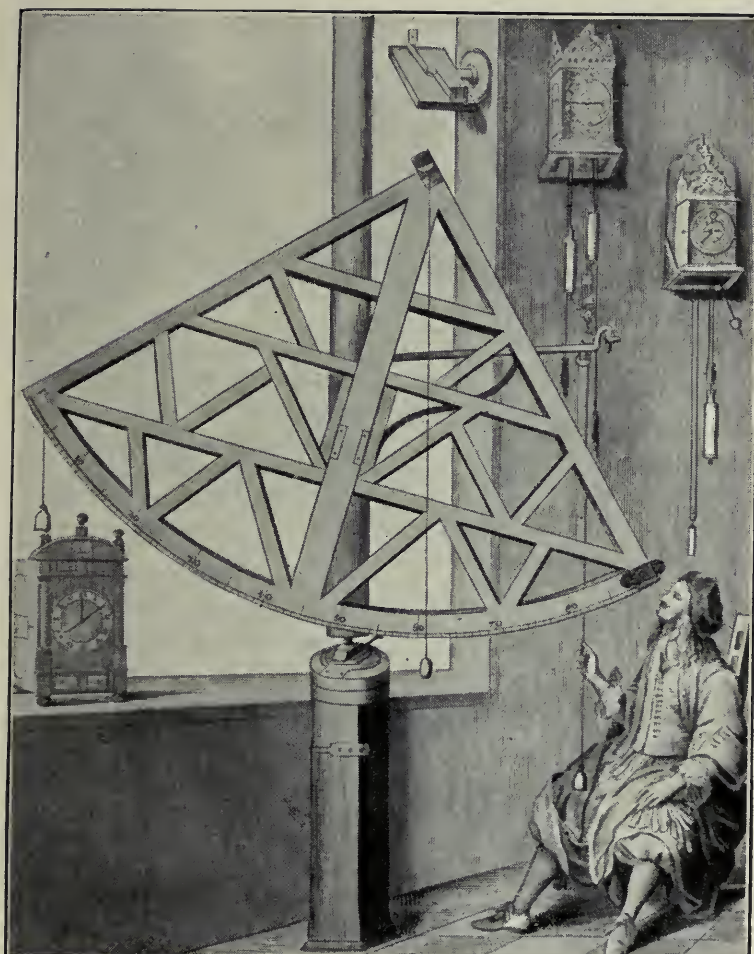


Fig. 24.—Hevel measuring Stellar Altitudes with the Quadrant.

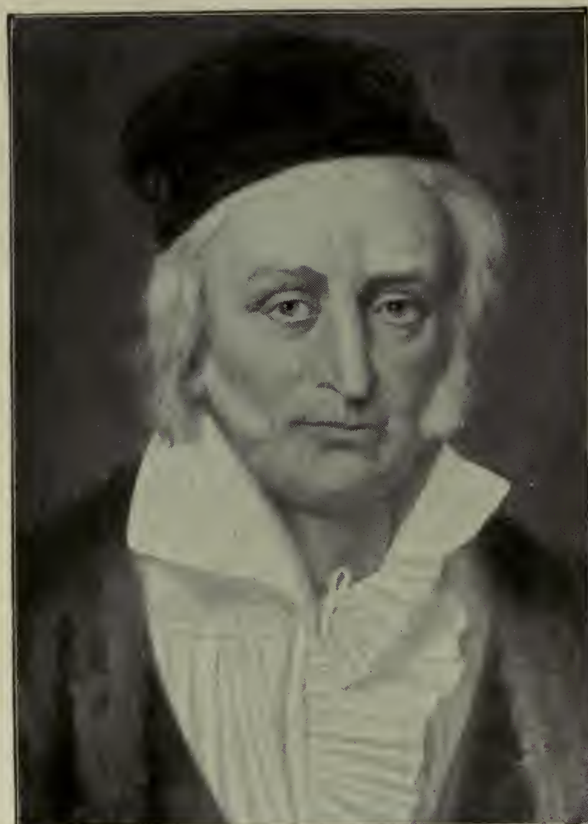


Fig. 25.—Charles Frederick Gauss.

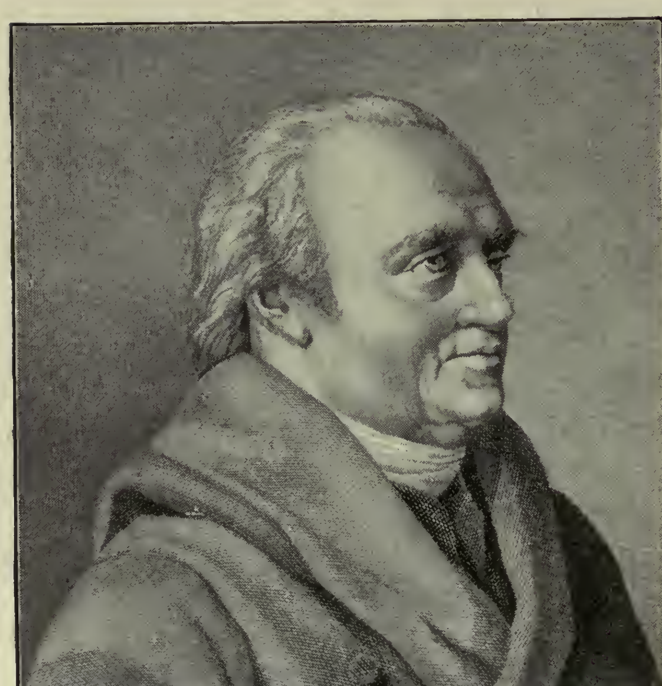


Fig. 26.—Sir Frederick William Herschel.

its due share of such! A naturalist must be fitted out with a gift for shrewd observation, with a logical and pre-eminently philosophical mind that does not lose itself in the narrowness of his own special branch of science, but endeavours to keep a wide grasp of the whole material, fitting his deductions at the proper time and place into the great general mass. An astronomer, especially, must be born and not made. There are people on this earth with whom it is impossible to enter properly into cosmic views, who cannot free themselves from commonplaces, cannot elevate their minds above a terrestrial level. They lack what I call the higher sense of space, without which it is quite an impossibility to grasp the idea of the universe and all its manifold worlds in its entirety. In the first place, mathematical gifts, a keen eye and an exceptional amount of patience are absolute necessaries; for patience, and only patience, can help an astronomer to his goal. Love of and a decided bent towards astronomy are usually born in people, and, once awakened by whatever slight external impulse, they can never again be lulled to sleep. This has been proved in countless cases, for no other science has attracted men from such different stations in life as astronomy, where labourers, business men, civil servants and peasants have devoted themselves to the history of the worlds above. A great number of the most eminent astronomers entered their life's studies from such divergent paths—*per aspera ad astra!*

Sir William Herschel. — Of all these persons Sir Frederick William Herschel, the greatest astronomer of the eighteenth century, claims the chief share of attention (Fig. 26). He was born at Hanover, the son of a poor musician, and at an early age entered the band of a local grenadier regiment as oboist. He went with his regiment to England, and afterwards left the army and gave private music lessons. After a painful struggle he was engaged as conductor of the Bath town orchestra. The poor little music-master had all his life taken a lively interest in the silent worlds overhead, and devoted his few spare hours to his hobby. As he could not afford to buy a telescope he set to work to build one (Fig. 27), and finally constructed a number of them, some of really gigantic dimensions, with which he scoured the skies. It was early in 1781 that he made the discovery which, apart from everything else, would have rendered him famous; he discovered a planet on the far side of Saturn—Uranus. This feat brought him honours

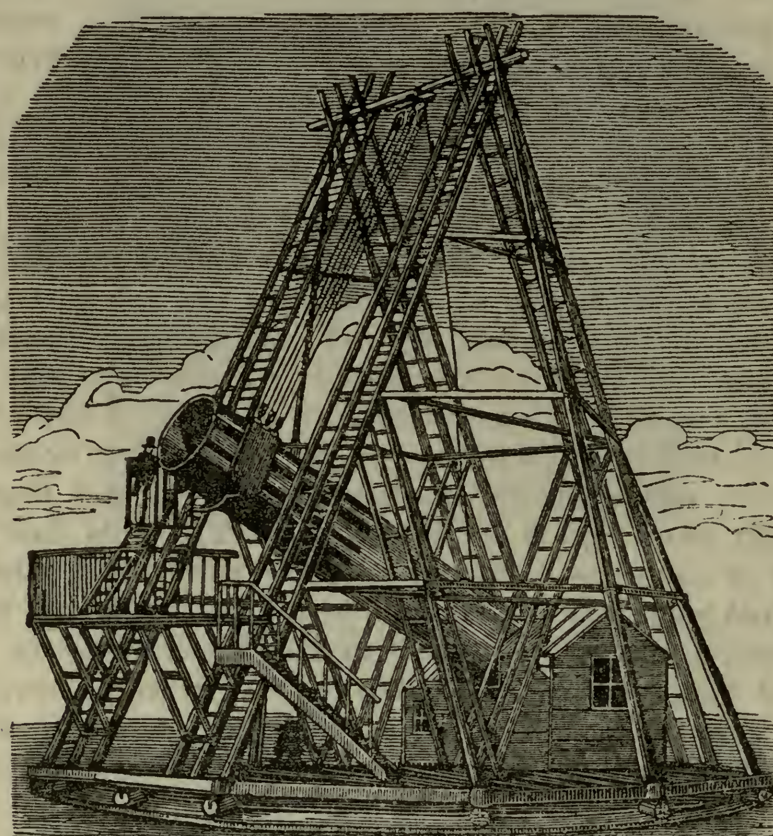


Fig. 27.—Sir William Herschel's Great Telescope at Slough.

galore; the King of England (George III.) appointed him his private astronomer at a salary of £200. He built his giant telescope at Slough, near Windsor, and with it made several valuable discoveries. He died in 1822, a king of astronomers, and with him went to rest a master of astronomical observation such as the world had not seen since the days of Tycho Brahe.

Urbain Leverrier.—A very similar case was that of Urbain Leverrier, the great French astronomer, who died in 1877, being then director of the Paris Observatory, the highest position the French astronomical world has to offer. Leverrier was a Customs official in the Excise department, but he had always occupied himself with engineering, and had a very mathematical turn of mind. He set himself the difficult task of ascertaining the cause of certain irregularities in the orbit of Uranus around the sun, and after months of most complicated calculations came to the conclusion that a planet hitherto unknown must be stationed on the far side of Uranus. In 1846 Galle at Berlin discovered a planet in the region indicated by Leverrier, to which the name of Neptune was given. Leverrier had found this celestial body, that had never before been seen by a human eye, whilst seated at his desk. It is one of the remarkable coincidences of astronomy that the problem had been simultaneously solved by the great Englishman, John Couch Adams, who divides the honours equally with Leverrier. This was a veritable triumph of human skill, and a proof of the intimate knowledge nowadays possessed of the laws governing the motion of the planets around the sun.

How Peter Hansen was Led to Study Astronomy.— The goddess Urania is a most fascinating lady, and they who have once been enthralled by her beauty remain her victim all their lives. Her fascination has made itself felt in the most remarkable fashion and amid most difficult circumstances. There was once a clockmaker's assistant of Tondern, whose duty it was to regulate the clocks in the mansion of a very learned gentleman. One day he was forced to wait a long time before the master of the house could see him, and to pass the time away he picked up a book that was lying on the study table. It was a mathematical treatise, full of unintelligible algebraical symbols and geometrical diagrams. Everybody else would have put it back in disgust, but the young watchmaker, whose name was Peter Hansen, was delighted with it, and begged the owner for the loan of the volume. Goddess Urania had flashed her eyes at young Hansen whilst he had sat and waited, and it was perfectly useless for him to fight against her sway; he simply had to become an astronomer, and he did. He gave up his work in Tondern, to the dismay of his family, who looked upon him as a lunatic. Hansen became a most eminent astronomer, and made a special study of the attraction which the different celestial bodies exercise on each other. He was appointed director of the Gotha Observatory, and died in 1874.

From Blacksmith to Astronomer.—The history of Privy Councillor Bruhns, director of the observatory at Leipzig, is even more interesting. This most charming philosopher and astronomer, who died in 1881, was originally a blacksmith's apprentice. He was pointed out to Humboldt as a curiosity, and he in turn called the attention of Encke, then at the head of the Berlin Observatory, to the intelligent young smith. Encke set him several mathematical problems, which he solved satisfactorily and which resulted in his becoming Encke's protégé. He took off his leather apron, and was given a post as one of Encke's assistants. Later he became professor of astronomy at the Leipzig University and head of the observatory there. His special objects of study were comets.

Other Great Astronomers.—Two other renowned astronomers, both Americans, were carpenters—namely, Asaph Hall, discoverer of the moons of Mars, and Simon Newcomb, the mathematician, who was professor of astronomy at Baltimore. Weber, one of the greatest solar experts, was a cowherd, and a peasant named Palitzsch, of Dresden, gained world-wide fame as a calculator. Mädler, of lunar celebrity, was a writing-master, and Bessel, one of the most prominent astronomers of all times, a clerk. Hermann J. Klein was originally a bookseller, and so was M. Wilhelm Meyer (Fig. 28), the most popular German astronomer, who founded the Berlin Urania Institute.

The Triumph of Intelligence.—All this teaches us that it is quite possible to become a good astronomer without a college education. Intelligence, genius and talent are born in man, and force themselves to the front in spite of all, and would do so in a much greater degree if insurmountable obstacles were not constantly placed in their path.

In perusing the history of science the fact is constantly impressed on us that it is the self-taught men who have turned out epochal work, and have made discoveries and

Fig. 28.—Dr. M. Wilhelm Meyer, founder of the Urania Institute, Berlin.

Fig. 29.—Mediæval Astronomer and Cosmographer in his Study.

(After an engraving by Johannes Stradanus.)

Fig. 30.—John Hevel and his Wife measuring Stellar Altitudes.
(*From Hevel's "Machina Cœlestis,"* 1673.)

inventions of the greatest importance to the world. Their brain is generally more unfettered than that of the scholar, who is apt to become entangled in the labyrinth of his own learning; they attack things more daringly, being less encumbered with theoretical ballast, and the very fact that they possess less book-learning than a specialist may, although it sounds paradoxical, often lead them to surprising results.

The Need for Specialisation.—In our own days, however, where knowledge in all its branches has spread out to huge dimensions, and where endless learning is necessary to master one's own special field of work, it has grown far more difficult to enter the wide halls of science without a thorough preliminary grounding; even an expert can no longer entirely control all the branches of his own particular science. The onward trend of medical skill has created specialists of all kind, and the physiologist, too, has to confine himself to a more or less widely defined field. It is the same with astronomy. This is divided into two main categories—observing and calculating—and the latter in turn is subdivided into measuring or astrometry, and into descriptive astronomy or astrophysics. Measurements made at the telescope by the observer afford the calculator the necessary basis for the determination of the position and motion of the celestial bodies. The astrophysicist in turn attempts to find out their substance, and the happenings on and in them. These combined forces render it possible to gain an insight into the marvellous workings of the universe, and the progress of our intricate science is being steadily maintained. Antiquated parts frequently have to be replaced (Fig. 29), wrongly set bricks to be removed, but the foundation and columns of the whole are as firm as ever—honour to the great architects who raised them up, honour to every workman who added a stone!

CHAPTER III

WOMEN AS ASTRONOMERS

ACCORDING to an old Spanish proverb, women are closer to heaven than men, for it needs the patience of angels to bear with them, and the home of the angels is therefore ensured to them! Abraham à Santa Clara held similar views, for although he was a holy man, he was somewhat of a cynic as well, and delighted to include sarcastic remarks on women in his sermons. Nevertheless, I am of opinion that women have always interested themselves in heaven, in the visible as well as in that which they hope to occupy at some future period. Woman's nature is far more poetically inclined than man's, and the beauty of the starry canopy has been more fully recognised by them than by the members of the stronger sex. The sublime and poetical aspect of the stellar myriads frequently induced women of past generations, when the question of women's rights was unknown and a learned woman was little short of a marvel, to busy themselves with the riddle of the skies, and led them on to astronomical pursuits. Long before the fair sex took an active interest in any other branch of science, numerous women had fully deserved the title and status of astronomers. It must have needed a certain amount of courage on their part, for men in past days held none too high an opinion of studious women, who to-day, on the contrary, have every possible encouragement held out to them. Even great and learned men thought but poorly of such women. Immanuel Kant vowed that "learned women use their book like their watch, only to carry it that it may be seen, although it mostly stands still or is not directed towards the sun." Lessing, Germany's great poet, wondered how "a man can love a thing that, for very spite of him, professes to think. A woman who thinks is just as detestable as a man who rouges." Perhaps it was not so much the thirst for knowledge as the love of the poetical and mysterious that drew women towards astronomy, and it is hardly surprising that womankind, which has ever had an open eye and heart for all that is beautiful and sublime, was magically attracted by the problems of the skies.

Frau Hevel.—The first woman astronomer to whom this title may be given with certainty was the wife of Johann Hevel, a Danzig city councillor and astronomer who died in 1687, and who possessed a very fine observatory called the Sternenburg ("The Starry Fort"), at Danzig. She was his trusty comrade, and of special service to him at the sextant, besides rendering him invaluable assistance by her accurate reading of the records (Fig. 30).

Maria von Lewen.—Maria von Lewen, the friend of the great astronomer Kepler, created a name for herself as a mathematician. She mainly occupied herself with calculating the movements of the planets in advance, and supplied Kepler with material for his laws governing the planetary motions. She died in 1664.

Madame Lepaute.—Maria von Lewen possessed an eminent successor in Madame Lepaute, who was an excellent mathematician. Madame Lepaute belonged to an old French noble family, and was born at Paris in 1723. She married a clockmaker named Lepaute, who was an extremely clever workman and made instruments for astronomical purposes. This most interesting woman assisted the mathematician Lalande in his work, and, together with Clairault, afterwards calculated the time for the reappearance of Halley's comet. This gigantic task took six months to accomplish, and was crowned by the arrival of the comet at the time announced. Perhaps some jocose individual who does not believe in the mathematical gifts of women may say that it was simply politeness on the part of the comet towards the lady to appear punctually at the rendezvous; but all who have an inkling of the nature of these rovers of the universe will freely own that this calculation was a most difficult piece of work. Madame Lepaute died in 1788, and the Paris Academy of Sciences was represented at her funeral by some of its most prominent members.

A Royal Astronomer.—Astronomy had a royal patroness in the Duchess Louise of Gotha (Fig. 31), who not only personally carried out observations, but was ever ready to support the science by the purchase of instruments and charts. It was on her initiative that the first astronomical congress was held in 1798.

Caroline Herschel.—The most eminent female astronomer of earlier days, however, was Caroline Herschel. Not only did she render her brother, Sir William Herschel, the most invaluable services, assisting him to build his great reflecting telescope and aiding him in his investigations, but she also worked entirely independently of him. After her brother's demise in 1822, she continued her work until death put an end to her active life in 1848, when she was ninety-eight years of age (Fig. 32). Caroline Herschel alone discovered eight comets and many other new celestial objects.

Sonja Kowalewski. — If the woman we have just mentioned was principally a working astronomer, the young Russian, who justly earned the fame of the best female mathematician the world has ever seen, was a theorist; we allude to Sonja Kowalewski, *née* Krutowska. She was born at Moscow, and in 1868, when barely eighteen years old, she married Professor Kowalewski (Fig. 33). Later she studied mathematics in Berlin and Göttingen, and took her doctor's degree in 1874. In 1884, after a year of widowhood, she was offered the Chair of Mathematics at the Stockholm University, which she held until 1891, when she died after a short illness. Sonja Kowalewski wrote a number of mathematical treatises, but her most interesting work is the book on the rings of the planet Saturn, whose structure and constitution she endeavoured to investigate mathematically. It brought the solution of a most intricate point in the mechanism of the heavens much nearer to us.

Madame Flammarion and Mrs. Asaph Hall.—Women who assist their husbands in their researches are not at all uncommon. The wife of the French astronomer, Camille Flammarion, who also helps him in his spiritualist studies, is an example of this. Mrs. Asaph Hall, wife of the American astronomer, deserves special mention, as she can

Fig. 31.—The Duchess Louise
of Gotha.

Fig. 32.—Caorline Herschel at the age of 98.

Fig. 33.—Sonja Kowalewski.

Fig. 34.—A Woman measuring Celestial Photographs.

to a certain degree claim to have discovered the moons of Mars. Asaph Hall himself says he was tired of the vain search for the two tiny satellites, but his wife induced him to persist, and the following night the discovery was perfected.

American Women Astronomers.—America may well be called the land of female astronomers, for the majority of observatories there have been founded by wealthy donors, and women have largely shared in presentations for these purposes. Miss Bruce and Miss Draper some years ago built a station for photography at Harvard, where twenty-five women are occupied. Thousands of photographic plates containing millions of stars have been taken there. All these plates have to be measured by means of special apparatus to which microscopes and measuring appliances are fitted (Fig. 34). The position of the stars to each other has to be exactly defined to permit of any changes being ascertained on comparison with later photographs. A single glance at any one of these plates shows how much time and patience is necessary to measure these great clusters. One of the ladies belonging to the institute, Miss Leland, has up to the time of writing calculated the positions of about 40,000 stars with the help of the instrument just described. Miss Catherine Bruce presented a sum of £45,000 for astronomical purposes, and also, as we have said (p. 17), an instrument to the observatory at Heidelberg. Another wealthy lady, Miss Surrey, built a large telescope for the Yerkes Observatory in Wisconsin. America's prominent astronomers include Mesdames Klumpke, Somerville, Mitchell and Fleming,* who have become known partly by their work on celestial photographic charts and partly by their observation of the light fluctuations of the so-called variable stars.

Miss Elizabeth Brown.—Women astronomers have taken part in many a dangerous expedition to serve their science, and in this connection special reference must be made to Miss Elizabeth Brown, who died some years ago

* Mrs. Fleming, who is a member of the Harvard Observatory at Cambridge, Massachusetts, discovered a new star on a celestial photograph early in October 1910. The new star, one of the tenth magnitude, is situated in Sagittarius; only fifteen new stars were discovered during the quarter of a century after 1885.

in England. She was a founder and vice-president of the British Astronomical Association and director of the Solar Section. Her state of health did not permit her to carry out night observations, so she made solar occurrences her special study. She shared in three long and fatiguing expeditions for the observation of solar eclipses—to Russia, Lapland and the West Indies—without being discouraged by the fact that in two of the three cases inclement weather made all work useless, and that at the decisive moment the sun hid itself behind thick clouds!

Women in the Observatories.—Patience is one of the chief virtues an astronomer must possess, and as women generally have more patience than men, they seem destined by Nature for some branches of astronomical science. They are employed in observatories all over the world as calculators and observers. There are lady computers at the Melbourne Observatory, at Cordova in the Argentine, at Columbia University, and at the Albany Observatory. Several women are employed at the Cape of Good Hope Observatory, and are also to be found in the mathematical department of the Paris Observatory.

So we see that women, too, have fallen beneath the sway of the stars. Up to the present they have not made any world-disturbing discoveries (neither have the majority of their male colleagues for that matter), but they are industrious and intelligent workers in the cause. Geniuses are rare, but a genius alone does not stand for progress, and the conscientious worker is no whit less important.



CHAPTER IV

A VISIT TO AN OBSERVATORY

There is something very mysterious and attractive to the uninitiated about the silent building outside the city, whose high domed roofs rise up from the green foliage like the ancient temples of the East. Far away from the town, with its mists and noises, closed against every stranger, the astronomer's tranquil home calls forth a feeling of the unearthly within us. Tales of dark deeds worked by the mysterious star-gazers of the Middle Ages involuntarily occur to our minds, and we remember how these persons abetted the superstition of the unenlightened people by reading, or pretending to read, the fates and fortunes of high and low in the stars.

Those times are past beyond recall, and the web of mysticism that ignorance and greed of gain wove around the astronomer's art has been rent into shreds. Superstition has been banished, and yet the wondrous revelations of modern science awaken deeper amazement in us than the astrologers and alchemists of the dark ages were able to call forth with all their magic arts.

A singular charm rests on the home of the stellar workers. It is here that man, earth's lord, communes with the Infinite; it might almost be called the gate to eternity. It is all so remote from ordinary mankind; every now and again the newspapers recount discoveries made by astronomers in their long night watches, but few people ever set foot in the temple consecrated to the stars. Let us be among the elect and enter that silent, peaceful building, whose high domes flash forth rays of light at the very dead of night, when all else is at rest, and only the glittering stars shine down upon the earth.

The Need of Quietude.—An unrestricted view and absolute quiet are main necessaries for work, and that is the reason why observatories are built as far away from traffic as possible. Even railroads may not be in the vicinity, as the extremely sensitive instruments in use record the slightest ground disturbances, when the stars begin to dance up and down in the telescope and spoil every chance of exact observation.

Mountain Observatories.—Besides, the air in the environment of a city is so often smoky that observatories are being moved out farther and farther into the country, or, even better still, they are being erected on hill-tops in pure mountain regions. One of the grandest of such is the celebrated Lick Observatory on Mount Hamilton in California, situated more than 3,000 feet above sea-level (Fig. 13); it contains one of the largest telescopes in the world. The coffin of James Lick, the remarkable man who set himself so noble and singular a monument, rests beneath the foundation-stone of the great telescope. In Fig. 35 is shown a view of the old Royal Observatory in Berlin. Another beautifully situated observatory is that at Potsdam, where solar research and stellar light examinations are principally carried on (Fig. 36).

The great telescopes are placed in lofty domed halls, the roofs of which are made of sheeted iron, and run on wheels, so that they can easily be turned by motor power. It is only necessary to pull a lever and the roof rolls round until the aperture for the telescope is placed at the correct angle. The aperture itself can be opened and closed mechanically.

The Invention of the Telescope.—No discoveries in science have been of so momentous a nature as those of the telescope and the microscope. Where would science be to-day without them? The one has opened up to us a world of things immeasurably great, the other a world of things incredibly minute. The visible world was suddenly extended

Fig. 35.—The Old Royal Observatory, Berlin.

Fig. 36.—The Observatory, Potsdam.

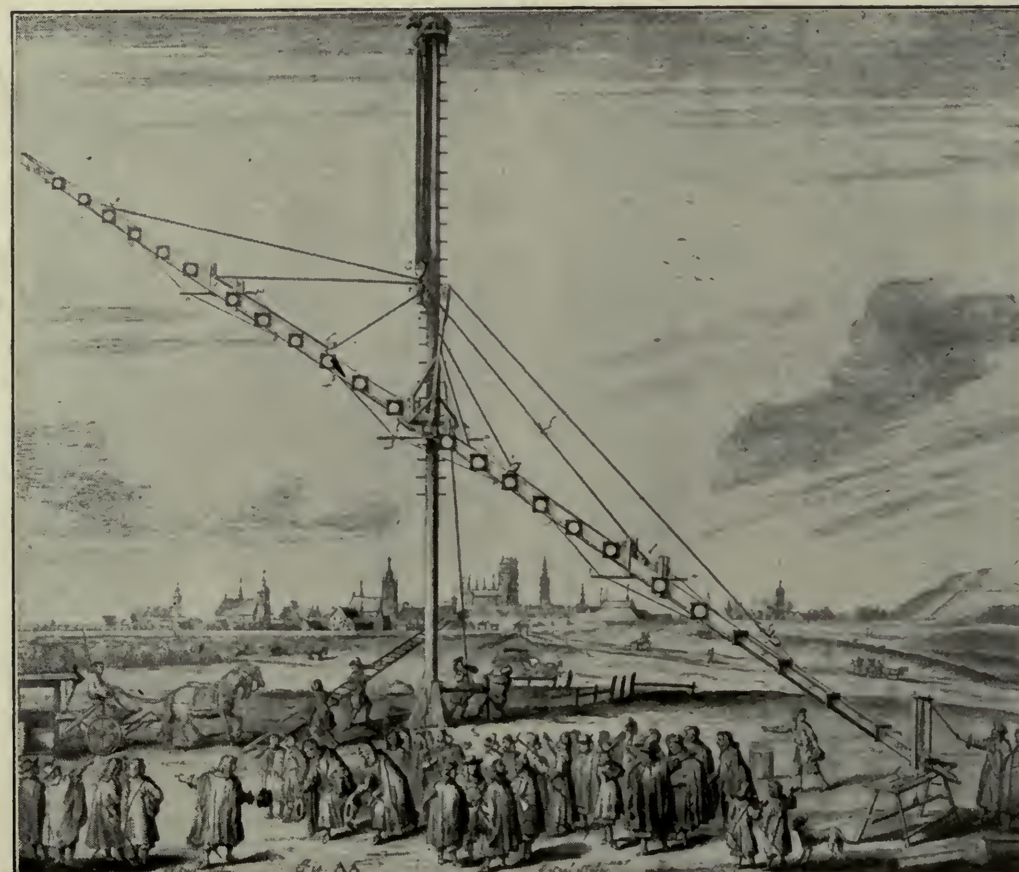


Fig. 37.—View of an unwieldy Telescope of the end of the Seventeenth Century.

(From Hevel's "Machina Cœlestis.")

beyond limit in both directions by the use of these two marvellous instruments, and things appeared to us of which the world had never before dreamed. Oddly enough, both instruments are the outcome of accident—at least, the telescope most certainly can be traced back to such. The children of a Middelburg spectacle-maker named Jansen, whilst playing with glasses and lenses, suddenly discovered that, by holding two glasses in front of their eyes at different distances, they could apparently bring far-away objects quite close up to them. Their father, who watched them at their play, began to improve on their game, and was soon able to put the first telescope together. According to ancient chronicles, however, the effect of such combinations of lenses was not entirely unknown in olden days; but, of course, this cannot be vouched for. Professor Harting has proved that the first accredited mention of a telescope dates from 1608,* when Hans Lippershai, a native of Wesel, who lived at Middelburg as a spectacle-maker, offered the Dutch Government "a far-gazing instrument for use in war," demanding a pension as an equivalent; he promised to keep his invention secret, only supplying his country with the information. Whilst negotiations were pending, a certain Jacob Metius approached the Government with a similar proposal, and as the secret no longer seemed inviolate, the purchase was not effected. Lippershai found a patron in the Duke of Nassau, and telescopes soon became popular. The great Galileo built one for himself in 1609, and a year later made several interesting discoveries with its aid, the first of which was that of Jupiter's moons. The astronomical telescopes of the following century were extremely long, although the lenses were very small indeed; astronomers in the seventeenth century worked with monsters, thirty, fifty, or even seventy-seven yards in length, this great length being given to diminish the drawback of colour-fringes (Fig. 37). Optical science was, of course, only in its infancy, and these clumsy instruments set up on tall frames were not half so effective as an ordinary large telescope of to-day.

Construction of the Telescope.—It is frequently believed that an astronomical telescope consists of a great

* F. M. Feldhaus reports an Italian telescope bearing the date 1590.

many lenses set one behind the other in the long tube. This is a mistake; it consists of the large front lens turned towards the object under investigation, the so-called object glass, which forms a small reversed image of the object near the bottom of the tube (Fig. 38). A magnifying glass at

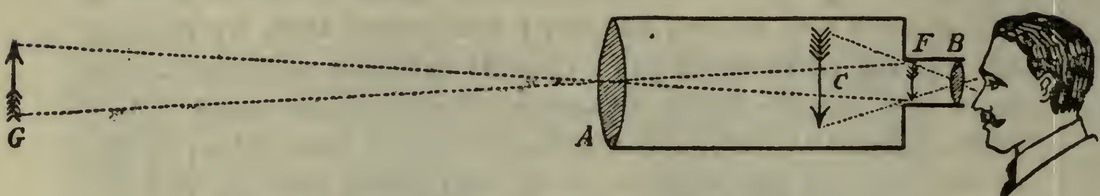


Fig. 38.—Diagram of an Astronomical Telescope.

The object-glass A throws a small inverted picture of the object G at F. This is observed with the aid of the eye-glass B, and appears enlarged but still reversed at C.

the lower end of the tube enlarges the image for examination. This magnifying glass is called the eye-piece. The greater the magnifying power, the nearer and larger the object appears, and a more or less powerful eye-piece is fitted into the tube as occasion demands. It has already been

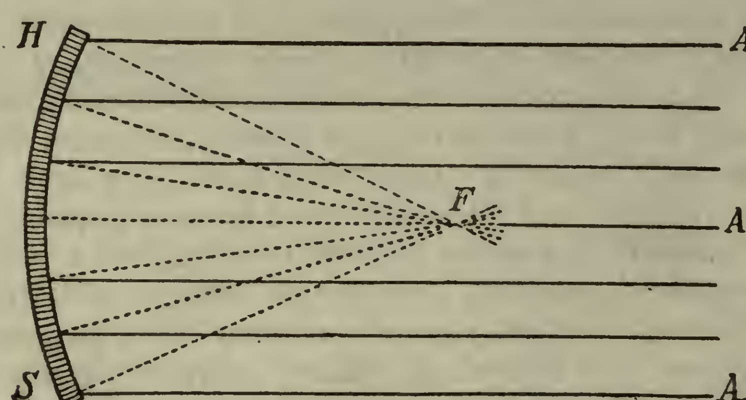


Fig. 39.—How a Picture arises in a Concave Mirror.

The rays of light from A A strike the mirror H S and the concave plane reflects them to F, where an image of the object is seen.

stated that the lenses reverse the image, and that therefore all objects appear upside down in an astronomical telescope, but this has no influence on the work. In telescopes intended for terrestrial observation another lens has to be inserted between the objective and the eye-glass, for the purpose of again reversing the object.

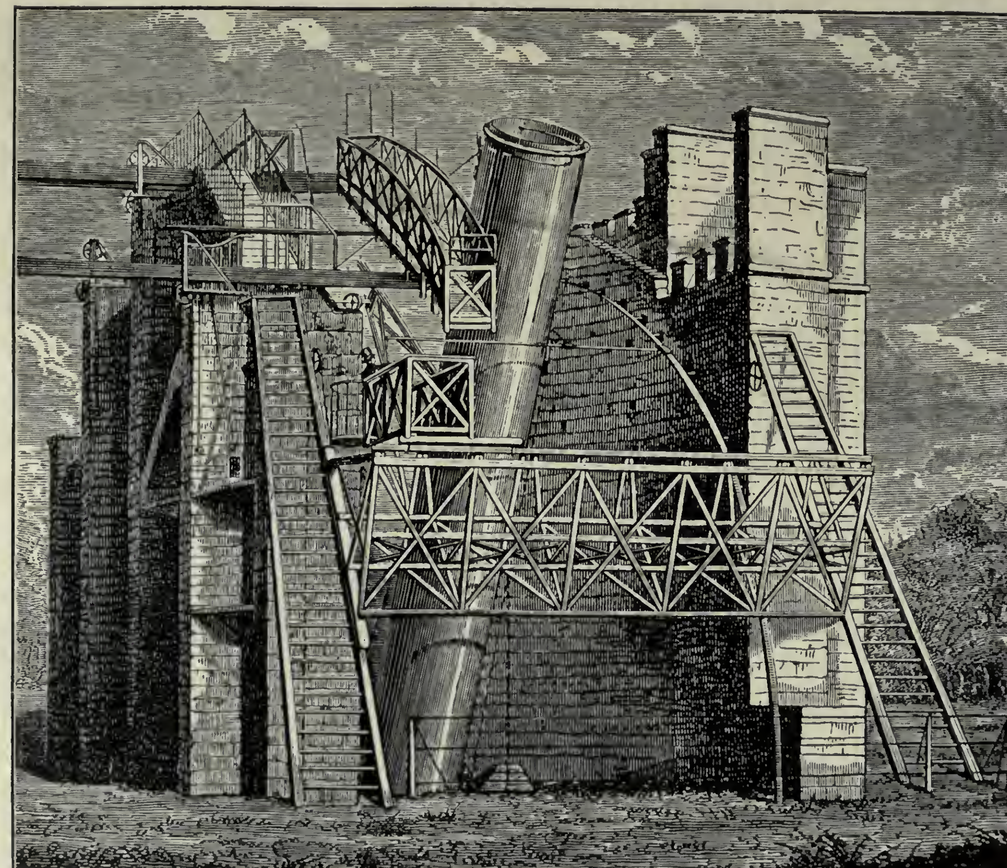


Fig. 40.—Lord Rosse's Giant Telescope at Parsonstown, or Birr.

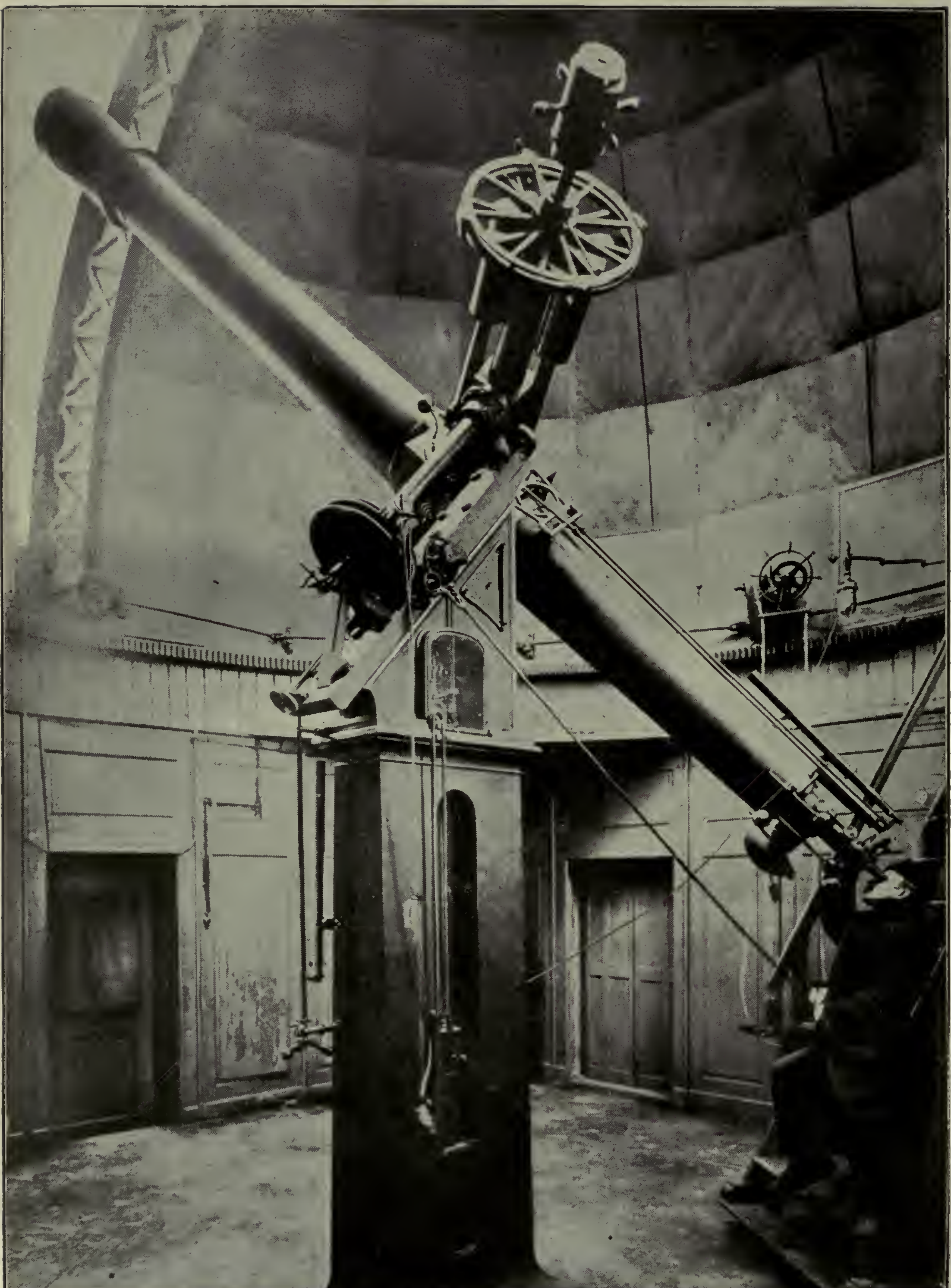


Fig. 41.—Observation at a Modern Giant Telescope.

Newton's Great Invention.—Besides other imperfections, the early telescopes had one very grave defect: in consequence of the unequal refraction of light of different colours by the lenses, all objects appeared with coloured edges, as they do when viewed through a prism. Sir Isaac Newton held that it would never be possible to rectify this glaring error — the so-called chromatic aberration—which so greatly interfered with the image in the telescope, and therefore constructed a totally new kind of instrument, the mirror or reflecting telescope. We all know that a concave mirror forms an image of the object towards which it is turned in front, exactly as the lens reproduces the image at its rear (Fig. 39). Newton attached a slightly concave mirror S to the bottom of a long tube, which threw the image of the star under observation on to a small, plane, inclined mirror *s* (Fig. 42); this second mirror, in turn, projected it through an opening in the side wall of the tube, to which an eye-lens was attached; here the observer scrutinised the star.

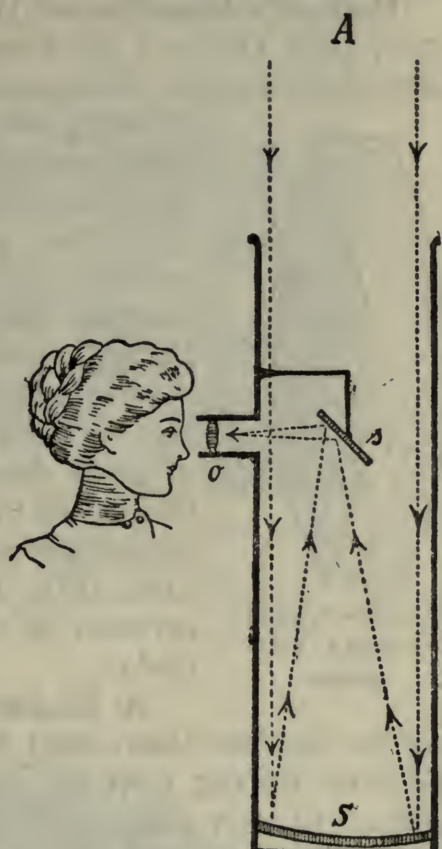


Fig. 42.—Diagram of a Newtonian Reflecting Telescope.

The rays from A fall on the mirror S, which reflects them to *s*, the plane mirror, which in turn throws them sideways to a tube-piece containing the ocular, *o*, through which the image is observed.

Herschel and Rosse Giant Telescopes.—Reflectors of various kinds are still in use, and for some work are preferred to refracting telescopes. The largest mirror telescopes were built by Sir William Herschel; his chief one had a mirror of 4 feet 1½ inches in diameter and was 36 feet in length. The instrument built by Lord Rosse in 1845, and set up at Parsonstown, or Birr, Ireland, was even more formidable; it was 56 feet long, with a mirror measuring 6 feet in diameter, a huge weapon with which the skies could be scoured to their farthest depths (Fig. 40).

Dollond's Invention of the Achromatic Telescope.—In 1757, John Dollond, the English optician, who in his youth had been a weaver, contradicted Sir Isaac Newton's assertions by designing a lens telescope, in which the disturbing colour borders were absent, and from that time reflecting telescopes dropped from their point of vantage, and the construction of lens telescopes recommenced. Dollond did away with the colour distortion by making an objective of two lenses joined together. One of these was of crown glass and the other of flint glass. These two kinds of glass disperse light differently, and the two lenses were so put together that the one counteracted the colour dispersion of the other (Fig. 43). Thus Dollond became the inventor of the achromatic telescope we use to-day.

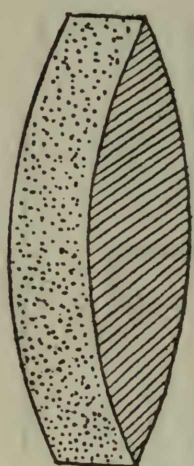


Fig. 43.—Object Glass of a Telescope.

A Modern Refractor.—How very different the modern instrument is from those of our ancestors! Without having seen an astronomical telescope it is most difficult to gain a fair idea of it. A monstrous tube, resting on an iron pillar, is fitted up with numerous levers, rods, wheels, counter-weights, screws, circles, magnifying glasses, and lighting appliances, until it has almost lost all semblance to a telescope, besides having two or three "small" telescopes, which, nevertheless, are quite several yards long, attached to it (Figs. 41 and 46). There is a dazzle of polished steel, brass, silver, glass and crystal about it, while complicated, intricate measuring apparatus, with silver drums and screws, and all sorts of other ingenious appliances are fixed on it to serve the astronomer in his watches in the darkened room (Fig. 44).

When desiring to find an object, it is not at all necessary to open immediately the aperture in the cupola; the astronomer first of all notes the co-ordinates of the celestial body (which is perhaps perfectly invisible to the unaided eye)

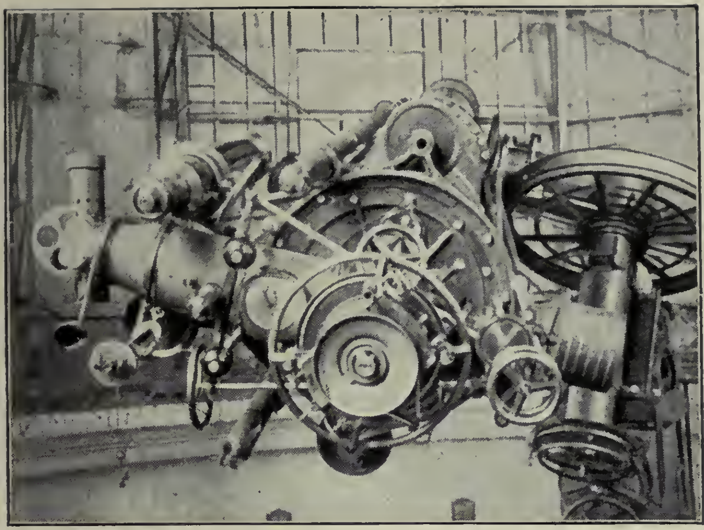


Fig. 44.—Eye-end of a powerful Telescope, with levers, shafts, measuring apparatus, etc., at the Observatory of Pulkova, Russia.

Fig. 45.—Micrometer.

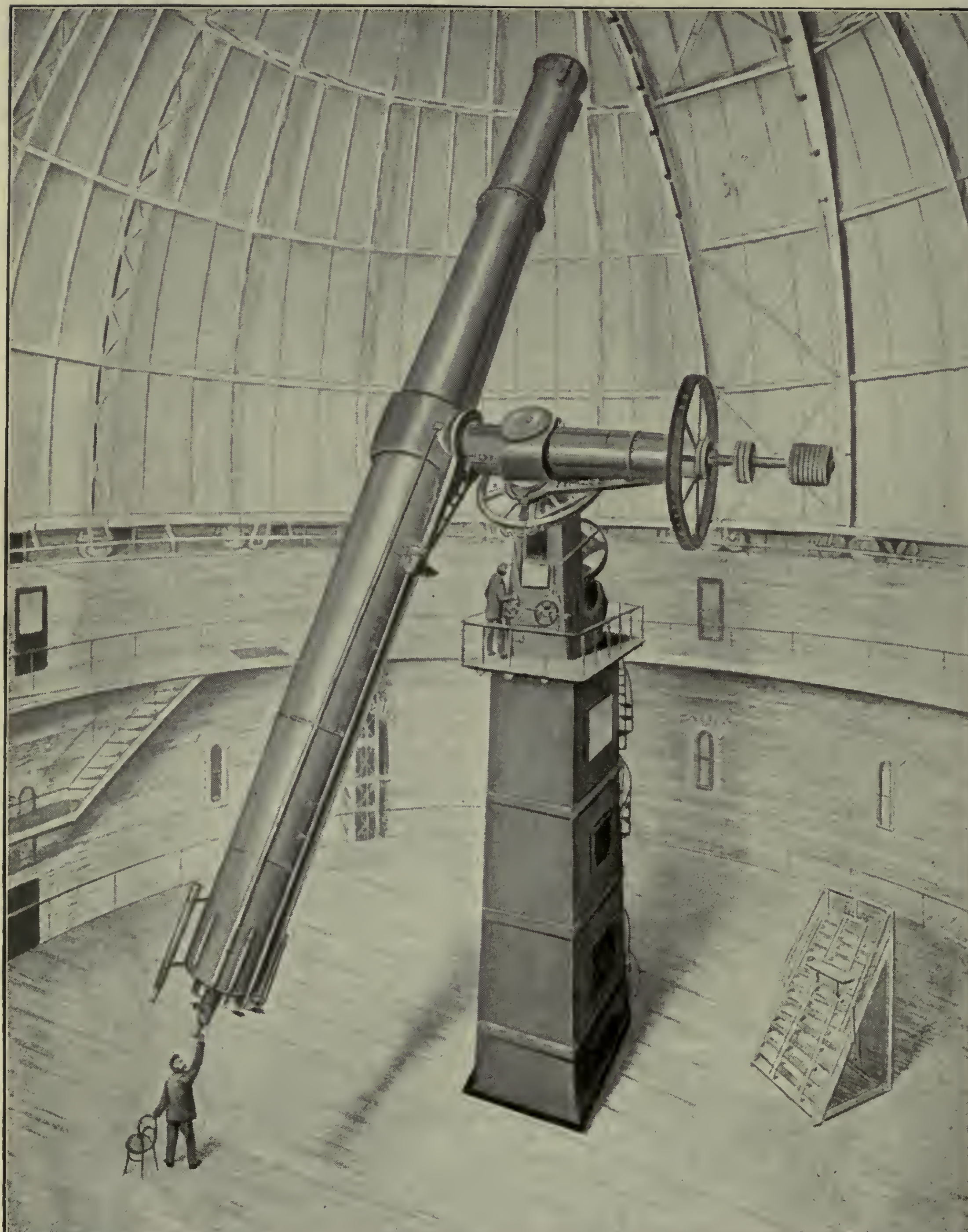


Fig. 46.—The largest Telescope in the World: the 25-yards Refractor in the Yerkes Observatory.

from his almanac or catalogues, and primed with this knowledge, he begins to turn his telescope in the two co-ordinates, until the pointers on two large graduated circles fixed to the instrument stand in the required readings. The roof is then opened, and the sought-for star will be found well within the field of view. We all know that the earth has been divided into longitudes and latitudes, which render the position of every spot on the globe easily determined; the celestial sphere, too, has been subjected to a like division, and every celestial body known entered in maps and catalogues according to its position. The graduated circles are adjusted to the necessary readings, and the star immediately appears in the telescope. By these means a stellar body invisible to the eye can be brought within the field of view both by night and day, for the more brilliant stars are visible in broad daylight.

Measurements by Spider Threads.—The astronomer not only has to observe the celestial bodies, but also to measure them and define their size, direction and the rate at which they travel. For this purpose a most delicate instrument—a micrometer—is attached to the eye-end of the telescope. A number of spider lines are stretched across the micrometer horizontally and vertically to afford the means of accurate measurement (Fig. 45). Some of these threads can be moved by the help of very fine screws. Should there happen to be two objects in the field of view, one stationary and the other moving, the threads will soon reveal their character to the astronomer. The following is the mode of procedure : Two of the threads are moved by the screws until they each exactly cover one of the objects. After a short lapse of time the stationary object will be found in the same position as at the beginning, whilst the other will have moved to the side of the thread. The direction and extent of the motion can also be ascertained by the threads and the measuring appliances connected with them. The delicate threads would, by the by, hardly be recognisable against the dark sky if they were not weakly illuminated by tiny incandescent lamps fixed into the interior of the telescope, which is, as we see, a most complicated piece of machinery.

Great Modern Telescopes.—The largest refracting telescope in practical use is the instrument at the Yerkes Observatory, which is 25 yards 6 inches in length; the objective is 40 inches in diameter (Fig. 46). The principal telescope of the Lick Observatory is 21½ yards long, with an object glass 36 inches in diameter. Then follow the telescopes stationed at Meudon, near Paris; Potsdam, near Berlin; and Pulkova, in Russia (Fig. 44). The Royal Observatory, Greenwich, has a 28-inch refractor and a 30-inch reflector.

What the Telescope Reveals.—The achievements of such giant instruments are most remarkable; they allow us even to recognise objects on the moon of only 150 to 220 yards in diameter! If we were stationed on the moon and armed with such an instrument we could see the pyramid of Cheops in the Egyptian desert, although only in the shape of a dot; but even the shadow it throws morning and night on the glowing sand would be revealed. With the help of these huge tools even the tiniest celestial bodies, millions of miles away from us, are distinctly visible.

Our giant instrument answers to the very slightest movement, and can be turned by the lightest touch of the hand. Let us take a peep through it; it is turned on to the planet Jupiter when in the earth's vicinity, that is *only* 373,000,000 miles distant. The glass reveals a disc much larger than the moon to the naked eye—a huge distant world; we can see great cloud-belts across its face, watch it turn slowly, and see other parts rise up from the night side of the sphere. Four large moons encircle that remote world, and, while we watch, the shadow of one of them passes across its disc in the shape of a dark circular spot. Now another moon enters the shadow of the sphere, and is extinguished in a few minutes—we have witnessed an eclipse of one of Jupiter's moons.

The Mechanism of the Telescope.—We should hardly be able to follow all these proceedings so thoroughly if a clockwork movement did not turn the telescope on to counteract the effect of the earth's rotation. The star floats smoothly and tranquilly in our field of vision, for the pillar of the telescope rests on a perfectly isolated column which reaches down below the foundations to be secured from even the slightest shock or concussion.

We now have to forsake the telescope, as the observer is on the look out for a small and distant comet whose discovery has interested the astronomical world, which is determined not to lose sight of it until its motion and position have been precisely defined for further calculations as to its probable re-appearance. Not even the faintest gleam of light may enter the domed hall, for a comet so far off appears even in the most powerful instrument as a dim cloud, only recognisable to a totally undistracted eye. It would be impossible for a novice to find it even with the help of a telescope, for observation, too, needs training, until perfection is acquired. The astronomer seats himself in the chair on the scaffolding, where, wrapt in heavy furs, he remains for hours despite the intense cold and the strong draught coming in through the open roof (Fig. 41). The rooms where observations are carried on cannot be heated, owing to the liability to disturbance of the image which is caused by currents of heated air.

The Meridian Chamber.—Every important observatory contains, besides the chief hall where the largest instrument is housed, a number of smaller buildings with less powerful telescopes, where work in connection with more radiant celestial bodies is carried on. This is usually done by young assistants or students, who follow up the changes of light in the variable stars, study the solar disc and its patches, or scan the skies for new comets. There is no need to tarry here, so let us enter the astronomical holy of holies—the meridian chamber. When the sun is exactly in the south, and has reached its highest point, it then stands in what we call the meridian or midday line of any particular place. As all the heavenly bodies appear to move from east to west, they must all once within twenty-four hours reach their highest point over our horizon—in the north or south—or, in astronomical phraseology, stand in the meridian. It is a matter of the utmost importance to know when the different stars pass the meridian, as their position and distance from each other can be determined by this means. This work is entrusted to the observer in the meridian chamber. His telescope is a most remarkable object (Fig. 47). It is fitted like a gun with wheels on both sides, and its axis rests on two massive pillars of stone, which reach down to the very foundations. The tube itself, which is but of moderate dimensions, points exactly north or south in the meridian. Spider lines are stretched in the focus of the objective, the vertical one in the centre marking the meridian line; to observe the time of the sun's centre crossing the meridian, we have to observe the passages of its first and second limbs, or edges, and take the mean of the two. As soon as any star crosses this thread, it is also stationed in the meridian.

Meridian Measurements.—As the time a star crosses the meridian must be noted to a hundredth part of a second, it is necessary for the meridian instrument to be immovably fixed in this direction; it cannot be turned either to the right or the left, but only up and down the meridian, and the roof of the chamber has only one broad opening through which the tube is set. The wheels on each side are silver-edged metal circles, divided into very fine graduation marks, by which, with the further aid of microscopes, the altitude of the stars is ascertained at the instant they stand in the centre of the spider lines to the twentieth thousand part of a full moon's breadth. No wonder the astronomer watches over his delicate instrument with eagle eyes, for it is so sensitive that small errors occur when the sun's rays have rested on one of the pillars but for a few minutes. Even this is sufficient to expand it by their warmth. If the axes are not set exactly parallel, if the one or the other were to incline towards north or south by the hundredth part of an inch, all the measurements and time determinations would be more or less faulty. Most delicate auxiliary arrangements are needed to measure these tiny deviations from exactitude and to obviate them. In practice they cannot be entirely corrected, but their effect is allowed for. The lamps that light up the fine divisions on the graduated circles are not placed in the chamber itself, but the light is thrown in from outside, for even their warmth would influence the instrument. We can from all this easily understand that the meridian chamber is regarded as the sanctuary of an observatory, and that a stranger is but rarely permitted to set foot within its doors.

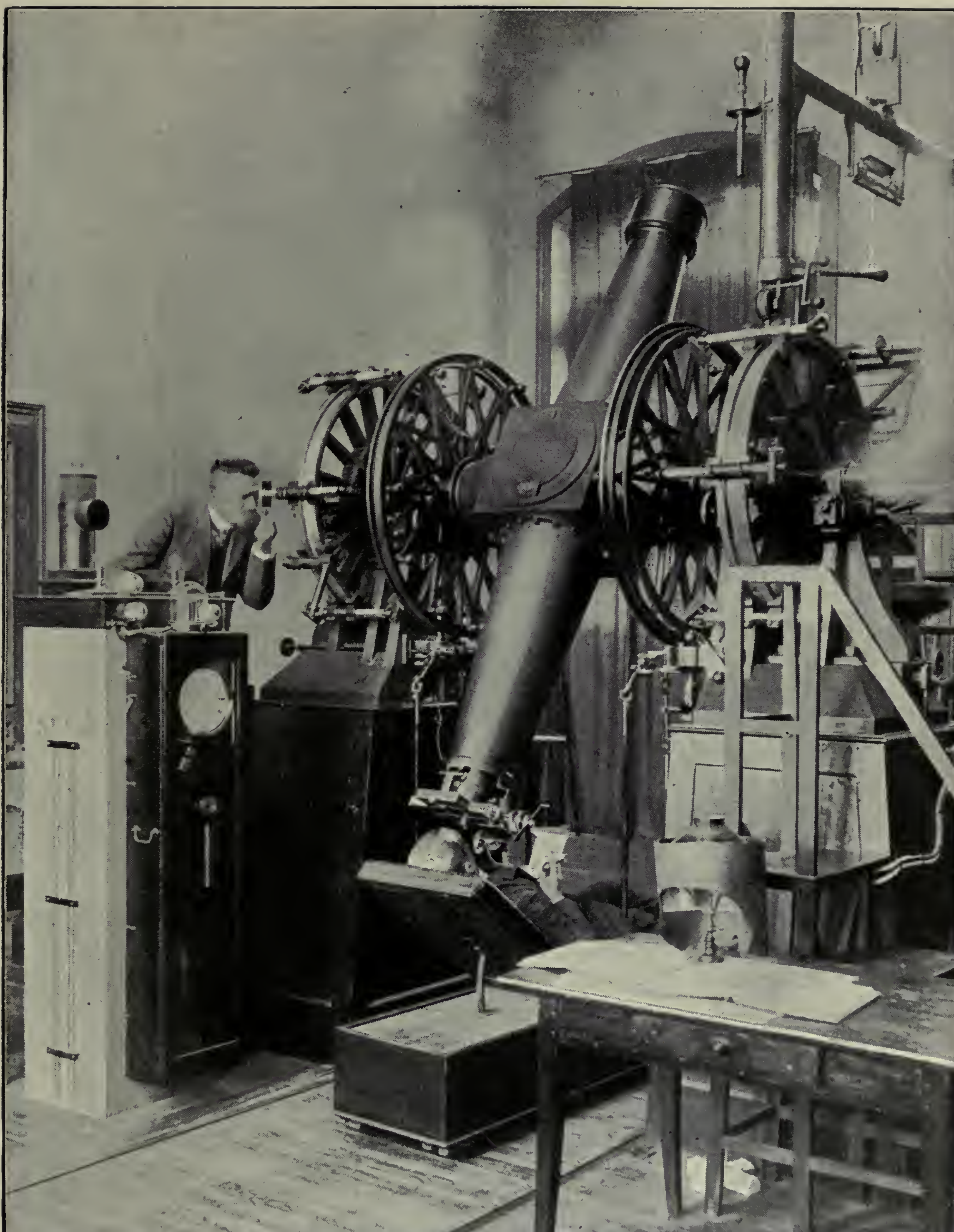


Fig. 47.—Meridian Instrument.

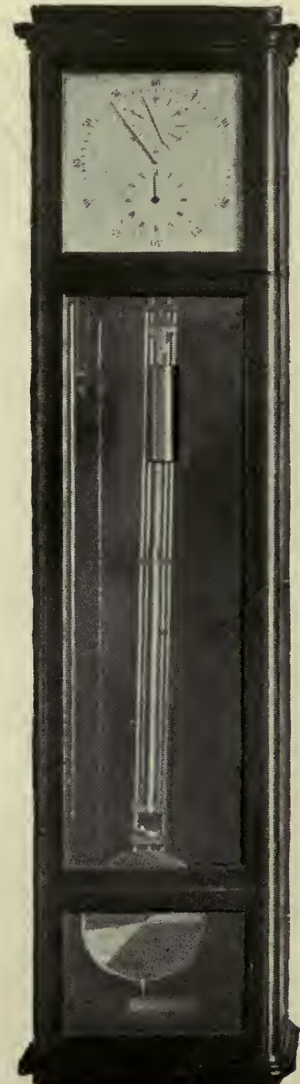


Fig. 48.—Astronomical Pendulum - clock for standard time at the Royal Observatory, Berlin.

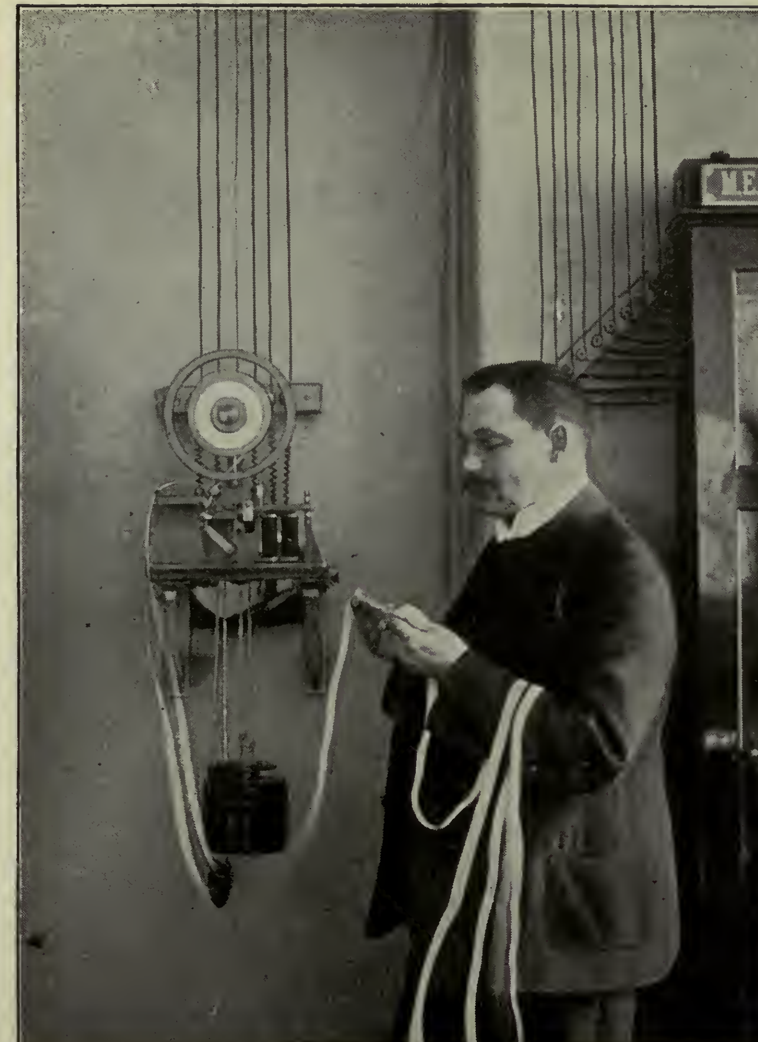


Fig. 49.—At the Chronograph.

The Observatory Clock.—This is the place where exact time is "manufactured." Few people ever give a thought to the fact that in setting their watch by a public clock they are in reality taking the time from the principal clock of an observatory, and that time-service is one of the chief occupations of an astronomer, as we shall learn later. His work simply could not be carried on without the greatest accuracy in time-keeping, and, next to the telescope, the clock is the most important object in an observatory. It is treated with the greatest deference, and constantly carefully regulated (Fig. 48).

An astronomical pendulum clock is one of the most precise pieces of mechanism ever invented. The pendulum swings once in every second, 3,600 swings in an hour, 86,400 in a day, and 2,592,000 in 30 days. And yet it keeps such magnificent time that it hardly varies a beat or two in a month; there are, in fact, clocks that do not deviate even to that extent in two months. The heavy pendulum moves to and fro, and the seconds hand, which extends over the whole of the dial, marks time with unfailing accuracy, hour after hour, day after day, year after year.

We all know that changes of temperature strongly influence the action of a pendulum clock. In warm weather the pendulum expands in obedience to recognised physical laws, and the longer the pendulum the slower its swing, the slower the clock's action. The contrary is the case in colder weather, when the pendulum shortens and the clock runs on too fast. Such alterations due to changes of temperature are eliminated in a modern astronomical clock, thanks to the ingenious construction of the pendulum, which automatically compensates all such changes.

Nearly all astronomical work is dependent on time. One of the co-ordinates of all heavenly bodies is defined by the time at which they cross the meridian, marked by the spider lines of the meridian instrument; the clock has to be resorted to for help: for instance, the time has to be ascertained between the passage of two stars over a certain thread. Formerly the second beats of the pendulum clock were counted; nowadays recourse is made to a separate instrument, a chronograph, which somewhat resembles a telegraphic apparatus (Fig. 49). The pendulum has a tiny point which dips into a drop of mercury at every beat, sending forth an electric current every second. The current pricks a dot for every second on a rolling paper ribbon driven by clockwork (Fig. 50). Thus the clock registers its own time, and it is only necessary to jot down the time shown on the dial next to the first prick to know which second corresponds to each dot on the tape. The astronomer stationed at the telescope has an electric button in his hand, and on his pressing this another dot is pricked on the tape below the seconds mark made by the clock. As soon as one of the stars under observation passes the thread, he has merely to press the button, and a dot appears on the tape below the second beats. The time difference in the passage of the stars is finally read; in the case in question it is 6.5 seconds

Fig. 50.—Chronographic Tape.

(Fig. 50). With the aid of delicate instruments, such as the meridian circle and the pendulum clock, measurements of time differences can be most precisely carried out, serving as a base for mathematical calculations, for we must not forget that all this is really but preliminary work. The main business is carried out at the desk by the aid of a thousand values gained at the telescope. We do not, however, intend to penetrate to the quiet study, where books, tables and lists full of algebraic symbols and figures without end are piled up in bewildering numbers.

The Varied Work of the Observatory.—Of course, astronomical work is far more varied than can be described here. One of the astronomers may be occupied for months in taking photographs of the skies, in searching for new stars, and compiling a new photographic chart; another is engaged on a spectrum analysis of starlight; a third is busy measuring the craters on the face of the moon; another the spots on the sun; yet another endeavours to unravel the markings of Mars, and a sixth traces the course of meteors.

Hour upon hour passes by, but the observer still tarries at the telescope in the great domed hall, measuring the movements of a comet wandering on slowly; an assistant compares the light fluctuations of a variable star with the brightness of others near by; and a third person is drawing the grey spots seen on Mars. The pendulum-clock beats in deep tones, the signals on the chronograph click out sharply, and the murmured ticks of the chronometer tell of the flight of winged time. The morn dawns in the east; the little clouds on the horizon take on a pinkish hue, heralding the sun. The cleft in the roof closes with a growl; the stars die away in the morning light.

Over yonder an early train crawls on towards the city, conveying the first battalion of workmen to the dusty machinery of everyday life. And we, sunk in deep thought, walk home from that silent house where a careful watch is kept on the worlds above.

CHAPTER V

PHOTOGRAPHY AS AN AID TO ASTRONOMY

Wonders of Modern Photography.—The invention of Louis Daguerre (Fig. 51) has penetrated into every department of life, art and science, and gained the position of a most useful, nay, in some cases, even indispensable assistant. The lay mind can hardly conceive the aid rendered to science by photography. Take the little photographic apparatus, for instance, which is let down into the stomach and photographs it by the help of a tiny incandescent lamp; others photograph the interior of the intestines, the back of the eye, or, assisted by Röntgen rays, the whole human body. Meteorologists are enabled to portray lightning and cloud formations that pass almost as soon as they are seen. Microphotography reproduces the tiniest living objects, the most delicate organs of microscopically minute beings, bacteria containing all sorts of dangers, things, indeed, that are invisible to the human eye, and reproduces them in huge dimensions.

There are apparatus that register earthquakes by photography, others that are let down to the bottom of the sea to picture ocean's mysterious depths. Cinematograph-like apparatus photograph the swiftest movements of man and beast in a fraction of a second—a bird on the wing, the wing-beats of an insect in flight. Hundreds of pictures of flying rifle- and cannon-shots can be taken in a single second—in fact, there are cannon-balls that take photographs themselves, and are fired into the air to snapshot the district. Pigeons and kites that take photographs are no longer a novelty; the aeronaut carries his camera aloft with him to get a bird's-eye view of the world at his feet. There are apparatus to reproduce music and speech by photographical means. The detective, the journalist, in short, everybody and everything, profit by Daguerre's ingenious invention.

Fig. 51.—Louis Daguerre, the Inventor of Photography.

Fig. 52.—Section of the Constellation Perseus, seen by the naked eye. (See Fig. 54.)

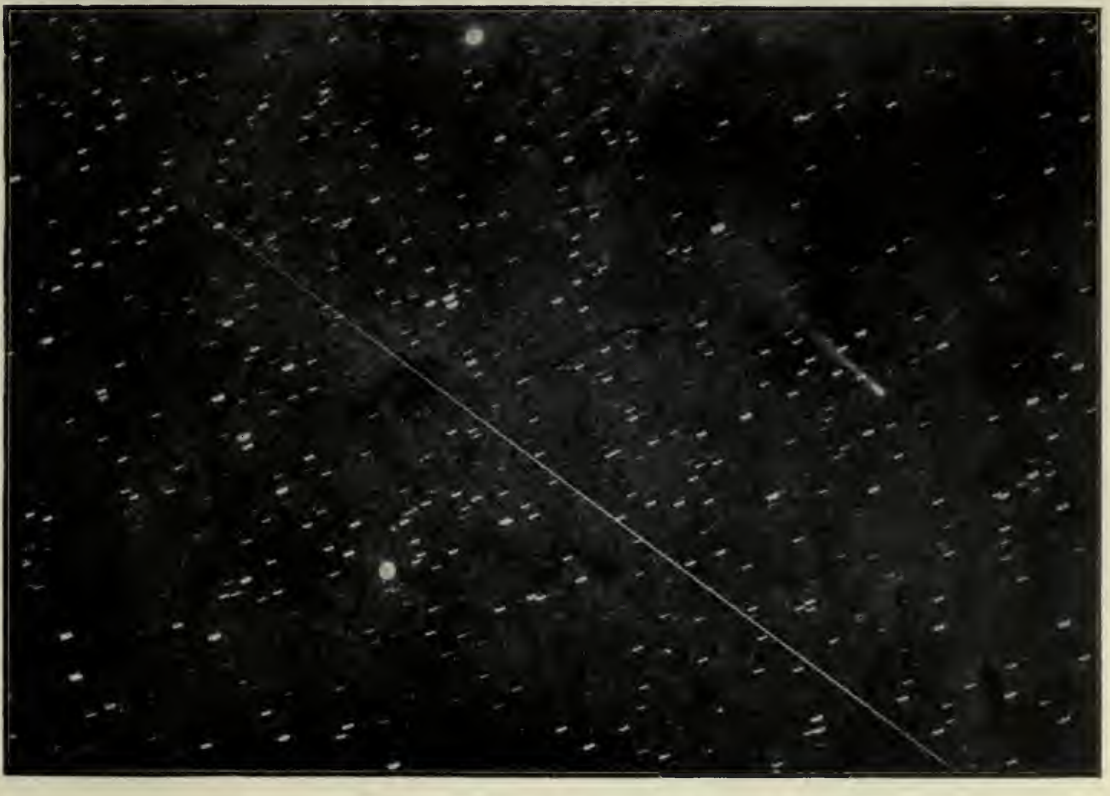


Fig. 53.—Accidental Photograph of a Shooting Star.
(Taken by E. E Barnard, Lick Observatory.)

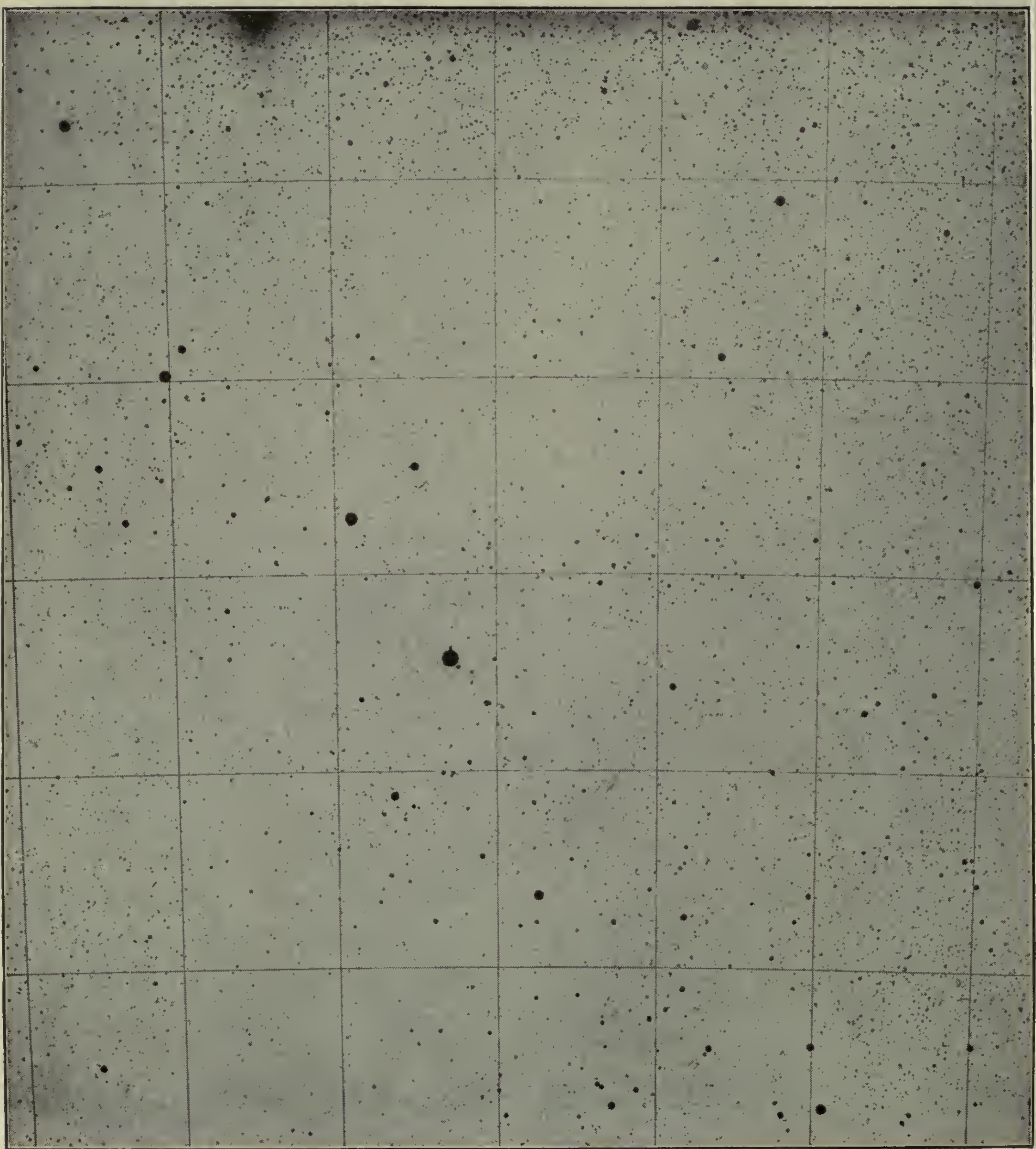


Fig. 54.—Photograph of a section of the Constellation Perseus. (See Fig. 52.)

(*After a Photographic Chart by J. Palisa and Max Wolf.*)

Photography as an Aid to Astronomy.—Astronomy, too, constantly turns to photography for aid. Things the eye can only discern with difficulty or not at all are vividly reproduced by the glassy orb of the camera on its retina—the sensitive plate. The statement that a camera sees more distinctly than a normal eye is hardly correct; we should rather say that the light impressions are collected on a prepared plate, by exposing it to the rays of light for the necessary time. Besides, the light to be considered not only consists of optically effective rays, *i.e.* those easily discernible to the eye, but, above all, of chemical ones, which do not influence the eye to any degree, but act strongly on the plate. The eye tires if it gaze at a weakly-defined object for any length of time, whilst photography reproduces it the more boldly the longer the camera is turned on it. This circumstance renders photography an excellent assistant to astronomy. There are districts in the fixed-star regions apparently almost barren; a normal eye can perhaps recognise three or four stars, the telescope may reveal thirty or forty, but the photographic plate, after having been exposed for three or four hours, will betray the presence of several hundred celestial bodies, which had even escaped the eye through the telescope (Figs. 52, 53, 54).

Ultra-violet Rays.—Some of the heavenly formations possess a quantity of ultra-violet light, which does not act on the eye, but greatly influences the camera owing to its richness in chemical rays. A certain kind of celestial body—the cosmic nebulæ—is very rich in such ultra-violet light, and many of them would have remained totally unknown to mankind had photography not brought them within the ken of science. There are, however, some creatures able to perceive these rays—ants, for instance. It is well known that ants always carry their eggs to spots where no light can penetrate. If they are exposed to these ultra-violet rays quite invisible to us, they will immediately begin to haul their offspring into the dark. The Henry Brothers, of Paris, two well-known French astronomers, once experimented with a little paper box containing ants and eggs, which they fixed to the eye-piece end of a telescope. The instrument was then turned on a part of the sky containing cosmic nebulæ, and the astronomers plainly heard the ants grow restless and scamper about, withdrawing their eggs from the light of those distant gaseous clouds in space.

Celestial Photography.—The first celestial photograph was taken by the astronomer Bond in 1850—a lunar landscape. The great susceptibility of present-day dry plates has helped photography to attain the important position it now occupies in astronomy; all large observatories possess several cameras for celestial photography. Ordinarily, the telescope is made into a photographic apparatus by fixing the box with the sensitised plate at the eye-end. There are, however, special photographic telescopes, whose object-glasses are so shaped as to bring all the chemically active rays to the same focus on the plate (Fig. 55).

With very few exceptions all celestial photographs are time exposures. As the stars do not remain stationary, but wander on from east to west during an exposure, which frequently lasts several hours, the photographic apparatus or the telescope has to be fitted with a clockwork movement which turns the camera in time with the star, and keeps its light focused on to one and the same spot on the plate. In order to control the precise working of the clockwork a second telescope is attached to the apparatus—a "finder"—which also shows the star in its field of view. Comparisons can then be constantly made as to whether the star is in the same position in both telescope and apparatus.

Solar Photographs.—Photography is of great importance for solar investigations; at Greenwich the sun is photographed daily, and at some observatories several times a day. Most intricate apparatus is needed for photographing the sun. The vast amount of light it emits either has to be greatly weakened, or the time of exposure shortened to a few thousandth parts of a second by shutters working at a great velocity. It is impossible for all the occurrences during a total solar eclipse, where most important astronomical events are crowded into two or three minutes, to be recognised and noted down; hundreds of photographs can, however, be taken within this short time, and cameras thus form an important part of the equipment of all the astronomical expeditions for the observation of solar eclipses (Fig. 57).

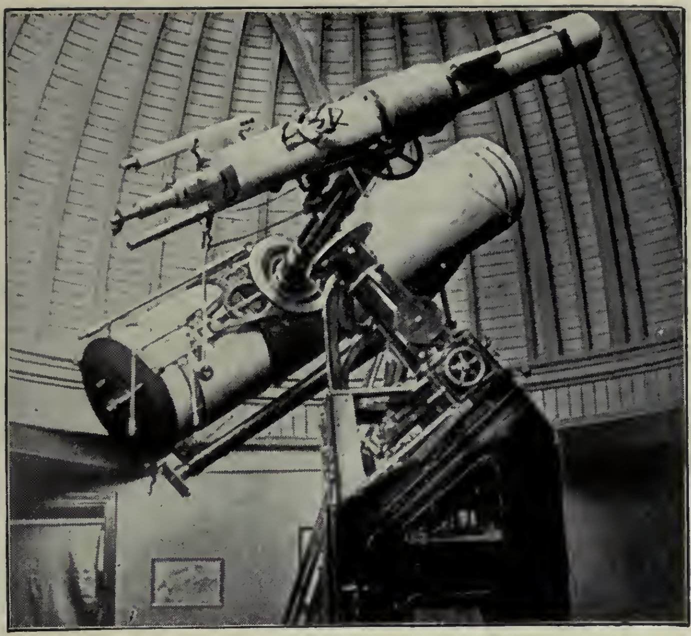


Fig. 55.—Photographic Telescope.

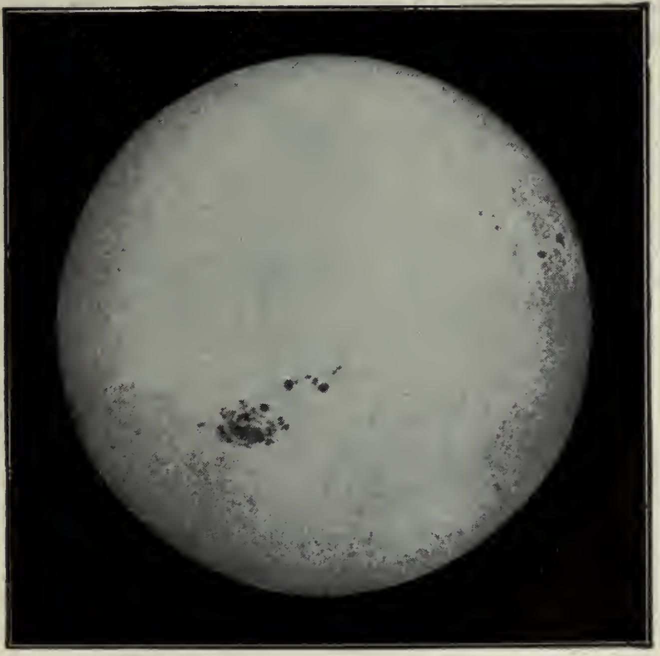


Fig. 56.—Photograph of the Sun.

(Taken at Potsdam, by Lohse.)

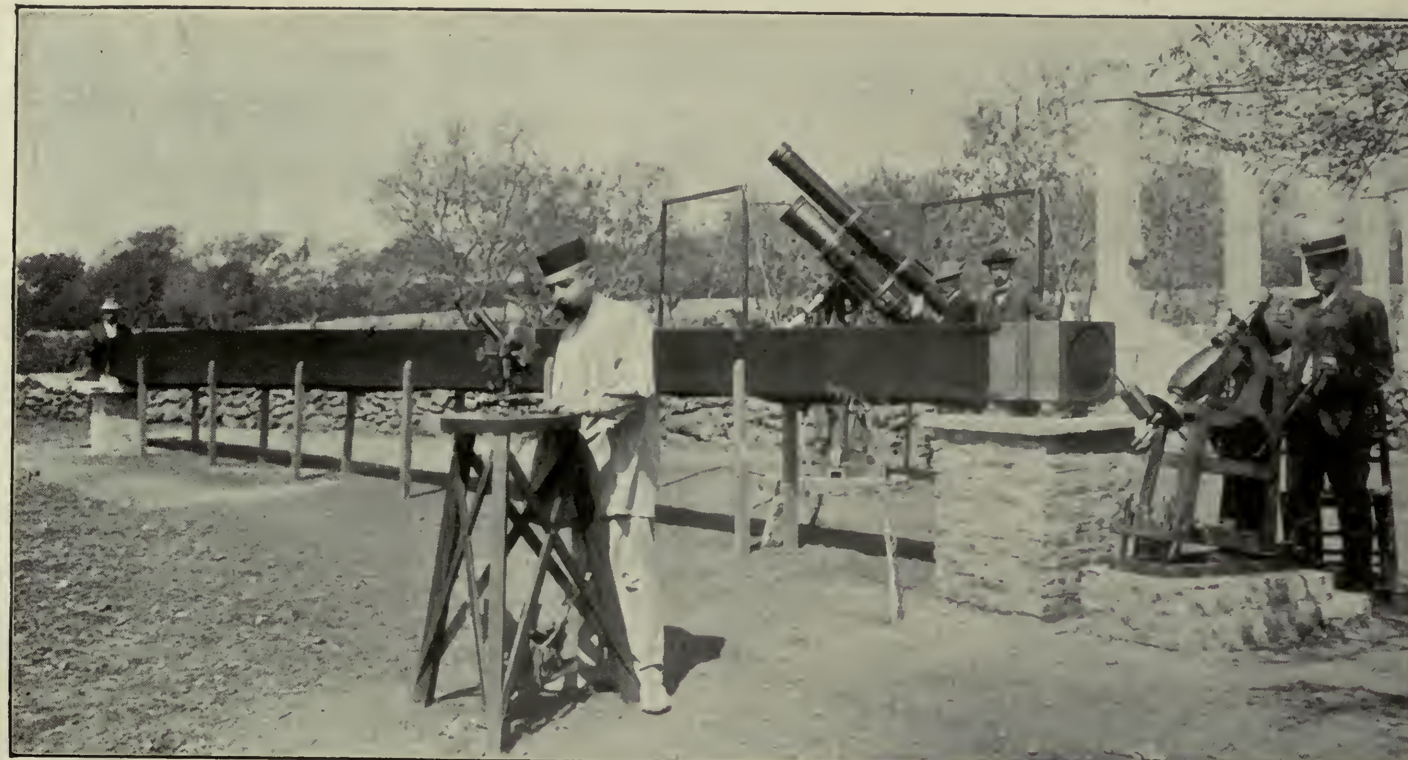


Fig. 57.—Giant Photographic Camera for Solar Eclipses.
(Situated horizontally in the background.)
(After a photograph by Dannenberg & Co., Berlin.)

Fig. 58.—The Ptolemy Mountain Regions in the Moon, according to Drawing.

Fig. 59.—The Ptolemy Mountain Regions in the Moon, according to a Photograph.

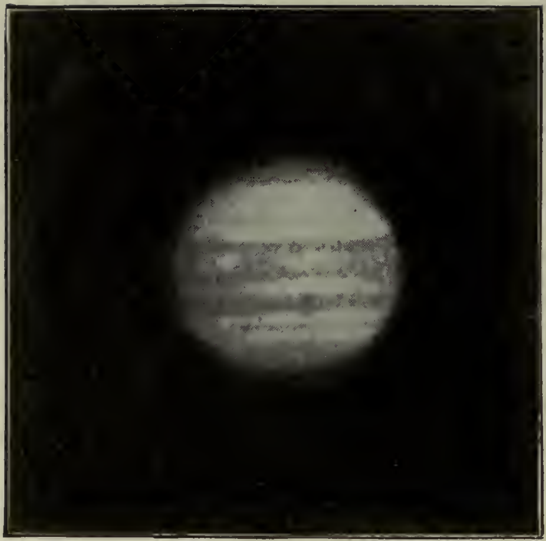


Fig. 60.—Photograph of Jupiter.

(Taken at the Lick Observatory.)

Fig. 61.—Photograph of Saturn.

(Taken at the Lick Observatory.)

Fig. 62.—Photograph of Mars.

(Taken by Percival Lowell.)

It is equally important to photograph frequently the surface of the sun itself (Fig. 56). A scrutiny of the sun through an astronomical telescope has shown that its surface, besides having large spots—or rifts in the clouds of metallic vapour —is riddled with millions of tiny dark and light dots, which almost give the impression of the disc having been strewn with gravel. This is termed the granulation of the sun, and investigation, only made possible by diurnal photography, has proved these dots not to be, as was formerly believed, aimlessly scattered about, but that, on the contrary, certain regular operations are carried on, whose influence on other solar happenings is not yet fully determined.

Lunar Photographs.—Lunar photographs have been almost equally productive of good results, although moonlight does not permit of instantaneous photography; the plates have to be exposed from one to three seconds. The difficulty to cope with here, should the air not be quite calm and tranquil, is the passing of aerial layers of varying thickness and temperature during this interval, each one refracting the light differently. That is why the more delicate lunar details appear just a trifle blurred. Nevertheless, excellent pictures can be taken with good cameras amid tranquil air conditions, which sharply set out thousands of circular moon craters (best seen near the "terminator," or boundary between light and darkness), mountain ranges, large spots—said to be the beds of former lunar oceans—and so on, as the photographs reproduced in Chapter XVI. fully prove. Now, although a good photograph will reproduce most intimate surface details, even to tiny cracks and craters clinging parasite-like to larger ones, the direct observation of the moon by a practised observer is often attended by more satisfactory results than photography can show. A really good telescope reveals far more minute particulars than can be supplied by the very best lunar photographs. If, in spite of this, the drawings of moon landscapes are less explicit than photographs, it must be put down to the almost bewildering richness of detail offered by the rocky uplands of the moon. It would take a draughtsman months to set down all that the camera notes in a few seconds (Figs. 58, 59).

Planets and the Camera.—Planet photography is still in its infancy. As the light of these distant bodies is very faint when magnified sufficiently to show detail, the plates have to be exposed for several seconds, and the motion of the air prevents anything like sharp pictures resulting. It is interesting to compare the photographs of Jupiter and Saturn reproduced here (Figs. 60, 61) with those shown in Chapter XIX. Attempts to photograph the Mars canals have been crowned with success; one of these is shown in Fig. 62.

The Non-Planetary Objects.—Celestial photography has been of the utmost value where non-planetary objects are concerned, such as fixed-star clusters and nebulæ and other cases, where exact detail is not so necessary as the reproduction of the object itself. A telescopic scrutiny of the sky on a clear night will reveal peculiar dim grey clouds of unvarying position, chiefly situated near the Milky Way. These are masses of glowing gases, floating immeasurable distances away from our solar system, which may, in millions of years to come, condense themselves into fiery, radiant suns. The scientific designation for these luminous clouds is nebulæ. These are the formations principally emitting the ultra-violet rays referred to on p. 45. Here photography is far superior to ordinary observation, as the delicate trails and branches of these nebulæ, which permit all sorts of calculations as to their motion to be made, cannot be seen by the human eye, whilst an exposure of eight to ten hours defines them very clearly in the camera. Photography scores here even over the best telescopic work of a most painstaking observer (Figs. 63, 64).

There are several cases on record where such nebulæ were only discovered by photography, and we have recently taken to photographing the skies systematically in stretches to get an exact idea of the whole number of nebulæ contained there. In so doing a somewhat similar vaporous structure has been met with from time to time, which was, however, soon revealed to be something utterly different. It moves on slowly and alters its position as regards the stars around it. This motion betrays its nature—it is a comet, which has penetrated into the planetary regions to pay the sun a visit (Fig. 65).

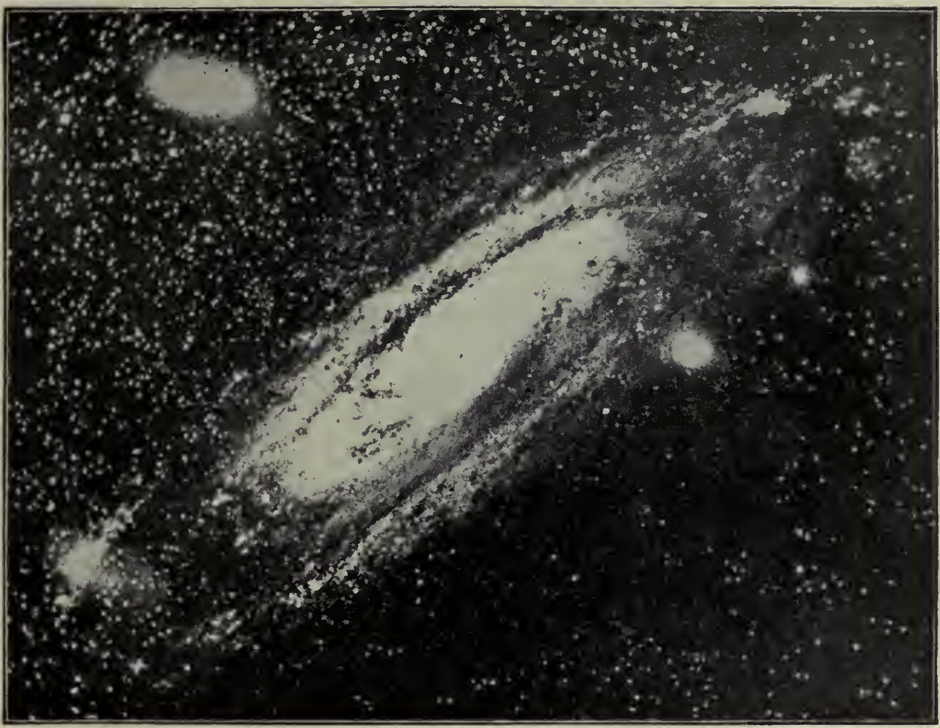


Fig. 63.—The Nebula in Andromeda.

(*After a photograph taken at the Yerkes Observatory by Professor Ritchey.*)

Fig. 64.—The Nebula in Andromeda.

(*After a drawing made at the Telescope.*)

Fig. 65.—Photograph of Perrine's Comet in 1902.
The lines are caused by the motion of the stars during the one-hour exposure.
(*After a photograph by Dr. Isaac Roberts.*)

Fig. 66.—Photograph of a Planetoid.

The Planetoids.—It would be impossible to do without celestial photography in looking up the tiny planets —planetoids or asteroids—which encircle the sun between Mars and Jupiter, and of which over 700 are listed to-day, although the first one was only accidentally discovered in 1801.

These tiny planets exactly resemble the small fixed stars and are betrayed by their motion alone, otherwise it would be perfectly impossible to pick them out from among the thousands of other similar stars. Fixed stars are motionless, whilst the planets, the "children of the sun," wander

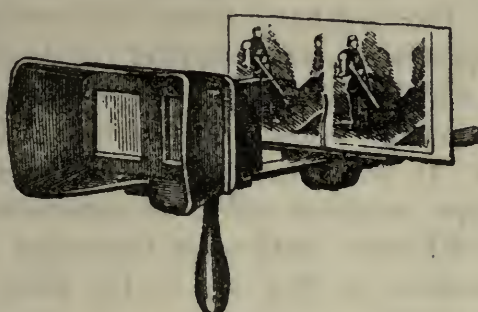


Fig. 67.—Stereoscope.

on restlessly. The fixed stars appear in the camera in dot shape; the planets, on the other hand, having moved during the long exposure, leave a trace of their passage across the heavens in the shape of lines (Fig. 66). When a tiny line, about the thirtieth part of an inch in length, is found on a celestial photograph, it is known to be the mark of a planet.

Photography also assisted in the discovery of the minute moons in the vicinity of Jupiter and Saturn which telescopic observation would probably never have revealed.

Stereoscopic Celestial Photographs.—A very special feature of celestial photography are the stereoscopic photos taken of the moon, stars and planets, which show them standing out in bold relief (Fig. 68). The stereoscope is a very interesting instrument, which can be used for scientific purposes as well as for instruction and amusement. We have all seen it in the shop windows—a small wooden box, with two glass eyes, in which two photographs of the same subject are inserted (Fig. 67). In gazing at them the two photographs seem to melt into one, thrown so well forward that it hardly appears credible it is really only a picture. We can only get a comprehensive view of the things around us with both eyes because we are able to look a little to the left with the one and to the right with the other eye, thereby embracing these subjects in our vision. This is no longer the case with things farther away—the moon, for instance—and that is why we do not see the moon as a globe, but as a disc instead. A one-eyed person cannot see anything stand out prominently—that is, not quite close to his vision—and this relates to the ordinary one-eyed camera as well. A "two-eyed" apparatus—one having two object glasses—takes pictures which differ a little from each other, the one portraying the subject more from the left and the other from the right side. If these two pictures are brought together in the stereoscope, what we call a "stereoscopic effect" will be the result. A different method is necessary in photographing celestial bodies, as they are so far away that the small space separating the two lenses of a stereo-photographic apparatus would not produce any difference in perspective. Two pictures—we will say, of the moon—are therefore taken by telescope at different times; the moon has changed its aspect a little between whiles, and the difference in angle of the two pictures has not been caused by moving the apparatus, but by the motion of the photographed object itself. The moon is plainly proved to be a sphere in the stereoscope, and not the disc it appears to us. The sun also stands out in globular shape, and its spots are seen to be formations floating across its surface.

The stereoscopic picture of a comet is always full of interest, as it clearly sets forth how very far in front of the stars the comet passes through space. A special instrument—termed a stereo-comparator—permits changes of star grouping, due to stellar motion, to be detected with the aid of such reproductions.

A Great Photographic Map of the Heavens.—The grandest achievement of celestial photography will, however, be the great photographic map of the heavens, on which work has been progressing for many years. It will consist of about 20,000 sectional pictures of the fixed-star heavens, and include all stars up to the fourteenth magnitude, about thirty millions in all. Eighteen observatories in different parts of the world share in the work, each having to take at least 1,200 pictures. This truly gigantic undertaking, when finished, and repeated after an interval of years, will afford us most valuable information as to the alterations in the stellar realms.

CHAPTER VI

WHAT THE PRISM TELLS OF THE STARS

I KNOW of a marvellous magic wand which far surpasses all the cunning of the great magicians from Bellachini to Lenormand. Hold it up in the bright sunshine or the light of the distant stars, and it will immediately begin to tell wondrous tales, to solve problems and riddles which seemed eternally unsolvable. Only an insignificant three-cornered piece of glass, such as hangs in dozens from many chandeliers; we call it a prism, and few people guess the splendours it contains. Did we not in our childhood delight in gazing through such a prism, and seeing a many-hued world suddenly rise up, red- and green-bordered houses, violet people, and yellow-red trees? These times have passed long ago, and we have seen things that seem far more wonderful than a piece of glass that colours the world; and yet this bit of glass is one of the greatest marvels known, and has taught the scientist the What and the How of the whole world-structure as far as the stars reach!

The Only Messenger in Space.—There is but one messenger to bring us news from the far land of Urania, and there is none that can travel faster—an express train going at a snail's pace in comparison. Hundreds of thousands of miles a second, from sun to earth and back again, in one single quarter of an hour! The great task set the astronomer is to translate correctly the language this messenger speaks, for, if we cannot decipher his communications, all the occurrences in the distant country of the stars will for ever remain unintelligible. A number of instruments had to be invented to assist in the translation of the speech of Light, this solitary messenger from afar—telescope, camera and spectroscope. The last is the subject of our present chapter, and its chief component part is naught but that magic glassy wand, the prism.

Fig. 68.—Stereoscopic Picture of the Moon.

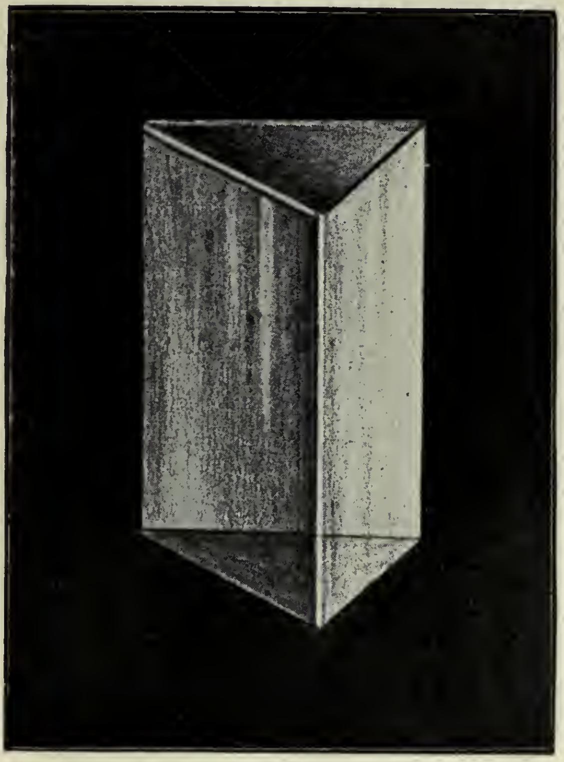


Fig. 69.—Glass Prism.

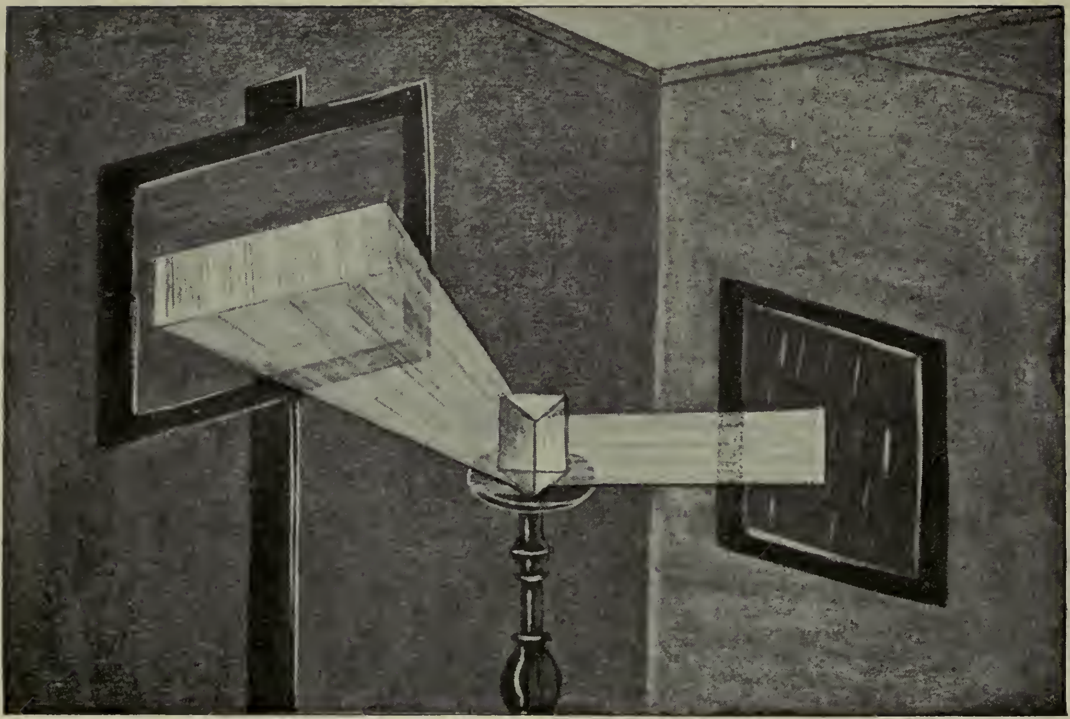


Fig. 70.—How a Spectrum is formed.

The ray of light coming in from the right through a chink in the shutter strikes the prism, which refracts and separates it, thereby causing the coloured ribbon of the spectrum to form on the screen on the left. The red end of the ribbon is on the left, the violet end on the right.

Fig. 71.—Sir Isaac Newton.

How do we Know?—A certain amount of scepticism prevails regarding the results of astronomical investigation. How can it be positively stated that those distant stars are so and so many miles away, have such and such a diameter, move at such and such a rate, and will be stationed there and there on a certain date? We shall leave an explanation of this to another chapter, and only occupy ourselves here with a branch regarded by the lay mind with the most utter scepticism, as positive results appear so very unlikely. I refer to astrophysics, the astronomical department dealing with the conditions, constitution and substances of other celestial bodies.

It is so easy to ask, "Pray, how do *you* know?" on reading that the sun contains hydrogen gas, sodium, iron, nickel, magnesium and other elements; that there is not a breath of air on the moon; that water vapour is found in the atmosphere of Mars; that the comets carry masses of hydro-carbon gases; and that certain substances can be found on certain stars as incandescent liquids or vapours. These things cannot be determined by telescope, and no chemist has ever mounted to the skies, armed with retort and reagent vessels—so, really, how could one find out?

Light: What It Is.—The ray of light which tells the telescope so many secrets brought all these discoveries in its train, and it only needed the services of a special interpreter, this being eventually found in the guise of the prism.

Light is an appearance that only occurs when all the infinitesimally delicate particles of the ether which fill the whole of space, and which we will, for easier comprehension, take to be an impalpable jelly, fall into a certain vibratory movement. Although these vibrations are extremely short, they are tremendously fast, and the whole motion can best be compared to that of waves. A stone thrown into a sheet of water disturbs it in such wise as to produce circles of ever-widening dimensions; and a source of light emits light-waves in all directions in very much the same manner. Light-waves are only about a forty-thousandth part of an inch in length, but they follow each other with such rapidity that many hundreds of billions of vibrations are sent out or, rather, meet our eye in one single second.

Colour of Light.—The difference in colour is due to the varying number of vibrations. Four hundred billion vibrations per second produce red, 560 billions green, and 750 billions violet light. White light, which is often regarded as the most primitive of all, is, on the contrary, the most complicated, as it can only be obtained when all the colours act in unison. A simple experiment will verify this statement. Paint a white circular piece of paper with red, orange, yellow, green, violet and blue colours (as shown in Fig. 72), run a pin through the centre and twirl it round

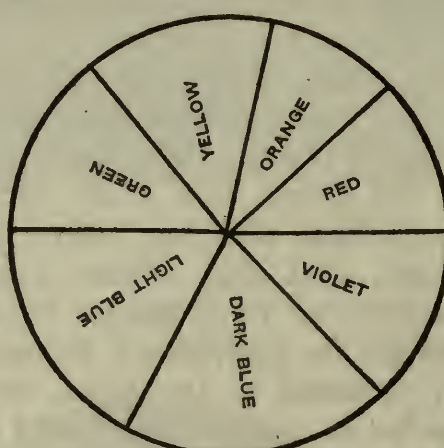


Fig. 72.—Colour Disc.

rapidly; we shall then discover that it is impossible to recognise the separate colours, as they have all united to make white.

The Action of the Prism.—The purpose of the glass prism (Fig. 69) is to deflect the rays of white light passing through it from a straight course; to "refract" them, to use the scientific term. If a ray of white light, say a sunbeam, were to fall upon a prism, it would not cast a white patch of light on to the wall straight opposite, but a broad, continuous ribbon of light would be formed a little farther on (Fig. 70). The most remarkable part about it is the fact that this band is coloured and reproduces the colours in their correct succession: red, orange, yellow, green, blue, and violet.

Sir Isaac Newton, who as a youth amazed the whole world by his great discoveries, was the first to draw proper

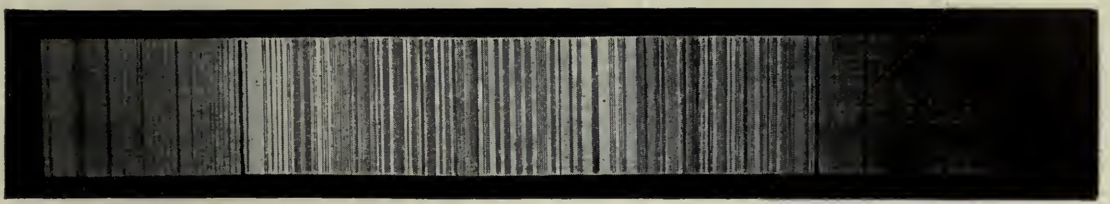


Fig. 73.—Fraunhofer's Lines in the Solar Spectrum.

Fig. 74.—Jóseph Fraunhofer.

Fig. 75.—Observation at the Spectroscope.

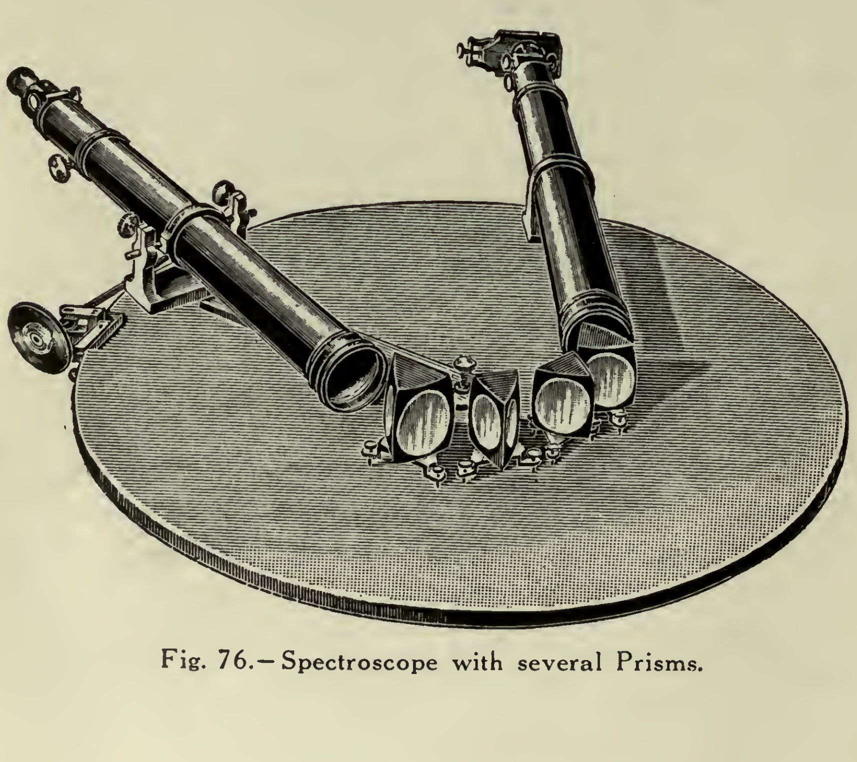


Fig. 76.—Spectroscope with several Prisms.

deductions from this simple experiment. He recognised that all these colours were contained in the sheaf of white light, that white light is composed of these different colours. If the coloured rays coming from a prism are collected by the help of a burning-glass, white light will again appear; but if any one colour, say blue, were cast out by covering it over, a reddish light would be the result. This is a most convincing experiment. It is impossible to create white light if one of the elementary colours is lacking.

The Coloured Band of the Spectrum.—The coloured ribbon of light called the "spectrum" contains a mass of extraordinary phenomena, affording science a great amount of work and totally undreamt-of results. If the spectrum of white sunlight be examined through a magnifying glass, it will be found to be streaked throughout with numbers of delicate dark lines (Fig. 73).

Josef Fraunhofer and his Discoveries.—A man lies buried in a Munich graveyard whose tombstone bears the inscription, "He brought the stars nearer to us." This man, named Josef Fraunhofer (Fig. 74), was born at Straubing in 1787; he died at Munich in 1826, at the early age of forty. Fraunhofer, who was an eminent optician, was the first to examine the lines in the solar spectrum, and was convinced of the great scientific importance of these insignificant streaks, which have been called after him. Had death not carried him off so soon, he would undoubtedly have made those remarkable discoveries which, fifty years later, were achieved by Bunsen and Kirchhoff. Fraunhofer was a born scientist. The son of a poor glazier, he was apprenticed to a Munich glass-cutter, and when a lad of barely fifteen met with an accident which nearly cost him his life. The glass factory at which he was employed collapsed, burying him beneath the ruins. He was rescued in a pitiable condition, and the King of Bavaria sent him a sum of eighteen ducats. The boy, thirsting for knowledge, bought himself scientific books and instruments with the money, and worked his way up gradually to be the chief optician of his day and a physicist of undying fame.

The Spectrum Apparatus.—The discovery of Fraunhofer's lines led to a careful investigation of the solar spectrum and to a comparison with the spectra of other sources of light, and it was found that every element contained an arrangement of the Fraunhofer lines peculiar to it and to it only. Special appliances had to be constructed for this work; one of these, the spectroscope, is shown in Figs. 75 and 76.

The principal part of the apparatus, the glass prism, rests on a metal pillar, and three small telescopes are turned on it. The tube on the right bears a contrivance which throws the light which is to be examined (a flame in Fig. 75) on to the prism through a very narrow, adjustable slit; the telescope on the left is used for examining the spectrum thrown by the prism; a third tube can be seen on the other side. A tiny glass scale is fixed into it and lit up from the outside. The markings on the scale are powerfully magnified and cast on to the spectrum, which is by these means divided into fractions. This is most important, in order to distinguish and number the many thousands of lines shown, for instance, by the solar spectrum.

The spectroscope showed sunlight to contain numbers of dark lines. The question arose how they originated; their formation must be governed by certain unalterable laws, as they always appeared in the same part of the spectrum. Light must have been deadened in these places, as black is synonymous with darkness.

Spectroscopical researches were then begun with terrestrial substances. The light of a metal wire heated to a glow only showed a uniformly-coloured band without Fraunhofer's lines, so it was evident that incandescence alone could not cause the lines, and that unknown processes must take place on the sun (which, according to all then known of it, was also an incandescent body) to produce these dark streaks.

Spectrum Analysis.—Two German scientists, Robert Wilhelm Bunsen (Fig. 77) and Gustav Robert Kirchhoff (Fig. 78) set to work to elucidate the spectrum problems, and arrived at that exact method of investigation we call spectrum analysis, probably the greatest aid to science since the construction of the telescope. Research was then begun with the spectrum of incandescent vapour; sodium,

Fig. 77.—Robert Wilhelm Bunsen.

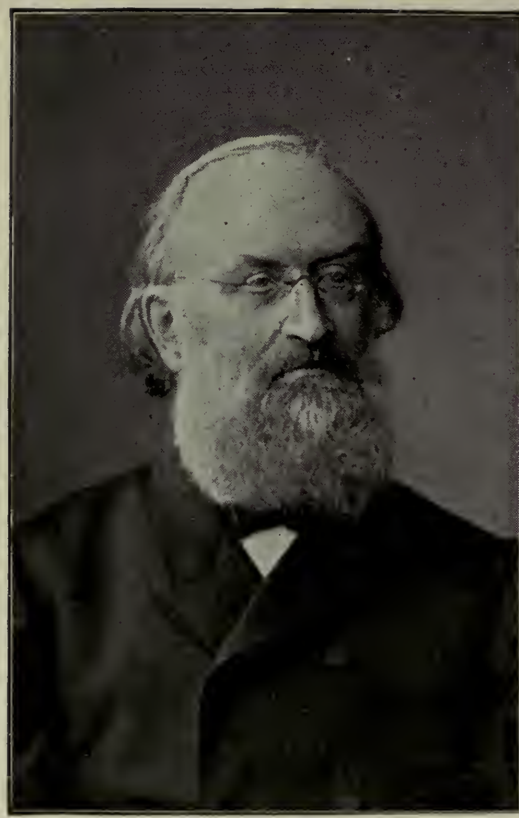


Fig. 78.—Gustav Robert Kirchhoff.

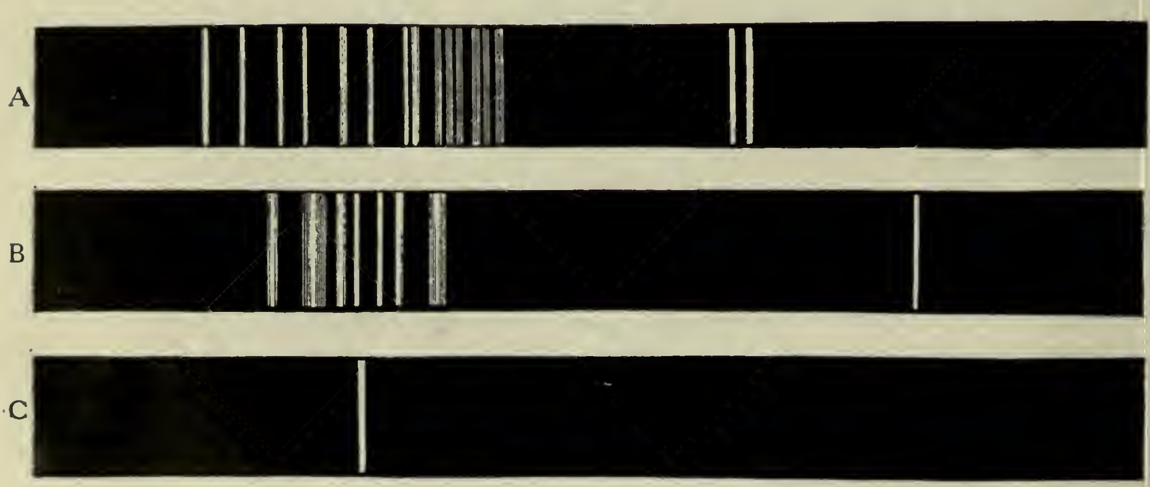


Fig. 79.—Spectra (bright lines) of Incandescent Gases: A, Caesium, B, Calcium, C, Sodium.

strontium and similar elements were vaporised in the colourless non-radiant flame of the Bunsen gas-burner, and surprising results followed. The ensuing spectra were of an absolutely different nature from those of incandescent solid bodies or that of the sun; only a few bright, various-hued lines were visible on a dark background—the whole band of light was extinguished with the exception of those bright lines (Fig. 79).

The importance of this discovery is easily understood. It is only necessary to point the spectroscope at a burning flame to be able to determine the element, as every substance possesses certain typical lines which invariably appear in the same position in the ribbon of light. Sodium, a compound of common salt, distinguishes itself by a double bright line in the yellow part of the spectrum; as soon as the slightest grain of common salt is dropped into a flame, the yellow sodium lines will appear in the spectroscope. To prove how very precise and sensitive this method of investigation is, it suffices to state that the 3,000,000th part of a milligramme of sodium gives out a plainly visible yellow line.

Why were the lines of the solar spectrum dark, whilst those of terrestrial substances were bright? This was the cardinal point. Investigators had recognised that many of the dark lines in the sun spectrum occupied exactly the same position as some of the bright lines of terrestrial elements, and this gave rise to the supposition that the incandescent fiery sun-ball contained these same substances. But why did they produce dark lines?

At last the riddle was solved. On placing a very bright limelight burner behind a flame in which sodium was vaporising (and which showed a bright yellow line in the spectroscope) in such wise that the flame of the limelight had to pass through the sodium flame to reach the spectroscope, the bright sodium line suddenly vanished, and a dark line appeared exactly in its place. The limelight burner, an incandescent solid body producing a coloured band without lines in the spectroscope, sends forth yellow rays as it gives a white light; these yellow rays, together with all other rays, had to pass through the yellow beams of the sodium flame.

All other rays were permitted to pass undisturbed, but the yellow rays of the same kind as it gave out itself were swallowed in transit.

It is plain that the particles of light swallowed by the sodium flame must be lacking in the coloured band of the limelight, and as the sodium vapour sucked up the same beams as it put forth itself, light was missing in this place in the spectrum, or, in other words, the yellow line had turned into a black one.

Spectroscopic observation laid down the following fundamental laws :—

1. An incandescent solid or incandescent liquid body gives a plain spectrum, a coloured band of light without lines.

2. Incandescent gas produces a spectrum consisting of bright coloured lines. The colour, position and number of the lines are dependent on the nature of the gas.

3. If the coloured ribbon of the spectrum shows dark lines, the light emanates from an incandescent solid or liquid body, and has to pass through a layer of gas cooler than the substance itself. The position and number of the lines are dependent on the chemical nature of the gas. The appearance of the spectrum lines permits conclusions as to the pressure exercised on the radiant body; widened lines mean high pressure. To repeat, if a spectrum shows dark lines, the rays of light producing it had to pass through a layer of gas in which those substances were contained whose characteristic dark lines appear in the spectrum.

The Astronomical Revelations of the Spectrum Analysis.—The value of this discovery was soon apparent. That distant ball of fire, the sun, must, in accordance with this finding, be surrounded by a gaseous envelope, for its spectrum betrays the existence of countless dark lines, and at one blow the inference does away with the former views of the constitution of the sun. Spectrum analysis has fully proved that the theory held a few decades ago that the sun was a dark globe in itself, surrounded by luminous gases, is absolutely false, as luminous gas alone would produce bright lines, and the dark lines of the solar spectrum only arise because the light of the incandescent ball—the real sun ball—

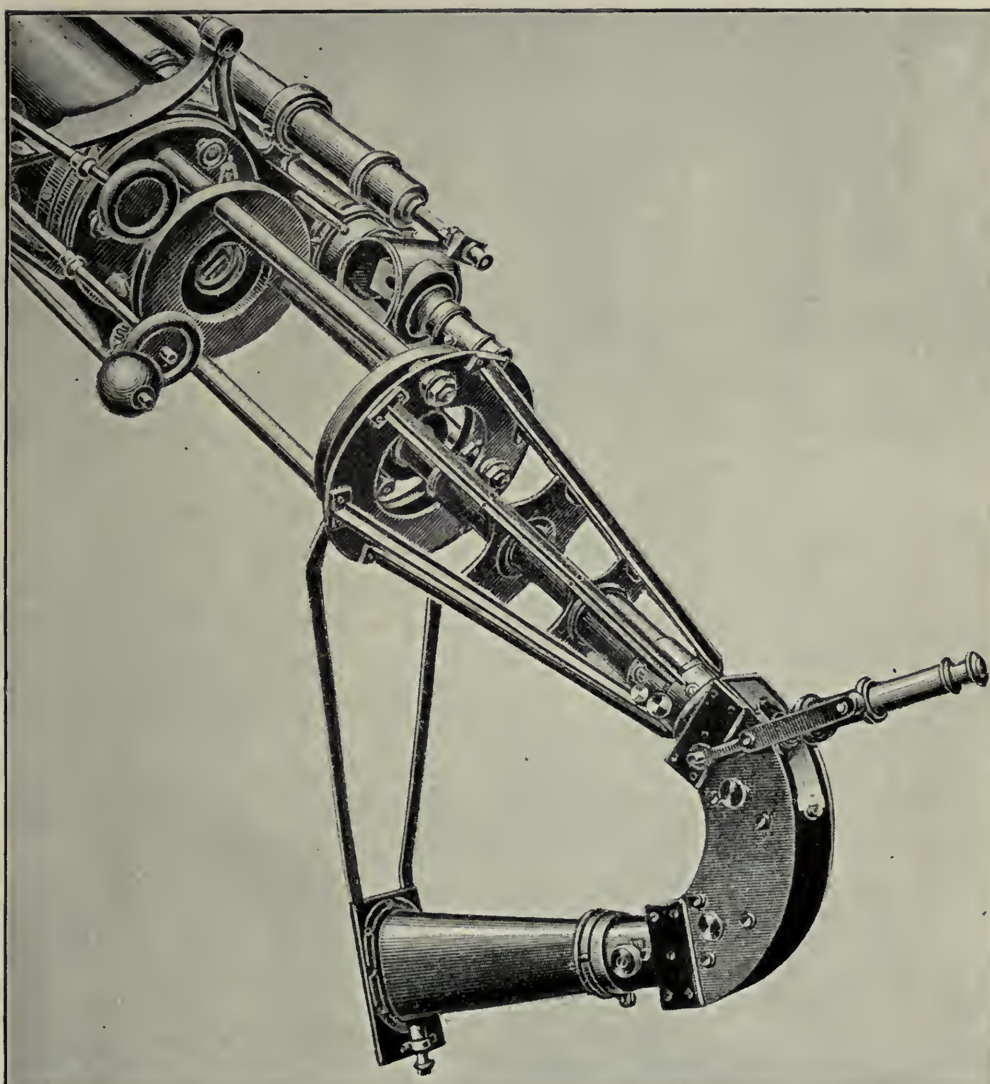


Fig. 80.—Spectrograph at the Observatory, Potsdam.

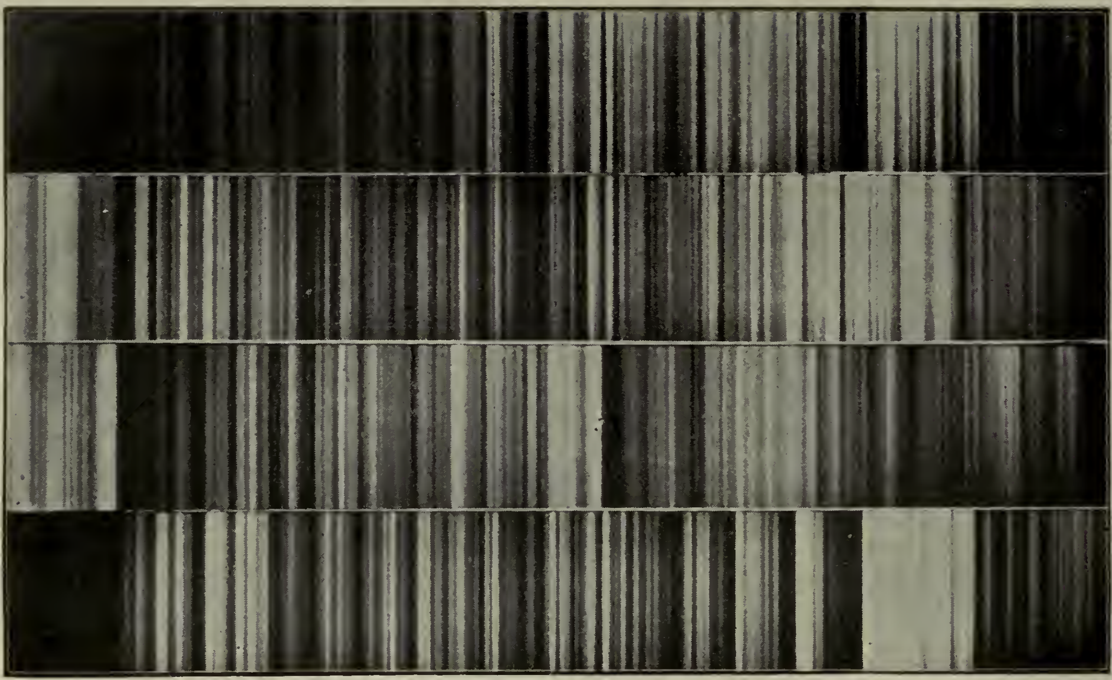


Fig. 81.—Spectra of various Fixed Stars.
The second lowest is that of the Sun.

Fig. 82.—Partial View of Stonehenge, showing the column behind which the sun rises on June 21st.

in the centre of the gaseous envelope has to pass through layers of gas.

To-day two thousand lines produced by sunlight have been measured and defined, and even identified, with terrestrial elements. We positively know that iron, nickel, sodium, hydrogen, calcium, barium, magnesium, chromium, copper and many other earthly substances are to be found on the sun in a vaporous condition, permitting an estimate of the colossal temperature. One fact leads to another, and results are achieved by this chain of evidence which seem impossible at first. Spectrum analysis is the chemistry of the distant stars. The lines belonging to gold and silver have not yet been discovered in the solar spectrum, and it would seem as though Dame Nature had not been lavish with the metals of Mammon on other stars either; but, on the other hand, elements have been found on the sun which led to their later discovery on earth—helium, for instance, recognisable by a line in the yellow part of the sun spectrum, was discovered on our planet by Sir William Ramsay whilst experimenting with clèveite.

The Spectrograph.—The ray of light in the spectroscope has not restricted itself to tales of the sun only, but has given an account of other celestial bodies floating in the farthest depths of the universe as well. The light of the stars is, however, too weak for the spectroscope alone, and the instrument has been connected with a telescope for this branch of work. The Astrophysical Observatory at Potsdam possesses one of these unique instruments, the so-called spectrograph (Fig. 80). It consists of a telescope with an extremely subtle and powerful spectroscope attached to the lower end. The refracting glass prisms are fitted into a crescent-shaped case, into which the light of the star is conducted by the long tube; the spectrum is observed through the small telescope that protrudes from the prism case. It can likewise be photographed, the camera resting in the funnel-shaped piece fixed horizontally to the prism box.

Examining the Stars.—Thousands of stars have been examined in the spectroscope, all of them showing numbers of fine lines (Fig. 81). It borders on the marvellous to realise that we know the elements contained in the incandescent gaseous envelopes of stars—so far away that the fastest express could not reach them in millions of years—which are revealed to us in the telescope as weakly glinting sparks. Aye, even more; the spectroscope has enabled us to estimate the age of the stars; we can tell if a star is at full radiance or whether it is in course of extinction. Stars burning whitish-blue are at full glow, whilst those of a yellowish hue, like that of the sun, or red, must have cooled off considerably, a supposition supported by the fact that the variable stars, *i.e.* those that shine more or less powerfully at times, are generally red.

How the Prism Reveals Stellar Motion.—The spectroscope has once for all established the absence of air and water on the moon; has shown Mars, the planet akin to our own earth, to possess an atmosphere with some hydrogen, and has, therefore, brought the habitability of the planet within the range of possibility. It has provided us with valuable information on cometary constitution, on the marvellous new stars that suddenly appear, on those gigantic gaseous clouds we call cosmic nebulæ so immeasurably far away; in short, on all celestial bodies yet to be mentioned in this book, and has created quite a new picture of the worlds above, not only of their chemical constitution and age, but of their motion as well. Even the fixed stars, those thousands of small stars that nightly twinkle in the skies, are not immovable; but their huge distance from us prevents our perceiving anything of their rapid transit, which can only be recognised by repeated measurements years or centuries later. We shall then see an alteration in the distances between the stars; some may have moved closer to each other, while others may have receded.

Tones and Light Altered by Motion.—There undoubtedly are some stars that approach or travel away from us in a straight line, like a train running on its rails. We cannot perceive any alteration in their position to the other stars, and the motion of these stars, which are rushing straight on to our earth and our solar system, would only have been noticeable by their increase or diminution of light after the lapse of thousands of years had it not been for the spectroscope. The motion of stars travelling straight on or away from us must call forth a certain change in their light, a statement I will attempt to illustrate. The height of a tone is dependent on the number of sound waves that strike our ear within a second; the more sound waves that reach us per second, the higher the tone. If we were to take up our position at a tram stopping-place, we should notice a certain car pass us at regular intervals of, say, ten minutes. If we were to walk in the direction from which the cars come and were to meet them, it would not take this time for the car to meet us; and if we were to walk in the direction they are travelling, more than ten minutes would elapse before a car would overtake us. The number of sound waves striking our ear per second will therefore also vary, should the source of sound be in rapid motion. A whistling engine emits a tone of a certain height if stationary at the time; if it were to approach us at a rapid rate, more sound-waves would meet our ear per second and the tone would rise in register; when a whistling engine passes us, the instant the approach turns into a retreat can be plainly recognised by the change of tone. This illustration holds good for light-waves too. The position of the lines in the spectrum varies according to whether the source comes rapidly towards us or travels just as rapidly away, and the motion of the stars in space should therefore be heralded by a proportionate change in the position of their spectrum lines.

Doppler and his Theories.—The first man to work out this idea was Christian Doppler, of Salzburg, in 1843, and he was severely attacked for his far-reaching discovery. His teachings were, later, more fully worked out by the Frenchman, Fizeau, who proved that there must be a derangement of Fraunhofer's lines in the spectrum of a star possessing such movement. Spectrum observations of the motion of stars in the line of sight are being systematically carried on at the present day at numerous observatories, and the alteration in position of the spectrum lines permits the direction and speed of the motion to be measured.

The stellar spectrum is compared with the spectrum of an artificial light placed next to the apparatus, and the linear deviations shown by a celestial body in motion can then be easily determined. If the lines are displaced towards the red end of the spectrum, the star is receding from, if at the violet end, it is approaching us. The annual motion of the earth around the sun is reproduced in these alterations, and the glass prism tells the story of the earth's wanderings in space. It has also informed us that the Pole Star approaches us at a rate of sixteen and a half miles per second, whilst the brilliant principal star in the constellation Taurus, ruddy Aldebaran, recedes thirty miles and a half in the same time. How tremendously far off these stars are if centuries and tens of centuries pass without our noticing anything of their movements with the unaided eye!

Uniformity of Substance in the Universe.—The prism has drawn full many a secret from the messenger of the heavens traversing space in his thousand-leagued boots, secrets astronomers of former days did not even dream of. And what may the future yet contain for us!

All in all, spectroscopic discoveries have shown that everywhere in the universe like elements act according to the same laws and build themselves up to mighty worlds. A uniform law pervades space, and we recognise those sparkling lights overhead to be bodies of the same importance as our earth, their past and future now being laid bare to us.

CHAPTER VII

THE USES OF THE STARS

Some persons habitually regard everything and everybody by the use that may be made of it or them, their idea of the word being very closely related to hard cash. If we were all to indulge in this eminently practical view, many of the things proudly considered by civilised humanity as among its highest and most lasting possessions would indeed be of little "use" to us, as their value cannot be appraised by this rule of the market-place. Milton would rank far behind a smart man of business, if the activities of the two men were measured by the prosaic everyday scale some folk are so ready to apply. It is a difficult task to estimate brain-work according to its material value. Schiller received the absurd sum of £15 for his "William Tell," but he might just as well have been presented with a castle on the Rhine, for it is enthusiasm and not cold calculation that plays the part of valuer in these cases. Nor must we forget that things of but little practical value may possess a very high ideal one. The delight in all that is lofty and sublime will act as a perfect tonic and recreation on the mind of man weary with his daily round of toil; it will strengthen him to battle with the strain of this life, and assist him to emerge successfully from the struggle.

The Lesson of the Stars.—The majority of those to whom I have shown the wonders of the heavens in the silent observatory halls have usually been impressed and subdued by the majesty of the universe; but, naturally, there were some who could not leave the world's dross behind, and who were anxious to ascertain the actual use of the stars to us. As a matter of fact, the stars are of great use to us, or, rather, astronomy has a very definite value, although in my own humble opinion their ideal influence ranks infinitely higher. Man, the insignificant parasite on the grain of sand called earth, floating in the infinite, is by nature a searcher in the quest of truth and eternity; he would not be satisfied if he could not gain a definite idea, based on scientific research, of those sparkling lights overhead. And even if he were still more advanced in the grim realities of life, he would be unworthy of the civilisation he revels in were he entirely ignorant of the problems nightly set to him by the starry heavens. The knowledge that the vast army of stars moves according to eternal, inexorable laws, that this very regularity guarantees its everlastingness, unwittingly influences human actions and creations. The grandeur of the universe should be a powerful agent in eradicating that empty pride and class distinction from which the private and social contrasts that burden mankind generally arise. A careful study of our all-mother Nature will assist us to do away with self-righteousness and overbearing demeanour, and teach us dignity and modesty in every walk of life.

Practical Value of Astronomy.—But it is of the usefulness of celestial science I wish to speak. It has been stated several times in this volume that astronomy originally was a definition of time, a calendar science. Civilisation is more closely allied to time determination and definition than may be at first believed possible. Primitive man, whose daily work consisted in the protection and nourishment of his body, and who rested in his cave at night, was content with the setting and the rising of the sun to mark his day. It is quite probable that he, too, noticed an alteration in the position of the sun at different seasons, the appearance of the constellations at various times of the year; and, guided by them, began the preparations necessary to guard him from the cold and the rains. The more the brain of man developed, the more complicated his needs became; the higher civilisation rose the more his conception of time increased, and the greater his interest in the course of days and years grew. Stonehenge, near Salisbury, that ancient circle of gigantic hewn boulders erected about three thousand years ago, is naught but a time and calendar definition of our forefathers. The huge stone blocks, 150 in all, are set up in two circles; an altar stands in the centre, on which animals were probably sacrificed on certain days. On look-

Fig. 83.—Monument at Nuremberg to Peter Henlein (Hele), erected by the German Clockmakers' Union.

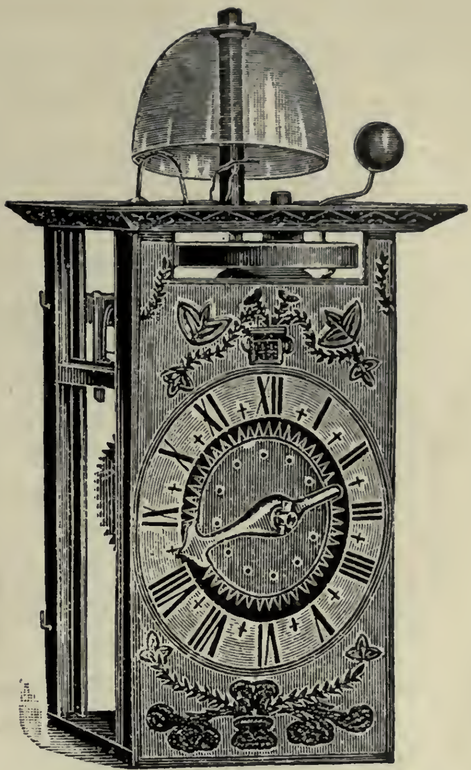


Fig. 85.—Old Household Clock.

Fig. 84.—Drum-shaped Watch from the Marfels Collection.

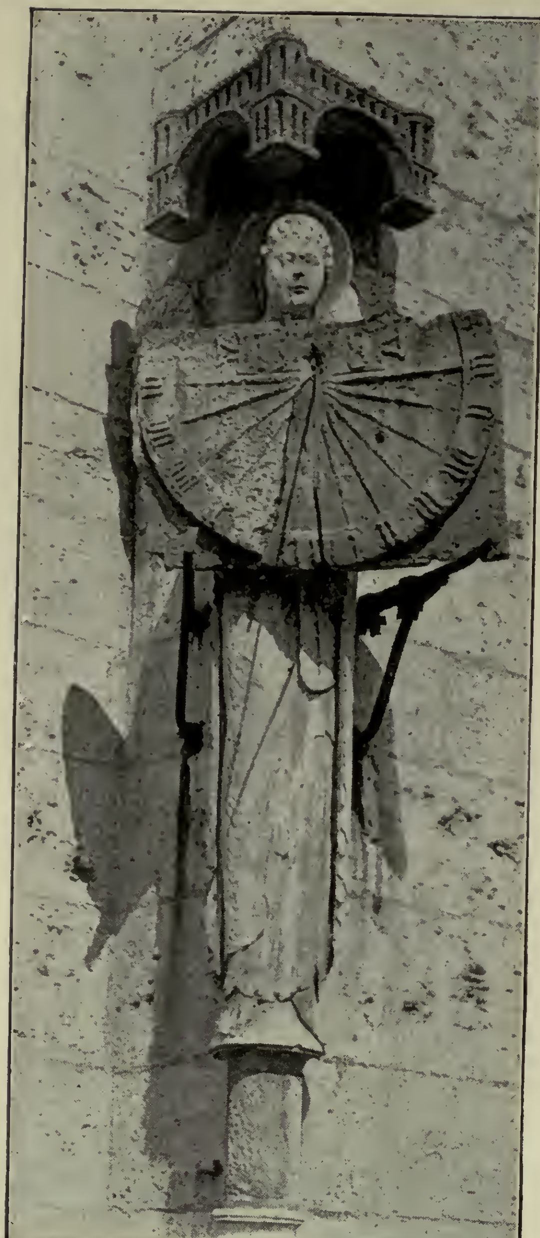


Fig. 86.—Sun Clock on Chartres Cathedral.

ing straight over the altar, the eye meets a stone column in the distance (Fig. 82), and on June 21 (summer's beginning) the sun will be seen to rise exactly over its top. Other boulders very likely served a similar purpose and were used as sun-dials.

Time's Changes.—They have gone past recall, those good old times when the post-chaise jolted one's bones over the country lanes and the postilion blew merry blasts on his horn. Past are the days when it took five minutes or so to strike a light or set the lamp burning, when telephone, telegraph, railway, motor-cars and all else that counts time by seconds were yet unknown. "Once upon a time!" We of the twentieth century, who grumble even at modern locomotion, pursue the very seconds. All this counting of minutes and fractions of minutes, rendered necessary by train and tram services, telephone and telegraph, which forces a more rapid mode of existence on us and permits us to accomplish more in an hour than was formerly possible in half a day, all this, I say, would be entirely impossible without the clock.

The Invention of the Watch.—Since when did we carry this ticking register of the fleeting hours about with us? It was a German who presented the world with the first watch, an honest locksmith of Nuremberg named Peter Henlein (or Hele, as it is popularly abbreviated), who constructed the first clumsy iron pocket chronometer (Fig. 83). The following account of it appeared in the *Cosmographia Pomponii Melae,* published in Nuremberg in 1511: "Every day finer things are being invented. Peter Hele, still a young man, has constructed a piece of work which excites the admiration of the most learned mathematicians. He shapes many-wheeled watches out of small bits of iron, which run without weights for forty hours, however they may be carried, in pocket or chemisette."

One of these earliest of pocket watches is contained in the celebrated Marfels collection (Fig. 84); it is made completely of iron, and the weird works show that the watchmaker's art was still in its earliest infancy. A very quaint feature is the pig's bristle in the centre of the works to regulate the movement—replaced now by the tiny throbbing spiral spring. This watch only has one hand, and a small knob is fixed above every figure on the handsome dial of punched bronze to enable the position of the hand to be told in the dark. The watch is not oval in shape, as is generally believed, but rather resembles a drum. The "Nuremberg egglets" are a decided improvement on these clumsy things, which were more suited to saddlebags than to a waistcoat pocket. Watches in those early days were expensive articles, purchasable only by gentlemen of rank, and circumstantial details are given in old letters and chronicles of the purchase or presentation of such an "egglet." Dandies for many years carried pretty little hour-glasses in their pockets. Mechanism in those days was hardly at its height; clocks and watches went very much as they pleased, and the lucky individuals of that period did not need to bother about fractions of a minute. Until the year 1700 watches only had an hour-hand, the minute hand was totally lacking, and it was impossible to tell time correctly within ten minutes or so; but in those days a quarter of an hour was of little importance. There was no boat-train to leave for Dover at 8.30 A.M., no electric car to be caught at a certain time, and the speed craze in all its shapes was yet unknown.

Early Public Clocks.—The people who dragged these timekeepers about in their pockets had no little weight to carry, and yet what a vast step in the right direction they marked! Until they were invented, in 1511, all smaller towns and villages had to depend entirely on sun-dials. True, in 996 the French priest Gerbert, who later reigned as Pope Sylvester II., constructed the first clock with weights and wheels, and some very rich communities had one such erected on the church tower or the town hall; but that was an extravagance only a few of the very largest towns could afford.* The oldest public clocks were those set up in 1314 on Caen Bridge, in 1340 at the Cluny Monastery, and the celebrated clock of Jacques de Dondi at Padua four years later. Instead of a pendulum these old clocks had a beam which swung horizontally and turned a spindle that

* Later researches by F. M. Feldhaus have questioned the correctness of the attribution to Gerbert of the invention of the wheelwork clock.

gripped the wheels. A precise movement such as the clocks have to-day was utterly unknown. Fig. 85 gives a picture of an old household clock.

Pendulum Clocks.—The connection of the wheels with the pendulum was another step onward. In 1639 Galileo proposed to use the regular beats of the pendulum for time determination and to keep it in motion by a wheel-work. The Dutch physicist Huygens constructed the first pendulum clock in 1657. These were naturally not intended for ordinary folk, and they did not need them either, as time was no object. Scholars and noblemen looked to hour-glasses and clepsydras (Fig. 87) for their time before pendulum clocks became popular. In both cases large glass bowls were used, filled either with fine dry sand or with water, which dripped away through a small opening into a smaller, notched vessel.

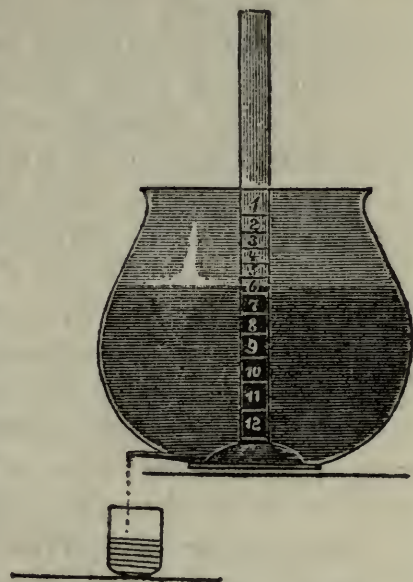


Fig. 87.—Clepsydra, or Water-Clock.

As an equal amount of sand or water flowed away within a certain period, there was not much difficulty in ascertaining the time up to a quarter of an hour or so. Smaller instruments, such as are to-day used for egg-boilers, measured off still shorter periods.


Fig. 88.—Shadow Column in Ancient Rome.

Sun-Dials.—Good water- and sand-glasses were, however, extremely expensive, and the lower classes pinned their faith to the sun clock (Fig. 86), which every paterfamilias of moderate skill could fashion for himself. The ancient civilised races knew of no other chronometer but this; in early Roman days there were special officials whose duty it was hourly to cry out the time as shown by the shadow columns (Fig. 88). Still farther back, people were content to tell the time by the direction of the sun or the length of the shadows thrown by trees and houses; ay, even their own shadows were used as clocks, for Pliny says: "I beg thee to honour my house when thy shadow will be six feet long." That most decidedly was the cheapest and least complicated movable clock in the world, always in action when its owner was in motion and the sun shone. I wonder what we should do with such chronometers to-day!

Astronomy and Time.—Few people ever give the fact a thought that time is "made" by the astronomer, who even sends it out into the world. We all of us regulate our watches by the chief clock in the observatory, for all public clocks, those of churches, stations, post-offices, etc., are either directly or indirectly regulated according to the observatory clocks.

Fearful confusion and endless railway accidents would result if station clocks, for instance, were not electro-magnetically regulated every day from the observatory head-quarters (Fig. 89).

Mariners and Time.—The astronomer sends his precise time determinations out into the sheer endless vasts of the oceans, for without this the ships would run risks too dreadful to think of. Each vessel possesses several clocks of great precision and particular shape and mounting, which render them independent of the tossing and rolling. These marine chronometers are veritable masterpieces of the watch-maker's art (Fig. 91). Many of them only deviate five seconds within a fortnight, during which period they have twice crossed the ocean. Sailors find occasion to regulate their watches in the ports of all countries, as the harbour officials generally send up a time signal at midday, and time is checked accordingly by the officers entrusted with the regu-

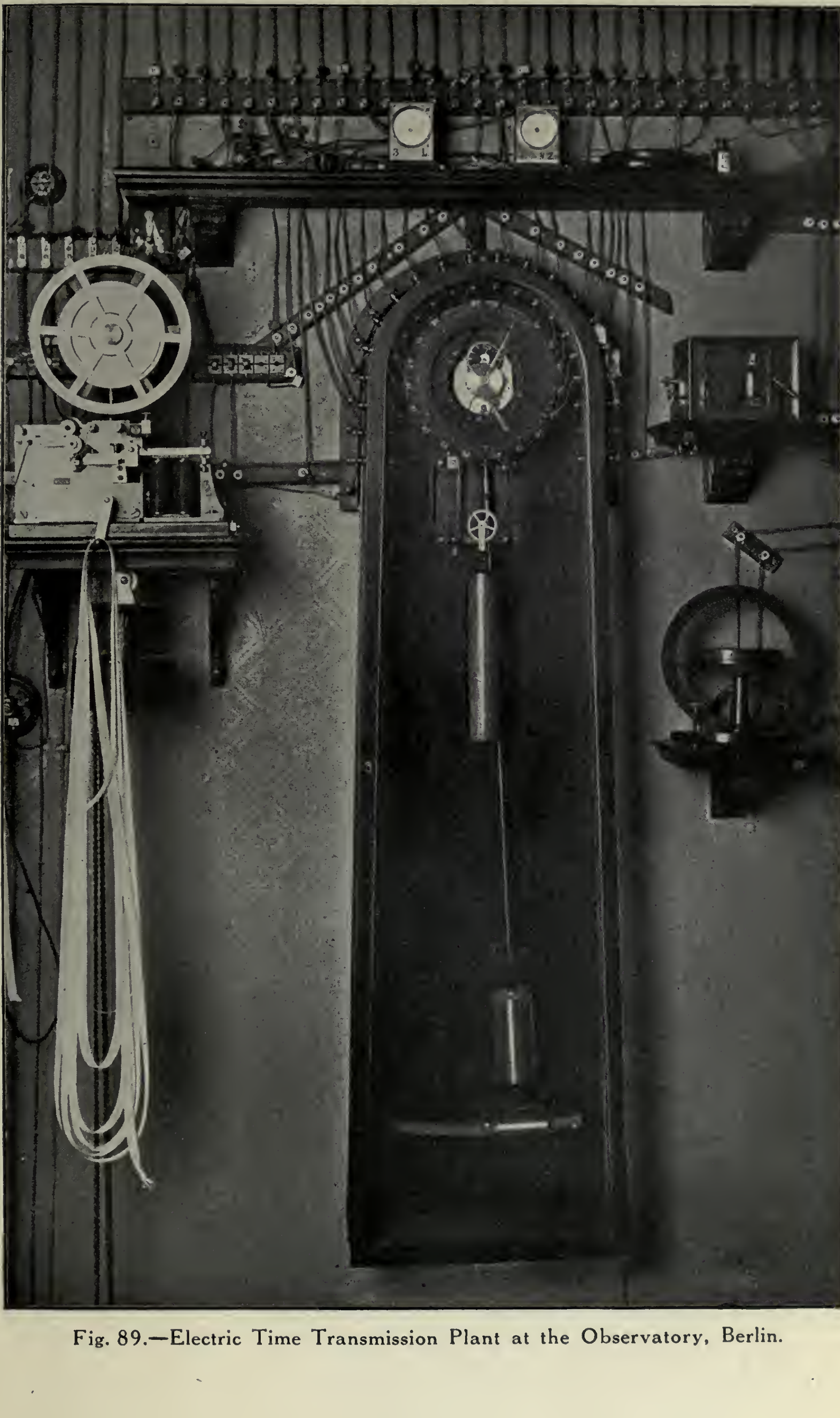


Fig. 89.—Electric Time Transmission Plant at the Observatory, Berlin.

Fig. 90.—Time-ball at Wilhelmshaven.

lation of the chronometers; this signal is usually given by a cannon, or the time-ball, a large ball attached by ropes to a signal tower, is dropped at a certain moment, say, 12 o minutes o seconds. This time-ball (Fig. 90) is worked by electro-magnetism from an observatory. As soon as the hands of the observatory clock indicate midday an electric current is transmitted to the cables that keep the ball in place

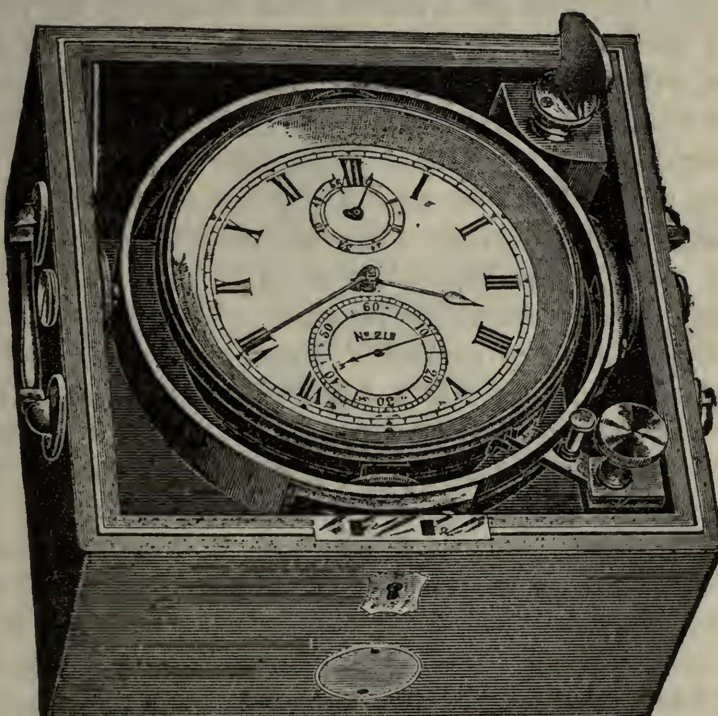


Fig. 91.—Marine Chronometer.

and releases it. Any slight remissness in the motion of watch or clock can thus easily be rectified.

The Astronomer the World's Timekeeper.—We shall recognise the great importance of this later; at any rate, we have learnt that the astronomer keeps time for the world. This duty alone should suffice to establish a high practical value for his work. He in turn takes his time from the most marvellous clock of all, which through all history has gone with unfailing accuracy, never fluctuating for a second, with the rotating earth for its works and the star-set heavens for its dial. The transit circle, the pendulum clock and chronograph aid him in reading the time from the stars.

The astronomer also attends to naval and explorers' chronometers, testing them in different temperatures, and working out tables in advance for their regulation in localities remote from civilisation.

The Nautical Almanac.—The ship driven from its course by tremendous gales, the expedition forcing its way onward through virgin forests or in the ice and snow regions of the Poles, are one and all guided back to safety by the astronomer's skill. A person familiar with observation and calculation will, if stranded at any desolate place in the world, soon be able to ascertain his bearings according to longitude and latitude to a very mile if an astronomical or nautical almanac, a chronometer and a sextant have been left him. All vessels carry such an almanac, in which the exact positions of sun, moon and planets have been determined for every day and hour, years in advance. The exact position of the moon is given for every hour, of the sun and planets for every day, of the stars for every ten days. The stars act as milestones and road-signs to the sailor who for weeks at a stretch sees naught but sky and water, and the Nautical Almanac may well be termed his sky Baedeker.

The Sextant and its Uses.—A small instrument called a sextant (Fig. 92) is used for the determination of the distance two stars are apart, or the distance between the moon and a star, or the altitude of the sun above the horizon. A small telescope is attached to this instrument; an adjustable mirror fixed to it is moved until the image of the star, whose distance is to be ascertained, covers that of the moon in the telescope. If the observation is correctly made, an indicator attached to the adjustable mirror will denote the exact angular distance between moon and star on the graduated limb of the sextant.

Astronomical Determination of Position.—We will now imagine a vessel to have been carried right out of its course; the captain can no longer tell his bearings or the direction in which he should continue. How can astronomy assist him in the circumstances? We will endeavour to elucidate this as simply as possible.

The division of the earth into a net of latitudinal and longitudinal degrees renders it possible immediately to recognise the position of any spot on the globe, when we know its geographical longitude and latitude. If a boat were wrecked 36 degrees 20 minutes (36° 20′) north latitude and 133 degrees 20 minutes east longitude a good map would at once inform us that this occurred near the Japanese coast, at the island of Oki-shima. As soon as a vessel has determined its whereabouts according to geographical longitude and latitude and can once more take up its proper course, it is saved from all the dangers connected with unknown sur-

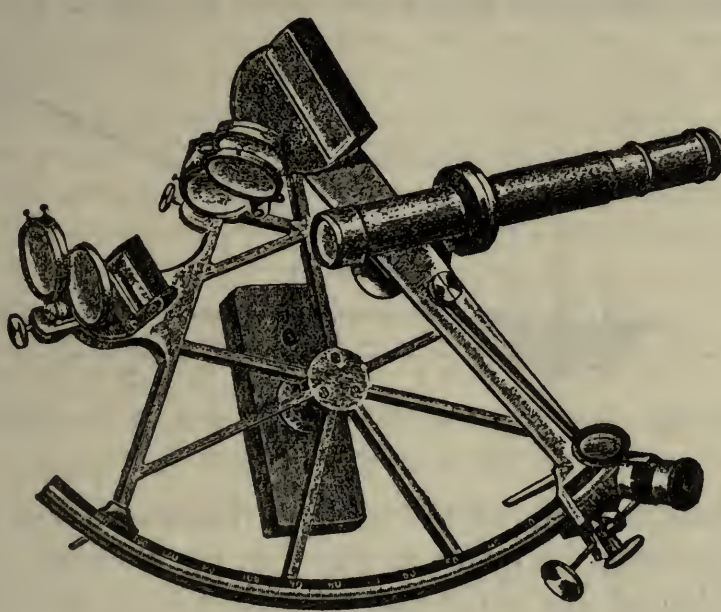


Fig. 92.—Mirror Sextant.

roundings, for a vessel can only be steered with impunity if the logs and charts distinctly set out the difficulties and peculiarities of the route. The captain will therefore, weather being propitious, have to turn to the skies for guidance. He first of all determines the geographical latitude. It is a clear starry night. The Pole Star, as we know, is stationed at the celestial North Pole. Now, the farther away a place is from the equator the higher the celestial North Pole rises above the horizon. At the terrestrial North Pole the Pole Star would stand right over the head of the spectator, in the zenith, at the equator it would just graze the horizon. The celestial pole is always elevated as many degrees above the horizon as the terrestrial place is removed degrees away from the earth's equator. For instance, at Berlin the celestial North Pole, near which the Pole Star is situated, is at an altitude of 52½°; Berlin is 52½° removed from the earth's equator, so its geographical latitude is 52½°. The altitude of the Pole Star above the horizon is therefore measured and the latitude* of the ship's position found. The sun serves a similar purpose in the day-time. At the instant the sun has reached its highest point above the horizon, when it is in the south at 12 o'clock midday, its distance from the water-line has to be determined with the aid of the sextant

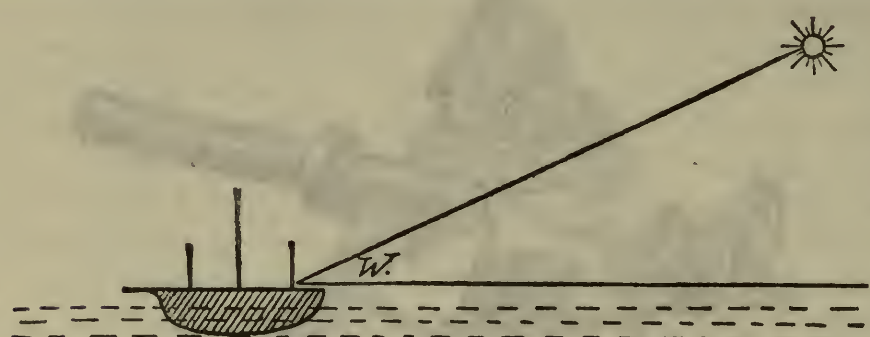


Fig. 93.—Measuring the Altitude of the Sun on Board Ship.
The angle w marks the sun's height above the horizon.

(see the angle w shown in Fig. 93). The distance of the sun from the celestial equator as stated in the Nautical Almanac is then looked up, and these two values soon determine the geographical latitude of the vessel's position. Let us imagine it to be 51° 10′ north latitude. One part of our task is now completed, but the longitude has next to be determined (this is the difference between the meridian of one's standpoint and that of Greenwich, 0, from which all calculations of longitude start). This should not be difficult in fine weather if the ship's chronometers are acting properly. The elevation of the sun above the horizon has to be measured at a distance from the meridian, when it is rising or falling rapidly. The chronometers set according to Greenwich time have immediately to be read off. The solution of a spherical triangle gives the local time, which has

* The Pole Star is in reality not quite at the celestial pole, but about 2½ full-moon breadths away.

to be compared with the Greenwich time. Suppose there is a time difference of three hours eleven minutes between the ship's position and Greenwich, where the day is more advanced. The vessel must therefore be west of Greenwich where the sun rises at a later hour. This time difference helps to determine the longitude. The earth rotates on its axis once every twenty-four hours, the sun therefore sweeps across all the 360 meridians of the earth during this period; every spot on the globe has its midday within these twenty-four hours, so it takes the sun the 360th part of twenty-four hours to pass from one meridian to another, and that works out at four minutes. Places with a time difference of four minutes are one degree apart. As a time difference of three hours and eleven minutes has been ascertained between the ship's position and Greenwich, or $47\frac{3}{4} \times 4$ minutes, the vessel must be $47\frac{3}{4}$ meridians to the west of Greenwich, or $47^\circ 45'$ west longitude.

We now know where the boat is:

$51^\circ 10'$ north latitude.

$47^\circ 45'$ west longitude.

The map shows this to be in the northern part of the Atlantic Ocean, half a day's journey east of Newfoundland, and if the vessel be bound for Halifax it will have to keep south south-west.

Should by mischance the chronometer have been rendered useless, the exact time can be ascertained by observing the stars with the help of the Nautical Almanac, for every kind of astronomical occurrence which a mariner can see with a small telescope has been calculated in advance and noted as a guide to sailors (the moon passing stars, its place among the stars at various times, etc.). At the instant any one of these events occurs the sailor knows Greenwich time to be such and such. The stars, however, assist him at other times than those of danger only; the vessel's time and place are determined daily by astronomical means, as all others would not be accurate enough and could not be fully depended on in these days of rapid locomotion. Travellers entrusting their lives to our modern floating palaces owe a very considerable part of their well-being to the observer measuring the transit of the stars in the meridian-chamber, to the mathematician who compiles the tables in the Nautical Almanac.

Astronomy and Aeronautics.—Latterly aeronauts and aviators have turned to the observatories for assistance. They frequently encounter grave difficulties when the mists and clouds beneath them make it impossible to study the chart, or when the balloon is carried away to districts of which they possess no maps. There are a few cases on record of aeronauts who had lost their bearings being driven out to sea, where a watery grave awaited them. A special kind of sextant has been designed by Marcuse, of Berlin, which serves for the astronomical determination of position for balloon and airship.

Astronomy and History.—The statement that astronomy has proved invaluable to historians may sound odd at first, and yet its truth is undeniable. All noteworthy astronomical occurrences have been chronicled since the earliest days, generally in connection with some one or other important political or religious event. It is often of the utmost importance to historians to be able to state the exact date of any one event, and as an astronomer is able to trace celestial phenomena in the past, often to the very hour of their occurrence thousands of years ago, historians have been helped out of a difficulty on innumerable occasions. We know that a battle was fought between the Lydians and the Medes on the Halys in the sixth century B.C., and that a solar eclipse occurred during the fight. It was determined astronomically that this was most likely the total eclipse of the sun on May 28th, 585 B.C., and that the great battle must therefore have been fought on that day. The ancient Chinese chronicle "Tshu-king" is fraught with the deepest interest for historians and astronomers. All the dates in the volume refer, however, to the reign of the sovereign in whose time they were entered, as, for instance, "in the eighth year of the Emperor Fu-hi" such and such an event occurred. This had to be converted into our time-reckoning to be of use to European historians. The "Tshu-king" tells of a great solar eclipse in the fifth year of the Emperor Tshun-khang's reign, which had not been announced by the Court astronomers, and, as the people could not be notified, a terrible panic ensued throughout the country. The two forgetful astronomers, Hi and Ho, were put to death by the Emperor's orders.

There is a very celebrated work entitled the "Canon of Eclipses," which was compiled by the great Austrian astronomer, Th. von Oppolzer, assisted by six other mathematicians, and in which all the sun and moon eclipses for centuries past and for the future up to A.D. 2163 have been calculated. This book, which is primarily intended for historical purposes, sets down the date of the eclipse which ended so sadly for Hi and Ho as the morning of October 22nd, 2137 B.C. The fifth year of the Emperor Tshunkhang's reign would therefore be the year 2137 of our reckoning, and the monarch ascended the throne in 2142 B.C. (Fig. 94 is a view of the old observatory at Peking, and in Fig. 95 is represented an armillary sphere, an ancient astronomical measuring instrument once used in the Chinese capital.)

So astronomy helps us to grope our way about in the grey labyrinth of ages long past, and the flaring torch of science lights up events which appeared as distant and as inaccessible as the stars above.

CHAPTER VIII

ASTROLOGY AND SUPERSTITION

Superstition, that extraordinarily rank weed, has struck strong roots in the very depths of human nature. Man, so little able after all to control the course of events and his own destiny, is again and again forced to recognise that he is but a toy in the hand of something so vast, so incomprehensible and so unknowable that it cannot be conceived or included as a unit in life's formula. Why, in a second the most carefully planned and constructed human creation—nay, even life itself—can be destroyed by a trifle of such insignificance that it almost seems ridiculous to contemplate, and yet we cannot fight against it even in thought. It is the story of a thunderclap in a bright sky all over again. And yet everything in this world has a firm, logical basis and occurs according to Nature's unvarying and consequential laws, and, strictly speaking, there is no such thing as *Chance*. Yet, if it is difficult for men acquainted with the laws of logic and theory, nature and philosophy, to recognise even the main principles only of those forces and happenings that influence a thousandfold human life and work, how much more difficult it must be to the untaught man, to the less intelligent races that lived in past centuries, to attempt to grasp the rudiments of these relations!

Basis of Superstition.—This inability forms the basis of all superstition. Secret forces and powers, good and evil

Fig. 94.—View of the Old Observatory, Peking.

Fig. 95.—Armillary Sphere (an ancient astronomical measuring instrument) at Peking.

Fig. 96.—The Astrologer.

(*After an etching by Rembrandt.*)

spirits, apparently enter into human destiny from reasons more or less clearly ascertained; it becomes necessary to win them over, to make one's peace with them, and to trace their mysterious powers to their source.

Astrology and its Origin.—Astrology, the ancient superstition bound up with the stars, is built on this foundation. The stars are throned above us, majestic, luminous, magnificent, far away from all things terrestrial, ever unattainable, eternally remote. Man of the highest culture and the crude child of Nature are equally enthralled by their fascination, the latter even more so than his civilised brother, as he is in closer communion with Nature, and on his hunts and marches the starry heavens for many weeks form the canopy of his sleeping-chamber. It is easy to understand that a restless, questioning mind would soon acquire the belief of an influence exerted by these apparently everlasting, indestructible stars on the things of this earth, on weather and harvests, human omissions and commissions, as the influence of sun and moon on climatic conditions, on the sea with its flow and ebb, is plainly perceptible. A desire to trace the cause of all events and happenings is firmly implanted in human nature, to connect and explain important and impressive occurrences, happening simultaneously or consecutively, with each other.

If a sudden spell of exceptionally cold weather set in, and a disastrous earthquake occur elsewhere at the same time, these two things will generally be brought into line with each other. If a comet were seen at a period when plague or war harassed mankind, the opinion was universal that the comet was to blame for these catastrophes; these poor, harmless, vagrant bodies were made responsible for the most remarkable happenings!

Astrology undoubtedly developed from observations of this character. Astrologers (Fig. 96) made especially conspicuous groupings of radiant stars, the position of the planets, of moon and stars, the subject of their prophecies; and nations possessed of very vivid imaginations and emotions soon pinned their faith to the teachings of the stars.

The Progress of Astrology. — Astrology flourished greatly among the Eastern races in the very earliest times.

Astronomy in those days was naught but a chronology, a calendar science, and the observation of the stars only undertaken for determination of time and the calculation of high days and festivals. Its more superficial and baser sister

Fig. 97.—The School of Astrology.
(From a mediæval print.)

Astrology occupied a far more important position. The oldest astrologers we know of were the Chaldeans, and star-reading was carried from them to the Egyptians and Babylonians. It marched in triumph through Greece and the Roman Empire, and in the latter part of the Middle Ages it held its own in the rest of Europe as well (Fig. 97). The

Arabians, Persians and Chinese were past masters in the art of star-reading, and even up to a few years ago Imperial astrologers were still on duty at the Peking court. Chairs of astrology were established at the old universities in

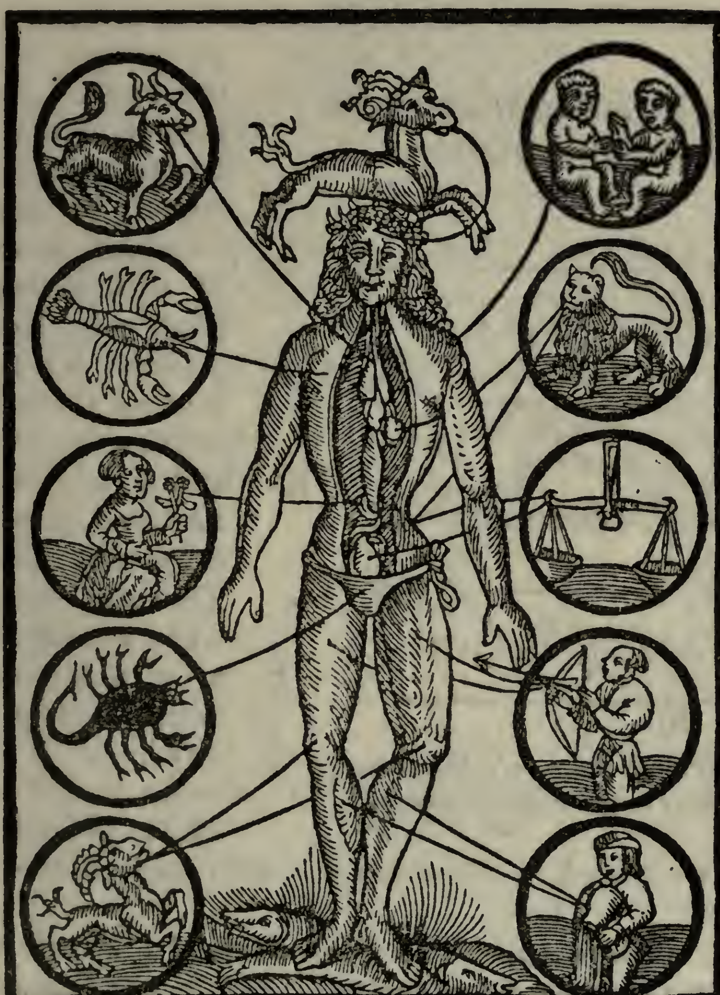


Fig. 98.—The "Little Leech."
(From an almanac of the seventeenth century.)

southern Europe and only abolished about the middle of the seventeenth century, whilst kings and princes of those days showed greater preference for the pronouncements of star-gazers than for those of more competent persons.

The Belief in Horoscopes.—According to astrologers, the position of the stars at the birth of a human being influenced his whole life. No important enterprise, no journey, wedding or law-suit was carried out without the advice of the stars being sought. They were even believed to be concerned in medical matters, in extraction of teeth, setting of leeches, letting of blood! When in a certain constellation, the planets and moon were said to possess a direct bearing on various organs of the body. An illustration of the "Little Leech," which is contained in some old almanacs, is evidence of this strange fact (Fig. 98). Nearly all princes and great soldiers turned to the astrologer for advice, and no big battle was ventured on without a horoscope being set. This was always done when a child was born to a noble or royal house. The "nativity" of a human being — that is, the whole course of his life—was set forth in a horoscope, which really means "hour-searcher."

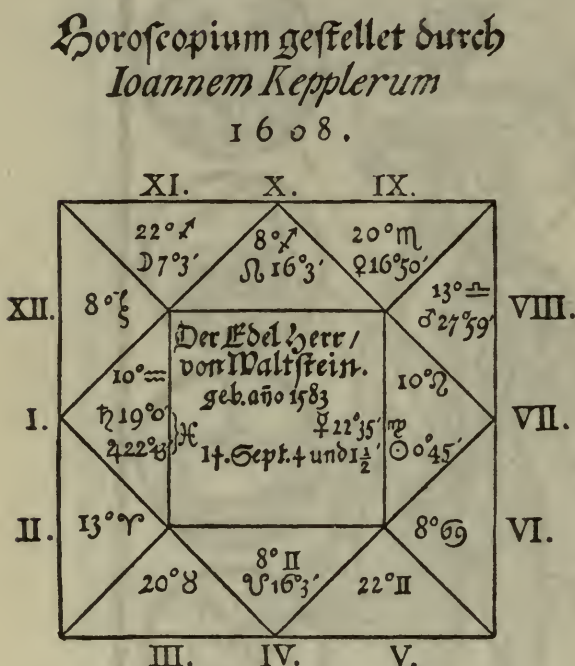


Fig. 99.—Wallenstein's Horoscope.

(Said to have been set by Kepler.)

How a Horoscope was Set.—First of all, that point of the ecliptic (the path the sun describes in the course of the year) which rose above the horizon at the exact birth-minute had to be sought for. The skies were then divided into twelve parts or houses; there was a house of life, a house of luck, health, marriage, family, religion, death, honours and dignities, friendship and enmity, and so on. The position of these celestial houses to each other was set down as a figure of the horoscope (Fig. 99), and the position of the planets, moon and stars carefully inscribed, to give a more general view of the various "aspects" of the stars to

Fig. 100.—Highly artistic Horoscope cut by Anton Wönsam, of Worms in 1531, for a wealthy believer.

Fig. 101.—Nostradamus, the King of Astrologers.

Fig. 102.—Murder of Wallenstein at Eger, during the night, February 25th, 1634.

(From an old engraving.)

each other. Each of these stars was believed to possess a certain influence and made for fortune or ill-luck; but this was partly dependent on the house in which it stood and the counteraction of any other star or stars.

> "Not roses only, thorns too, the heavens possess;
> What Venus knots, luck's generous giver,
> Dire Mars, ill-fortune's star, can quickly tear asunder."

Saturn and Mars were generally looked upon as stars of ill repute; Jupiter and Venus were lucky stars; the moon possessed a restless and variable influence, and so forth. Of course, the divination of the horoscope (Fig. 100) often differed, and different nations and periods owned most varying systems of astrology.

Celebrated Astrologers.—Probably the greatest astrologer of the most ancient times was the priest of Baal, Berosus, of whom it is recorded that nearly all his prophecies were fulfilled. He was a clever, far-seeing man in close touch with the temporal powers, and his peeps into futurity were established on a well-grounded basis. At his death a statue was erected to his memory, and he is represented as having a golden tongue. The great Roman astrologer was Firmanus, who read the date of the foundation and of the destruction of Rome in the stars; and it is a fact that Sulla told Caligula when he would die. Nearly all the astrological methods of the later times were introduced in the fourth century by Firmicus Maternus, who gave lessons in his art. Another eminent man of the same class was the Arabian sage, Abumansur, who lived in the ninth century. The fame of Nostradamus, the greatest astrologer of the sixteenth century, has lasted until our times (Fig. 101). Two French kings made him their favourite, and his prophecies, set forth in a pamphlet, were read all over the world. Although he died in 1566, his forebodings were believed in as late as the eighteenth century, for at its beginning a Papal Edict forbade the sale of the booklet, as it proclaimed the downfall of the Papacy. Even the illustrious Kepler occupied himself with astrology, but, as we shall see farther on, more from poverty than conviction. It was he who set the horoscope (Fig. 99) for the celebrated Field-Marshal Wallenstein, who was a fervent believer in the art; but in spite of his constant observation of the position of the planets they did not warn him of the murderous dagger awaiting him in the Bohemian town of Eger (Fig. 102). Wallenstein had the horoscope set for him by Kepler imitated in gold, and wore it around his neck as an amulet. It is still in existence (Fig. 103).

Evils of Astrology.—Of course, astrology created a great deal of trouble and mischief, for it hardly tends to

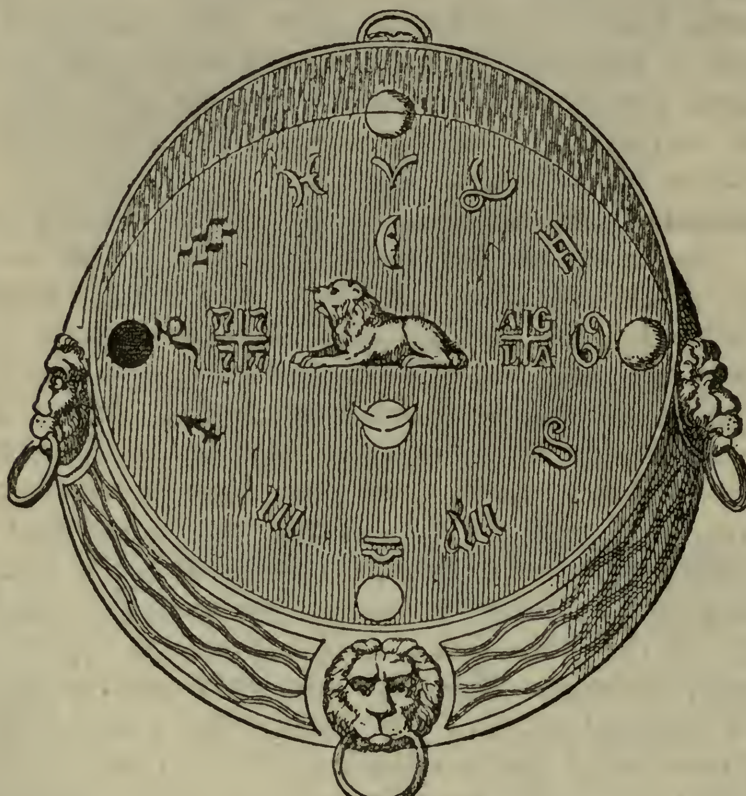


Fig. 103.—Horoscope Amulet of Gold set with Stones, worn by Wallenstein round his Neck.

strengthen weak minds to take a glimpse into the future, especially if ill-fortune is said to loom ahead. Many a life has been rashly terminated owing to absurd prophecies. Court astrologers, too, were skilled in the art of "putting their enemies away." The astrologer at the court of Tiberius is known to have played many of the tyrant's opponents into the executioner's hands. King Eric XIV. had his statesman Sture and all his family put to death in 1567, merely because he had been informed by an astrologer that he would be dethroned by a fair-haired man of his court, and all the Stures were fair. Many an evil deed of the unenlightened days can be traced to these dark arts.

"End of the World" Panics.—The repeated prophecies of the end of the world did a huge amount of mischief, and the episode of the Berlin (Fig. 104) panic really deserves to be chronicled here. In 1518 Stoeffler, then a very celebrated astrologer, prophesied a tremendous flood for the year 1524, which was to devastate the entire earth. He had calculated that Saturn, Jupiter and Mars would meet in the Constellation Pisces in February of that year, and this, in his opinion, would undoubtedly cause a deluge. A fearful depression seized mankind, and the nearer the ominous day approached the greater the general fear and stupidity grew. Trade and commerce were at a standstill, the peasants let their fields go to rack and ruin, work ceased everywhere, no debts were paid and money was spent lavishly in riotous living. The richer classes tried to outdo their poorer brethren in cleverness; some of them travelled to mountain districts to escape the waters, and others even had arks built like Noah's! Some led as rapid lives as possible to spend their very last cent before the catastrophe came; others grew the more pious the closer their wet grave loomed—it was a mad, mad time! But February of the year 1524 came and went, and no flood put in its appearance. A wave of relief swept over the world; only the Electorate Castle at Berlin-Cölln on the Spree could not free itself of fear and a dull sense of calamity. The Elector Joachim I., who was a star-reader himself and possessed a kind of observatory in a castle turret, was informed by his learned and trusty Court astrologer, Johannes Carion, that Stoeffler had erred in his calculations, and that the flood might be expected on July 15th, 1525; neither would it extend over all the earth, but only scourge German territory and especially Berlin-Cölln. The Elector commanded this information to be kept a dead secret, and on the afternoon of July 15th, 1525, when a threatening bank of clouds appeared on the western horizon, the gates of the castle were suddenly flung open, and a whole procession of state coaches went tearing along as fast as they could towards the small hillock Berlin calls its own in the Kreuzberg—the Ararat of the royal house! The whole Electoral family, with its ministers and household, not forgetting the state cash-box, were all brought into safety on the heights of the Kreuzberg. The peaceful burghers watched these extraordinary proceedings open-mouthed. Later, when the reason of the flight became known, terror seized the citizens, coupled with fury at the cowardly way in which their sovereign had sought safety without a word of warning to his humbler subjects, whom he would have let drown like so many wretched rats. At nightfall a slight storm burst, and the gentlemen on the miniature Ararat began to feel qualmish and very ill at ease; but when the sun took a final peep through the clouds the only "man" present, who happened to be the Electress Elisabeth, persuaded her consort to return home, as the end of the world was apparently not due that day. Home they went, not greeted by exactly pleasant looks on the burghers' part; and just as they entered the courtyard a flash of lightning, heralding an approaching storm, killed the postilion and all the four horses of the royal carriage. The Elector, who almost died of fright, barely escaped falling a victim to his own crass timidity. This is taken from an account by the chronicler Haftitz.

The Use of Astrology.—Even highly educated people of level minds, such as Luther, believed in the stars as predicters of fate. There always were enlightened men among the princes and priests, however, who opposed this superstition to the best of their power, and astrologers have been frequently banished by rulers, both secular and spiritual. This form of madness, however, flourished until the end of the seventeenth century. Jean Baptiste Morin, who died at Paris in 1656, may be regarded as the last of the great astrologers.

Nevertheless, astrology had some good points since to some degree it aided science. Just as the alchemists, who in their secret laboratories sought for the Philosopher's Stone, which was to grant eternal life and held the secret of the transmutation of base metals into gold, now and again hit upon chemical discoveries whose importance is recognised even to-day, so the astrologers finally were of use to astronomical science. Their careful compilations of the courses of the stars, their positions and happenings, formed notes which later undoubtedly were of assistance to astronomers.

Revival of Astrology.—Yet what is one to say to the fact that this exploded belief has been revived in our own age, in this era of enlightenment and progress, and has put forth fresh and hardy shoots? Astrology in the twentieth century! Alas, it is so!

Any careful reader of the daily papers and the magazines will come across advertisements of the following character:

> THE STARS RULE YOUR DESTINY.
>
> Life's pathway smoothed. When in doubt consult the stars. Results absolutely establish the reliability of Astrology. A truthful forecast of your future. Thousands of letters of appreciation. Test horoscope sent on receipt of birth-date, with 1s. P.O. and stamp.

Such announcements can be seen everywhere, and the advertisers appear to reap gratifying results from their nonsense. Or little cards are pushed in at the doors informing us that a specified lady enjoys

> World-wide fame and reputation as a clairvoyante. No spiritualism. The art of the planets and the cards has been carefully studied for years. Palmistry, crystal gazing. Grateful appreciations from well-known persons. Public recognition of numerous successes.

So we see that mediæval fortune-telling goes on merrily even in this century of natural science!

Some little while ago a young astronomer was offered a position at an observatory at the princely salary of £45 per annum, and on expressing his disgust at this salary, which is one given to a better-class servant, a well-known scientist told him to open an astrological institute in a fashionable quarter of the metropolis, and he would make his fortune in a very short time. This is perfectly true.

Astrology of To-day.—In London and Paris star-readers have flourished for some years, and they are principally patronised by educated people, especially ladies. One

London astrologer actually publishes extracts from letters sent him by very prominent public personages, in which they express their admiration of his art. His advertisements conclude by saying: "Send me a shilling and particulars of your birth, and you will receive your horoscope. You will be surprised at the correctness of our statements."

It would be easy enough to take a high-handed view of this ultra-modern humbug and wave it away with a superior smile, but the very fact that this branch of superstition is spreading with alarming activity makes it necessary to utter a protest.

What are the Facts?—The palpable materialism of the past few decades appears to be followed by the desire, as this and similar excrescences show, to fly to the other extreme. In my capacity of astronomical correspondent to several large papers, I frequently receive queries from my readers as to the stars which rose or set in the heavens on a certain date, generally a birthday or death anniversary. All these questions seem to tend slightly towards astrological superstition, and I generally read the applicants a private lecture on the vast remoteness of the stars and the foolishness of believing that these distant heavenly bodies have any influence on human life. The only orb which exercises such on terrestrial organisms is the sun, without whose action life on earth would be entirely impossible. I also frankly admit that the sun has a very direct bearing on human temperament, for on dull days, when the sun does not shine, nervous people easily tend towards melancholia, and statistics show that suicides are on the increase in the dismal months of the year. The moon also has a certain narrowly-bounded influence on the weather, but that is absolutely all. The more remote stars have no influence whatever on our planet.

Yet these hard facts do not convince! Fortune-telling from coffee-grounds, tea-leaves, yolks of eggs and even cards have had their day, and now the stars come to the fore once more. It sounds so nice and learned, and the public at large easily confuse astrology with astronomy. *Mundus vult decipi* —the world wants to be deceived.

Kepler's Influence.—Of course there are astrologers who are perfectly honest in their belief that the stars influence human life. An accident brought me into contact with one of these convinced adherents during a stand I made against such superstition. Their champion motto is Shakespeare's "There are more things in heaven and earth, Horatio, than are dreamt of in your philosophy," and they quote this with undying zeal. Perhaps no quotation has ever been so frequently misapplied as this, but the most powerful dart in their quiver is the fact that one of the greatest astronomers of all times was an astrologer also. I refer to Johannes Kepler. It is perfectly true that Kepler occupied himself with astrology, and laid some stress on this, too, as the pamphlet he wrote in 1610 shows: "Tertius interveniens: that is a Warning to sundry Theologos, Medicos and Philosophers not to Pour away the Child with the Bath in their cheap Denunciation of Star-Reading Superstition and thereby Ignorantly act Counter to their Profession."

Kepler lived from 1571 to 1630, and was a child of his time, which had a strong leaning towards mysticism. Moreover, three centuries have passed since then, and Kepler declared frequently enough that poverty alone forced him to this work. In spite of his enormous learning and abilities, he would have starved but for this source of income. The Imperial Exchequer discontinued his salary in those troublous times of war. Even Wallenstein, to whom he appealed, could not assist the sage he so admired, and when in 1610 Kepler, driven by starvation, journeyed to Regensburg to demand the 12,000 guldens the Imperial Diet owed him, the difficult journey brought on an illness which hastened his death. He died of malnutrition.

Kepler himself once said: "Astrology is not worth spending any time on, but folk have the idea that it is part of a mathematician's work." He still more emphatically expressed himself as follows: "Astrology verily is a crazy daughter; but what would its mother, most sensible Dame Astronomy, do without this mad offspring?" "The income of mathematicians is so remarkable and slight that the mother would undoubtedly starve were it not for the earnings of the daughter."

Kepler excuses himself on the score of his pecuniary position, and is further excused by the age he lived in. Modern astrologers violate our enlightened era with their *work,* if this be not a profanation of the word, an era in which countless energies are occupied in dispersing the fogs that are mankind's worst enemies, the fogs of ignorance. And the words with which trusty Illo warned Wallenstein against rushing headlong to his doom, in his blind confidence in the stars, hold good for them too:

> "In thine own breast are thy fortune's stars:
> Confidence in thyself, determination
> Be thy Venus."

Fig. 104.—An Astrologer's Prediction – the End of the World, caused by the Collision of the Earth with the Stony Nucleus of a Comet.

(After a drawing by Heinrich Harder.)

Fig. 105.—Land Surveyor at Work.

The distance of the tower A is to be measured; the line B C is the base. The angles at B and C have to be determined.

Fig. 106.—Claudius Ptolemy.

From a French engraving of the seventeenth century.)

CHAPTER IX

HOW TO FIND THE DISTANCE AND DIMENSIONS OF THE CELESTIAL BODIES

There was once upon a time an old country gentleman who was very fond of spinning a yarn, and who, according to report, could even outdo a sailor bold in the length and breadth of his tales, in which he developed an inventive genius remarkable for its ingenuity. He was extremely proud of his talent, and delighted in receiving compliments on his virtuosity in mendacity, which he always modestly acknowledged, stating, however, that he knew of a better tale-spinner than himself, for he had once met an astronomer who, with the straightest face in the world, had publicly told him and some friends that he had actually measured the height of the hills on the moon! This to the old gentleman seemed the very summit of barefacedness, and he therefore awarded the palm of lying to the poor astronomer.

What would the old gentleman have said if he had learnt of many far more difficult achievements accomplished by astronomy in its various branches?

Achievements of Astronomical Calculation.—Astronomers are not only able to ascertain the distances and dimensions of the moons and planets, to reckon solar and lunar eclipses for centuries, both in the past and future, but they can also trace comets, coming from vast distances towards us and withdrawing again into infinite space, to the very uttermost fastnesses of our system. Long after they have vanished from the sight of even the most powerful instruments, the mathematician is able to state their position and relation to the members of the solar system. He can calculate the reappearance of these remarkable tailed stars for hundreds of years to come, as well as all disturbances they may suffer in this long period by reason of other bodies hindering them on their way or even turning them aside from their path. The astronomer has even dared to penetrate to the remote spaces of the fixed stars; the distances of many of these suns have been ascertained—ay, it has been possible not only to discover partly invisible, dark celestial bodies which encircle and accompany brighter ones, but to calculate their orbit as well as their magnitude and distance from the radiant orb. How trifling is the determination of the height of the lunar mountain ranges in comparison! The calculating astronomer can not only inform us of the size of the moon and planets, but also of their weights, just as the weight of the earth has been determined with every appearance of exactitude.

There are a good many people in this world who share our old gentleman's opinion that star-gazers are not very particular as to the truth of their statements and are, indeed, quite expert "fibbers," who do not trouble about an odd million or two in their figures.

A Royal Sceptic.—A former director of the observatory at Göttingen, Professor Klinkerfüs, who enjoyed widespread popularity, once had a royal visitor, a lady greatly feared for her sharp and critical remarks. She was shown the moon and various stars through the telescope, and asked a large number of questions. And then the following dialogue ensued:

"What is the name of that very bright star, Professor?"

"Aldebaran, your Royal Highness."

"How far away is it?"

"About twenty-five to thirty years of light."

"What does that mean?"

"A year of light, your Royal Highness, is the distance a ray of light—which travels at a rate of 186,400 miles a second—can cover in a year. A year of light is about six billion miles; Aldebaran is about 173 billion miles away."

The royal lady half closed her eyes, and said ironically, "Well, my dear Professor, I can only express my astonishment at your being able to learn the name of a star so tremendously far away from us."

Her suite, delighted not to be, for once, the target of her sarcasm, smiled widely; but Klinkerfüs, who was one of the wittiest and quaintest of men, answered in his quiet way, with a slight smile, "It really was quite by accident, your Royal Highness. Fortunately for us, the label was still tacked on to the star."

The Punctuality of Eclipses as Proofs of the Exactitude of the Calculations.—The sun and moon eclipses, which take place just as predicted, should be sufficient to convince any fair-minded person that the astronomer is able to elucidate the relative position and motion of the earth and moon to the sun exactly enough, and it is within everybody's power to check the statements of the almanac. The reappearance of comets true to computation, the transits of various planets across the sun's disc, the precision of dates in the Nautical Almanac, the sailor's great stand-by, these all confirm the trustworthiness of astronomical calculations. The layman has either to believe or disbelieve statements such as that the diameter of the moon is 2,159½ miles, that the sun is 92,800,000 miles away, that the globe of the planet Jupiter is 1,330 times larger than that of the earth, that our nearest fixed star is 275,000 times more distant than the sun, for he cannot prove their correctness. He will hardly find his faith misplaced. Apart from the fact that science is the powerful and chaste guardian of truth of the present age—in which faith and belief are not everyday occurrences—the laws of mathematics in particular, the purest and least anticipating of all sciences, possess an eternal value and a universal credence; their results are far more secured than those of any other branch of science.

How to Ascertain Distances.—And yet there are thousands to whom even the simplest mathematical laws are unknown, and who cannot understand how the astronomer has arrived at all these findings, for he could hardly have made them with a yard- or tape-measure. In the following paragraphs I shall endeavour to show how, without calling mathematics to our aid (the very word is anathema to many!), it is possible to determine distances and sizes in the universe. Of course, we shall have to keep to outlines only, and I hardly need to say that astronomers themselves work on far more precise lines to arrive at their very exact results. Nor need it be added that modern methods are vastly different from those that were supposed to prevail "once upon a time," so quaintly illustrated in Fig. 107.

It apparently troubles many people to find out how the astronomer can measure the distance of a star, "as he can't

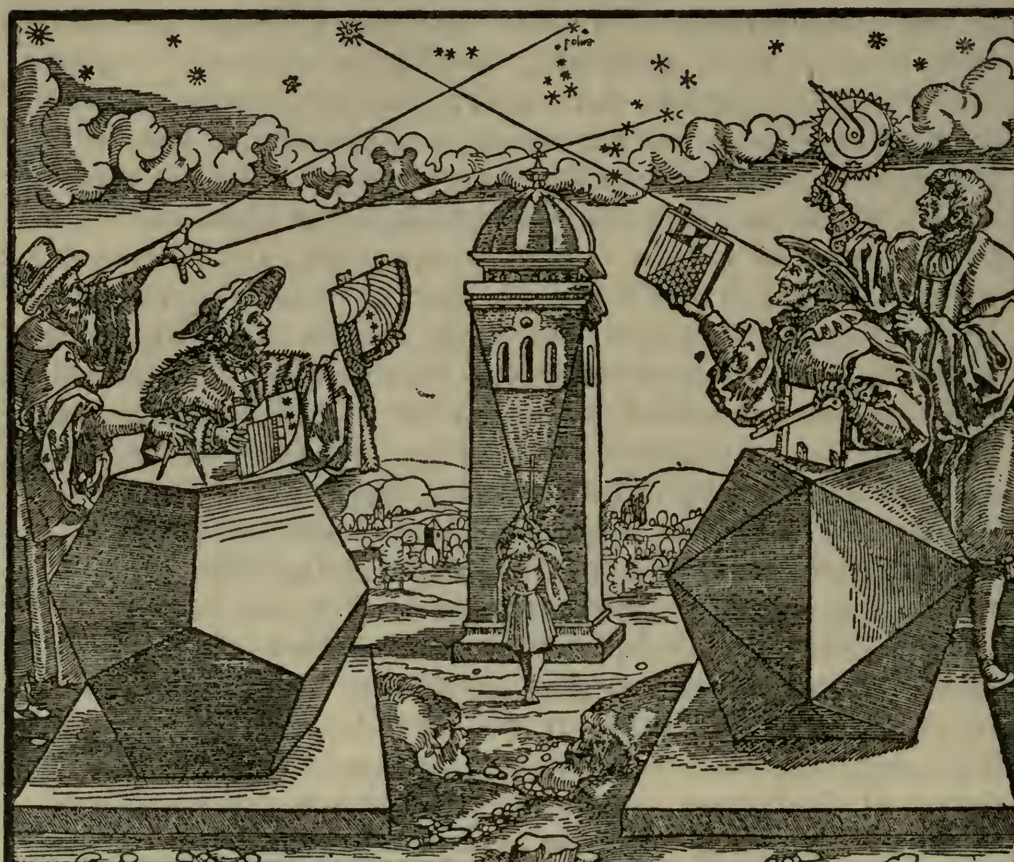


Fig. 107.—Measuring the Distance of the Stars, according to a Representation of the Middle Ages.

get up there himself." Neither can land surveyors always get to the object of their calculations. Let us suppose a railway line is to be laid, and that it is necessary to measure the distance of a neighbouring village from a certain spot in the fields. It would be a very roundabout task to set about it as though a room were to be measured for a new carpet. Lakes, streams or marshes often lie between the two points in question, so the surveyor has to come to our aid with his theodolite, an instrument for measuring angles, heights and distances, by whose help work is quickly and easily accomplished (Fig. 108). Surveyors need to have a good grounding in mathematics, as they constantly use it in their profession, but as I do not desire to scare my readers, I will now show how to measure distances without it. It is

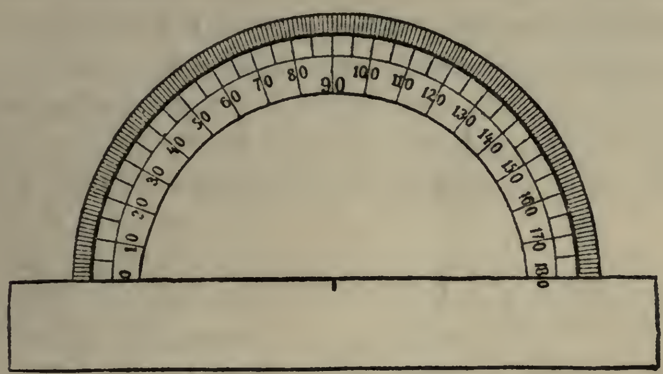


Fig. 108.—A Protractor.

only necessary to have a little instrument we all remember from our schooldays, a protractor (Fig. 108), with which the size of an angle formed by two lines is measured in degrees.* Place the protractor on two lines forming an angle, as shown in Fig. 109, and we shall immediately see

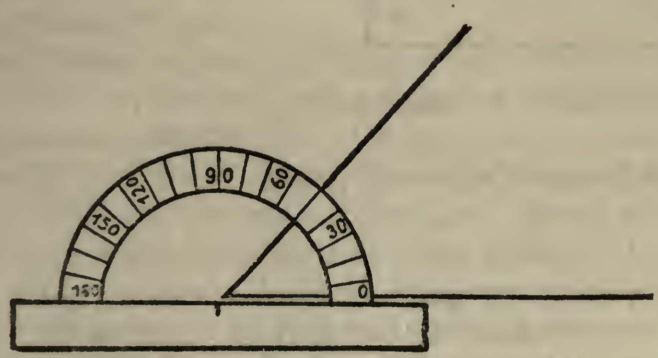


Fig. 109.—Measuring an Angle.

that the angle is one of 50 degrees. Armed with a large protractor, a number of posts and ropes, we now set out to measure the distance of the church from a remote spot in the fields (Fig. 105). The church is situated at K in Fig. 110, whilst we stand at A. First of all, we must line

* A circle is divided into 360 parts or degrees; a semi-circle has 180 degrees, and so on.

off a base. The farther away the object which we desire to measure the longer the base must be; it will be 110 yards in this case. We now ram a post into the ground at point A, and measure off 110 yards, where we place another post at B. After having fixed our base, we have to determine the angle formed by the two lines drawn from A and B to K with the line A B. A little farther away two other sticks are put in the ground, marked *a* and *b* in Fig. 110, so that when bringing one's eye to the level of post A or B, eye, stick and church tower are all in one straight line. The four posts are now connected by a rope; this is indicated by the thick black line in the diagram, and leads from *a* to *b* by A and B. Now we set up our instrument at A and B, and measure both angles; they should be 65 and 80 degrees respectively. Our work in the open is finished, as we can easily do the rest at home on a piece of paper.

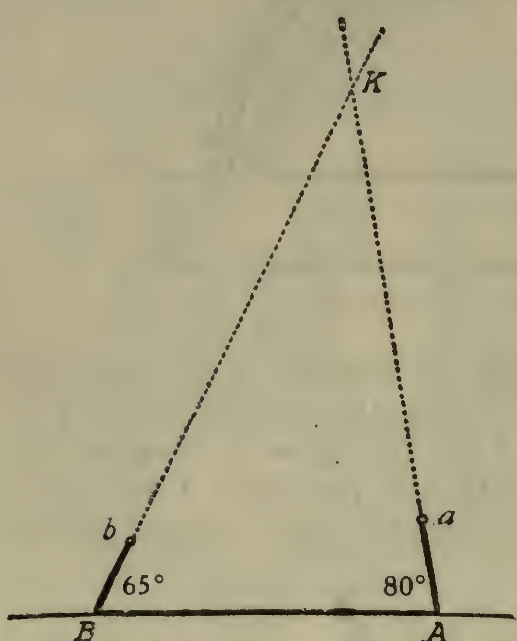


Fig. 110.—Measuring by Triangulation.

We have to repeat what we did in the fields, i.e. draw a base on the paper, of course, on a much smaller scale (a thousand times reduced). The two end points are again marked A and B. We then draw the two lines, at angles of 65 and 80 degrees, that we marked out on the fields with the second set of posts and the rope. We now have the precise figure we had in the first instance, only, of course, on a scale a thousand times smaller. It was impossible for us to extend the lines A *a* and B *b* to K in the open, but this is very easy work with a ruler on our small plan. Now continue both lines until they intersect, which, if the angles have been correctly measured, should happen at K. The line B K must now be measured. As the base of this triangle is 1,000 times shorter than that of the triangle in the fields, the other sides are also shorter. Multiply the distance from A to K a thousand times, and the result will be the exact distance the church K was from our point of observation at A.

Any schoolboy can determine a distance on these lines. A surveyor, naturally, has to proceed in a somewhat different fashion. He has to measure off his base in a similar manner, but the two angles are measured with the theodolite; neither does he work out the results by diagram, but according to trigonometry. If the length of a line and the two angles

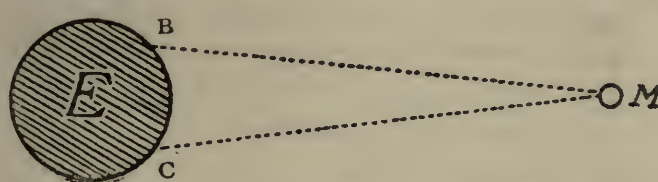


Fig. 111.—Measuring the Distance of the Moon from Two Points on Earth.

of a triangle formed by it are known, or if two sides and the angle formed by them are known, the other parts of the triangle can be easily calculated according to trigonometrical principles. The astronomer, of course, proceeds on these purely mathematical methods.

How the Distance to the Moon was Measured.—These triangular measurements have assisted in the determination of the distances between the largest cities and most important points of the earth, even in arriving at the size of the entire globe; and, taking well-known terrestrial distances as a base, distances in the universe have likewise been measured by these methods. The distance of the moon was found by taking the stretch from the Cape Town Observatory to that of Berlin as a base. E represents the earth and M the moon in Fig. 111. If the angles formed by the lines B M and C M with the base B C were measured simultaneously by observers at Berlin (B) and Cape Town (C), the moon's distance can be quickly determined, for the distance Berlin to Cape Town is a known one and the angles at B and C are not difficult to fix. There are divers other methods of greater precision for measuring the moon's distance, but they would lead up to mathematics, so we have to pass them by.

Distance from the Earth to the Sun Calculated.—As the distance of the sun is many hundreds of times as great as that of the moon, its determination is much more difficult. It is useless to approach the problem directly, and it is solved by many indirect methods. Mars and a tiny planet called Eros at times approach us fairly closely on the side opposite the sun. At such times observations of them are made at widely separated observatories, and their distance is deduced in the same manner as that of the moon. Now mathematical astronomy enables us to say exactly what

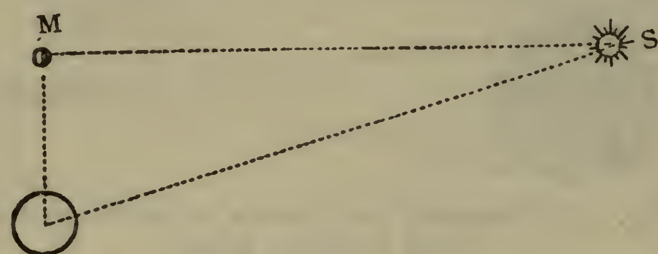


Fig. 112.—Sun, Moon, and Earth form a Right-Angled Triangle when the Moon is in her First Quarter.

fraction their distance is of the sun's distance, so that the latter quickly follows.*

Another method uses the velocity of light, which has been found by employing a beam of light passing between two stations some miles apart, and reflected by rapidly revolving mirrors which turn through an appreciable angle during the passage of the light. The time that light takes

* Another suggested method of calculation is as follows: A long measured distance can in turn be used as a base for points still farther away. The base B C helped to decide the distance of the moon, and, taking the known stretch earth to moon as a base, the distance of the sun, which is several hundred times greater than that of the moon, can be determined. When the moon is but half illuminated, when it is in its first quarter, the sun, earth and moon occupy the positions to each other shown in Fig. 112. If two lines were drawn from the centre of the moon (M) to the earth's centre and the sun's centre, they would exactly form a right angle in the moon's centre. The base M E (moon to earth) is a known one, as is the angle at M, for at the time of the first quarter it is a right angle (90 degrees), as shown by the moon's illumination on the part of the sun. It therefore only remains to measure the angle at E, which hardly offers any great difficulty. Knowing the length of one side and the two angles, the length of the line S E, the distance of the sun from the earth, can either be calculated by an easy sum or by the simple method already described.

to cross the earth's orbit has been found to be about 16⅔ minutes, from the fact that eclipses of Jupiter's satellites occur 8⅓ minutes before their predicted time when Jupiter is nearest the earth, and an equal amount behind it when he is farthest from us. A simple multiplication gives us the sun's distance.

In Chapter XIII. will be found another method of determining the distance between the sun and the earth (p. 149), which is the chosen unit for all astronomical measurements, and which has been termed the "ell of the universe," as the majority of all other measurements in the starry realms are based on it.

The Meaning of a Parallax.—The scale of these measurements is very precisely graduated: First of all come the measurements on earth, then the distance between earth and moon, then the sun's distance, and so on. The base is constantly extended, and with it the possibility of ever-increasing measurements.

If we hold up a finger close to our eyes, and, closing one eye, gaze past the finger at the wall, we shall find that a certain spot or object on the wall is covered by the finger. Now close this eye and open the other, and we shall find our finger covers a totally different spot; it seems to move according as the right or left eye is employed. Repeat the experiment with the outstretched arm, and the apparent difference is much less than before. If a stick is used instead of a finger, and moved farther and farther away from our eyes, we shall hardly be able to notice any removal in place when gazing with alternately closed eyes. This apparent change in position of an object to its background, when viewed from different points, is termed a parallax, and

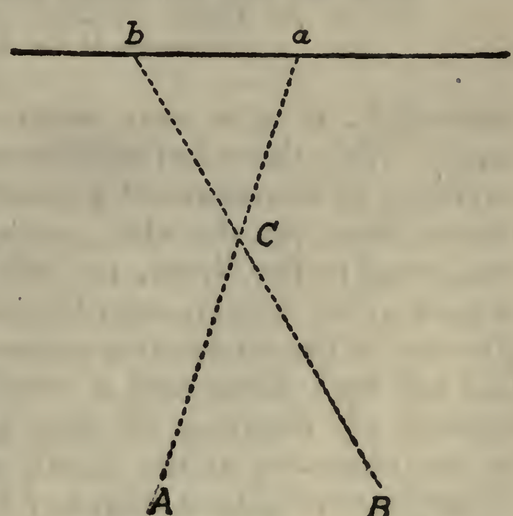


Fig. 113.—Illustrating Parallax.

it is of great importance for measurements in space. Our eyes may be treated as two different observers regarding the same object from various points. Observer A in Fig. 113 sees the solitary tree stationed at C at *a* in the background of the landscape; whilst B sees it stand at point *b*. The farther the tree is from the observers the smaller the displacement, the smaller the parallax; and the farther away any object under observation is, the farther the observers have to move away from each other to detect any shift. Two observers only a thousand yards apart would see a star stationed near the moon in almost exactly the same position; if, however, they were separated by a few hundred miles, the one farthest away would find the position of the moon to the star to have considerably altered. The moon is our nearest celestial body, so a change of position is still

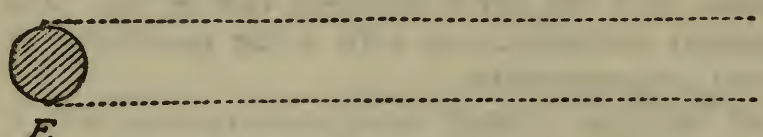


Fig. 114.—Two lines drawn from opposite points on earth to any one fixed star remain parallel, owing to the minuteness of the earth's diameter compared with the vast distances of the fixed stars.

perceptible, as it is with several planets that approach the earth. With those farther distant, such as Saturn, scarcely anything in the nature of a parallax can be noticed, even if the observers put the whole earth between their standpoints, one going to the North, the other to the South Pole. For objects so far distant, even the immense base offered by the diameter of the whole earth is too small, and if other methods had not been discovered it would have been impossible to measure the distances of these planets. Two lines drawn by the observers at the North and South Poles to these remote stars would not form any angle at all, but run parallel to each other (Fig. 114).

The Distance of the Fixed Stars.—A still greater base line is necessary to determine the distance of the fixed stars, those remote celestial bodies that nightly sparkle in their millions in the skies, and this base is given us by the earth itself in its annual journey around the sun. During the course of a year the earth describes an almost circular path around the sun, keeping at a distance of 92,820,000 miles. The entire diameter of the earth's orbit may be set at 185,640,000 miles. If an astronomer were to carry out a measurement for the determination of the distance of a fixed star on, let us say, March 21, and were to repeat it on September 23, or six months later, he would, in the meantime, have moved 185,640,000 miles from the place of his first measurements, and therefore have gained a base of these gigantic dimensions. In Fig. 115 S represents the sun; the earth's orbit is drawn round it. The earth's position on March 21 is indicated by the letter A, and on September 23 by the letter B; F is a fixed star. The length of the base A S B is 185,640,000 miles, and should the measurement of the angle at F, the star's parallax, be carried out successfully, the distance of the star can then easily be calculated. All endeavours to determine a displacement of the fixed stars, their parallax, were for many years in vain; even this immense base proved to be too small. The fixed stars are so extremely distant that the 185,640,000 miles of the earth's orbit dwindled to a vanishing point in comparison with these immeasurable spaces. The two lines extended towards the fixed stars under observation (A F and B F of our diagram) ran parallel each time. Not the slightest change of position of the fixed stars was perceptible, and the opponents of the Copernican theory that the earth revolved around the sun were strengthened in their belief by this circumstance. It was impossible in those days to grasp the fact that the fixed stars were at such an enormous distance away that the annual revolution of the earth did not lead to a parallax—a deduction Copernicus had already arrived at from this

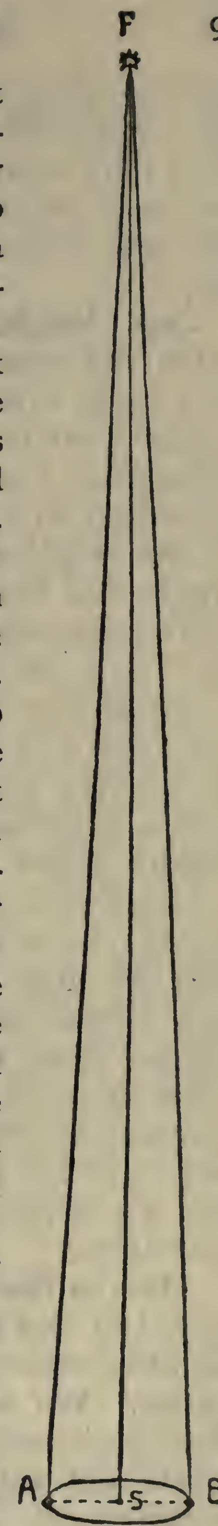


Fig. 115.—Measuring the Distance of a Fixed Star.

very circumstance. Thanks to the more delicate measuring instruments of recent times, a displacement of some few fixed stars nearest to us was finally discovered as a consequence of the annual revolution of the earth around the sun. The first to be successful in this direction was Bessel, in 1837.

Our Neighbouring Suns.—The first fixed stars of which the measurements were crowned with success were 61 Cygni, a small star in the constellation Cygnus, and Alpha Centauri, the brightest star in the constellation Centaurus, a group of stars in the southern hemisphere. According to our present-day knowledge, these two stars are the neighbours of our sun in space, for fixed stars are naught else but suns enormously remote. Alpha Centauri is the nearer of the two. And what is the size of its parallax? It is so tiny that the lay mind will hardly be able to grasp how the astronomer managed to determine it. The angle at F in Fig. 114 is but 0.75 second of arc—that is, the seeming displacement of this star by the change in the earth's position only amounts to the 2,500th part of the breadth of the moon at full. As the length of the base is a known one, the distance dividing us from the star can speedily be worked out. It is 275,000 times farther away from us than the earth is from the sun, or just about 25½ billion miles; and light, which travels at a rate of 186,420 miles per second, would need four and one-third years to come to us from that neighbouring sun! The distances of suns farther away than eighty years of light—and there are but few of them so close to us as all that—can no longer be measured; we have to take refuge in estimation.

How to Find the Size of the Moon.—Now that we have gained an idea how to determine the distances of the universe, we will endeavour to find out the sizes of the various celestial bodies. We all know that the farther an object is away from us the smaller it appears. A house possesses a certain height and width seen a hundred yards off; at two hundred yards it only appears to be half the height; and at three hundred yards it has dwindled to a third of its original height. The dimensions in which objects appear to us therefore stand in a certain defined relation to their distance, and their size, if known to us, permits an estimate of their distance, and *vice versa*. Armed with this general and commonplace knowledge, we will try to calculate the size of the moon, as we know its distance. In order to do so, a five-shilling piece is attached to the window-pane with a little wax—this at the time of full moon. We then stand back far enough to let the coin appear exactly as large as the lunar disc, which it should cover. This should be done several times to exclude all possibility of error; whereupon the distance of our standpoint from the window is measured. This is 4 yards 21⅓ inches. The moon is 238,876 miles away from us, about 91½ million times farther than the coin; and, as this equals the moon in size at the distance stated above, the moon must be 91½ million times larger than a crown piece. Now multiply the diameter of the coin by 91,500,000, and we shall get the total of 2,160½ miles. The moon's diameter is, as we shall learn a little farther on, one of 2,159½ miles, which comes very near to the calculation made in our own home with a yard-measure and an ordinary coin. This is a very easy way of solving a task that appeared so difficult. The proper astronomical methods are, naturally, far more precise and involved.

The Size of the Sun.—The size of the moon aids us in determining that of the sun. To our vision they both appear very much of a size. This would be correct were the sun exactly as far away from us as the moon, namely 238,876 miles; but the sun, at its mean, is 92,600,000 miles distant, or 388 times farther than the moon. As it apparently equals the moon in dimensions, its diameter must be 388 times larger than that of the lunar body, and a sum in multiplication sets down the sun's diameter at 839,039 miles. In reality it is computed at 863,722 miles, but, considering our rough calculation, the difference between the two is not very great. It is caused by the fact that the apparent solar diameter, which to the unaided eye appears to equal that of the moon, is a 31st part larger than the apparent diameter of the moon. If this be taken into account, we can understand the flaw in our calculation. Of course, other dimensions can be worked out in the same manner.

The Density of the Sun.—If the diameter of a sphere is known, its circumference, surface, capacity can all be determined with ease, and it need no longer surprise us to learn that 1,250,000 of our earths could be packed away within the sun. Astronomers can even inform us of the weight of the moon and planets as compared with that of the earth, for the attraction exercised by one celestial body on another is dependent on the distance they are apart and their size, or, more correctly, on their mass or weight. If a body possess a thousand times more mass than another—that is to say, if it is a thousand times heavier—it exerts an attraction equally powerful on the lesser body. The attraction the sun exercises on the earth forces the latter to carry out certain recognised motions. The speed of such motions has been measured, and enabled us to decide the attractive power of the sun. This led to a determination of the mass of the sun in proportion to that of the earth. It is estimated that the sun has 323,000 times more mass than the earth, and if they were placed on a scale it would take 323,000 earths fully to balance the sun. And this leads up to another deduction. As it would take one-and-a-quarter million earths to form a body as large as the sun, whilst 323,000 earths would suffice to equal its weight, the conclusion forces itself on us that the matter the sun consists of must be less dense than the terrestrial matter. This shows how purely mathematical calculations lead us on to other discoveries and help us to ascertain the physical constitution of the astral bodies.

How the Mountains of the Moon are Measured.—The present chapter opened with an anecdote of an astronomer who gained an unenviable reputation as a liar by declaring that he had measured the height of the moon mountains, and we will finish the chapter by showing how such measurements are carried out. They are usually done by a telescopic measurement of the shadows thrown by the mountains. We will first learn how to determine the size of an object by the shadow it throws. Suppose we are taking a country walk, and see an especially fine tree whose height we should like to know. The sun shines brightly, and all objects throw sharply-defined shadows. Suppose we carry a stick we know to be a yard long. We fix it in the ground with the help of a few stones, and measure its shadow, which is two and a half yards, or two and a half times longer than the stick itself. The shadows thrown by all upright objects at the hour chosen must be two and a half times longer than the objects themselves. We now proceed to measure the length of the tree's shadow from the foot of the tree to the tip of the shadow, and find it to be 75 yards. This informs us that the tree has a height of 30 yards, as its shadow is two and a half yards longer than itself at the time of measuring.

The shadows thrown by the mountains on the moon show up very clearly in the telescopes, as will be seen by the

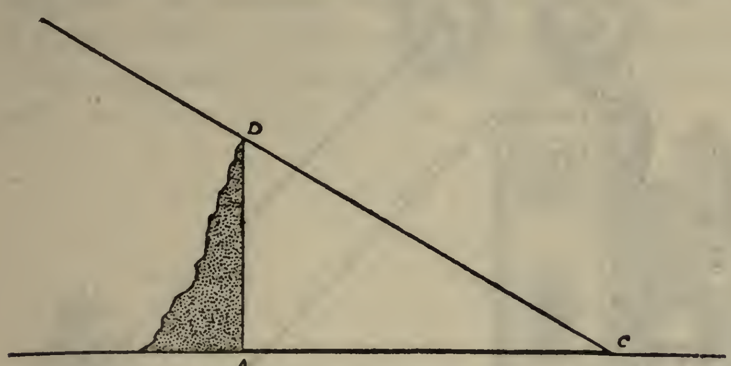


Fig. 116.—Measuring the Height of a Mountain.

pictures after photographs (Figs. 173, 175, 176). The length of these shadows increases (apart from the height of the hills) the lower the sun sinks, and decreases the higher the sun rises above the horizon of that particular lunar district. In Fig. 116 A is to represent a moon mountain on which the sun shines, the shadow reaching to point C. The astronomer measures its length with the help of the spider lines with which we became acquainted (p. 37) during our visit to the observatory, and we will say it measures the 435th part of the moon's diameter, which is, as we know, 2,159½ miles. A line drawn from the point of the shadow at C across the summit of the mountain D to the sky would meet the sun. This forms a triangle, A D being the height of the mountain, A C the length of the shadow, and the angle at C the height of the sun. We know the length of the line A C, as also the angle at A, as it is a right one, and it remains for the angle at C, the height of the sun above this district, to be determined. This is not a very difficult matter, as the astronomer is acquainted with the relative position of the sun and moon at every hour. In our case we shall put the sun at 30 degrees above these lunar regions; so the angle at C is one of 30 degrees, and the construction of the triangle, carried out on the lines explained early in this chapter, shows the hill to be 15,144 feet high. Although it may at first sound a little incredible to be informed of the height of mountains on a celestial body hundreds and thousands of miles away, there is absolutely nothing supernatural in the way this know-

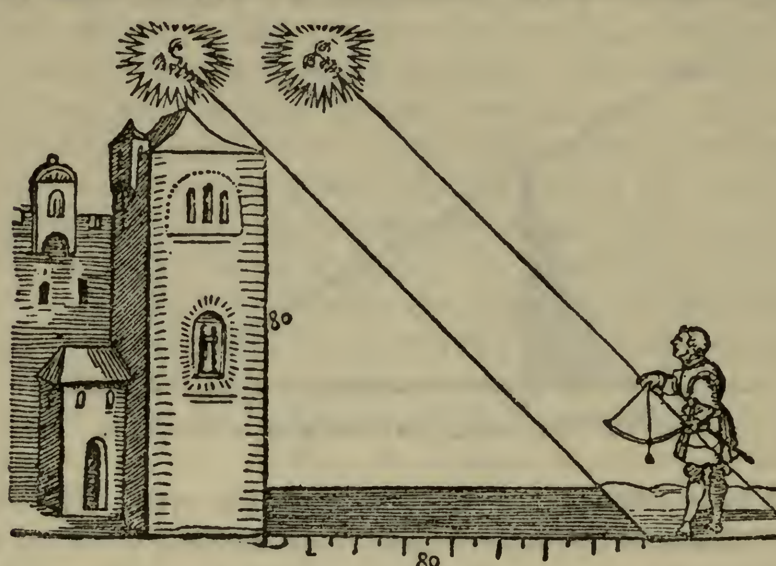


Fig. 117.—Measuring the Heights of the Sun and of a Building in the Middle Ages.

(From Peter Apian's "Book of Instruments," 1533.)

ledge is arrived at, as we have now learnt. Antiquarian interest at least attaches to Fig. 117, which is an attempt, dating from the Middle Ages, to render pictorially the method of measuring the heights of the sun and of a building.

By the by, the astronomer does not see the mountains on the moon in the manner shown in our diagram, for he gazes down on them instead. An aviator, only seeing the platform of the tower over which he flies, is able to gain an idea of its height and shape by the shadow the tower throws;

and all the astronomer sees of a moon mountain is a radiant spot and the shadow cast by the sun, as the lunar photographs distinctly show. But as he only needs to know the length of the shadow and the height of the sun, this amply suffices.

We have now finished our chapter of explanations, and I dare say a good many of my readers are tired of its dryness. It is, however, impossible to attain the pure heights of astronomical science without having passed through a chaos of figures and formulæ, without having thrown a fleeting glance at the labyrinth of mathematical findings in which the calculators are engaged, to convey a correct idea of the structure and wonders of the universe. And deeper penetration into these dry figures shows them possessed of a peculiar and wondrous charm, for they are the keepers of the key that unlocks infinity to us.

CHAPTER X

OUR HOME IN SPACE

Our earth is but a drop in the infinite ocean of the worlds, comparable only with the snowflakes that dash past us in swirling millions, driven by the storm, and engulfed and lost in the chaos of the whole. The space around us is infinite, filled with radiant worlds as far as the eye can see. Where in the universe has the globe we inhabit its allotted home? Where is there a haven of rest for us in the whirl of the celestial bodies? How often we despair of ever finding our way about in this gigantic structure when we see star jostling star, knowing that the telescope will reveal ever new armies of stars to us, hidden from the naked eye! We know that these wee twinkling stars are in verity huge spheres immeasurable distances away, and the knowledge is borne in on us that they are hardly so closely situated to each other as it would appear. Immense distances separate these vast worlds, for their crowding is only apparent, and a ray of light which rushes through space at so terrific a velocity often has to travel for many decades to span the gulf between two neighbouring stars. If we could stand at a point in space that presented us with a full view of our own position among these countless worlds, comprehension would be greatly facilitated. Were it possible for us to leave the earth and soar higher and higher until this globe, which serves as a shelter for 1,500 million people, were but a luminous disc like the moon, a globe shining in the light shed by the sun, all problems would be solved at once, riddles that it took mankind thousands of years to grasp until a Copernicus appeared and recognised the motion of the earth and its kin around the central luminary, the sun. And if we rose still higher, the earth would begin to fade from our view until it became but a glittering star encircling a much larger and brighter one at a respectful distance. We should also see that it does not wander alone around that ball of fire, but that other similarly-constituted celestial spheres revolve around the radiant central star as well, at distances more or less remote.

The Sun and the Planets.—There are eight such worlds, all far apart from each other, describing different circles around the remarkable star that furnishes them all with light, and we should see other small satellites, usually several in each case, wandering around their own especial world, like the faithful moon which dances incessant attendance on our earth. Besides this flaming central star, with its eight worlds and their moons, there would be no very conspicuous stars near; those we can see nightly in the skies are far, far away.

It is our home in the universe we saw on our imaginary journey through the ether, the sun and its planets and satellites, our own solar system.

Later we shall be informed that the millions of stars sparkling in the skies are suns like ours, incandescent globes of immense size, probably surrounded, like our sun, by smaller darker spheres, such as our own earth. There must be millions of such groups of celestial bodies, such suns and planets termed solar systems, in space. Each one of these forms a province of its own in the Empire of Urania, and our own solar system, therefore, really is our home in the universe. Across its borders is a desert stretch, and endless voids divide us from the nearest province.

The Great Wanderers.—Eight large wandering stars or planets revolve around the sun. The earth has seven brothers and sisters, which we see in the guise of radiant stars in the sky. They do not, however, retain their position like the fixed stars, which form well-known groupings and configurations of exactly the same aspect to-day as they had thousands of years ago, and will, in all probability, retain for centuries to come, as the stars they consist of have not moved very much during all this long period. The planets, on the other hand, have to describe their paths around the sun and wander on among the fixed stars; their motion and tranquil light distinguish them from the other stars even to an unassisted eye.

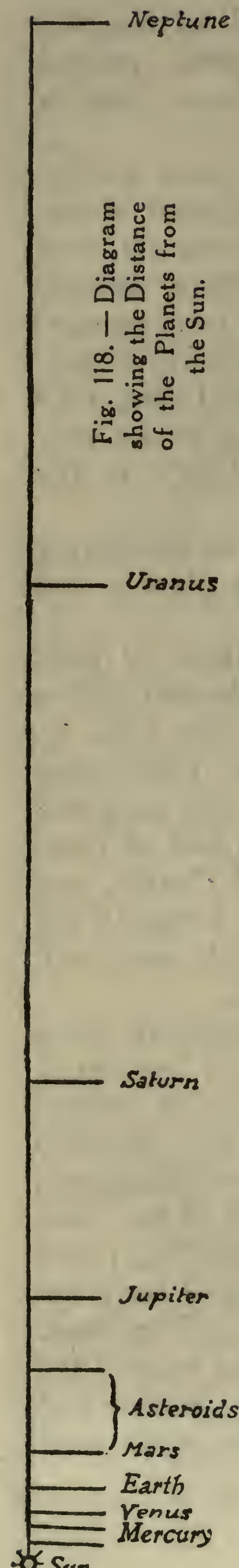


Fig. 118. — Diagram showing the Distance of the Planets from the Sun.

The Solar System.—Fig. 119 shows us a map of our home in the universe, our solar system. The sun is in the centre, and the planets move around it in almost circular orbits. A number of comets likewise revolve around the sun, the orbit of Halley's comet being marked on the chart; but these will be dealt with in Chap. XXIII. The planet Mercury is nearest the sun, and therefore completes the smallest circle, for it is only 36,000,000 miles away from the sun's centre. Beautiful Venus, the "evening" and "morning" star, the most radiant of all planets, is nearly as far again, as 67,000,000 miles separate it from the sun. Our earth is the third planet, and runs its course at a distance of 92,820,000 miles; Mars follows with 141,000,000 miles, and then comes a tremendous stretch, which was formerly believed to be empty. Our chart shows it filled with dots, and we shall learn a little later that an immense number of tiny bodies revolve in this space. They are called asteroids or planetoids, formerly supposed to be the fragments of a single planet which was destroyed æons ago by some unknown event.

Far away from Mars, far, far from the sun, lies the orbit of Jupiter, the fifth and greatest of all the planets; 478,500,000 miles divide it from the sun, which, seen from there, has greatly lost in dimensions. Saturn's course is almost as far off again—885,500,000 miles. All these planets are bright stars known to the ancients and, the earth naturally excluded, visible to the unaided eye. The planet in next order, Uranus, is so far away from the sun that it appears to us a small, insignificant star. It was only discovered by Herschel in 1781, and is just as far away again

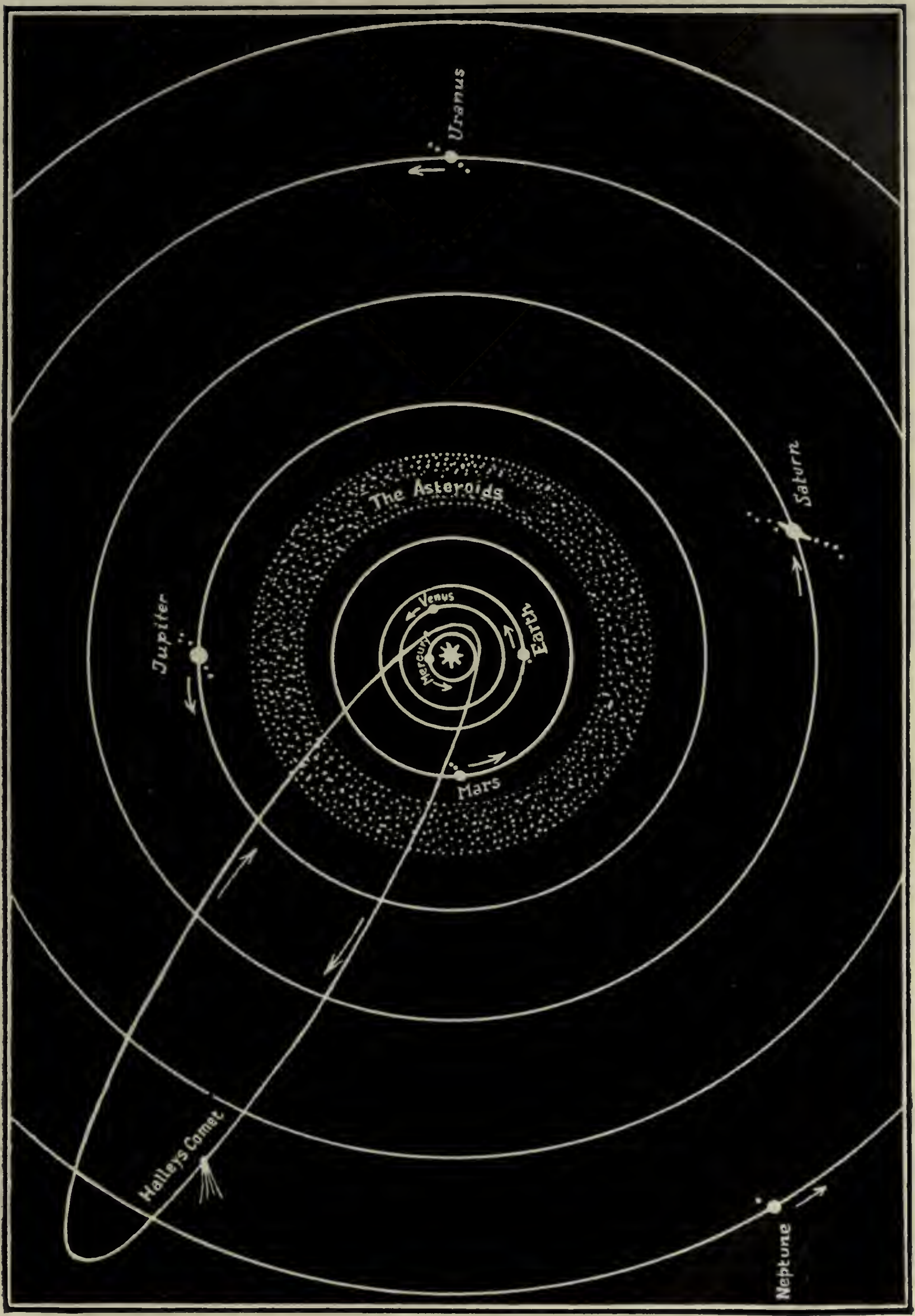


Fig. 119.—Diagram of the Planetary System.

The orbits of the Planets around the central Sun are shown, as well as the orbit of Halley's Comet and the position of the Asteroids. (See also Fig. 118.)

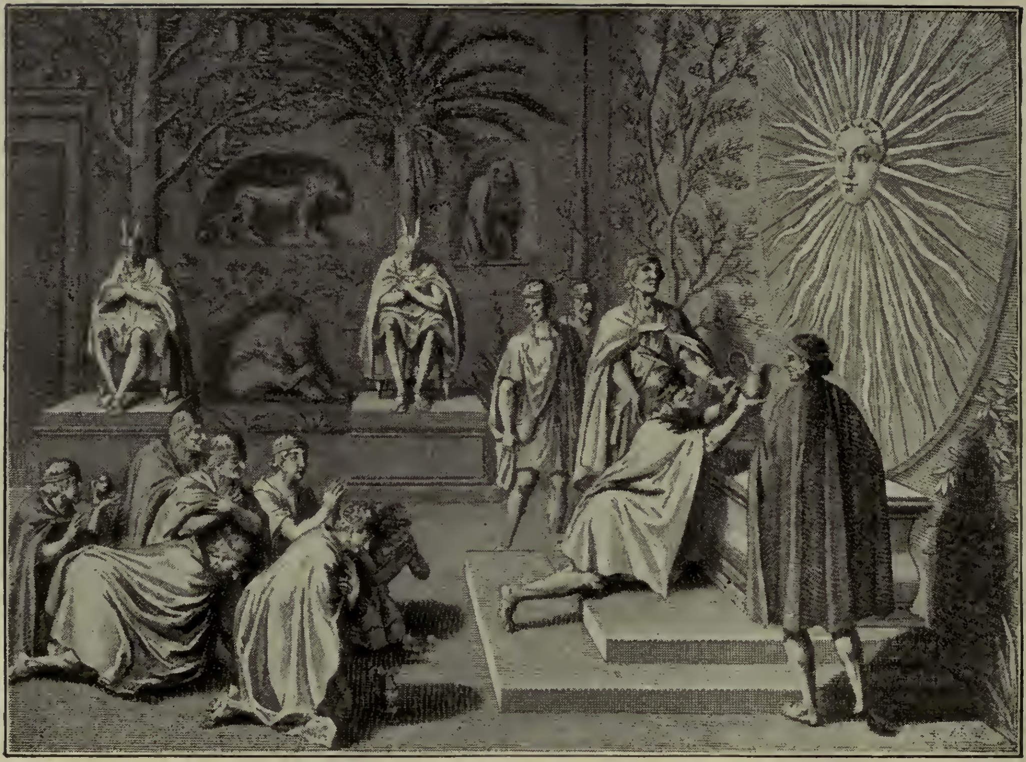


Fig. 120.—Incas of Peru praying to the Sun.

(From Bernhard Picart's "Cérémonies et Coutumes religieuses des Peuples idolâtres," 1723.)

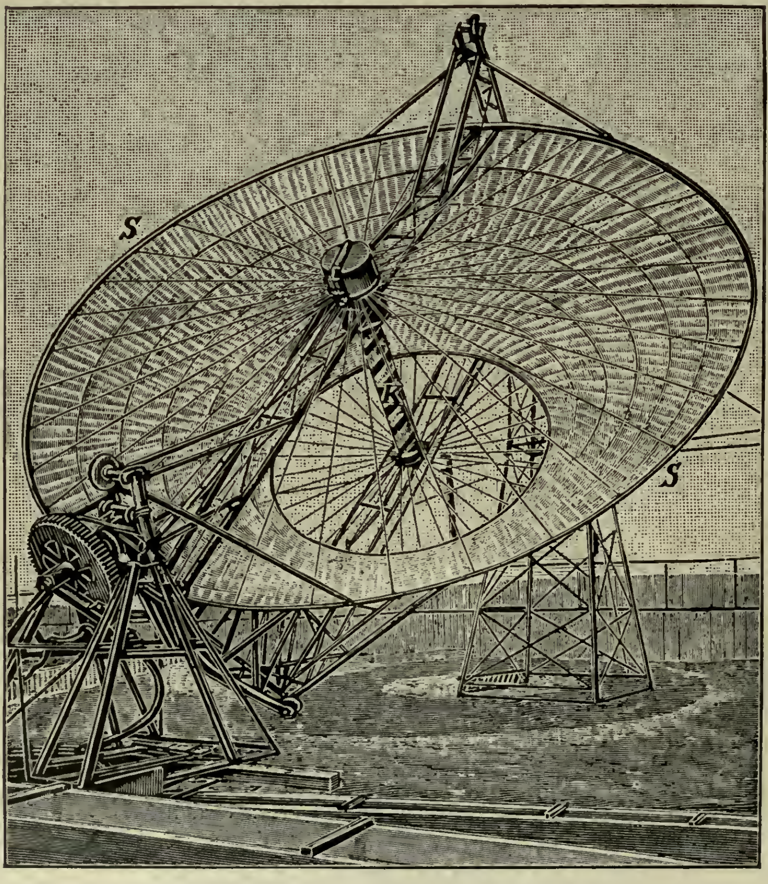


Fig. 121.—Sun Motor on an Ostrich Farm in California.

from the sun as Saturn, namely 1,777,000,000 miles. Neptune, the eighth planet, marks the border-line of the sun's realm. It is only visible in the telescope, and was mathe-

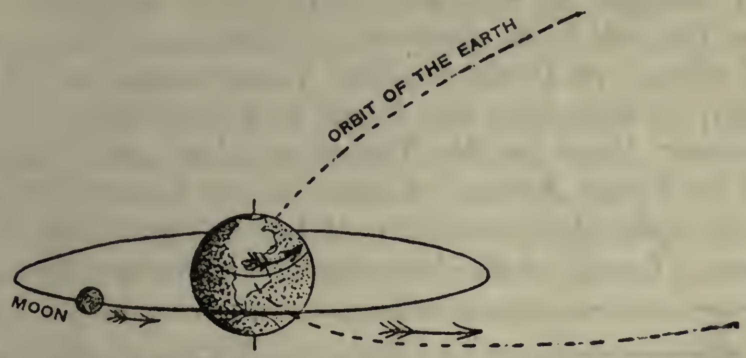


Fig. 122.—Illustrating the Rotation of the Earth on its Axis.

Its orbit round the sun and the moon's path round the earth, all in the same direction, as the arrows indicate, are also shown.

matically located by Adams and Leverrier in 1846, and found in the sky by Galle, of Berlin. It describes its gigantic solitary course at a distance of 2,790,000,000 miles in a dim, grey twilight.

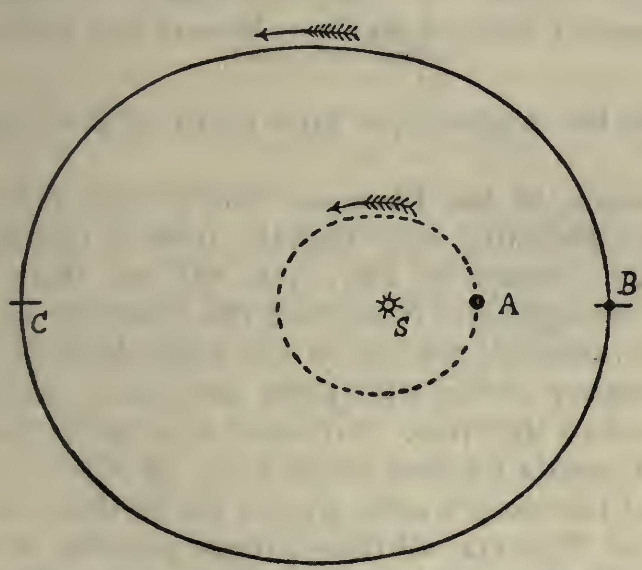


Fig. 123.—Variable Position of two Planets to Each Other.

The Planets' Distances from the Sun.—Lack of space made it impossible to give the correct relative distances in Fig. 119, but these are supplied in Fig. 118. It will be recognised that the planets nearer the sun are not so far apart as are those farther away. In any case, it is extremely difficult to gain an equivalent idea of these immensities, and we will attempt to elucidate them on a terrestrial scale. Suppose the sun to be stationed at Berlin, and Mercury, its nearest planet, at Dresden; then Venus would be at home at Pilsen, in Bohemia, the Earth near Ingolstadt, Mars at the Brenner Pass in the Tyrolean Alps, and Jupiter at Tripoli in North Africa. Saturn would have its stand in the heart of the dark continent at Lake Tchad, and Uranus in Ovambo Land, whilst Neptune would have to be sought

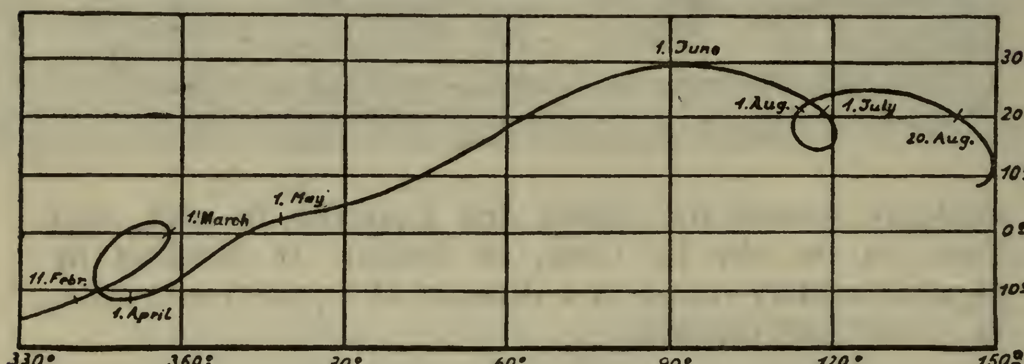


Fig. 124.—Apparent Motion of the Planet Mercury from February 10th to August 20th, 1885.

for deep in the Antarctic, a little north of the South Polar Circle.

Movements of the Planets.—The planets move around in ellipses, deviating very slightly from a circular shape, and, as the arrows in Fig. 119 tell us, their direction is similar throughout. Nearly all the planetary moons, our own moon included, revolve in the same direction, and the rotatory motion of the sun, earth and other planets forms no exception to this rule. To assist to a better comprehension of the earth's rotation on its axis, its revolution around the sun and the moon's orbit around the earth are all marked by arrows in Fig. 122, all these arrows pointing in the same direction. These movements are carried out from west to east, as can be observed from the daily rotation of the earth and the motion of the moon in the sky. Twigs twirling around in the same direction in a tub of water lead to the conclusion that the water has been set into a regular motion in which all the bodies swimming on its surface have to participate. The motion of the planets and moons of the solar system permits a similar deduction, and leads us to believe that at the time this gigantic stellar structure developed the matter forming it possessed a uniform motion corresponding to the present one.

The whole subject of planetary motion would be a very simple one to a being floating above the solar system. He would witness a faster movement on the part of the nearer planets, whilst the more distant ones described slower circles around the sun. It is a totally different matter on the earth which itself moves, and the proper motion of the earth and the motion of the planets in the skies produce more or less intricate curves. These are the result of the circling movement of two bodies, now moving in the same direction, now in different ones; hence they approach and recede, as is shown in Fig. 123, where S stands for the sun, A for the earth, and B for a planet. As the earth, in its smaller orbit, moves faster than this other planet—which we will take to be Mars—the above singularities when passing the planet make it appear to lag behind it. The planet thus appears to us to move backwards and forwards in the sky, or even to stand still; and if we trace and note down the motion of a planet during a period of several months, all these movements combine in a twisted curve. Fig. 124 shows this apparent motion of Mercury.

Ptolemy's Theory.—It naturally proved a baffling task to the ancients to understand the planetary motions, as they believed the earth to be stationary in space, whilst all else revolved around it, the hub of the world (Fig. 127*a*). The world system set up by Ptolemy (see Fig. 125) was adhered to until Copernicus came. The stationary earth is in the centre, and around it, at ever-increasing distances, the Moon (☾), Mercury (☿), Venus (♀), the Sun (☉), Mars (♂), Jupiter (♃) and Saturn (♄). The most distant planets, Uranus and Neptune, were not yet discovered, and Ptolemy (Fig. 106) pronounced the great hollow dome to which the fixed stars were attached to be on the far side of Saturn. The supporters of his theory were puzzled to explain the intricate movements of the planets, caused, as we have just learnt, by the earth's own motion; for, according to their teachings, the earth rested in the centre of the universe, and did not turn on its axis. They therefore set up a most complicated machinery which worked behind the scenes of the universe: numbers of transparent spheres, to which the celestial bodies

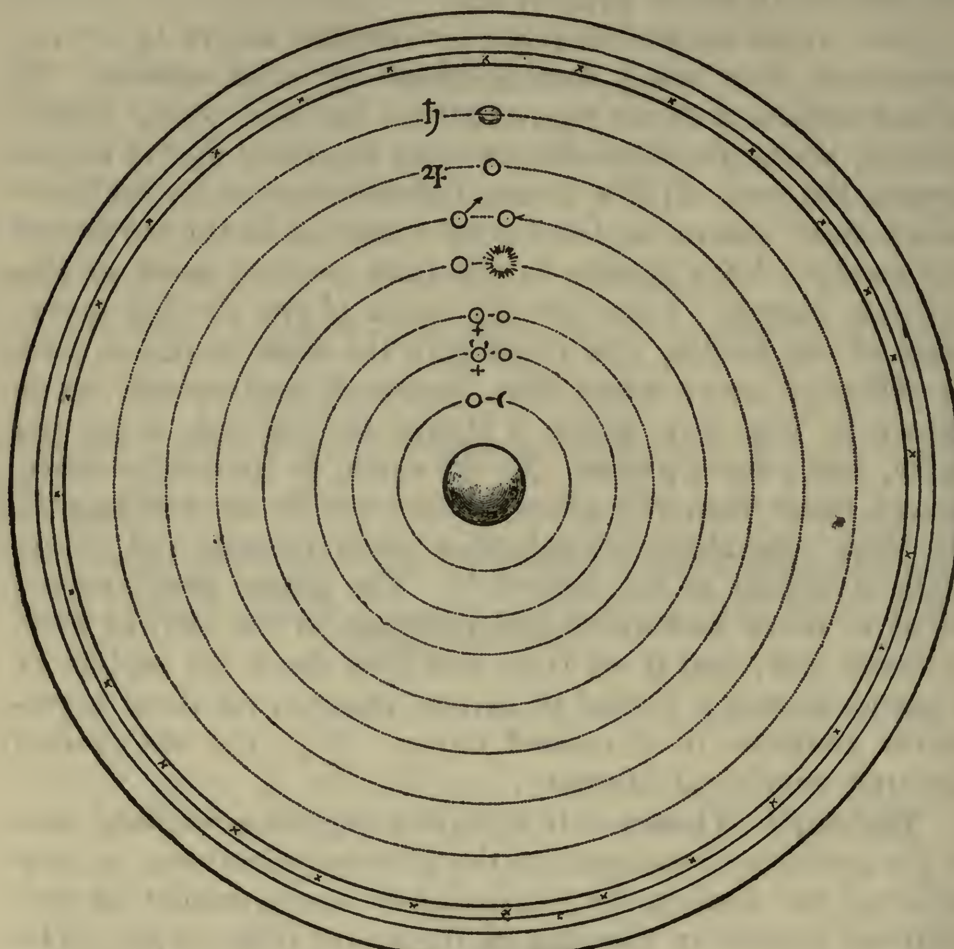


Fig. 125.—Diagram of the Ptolemaic System.
The earth is in the centre, and the moon, sun and planets revolve around it

were fixed, revolving in and around each other in main and auxiliary circles (see Fig. 1). King Alphonso of Castile, who reigned about the middle of the thirteenth century, and who was an ardent lover of astronomy, on attempting to grasp Ptolemy's system, gave utterance to the statement that he would have worked the celestial bodies in a simpler manner had he had the power—an opinion that cost him his throne, as it was regarded by the Church as rank blasphemy to cast the slightest doubt on the conception of the earth being the heart of the universe (for it was here the Saviour had suffered and God's creative power was revealed).

The Teachings of Copernicus.—Nicholas Copernicus* (Fig. 18) lifted the earth out of its central resting-place. The magnificent force and lucidity of his teachings blazed out like a beacon:—*The sun is motionless; the planets, the earth not excepted, move around the sun, and the daily revolution of the starry skies is but an apparent one caused by the diurnal rotation of the earth on its axis.* Of course, these great fundamental principles met with powerful opposition and counterblasts of all kinds. It was stated that the earth's movements, if there were such, would make themselves felt, and that mankind would undoubtedly experience unpleasant results if the earth were to spin round like a top. No proper idea could be formed of a rotating globe floating detachedly in space; but the Copernican teachings slowly fought their way all over the earth, never to be displaced.

Planetary Years.—The time a planet needs to journey once around the sun is called its year; the farther away the star is from the sun the longer its orbit is, and consequently the longer its year. Mercury completes a circuit in 88 days, Venus in 225, and the Earth in 365 days. Mars takes a year and 322 days, Jupiter 11 years and 315 days, and Saturn's year equals 29½ of ours. Uranus only revolves around the sun once in 84 years, and it actually takes Neptune 164⅔ years to pace out its remote and immense course. The planets at a distance move more slowly than those nearer the sun. Mercury's speed is assessed at 29½ miles per second, that of the earth at 18⅓ miles, and Jupiter's at 8 miles; whilst Neptune only moves at a rate of 3½ miles per second. This decrease of motion in the more remote planets corresponds to the lessening of the sun's attractive power.

Why the Planets Revolve Round the Sun.—This is where the question arises as to how it is possible for the

* Nicholas Copernicus was born at Thorn in 1473 and died in 1543 at Frauenberg, where he was Canon. He had evolved his theory of the universe in 1507, but it only appeared in print a few months before his death.

celestial bodies to revolve around each other; for the moon to revolve around the earth; the earth around the sun, and so on. What forces these bodies to encircle their central star in a certain unalterable manner within a regular period? Why do not earth and moon travel through space in a straight line, heedless of the other bodies? First of all, we know that these bodies attract each other. This power of gravitation or attraction, whose laws were set forth by the illustrious Sir Isaac Newton, is contained in every heavenly body, and is proportionately greater with the increasing size, or rather weight, of the body. The actual force between the earth and moon acts equally on each body; but the smaller body, the moon, is much more moved by this force than the larger body, the earth. Both move round their centre of gravity, which is 3,000 miles from the earth's centre. And as the sun is immensely greater than the planets, the latter are forced into subjection. We do not know the primary cause of this law of attraction—how the one body begins to compel the other towards it; but then, the innermost principles of electricity and magnetism are also as yet unknown to us, although we have established the laws of both these powers and work with them. We will now endeavour to find out how the planetary orbits originate.

The Laws of Attraction and Gravitation.—If the billiard ball K in Fig. 126 were hit in the direction of A, and another stroke immediately following were to drive it towards B, the ball would answer both forces simultaneously and roll towards C, carrying out the diagonal K C of the parallelogram K A C B K. The planets, also, move under the influence of their own momentum and the sun's attraction. The earth possesses a certain momentum which would compel it to fly straight ahead through space if the attraction of the sun did not alter this. If, on the other hand, there were only the sun's attraction to be reckoned with, the earth would rush on toward the sun, and be swallowed by it. Both tendencies, however, combine to form the somewhat flattened circle described by the earth. In Fig. 127 S represents the sun and E the earth. If there were nothing to affect the momentum of the earth, it would arrive in due time at *a*; if the sun's power of attraction were alone at work, the earth would travel towards *b;* both, however, acting in unison, force the earth on to *c*. Its own momentum would drive it on to *d;* the sun pulls towards *e;* and so the earth, replying to both, passes on to point *f*. Instead of travelling to either *g* or *h*, for the same reason, it flies to *i*, and so the circular path is gradually evolved. Kepler was the first to recognise the laws according to which the planets move, and he laid them down in his three celebrated theses.

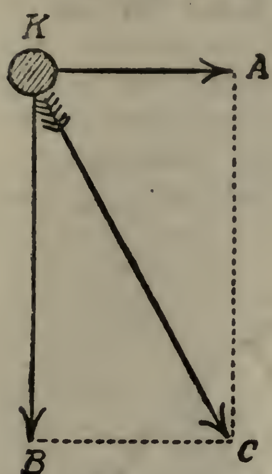


Fig. 126.—Illustrating the Parallelogram of Forces.

The Size of the Sun and Planets.—The gigantic sun-ball is the mainspring of this stellar family, in which all is subject to its enormous power and size. Fig. 3 shows us the proportions of the sun and planets. All the latter together, if placed into the body of the sun, which we will imagine to be hollow, would only fill its 560th part! If we placed the earth in the centre of the sun, and the moon at its proper distance away, there would almost be sufficient room for the moon's orbit twice over. Mercury and Mars are much smaller than the earth, Venus nearly equals the earth in size, whilst Uranus and Neptune are much larger. Jupiter and Saturn are the sun's giant offspring; the one is 1,300, the other 700 times larger than the earth, and with their numerous satellites, of which Jupiter possesses

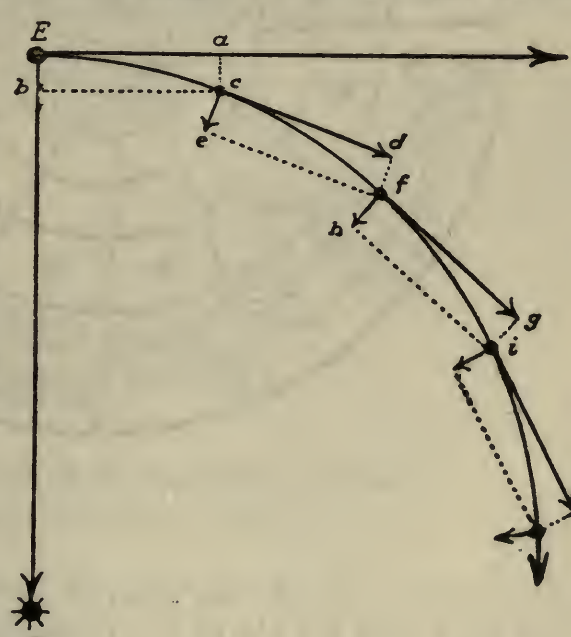


Fig. 127.—How the Orbit of a Planet Develops.

eight and Saturn nine, they form stellar families of their own of quite respectable dimensions.

The Comparative Smallness of the Solar System.—Eight large planets, with 25 moons all told, more than 700 planetoids, and a whole number of comets, form the family of the sun. If we were as far away from this solar system as the fixed stars are from us, we should know nothing of it, for, seen from such a distance, the sun would only appear

Fig. 127A.—The Earth as the Centre of the World.
(From a sixteenth-century engraving.)

as a small star, and no trace of its satellites would be seen, not even with the aid of a very powerful telescope—only that one solitary star, a distant sun. And this is what happens to us, with all these other brothers and sisters of the sun, the millions of stars overhead. We only see the sun-star of these millions of solar systems, not the millions of earths and moons that surely exist, for the universe is fashioned on the same principles throughout.

In this chapter we have glanced into the immeasurable space surrounding us, and have learnt that the number of the worlds is even greater than we dared believe. Nothing deters us from assuming that there are millions of earths, with millions of living creatures, in these millions of solar systems. It is less absurd to accept their existence as a fact than to believe that the earth is the only spot possessing rational life in the whole of the universe. This is a new centralisation delusion which needs a new Copernicus to destroy! But such an assumption does not bring us a hairbreadth nearer to the solution of the eternal problem of the cause, the why and wherefore of the whole enormous universal system; it only renders it more mysterious, more complicated still, and I can but quote the poet's words:

> "The infinite has no Why,
> It is what Is: a circling wheel
> Of Eternal Being, an Individual
> That knows no other measure but itself."

CHAPTER XI

THE SUN—A BALL OF FIRE

THE sun's fiery chariot speeds on incessantly over the heights, deep down into the valley, and when the sun-god triumphantly breasts the mountains our old battered earth awakens to fresh glory and puts forth her fragrant blossoms and green gleaming leaves; the air is filled with the hum of insects and the song of birds. Joy reigns everywhere, for summer has come. But when the sun-car rolls down into the valley, the mists draw up and enfold the god, whose beaming arrows begin to lose their power and can no longer warm us. The flowers fade, the foliage withers, and north winds tear through the land. Crystal drops form where the green leaves fluttered, glistening needles are showered down upon us, and a white pall hugs the earth. Men collect within the sheltering walls of the city to await the end of the winter and the upward course of the radiant sun-chariot. It mounts again in spring, and the earth hastens to deck itself for its most welcome guest. Stern winter and its vassals in vain attempt to stem the onrush of the chariot-wheels, their icy ammunition is shed in vain; the north winds are beaten back to their fastnesses. The darts of Eos aim well and true, and the wintry army retires growling to its regions of ice and snow. We experience this every year anew, and each time the coming of spring is vested with charm and novelty. New life and new power seem to pulse within us when the flaming globe above travels upwards. There are none too old to feel refreshed, none too ill to have new hope infused; and with the awakening of summer the general state of human health takes a decided turn for the better.

What the Sun Does for Us.—If we argue out the subject we shall find that all the energy within us is but transformed sun-power. For man is what he eats, and all we eat grows, flourishes and lives in the ray of the sun. No plant can exist without sunlight and warmth, and every member of the animal kingdom is dependent on plants for its nourishment, whether it feeds exclusively on them or whether it lives on other beasts which, in turn, subsist on plant-food. Sunlight and warmth are necessary for every expression of activity in life, and the muscular power of man and beast is, in its primary state, transformed sun energy. And not muscular power only; for the brain power needed to write this book, and the mental exertion on the part of my reader in following my ideas, both have their origin, if we trace them back to their beginning, in that ball of fire millions of miles away.

The Source of all Energy and Heat.—The star we call the sun—for after all it is naught else but one of the fixed stars which nightly adorn the skies, and, seen from those vast distances, is but a little star itself—is the heart and life-spring of the planetary system. It is the enormous furnace that heats all boilers, and nearly all forces on earth and the other planets originate there. We can well understand that very intelligent and cultured races, such as the ancient Indians, Mexicans and Peruvians, prayed to the sun (Fig. 126).

It has been given to astrophysics to measure the heat generated by this gigantic seat of fire, and calculate the force emanating from it. We know that the surface of the sun gives out a heat estimated to be between 6,000 and 8,000 degrees, and that its light equals that of 27,000,000,000 candles a quarter of a mile away. The heat which the earth receives from the sun in the course of a year would suffice to melt a belt of ice about 55 yards in thickness extending right round the earth. Only the 2,735-millionth part of the total energy given off by the sun reaches our earth and, if this were lacking, this planet, with all its thousandfold life, its thick forests and fruitful plains, would turn into a dead, rigid ball of rock, for the average annual temperature, which is now one of 13° of warmth for Europe, would, without the heat of the sun, sink to 73° of frost.

An attempt was made to convert the power of this vast heat-producer into horse-power, and the figure arrived at was stupendous. This is hardly surprising when we remember that, apart from some few special manifestations of energy, all terrestrial force is derived either directly or indirectly from the sun's energy.

Every sort of light with which we illuminate our home when the greater light has sunk beneath the horizon, every fire that warms us when the solar rays can no longer do so, is a product of the sun. The chip of wood with which the untaught son of nature brightens his hut, the twigs with which he stokes his fire, what are they but pieces of trees that grew in the sunlight? The gas of the city dweller, the coals with which he heats his house and from which the gas has been sucked, what are they but transformed sunbeams? The coal in the grate is the petrified wood of perished forests that covered the earth's surface millions of years ago, and flourished in the rays of the same sun that ripens our corn to-day. Petroleum, that mysterious earth-oil, comes from the bodies of millions of dead and gone animals, chiefly natives of the sea, which lived in the grey ages and fed on things growing in the sun. Alcohol is also a plant product, and the candle our ancestors took to be an ideal light is won from the animal and plant kingdom. The smoking fish-oil lamps of the Eskimo are indirectly dependent on the sun for their fuel. And what of our own electric light? The dynamo developing the electricity is driven by steam, and the steam-engine has to be fed with coal or with other materials gained from the animal and plant kingdoms.

All these tortuous paths lead back to the sun, and it is the sun energy of long centuries past that carries us by train and boat through distant countries and over far seas, that takes us up in lifts, that elevates the mighty steam-hammer and drives millions of wheels daily. The sunlight of days of long ago twinkles at us in the flare of the candles, in the gas of a lantern, in the incandescent and arc lights of great cities. What else is all this but a fairy tale, beginning very properly with the words "Once upon a time"?

The Sun and Niagara Falls.—But, I hear somebody argue, steam-power is no longer used where water-power is available, and turbines driven by the falling water are put in its stead to operate other various kinds of plant and machinery. The greatest works of this description are at the Niagara Falls. Half a million cubic yards of water thunder down there per minute, developing 17,000,000 horse-power. The plant to-day works with 130,000 horse-power. No coal, no gas, no petroleum, no wood is burnt here; in short, these immense engines are driven, so it is said, without any sun energy at all.

Careful reflection will show this to be a somewhat rash statement, for if it were not for the sun those very water-falls would soon cease to exist. How is the water taken up to those heights whence it is precipitated with such great force? By the sun! Its heat evaporates the water of seas and lakes, rivers and streams; it ascends as water-vapour, and we watch it pass over our heads in cloud-shape. The water raised in such manner falls to earth as rain and snow and streams down from the mountains into the valleys. Water can only work in districts with steep gradients, but as it cannot flow uphill it has to be lifted, and the sun acts as the great pump. So it is the sun that indirectly drives the huge turbines at the Niagara Falls, as well as the water-wheel of the humble miller.

The wind which the miller forces into his service and which we need for wind-motors and sailing-vessels is converted sun energy. Wind and storm are powerful air-currents produced by the varying action of the sun's heat on the layers of air. Were there no sun these layers would surround the earth at a uniform rate and a perpetual calm would result. Whether, therefore, it be a steamer whose screws and wheels are driven by coal, or a sailing-vessel pushed along by the wind, it is all sun energy in one or the other form.

Lost Power.—If we remember how wastefully even our best steam-engines work—that they only put forth the seventh or eighth part of the heat procured from the fuel, and that the greater part of the costly and decreasing coals are burnt without any good accruing—we can quite comprehend how very important it is to yoke the sun-power lost daily in waterfalls and wind for our industrial purposes. An effort of this kind has been made here and there, and it has been calculated that all the machinery of the United States could be driven by the power embodied in the waterfalls of the country without burning a farthing's worth of coal. All these vast buried riches could be utilised for the national welfare.

Time may perhaps teach us how to make better use of the wind, which at times has a pressure of ten cwts. per square metre (1 metre = 39½ inches).

Sun Motors.—If it were rendered possible to use the sun's heat itself for the firing of furnaces an ideal state would be attained. There is a sun motor in constant use on an ostrich farm in South Pasadena, California. This consists of a concave mirror made of single glass planes set together, and is about twelve yards in diameter. The sun's rays are collected and focussed on to a water-tank which is let into the mirror in the shape of a cylinder 4½ yards long and acts as its axis. Should the tank remain empty on a sunny day, its walls grow red-hot in less than an hour. The 400 quarts of water it contains are brought to boiling-point in fifteen minutes, and the steam developed drives a motor of 10 horse-power which in turn works a pulley raising 5,600 quarts of water per hour, a decidedly noteworthy performance.

If the Sun were to Fail.—Without the light and heat of the sun our own earth would be an inanimate cinder, an uninhabitable planet, on which all higher organised life were impossible. Where the sun's rays do not penetrate, or only very obliquely, for a lengthy period, as in the Polar regions, snow and ice abound, and the organic world carries on a miserable existence. How tremendous a source of heat must be that which, although it is millions of miles away, is yet capable of creating conditions on earth which render it possible for organic nature to flourish in never diminishing fruitfulness.

The Power of the Sun.—Astrophysicists have long endeavoured definitely to determine the light-energy and temperature of the sun. It was hardly so difficult to ascertain the former photometrically, with the help of very bright artificial suns (powerful electric arc lamps) as comparative sources of light. The result showed that an electric arc-

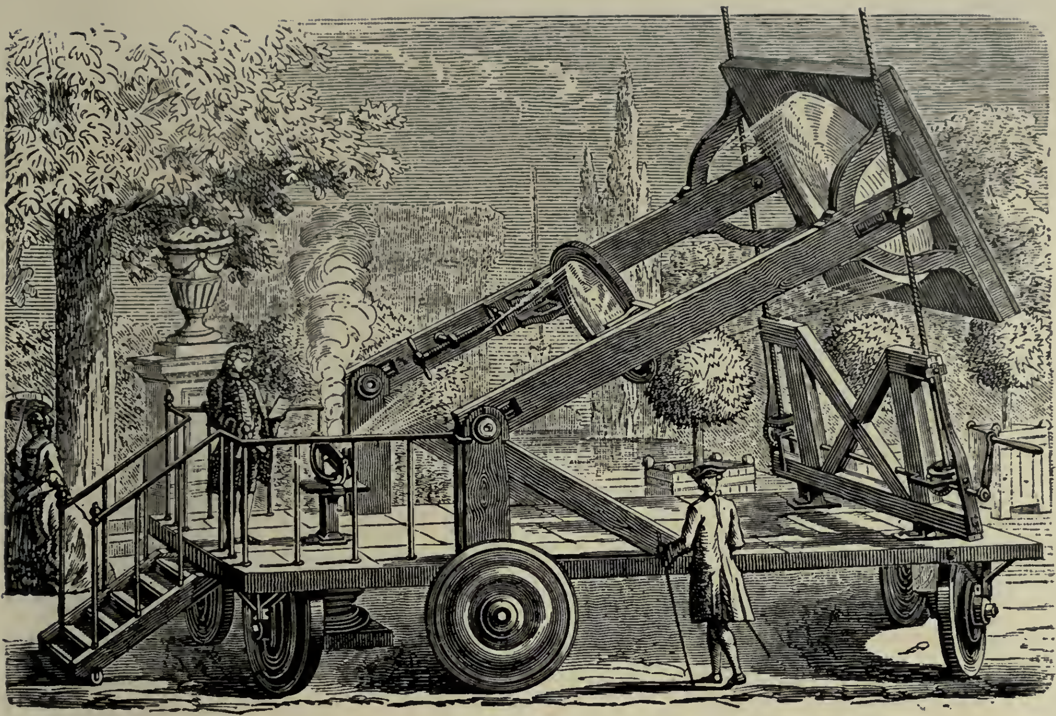


Fig. 128.—The Abbé Bernière's Huge Burning-glass.
(*After an old French woodcut.*)

Fig. 129.—Projecting the Sun on to a White Surface.

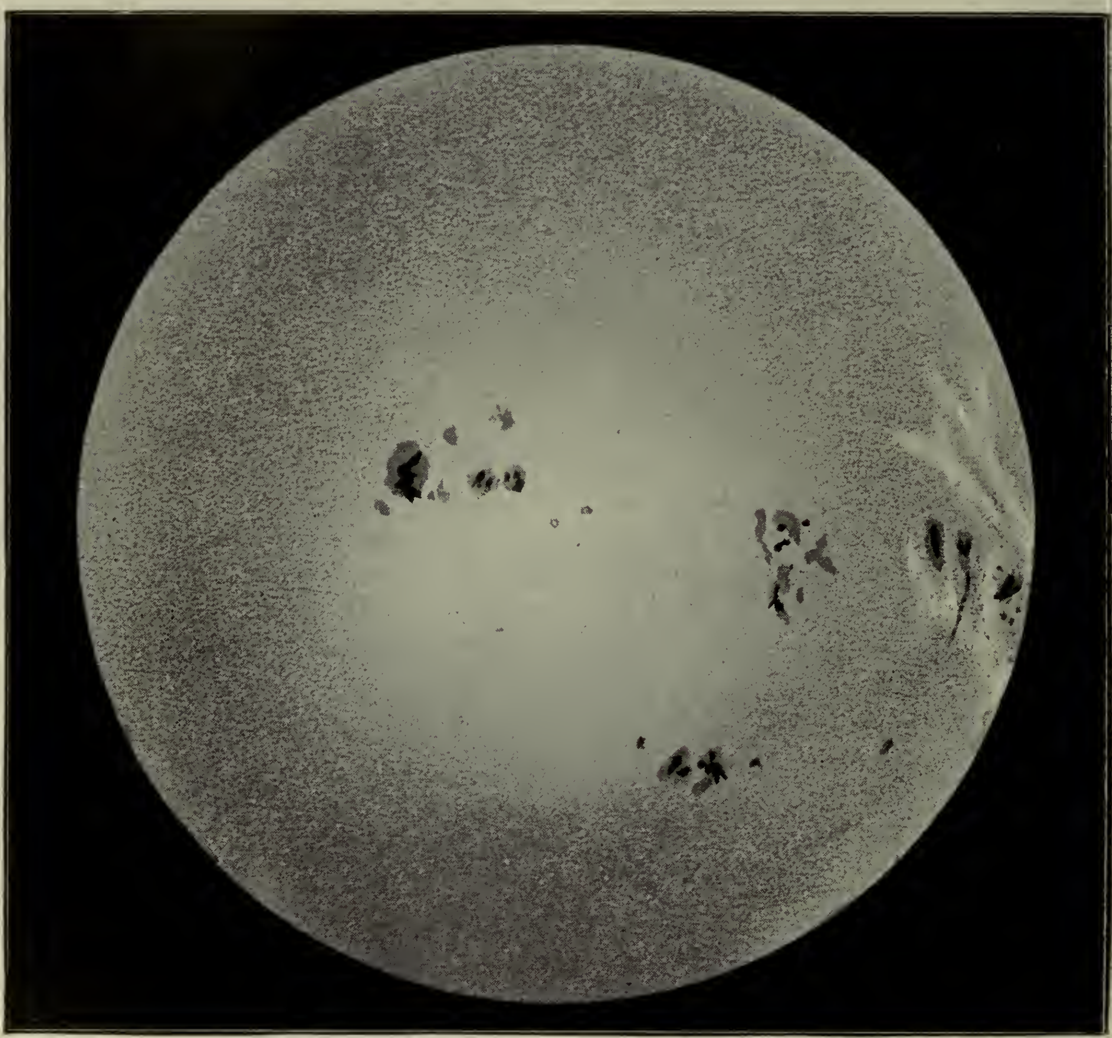


Fig. 130.—The Sun with Spots and Faculæ.
(From an observation by the Author, October 25th, 1895.)

lamp of 10,000 normal candle-power (the ordinary arc lamps have only about 800 candle-power) lit up a screen eight inches off just as brightly as the sun. Thus it took 288,000 candle-power placed at a distance of 39½ inches from a sheet of paper to illuminate this with a brightness equal to that of the sun, which is about 150,000 million times more remote. Investigations by Langley and Crova have proved that nearly one-half of the sun's radiance is swallowed by the dust and water vapours of the terrestrial atmosphere. Outside the earth's atmosphere it would take as many candles again (576,000) to illuminate a screen a little over a yard off as vividly as the sun does.

Taking all these factors into consideration, and especially the law that the intensity of light increases or decreases as the square of the distance, the light-energy of the sun may be set at 27,000,000,000 candle-power. Molten Bessemer steel, which, seen in the dark, gives forth a dazzling dead-white light, looks, if we let it shine at us simultaneously with the sun's rays, like the dull flame of a sooty oil-lamp in comparison.

The Sun's Terrific Heat.—Just as little as we can equal the sun's immense lighting powers on earth can we hope to equal its heating properties. The most intense heat we can produce on earth is that of the bow-flame of an electric arc-lamp, 3,500° Celsius. The acetylene flame is 2,200°, or thereabouts, the candle-flame only 1,800°. The extremely high temperature of the sun's bulk is shown by the ease with which, with the aid of burning-glasses to concentrate the beams, wood can be set on fire in a very few seconds. Huge burning-glasses have been constructed to melt metal, the most widely known being the giant lens apparatus built by a French physicist named Bernière in 1757, which is illustrated in Fig. 128.

How to Measure the Radiate Energy of the Sun.—Although it is not very difficult to measure the intensity of sunlight, yet the determination of the sun's heat, *i.e.* the mass of heat the sun sends to a certain spot on earth within a certain time, has not always been attended by success. This value has to be found, if the temperature of the sun's body itself is to be determined, as it forms the base of such determinations. As it has to be deduced from the total radiation of the sun, ordinary instruments, such as thermometers, are perfectly useless, as they do not return a correct measurement of the heat rays contained in the light rays. A thermometer, with a soot-blackened mercury ball, will show an entirely different reading in the sunshine from an unblackened one. The best way to measure the radiated energy of the sun would be by means of an instrument capable of answering to all the rays coming from the sun; for the sun not only sends out heat and light rays, but rays of an electrical nature as well.

Pouillet's Calculations.—The French physicist Pouillet carried out experiments with an instrument of this character in 1850, and found that outside the earth's atmosphere (which absorbs about four-tenths of all rays) every square centimetre (1 centimetre = two-fifths of an inch) of the earth's transverse takes in 1.76 gramme calories of warmth per minute. A gramme calorie is the amount of heat necessary to raise a gramme of water of a certain temperature (1 gramme = 15.4 grains) a degree higher, for instance, from 15° to 16° Celsius. (15° Celsius = 59° Fahrenheit.) According to Pouillet, every square centimetre of the earth's transverse would only receive about one and three-quarter gramme calories per minute. This does not sound much, but closer inspection will show it to be a remarkable total performance, for the amount of heat the earth obtains in a year would suffice to melt that very solid belting of ice mentioned elsewhere (p. 119). The amount of heat reckoned in gramme calories that every square centimetre receives from the sun per minute is termed "solar constant."

Later Calculations.—Later and more precise researches have produced far higher amounts: according to Pouillet, the solar constant is 1.76 gramme calories; according to Pernter, it is 1.7; to Scheiner, 2.3; to Langley, 3.1; to Omström, 4.0 gramme calories. The Langley finding, say 3, is probably the most correct.

Professor Scheiner's Method.—Professor Scheiner, of the Potsdam Observatory, arrived at his deductions after years of careful work with most delicate instruments. He made extensive use of the Omström actinometer. If two different metals soldered together are heated at their soldering point they will give forth a weak electrical current, similar to a tiny element. A combination of this kind is called a thermo-element (warmth element). Omström's actinometer consists of such thermo-elements, but extremely small ones. The tiny metal strips (copper and manganine) are only a few millimetres in length (10 mm. = 1 centimetre; 1 centimetre = two-fifths of an inch), about the two-hundredth part of a millimetre in thickness, and hardly a two-hundredth part of a gramme in weight. If one of these minute thermo-elements is exposed to the sun's rays, it grows warm and sends out a weak current, which moves the needle of a very sensitive electrical measuring appliance from its position, and in so doing indicates the power of the current. The energy of the sun's radiations is calculated from this. Based on his measurements, Scheiner has worked out the absolute temperature of the sun's surface, and set it down at 7,065° Celsius, a value that deviates possibly only 500° either way from the real temperature of the sun.

Source of the Sun's Heat.—What are the sources from which the sun constantly replenishes its immense expended energy? The temperature of the universe is a very low one, and as every warm body amid cold surroundings imparts its heat to this and gradually decreases its store until it finally arrives at the temperature of its environment, so the sun, too, must cool by degrees until, when millions of years have elapsed, it will slowly extinguish like a smouldering piece of coal. Calculations show that if the sun were to consist of pure coal it could not burn for longer than 25,000 years, when its power would be used up and the former ball of fire have changed to a cold, dark cinder. The sun would lose 2° Celsius in warmth annually, were this loss not replenished by agents unknown to us. If the solar temperature were diminished by 400°, then Europe's mean annual temperature—now one of 13° warmth—would sink to zero, and, without the sun's rays, drop to 73° Celsius below freezing-point.

Spectroscopic scrutiny has classified the sun among those fixed stars which have passed the period of their highest temperature; it undoubtedly has been hotter in a former age. Despite this, the decrease in temperature is a much slower one than might be expected theoretically. The greater part of the radiated energy is made up again by the sun, and the salient question how this is accomplished has not yet been answered.

It was believed at one time that the huge masses of meteors dashing down on the sun recuperate this loss, for about 10,000,000 meteors strike the earth alone within twenty-four hours, and our globe derives (according to M. W. Meyer) per century an increase of about 44,000,000 pounds in weight from them. It has, however, been calculated that the annual loss of solar heat could only be made up again by a mass equalling the weight of an iron globe of 18½ miles in diameter falling on to the sun. But a weight increase of such proportions would, in consequence of the sun's heightened power of attraction, influence the earth's motion around the sun to such a degree as to lengthen the terrestrial year by a second. As nothing of the kind has been registered, the meteor masses striking the sun cannot have reached this standard, and therefore cannot be able to replenish the entire loss of heat.

Helmholtz's Theory.—Helmholtz, the eminent naturalist, held the theory that the sun replaces its expended energy by contraction; the tremendous pressure exercised on its own matter is thereby turned into heat. The sun's diameter must in time decrease according to a certain calculated scale if this theory be correct. Whether it really does decrease will have to be proved by comparative measurements at some future period.

The Sun's Measurements.—Although 92,820,000 miles separate us from the central star of our planetary system, it still appears to us about the size of the moon, which is so much nearer that a cannon-ball fired from earth would reach it after a journey of nine days, whilst it would need just as many years to get to the sun. If we remember that the moon possesses quite respectable dimensions, its diameter being almost a fourth of the terrestrial one, the apparently similar size of the sun, in spite of its stupendous remoteness, will teach us what a huge body it must be in reality. It is of perfectly astounding dimensions, dimensions we can only

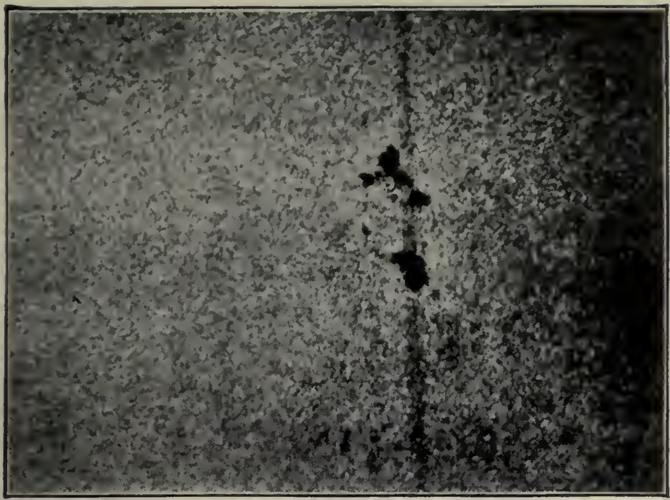


Fig. 131.—Granulation of the Surface of the Sun.
(After a photograph by Janssen taken at Meudon, near Paris.)

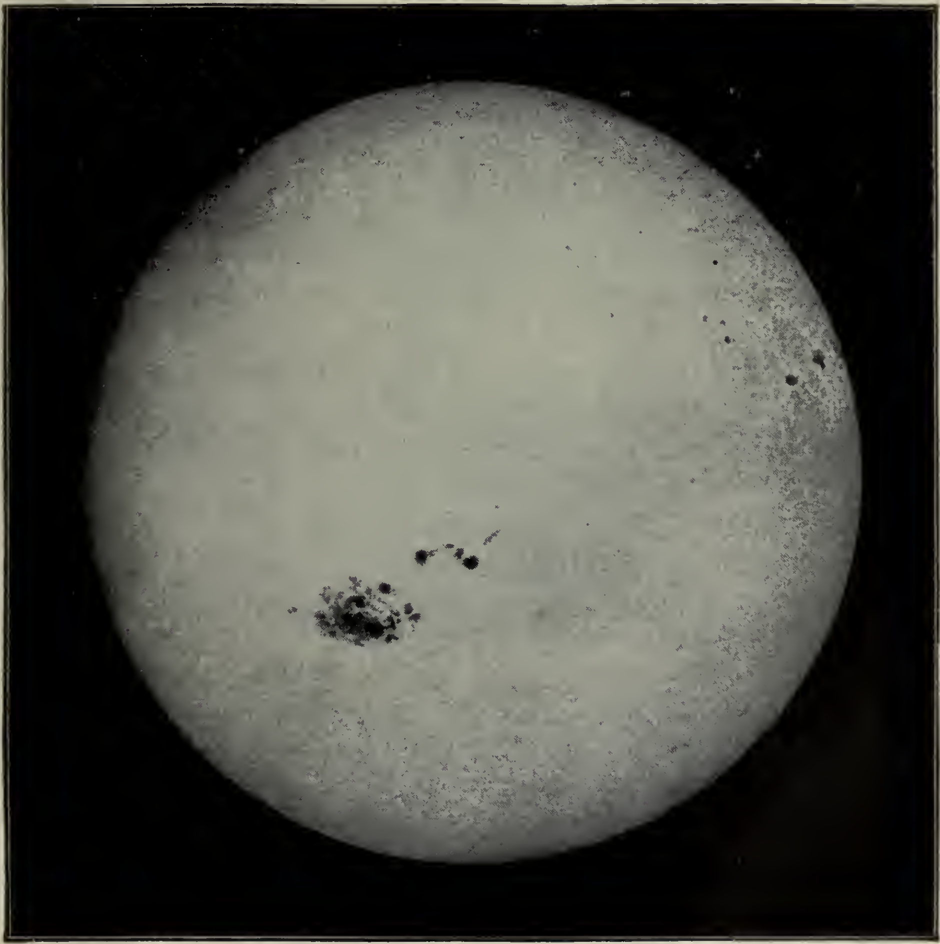


Fig. 132.—The Sun with an unusually large Group of Spots.
The main group on the left is fifteen times the earth's diameter in length.
(From a Sun photograph taken on February 13th, 1892, by Lohse, of Potsdam Observatory.)

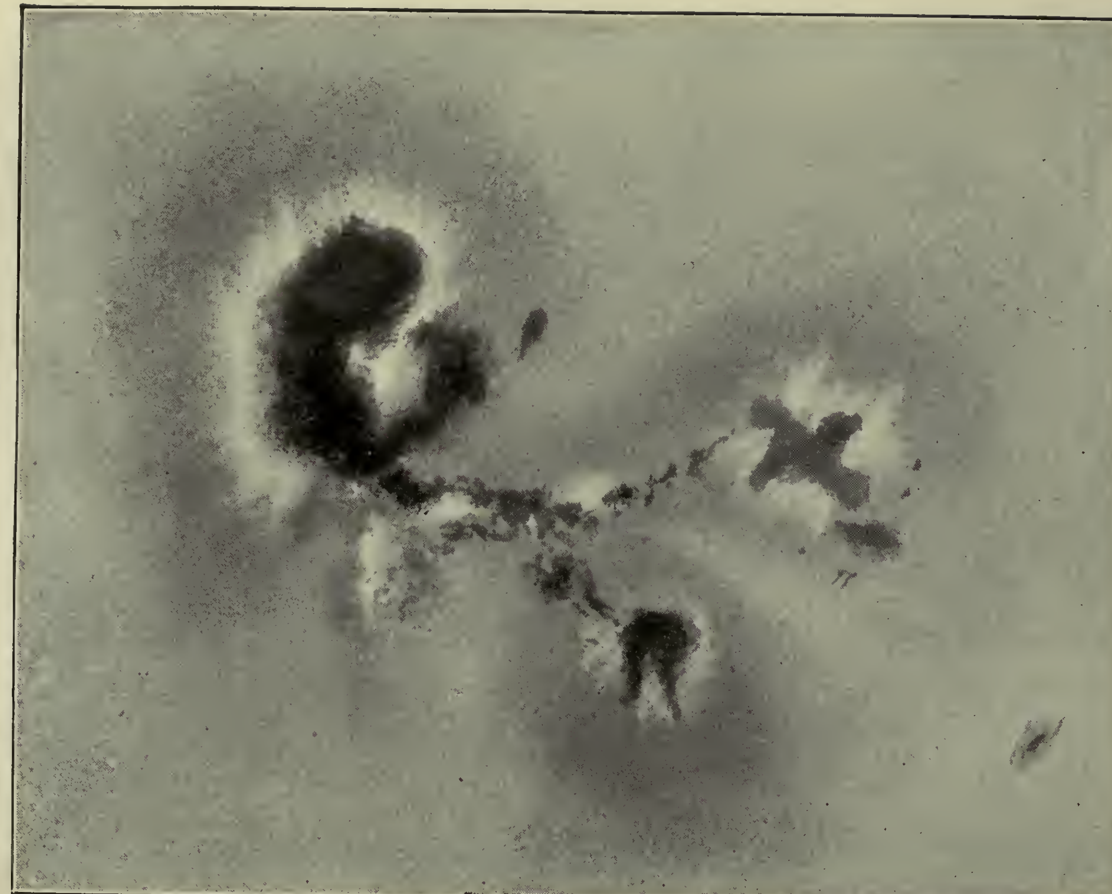


Fig. 133.—Large Cluster of Sun Spots observed on September 2nd, 1895, at 1.30 p.m.

Represented on a like scale, the earth would be of the size of a pea.

grasp by means of comparison, for it is not given to our comprehension to realise what a diameter of 863,782 miles means. If we were to imagine the diameter of the sun a thread to string beads on, and were to use beads the size of our earth, it would take 109 of these tiny beads, each 7,926 miles in diameter, to fill the thread. Mother Earth's waist is not to be smiled at, for she needs about 25,166½ miles of material for her belt; but it would take a belt over 2,500,000 miles in length to reach around the sun's great bulk, in which 1,250,000 terrestrial globes could find a resting-place (Fig. 3).

We will leave these figures, which are well-nigh meaningless, and see what the astronomer can tell us.

What the Telescope Reveals of the Sun.—Telescopes intended for sun scrutiny have to be fitted with an appliance for protecting the eye from the great heat and light emitted by the sun. The simplest method is to use glasses that absorb light and heat, but another method is not to gaze through the telescope oneself, but to place a piece of cardboard behind the instrument, on to which the sun's image is projected (Fig. 129). A very distinct decrease of light will be noticed towards the sun's edges (Fig. 130). This is explained by the fact that the sun, like the earth, is surrounded by a gaseous envelope that absorbs a fair amount of the light that passes through it. The farther the light has to travel through such a gaseous envelope the more it is absorbed. The rays sent out by points near the limb have to travel a longer distance to meet our eye than those of the centre, as they cut the solar atmosphere in an oblique line, and their absorption is therefore much greater.

The Sun's Granulation.—A better telescope will disclose another peculiarity, the whole disc of the sun is strewn over with dark and light spots, as though it had been gravelled. This is termed "granulation" (Fig. 131), of which as yet no satisfactory explanation has been forthcoming. Some state it to be analogous to our terrestrial cirrus clouds, only that the solar clouds consist of metal vapours; others deny that such clouds could be formed in the glowing solar atmosphere. There is no other celestial body concerning which opinions differ so greatly as the sun. The constitution of its composing matter and the changes this undergoes are either still wholly unknown or made the subject of more or less uncertain hypotheses, although the sun phenomena have been known for a long time.

Sun Spots.—The same may be said of the sun spots, the most interesting, most conspicuous, and most varied of all the more remarkable phenomena our sun offers. A telescope will almost always reveal one or more dark spots standing out boldly from the luminous background. Sometimes extremely small, and few in number, they are at other times of enormous size and extension. Frequently several "streams" of such spots, besides a number of isolated ones, are visible on that side of the solar globe turned towards us, as Figs. 130 and 132 show.

The structure of sun spots varies greatly; at times they are round or oval, at others long and curving. Their colour, which seems to be a blackish-brown, is really only darkened by the radiant background, for the intensity of light these spots possess is thousands of times more powerful than that of the full moon, and they probably are in an incandescent state. The nucleus of the spot is surrounded by a greyish-brown border, termed the penumbra. This apparently possesses colossal eruptive forces, as clefts and tears run through it like veins, varying in breadth and length. The sun altogether is the scene of fearful disturbances, a fiery, lurid sea in constant upheaval, a symbol of purgatory.

The size of these solar spots is gigantic. The very smallest of those shown in Fig. 130 covers an area far greater than the whole of Asia, and their disappearance or reappearance in the course of a few minutes shows how incessantly operations must be going on below the surface. Sun spots as large as those of Fig. 133, which the author noticed in the month of September, 1895, are not at all uncommon, although they were about thirty times the size of all Europe. Structures have been seen which were fifty to sixty times larger than the whole of the terrestrial surface. Parts larger than all the five continents often disappear within a few hours. Three phases of a solar spot, which occurred in the lapse of a few hours, are visible in Fig. 134.

These appearances reveal to us the mighty and ceaseless action of the hammers in Nature's workshop, where the structures of the universe are shaped incessantly.

The rapid alterations of the sun spots mentioned above must not be taken as a fixed rule, as some have existed for months at a stretch. Schwabe, the great solar investigator, observed one cluster of spots for a year and a half.

What the Spots Revealed.—The solar spots, which were discovered in 1610 by the Jesuit priest, Father Scheiner, guided us to the determination of the sun's rotation on its axis. The spots all show a uniform motion, moving from east to west across the solar disc, and then vanish, to reappear, if circumstances permit, on the eastern edge after a fortnight or so. It was quickly recognised that this motion was not peculiar to the spots alone, but was due to a rotation of the solar globe; and further observations elicited the fact that the sun turns on its axis once in a period of about 25¼ days.

Nevertheless, the sun spots—apart from the motion called forth by the rotation of the sun—possess a motion of their own, and as this is partly of a regular, partly of an irregular character it greatly enhances the difficulty of precisely determining the rotatory period of the sun. The irregular motion of a spot usually heralds its destruction; radiant veins appear and separate it into several parts, which move away from each other and rapidly fade, and soon nothing is left of those gigantic spots that but a little while ago robbed us of a part of our God-sent light (Fig. 134).

What are Sun Spots?—What are these solar spots and how do they originate? Opinions are very divided on the question. They are pronounced by some to be clouds of metallic vapour floating in the sun's atmosphere, and caused by depressions in temperature. For a long time they were supposed to be great cinder fields, burnt-up portions of the solar body, which would eventually be flooded over and swallowed up by the liquid matter on which they swam. The greyish borders around the spots were taken to be parts already partially covered up again. A theory which existed for a long time, in spite of its contradictoriness, asserted the nucleus of the sun to be dark, and its light to emanate from a gaseous envelope surrounding it; fierce storms tore funnel-shaped holes in the radiant envelope, and the dark nucleus of the sun became visible, appearing to us as sun spots. They do, indeed, sometimes convey the impression of cavities in the fiery solar ocean, especially if they are situated at the edge of the solar disc, as illustrated in Fig. 135. It is not at all improbable that the spots do lie deeper than the upper shining gaseous layers of the sun's atmosphere, and this would not be in opposition to the belief that these formations are clouds, a belief which, on the other hand, grows more likely.

Similar to the water-vapours of the terrestrial atmosphere, which knit themselves into clouds at a certain altitude and temperature, the metallic vapours of the solar atmosphere would, on a like principle, condense themselves to clouds of metallic vapour at a certain elevation where the temperature is lower.

These huge sun-patches have another characteristic feature which again teaches us that all these glittering worlds, be they ever so far distant from each other, are connected by mysterious links, which will probably always remain inexplicable to us. Astronomy has discovered that the size and frequency of the sun spots undergo certain distinctly defined periodical variations; statistics have established a period of eleven years and a third. During this time the activity in spot production sinks to a minimum, and then, gradually, reaches its maximum again, and so on *ad infinitum.*

Influence of Sun Spots on the Earth.—Another riddle for which no solution is at hand at present! A theory exists that the gigantic planet Jupiter, which completes its circuit around the sun once in every twelve years, causes these upheavals through its powers of attraction, its influence being the stronger the nearer it approaches; but this is hardly a satisfactory hypothesis. The most mysterious and most startling of all is, however, the connection between these solar occurrences and terrestrial events. Statistics distinctly prove that the aurora and magnetic needle deviations correspond with the formation of sun spots on the fiery ball so many millions of miles away. A connection has also

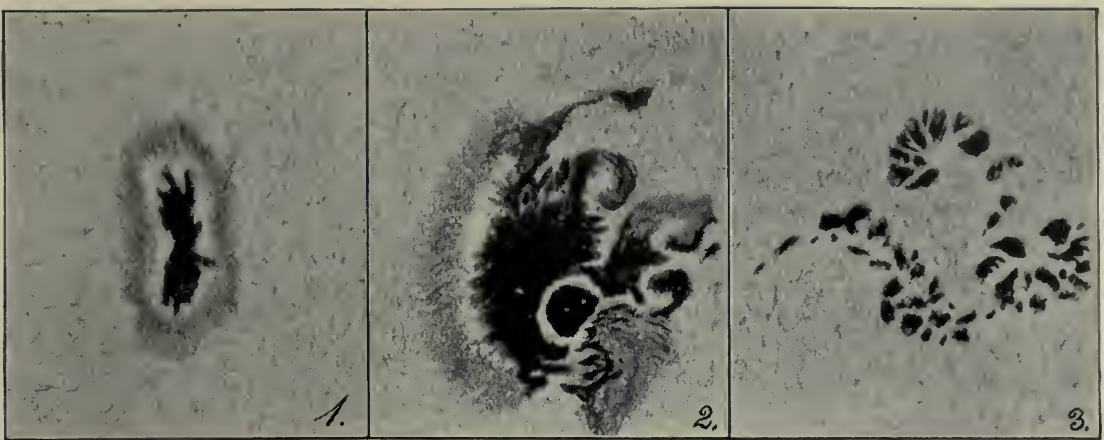


Fig. 134.—Alteration of a Sun-spot, shown in three phases.

Fig. 135.—Spot on the edge of the Sun giving the impression of a depression in the solar globe.

(From an observation by the Author on April 13th, 1899, at 9 a.m.)

Fig. 136.—Corona of the Sun during the Total Eclipse of May 22nd, 1900.
(From a photograph by Edward E. Barnard, Lick Observatory.)

Fig. 137.— Protuberances at the edge (top) of the Sun, during the Total Eclipse of April, 1898.
(From a photograph by the Lick Expedition.)

been suspected in the case of Indian monsoons and famines. Tables of curves, based on the deductions of many decades, relating to the annual frequency of sun spots, aurora and magnetic needle deviations, show the curves of these different phenomena to run concurrently. Fig. 138 represents the curves of a whole century, and their dependency is very plainly recognisable.

As soon as a large group of solar spots and strongly-marked protuberances, to which we shall refer a little farther

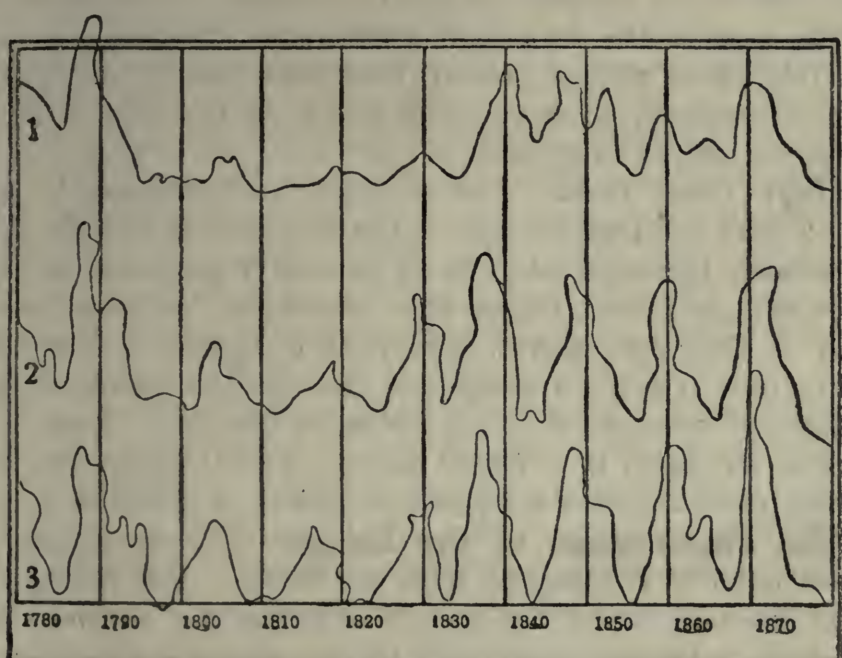


Fig. 138.—Concurrent Curves showing the connection between Sun Spots and (1) the frequency of Northern Lights ; (2), Magnetic-needle deviations ; and (3), the number of Sun Spots during the century 1780-1880.

on, are noticeable on the sun, the magnetic needles at the observatories begin to grow restless and deviate from the north to south direction in a very marked manner, as though a powerful magnet were being moved close to them. Grave disturbances make themselves felt simultaneously in telegraphic intercourse, and telegraphy may be interrupted for days in different districts. This is nothing more or less than a kind of wireless telegraphy transmitted from sun to earth. Some years ago, at a time when an unusually fine group of spots crossed the sun's centre, telegraphic communication was cut off for two whole days on various French lines. Sparks flew out of the apparatus, which even occasionally ticked of their own accord. These magnetic and electric disturbances are accompanied by a most beautiful phenomenon—marvellous northern lights, visible even to us. All these appearances must be caused by a very powerful disturbance of the magnetic and electric condition of the entire earth. The disturbances corresponding to the solar spots are termed "magnetic storms." Investigations on the part of the American astronomer, Professor George E. Hale, have shown powerful whirl-storms, productive of electric currents, to have their being in the region of the sun spots on the solar disc.

Many other climatic occurrences are presumably connected with the happenings on the sun, and it was the great astronomer Herschel who, in all sincerity, proposed to bring the wheat and corn prices into line with the solar events. Even if this speculative theory may appear a somewhat daring one, it is an unassailable fact that the heart-beats of our central orb are felt in all the other members of our solar system, although in a lesser degree, and that our relations are far more intimate than would appear at a casual glance.

The Phenomenon of the Eclipse.—All the riddles we are constantly confronted with in Nature—the falling leaf swept towards us by the autumnal storm, the eternal ocean of stars on whose luminous waves we sail through the depths of the universe—penetrate to us from that incandescent ball as well, although it is not often given to us to elucidate the hieroglyphics in which the great secrets are set down. The relations in position and motion of the three bodies, earth, sun, and moon, to each other are, as we all know, such that, viewed from the earth, the moon periodically acts as an opaque screen between us and the sun, thereby securing to us the interesting phenomenon of a solar eclipse. The origin of the total, partial and annular eclipses will be dealt with in Chapter XVII. Here, I only wish to describe the wonderful features presented by the sun during the phenomenon.

The Corona.—During a total eclipse the obscured sun is encircled by a marvellous white wreath of rays, gleaming like a halo around the disc, and fascinating the spectators beyond description. This radiant light is the sun's corona. It gradually loses itself in the dark background of the sky as it moves away from the sun, and differs at every eclipse in size and brightness. Figs. 136 and 140 afford two different aspects of this most attractive phenomenon, whose structure was differently reproduced by every observer until photography, astronomy's incorruptible assistant, revealed its true construction. Although, as it usually can be seen without instrumental aid, drawings of this appendage exist dating from the seventeenth century, the astronomical world only really became fully aware of it during the total eclipse of July 8th, 1842, and since 1860 few solar eclipses have been permitted to pass without the corona being photographed.

It was at first taken to be an optical delusion produced by the refraction of the sun's rays on the edge of the moon. In this case the aspect of the corona would have quickly altered as the moon moved on. It was soon established that nothing of the kind happened, for the corona was seen in all its unaltered splendour, although the earth's satellite, darkening the solar disc, had moved on a little. Science has not arrived at a definite conclusion as yet, but the supposition that the corona is the most extreme part of the incandescent solar atmosphere may be regarded as nearest of all to the truth, for the spectroscope shows us that incandescent gases, mixed with solid particles, form the source of this mysterious light. The long, varying sheaf of rays emitted by the corona lead to the conclusion that very powerful electrical repulsive forces are present on the sun.

Solar Protuberances.—Another phenomenon of equal interest whose grandeur and immense manifestations of power compel our admiration are the protuberances. During the eclipse we mentioned in 1842 the astonished astronomers caught sight of several ruddy flames, which played around the eclipsed solar globe and apparently sprang from the edge of the moon. They all differed in shape; some looked like small flaming hills, others were spaced and fringed out at the tips, and yet others floated disjointedly above the sun in space. The protuberances in Fig. 137, a photographic reproduction of the eclipsed sun and corona, attained a height of 50,000 to 60,000 miles. Sometimes protuberances of almost incredible height are seen. Mr. Young, the American astronomer, informs us of a protuberance which reached a height of over 50,000 miles at the beginning of his observations, and which, waving to and fro, was tossed into ever higher regions until, after a lapse of thirty-five minutes, the whole structure was divided into numerous small flames, the top one reaching the immense height of 205,062 miles. An hour and a half later hardly any traces were left of this enormous eruption. The protuberance in Fig. 139 was 142,922 miles high. Far greater than these was the immense sheaf of flame ejected into space on August 30th, 1880, and observed by Thoulon. It reached a height of 335,556 miles, or more than forty-two times the diameter of the earth. Imagination cannot picture these celestial fireworks as they really are. Fancy the exuberance of energy necessary to set this glowing fountain in motion, in which our earth could play up and down like the glass balls in our garden fountains.

The spectroscope has shown us that we have here to deal with enormous masses of incandescent hydrogen gas forced up to these tremendous heights by extremely powerful eruptions. Nowadays it is no longer necessary to wait for a solar eclipse to see a protuberance, for once more the spectroscope comes to our aid. If the lines of incandescent hydrogen are revealed in a spectroscope turned on to the sun's edge, it means that a protuberance has been located, whose shape and height also become recognisable in the instrument.

The Faculæ.—We must not forget another characteristic of the sun, which is shown in Figs. 130 and 135, and noticeable in nearly all solar representations—the faculæ. These are bright veins of light generally surrounding the sun spots, and very conspicuous at the edges of the solar disc (Fig. 135). At times these faculæ cover a wide region; their spreading and curving branches frequently embrace an expanse large enough to confine all the earth's continents thousands of times over.

We can hardly doubt that all these phenomena are very closely related to each other, and that the one is but the

Fig. 139.—Protuberance at the edge of the Sun.

For comparison the Earth is shown at the top right-hand corner.

(After a photograph, taken on March 25th, 1895, by Professor Hale, Kenwood Observatory, Chicago.)

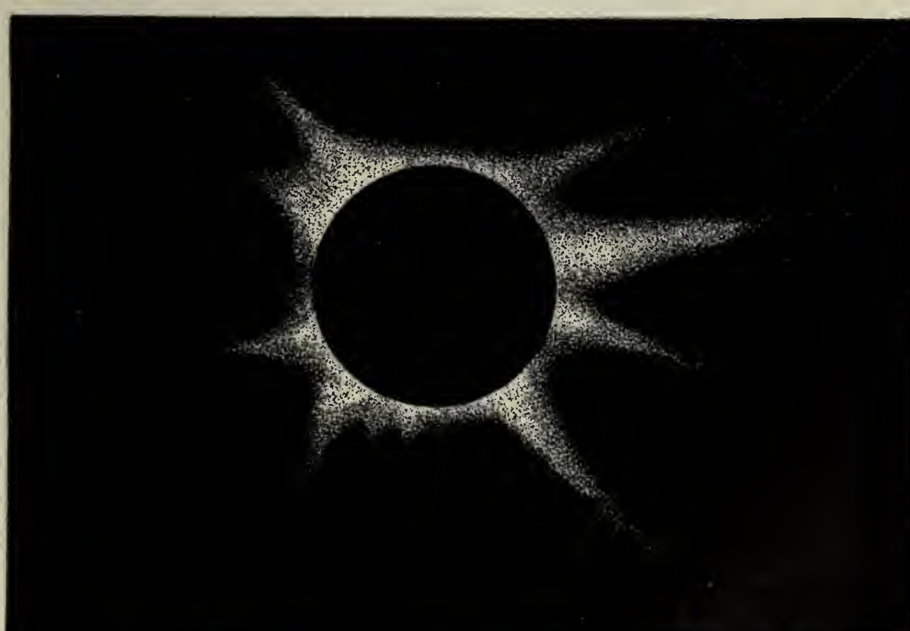


Fig. 140.—Rays of the Sun's Corona during the Total Eclipse of August 19th, 1887.

Fig. 141.—The Zodiacal Light.
(After a drawing by M. Eiffler.)

result of the more advanced phase of the other. The faculæ generally herald the formation of solar spots, and the spots are closely connected with the prominences. This belief is strengthened by the fact that the period of eleven years we mentioned as a characteristic of the sun spots is peculiar to them all, and that the sudden appearance of prominences and faculæ brings heavy terrestrial magnetic storms in its train.

The Sun's Constitution.—Now, what is the general idea we have formed for ourselves of our glorious orb, the sun? What is it composed of, and how is its constituent matter ranged in its vast body? Daring and momentous questions these, for the wise men of to-day have not yet arrived at a final decision as to the constitution of the sun. While discussing sun spots we learnt that some astronomers believed the nucleus of the sun to be solid, comparatively dark, and only surrounded by a luminous atmosphere. This theory, primarily expounded by Sir William Herschel, is totally set aside to-day, as in most points it runs entirely counter to our more improved modern scientific teachings. The sun, according to our knowledge, is a globe consisting of incandescent gases, where no hard and fast rules as to solid and liquid can be laid down. Everything plays about in chaotic fashion; matter to-day resting on the surface of this vast ball of fire may to-morrow be swallowed up in its depths. A return has in some quarters been made to the hypothesis propounded by Galileo 300 years ago, to the effect that the sun consists of an incandescent liquid nucleus surrounded by gaseous envelopes; and although this theory has not lost any of its faults during its lengthy repose, yet it is possessed of a certain amount of probability. Our day-star would therefore be, in the first place, an incandescent liquid ball, perfectly invisible to us, as it is enclosed in an envelope seemingly in a mean state between liquid and gaseous. This is called the "photosphere." On it rests the "chromosphere," a gaseous layer which principally contains incandescent hydrogen gas; this is the spacious playground of the protuberances. The whole is finally surrounded by the delicate gas covering of the corona, which, gradually growing rarer, loses itself in space. The temperature of the sun is so high that all matter can only exist on it in an incandescent liquid shape or as incandescent vapour. The spectroscope has revealed the presence of iron, carbon, hydrogen, chromium, calcium, nickel, lead, oxygen, sodium, and numerous other terrestrial substances on the sun; and, on the whole, the chemical constitution of the sun resembles that of the earth.

A Weird Perspective.—Some time ago a French artist of great imaginative power painted an extraordinary picture called "The Last Man and Woman." Two skeletons, huddled together in a close embrace, crouched in a weird icy cavern, from whose roof huge icicles depended, while the walls and floors glistened in set glassiness—the last human couple frozen to death. The painting left a deep impression on all who saw it, and was a pictorial representation of the theory that the earth must steadily grow colder in consequence of the decrease in solar heat, and that the last generation will perish of cold at the equator as a tribe of Eskimo.

A truly ghastly outlook! But later discoveries assert that, one of these days, life will be exterminated in quite a different fashion, and that the sun will, in any case, rejoice us with its heat and light for ages. The astrophysicist See sets the figure of the sun's duration at another thirty million years—so we need not worry, for the present at any rate!

CHAPTER XII

THE ZODIACAL LIGHT

WHEN the last hardy flowers fade, and the foliage decks itself in gay colours, when the autumn mists rise in chilly wraiths from the ground, Urania spreads out her dark, bediamonded robe with enhanced splendour. Even the smallest sparklet of her glittering jewels is clearly visible, and the hem of her garment—the Milky Way—sheds its mild light more bountifully than before. The skies of the late autumn are of sublime beauty. The townsman, dwelling beneath a sky studded with many-hued electrical suns and moons, sees but little of this loveliness, and sometimes almost forgets the existence of those radiant worlds above.

Whilst the comparatively dark suburbs permit us to see the stars of at least five magnitudes, only the very brightest—four or five all told—can be seen in the well-illuminated main arteries of a very large town. At the more dimly-lighted spots stars of the second magnitude are visible, and in districts lit up by gas lamps, and where no shops are near, stars of the third magnitude appear. Those of the fourth and fifth remain invisible, and the Milky Way, the luminous band woven of millions of stars stretching across the skies, is hidden in the vapours of the city, in the sea of light extending over the home of millions of human beings.

What is the Zodiacal Light?—Very few of my readers have probably seen the strange light to which I here refer. In northern regions it must be classed with uncommon appearances, rarely met with even in the open fields, where no artificial lights dazzle the eye. At the spot where the sun has set in spring, and in autumn before dawn where it is to rise, a very faint light may be seen, shaped like a broad cone, its point resting about half-way from the zenith (Fig. 141). I myself have only seen this cone of light two or three times in the course of many years, during which I kept a careful look out for it. It is far weaker than the Milky Way, and is easily taken for the twilight or dawn. In certain districts, the tropics for instance, and, above all, the great Mexican plains, this phenomenon is pronounced to be a daily occurrence, noticeable all the year round. Drawings by the ancient Egyptians show that it was well known to them, and probably bore a symbolical meaning. According to the accounts of explorers, the light as seen in Mexico is more luminous than that of the Milky Way; but in Europe it must always have been almost imperceptible, for attention was first called to it in the seventeenth century by a clergyman named Childrev. At the end of this period Cassini made it his special study. However, the light even to-day is astronomy's child of woe, and we cannot say how it arises.

The narrow zone in which the constellations Aries, Taurus, Gemini, Cancer, &c., lie, and through which the sun passes in the course of a year, is called the Zodiac, and as this extraordinary light is always witnessed in this zone, it has been named Zodiacal Light. A straight line drawn from the point of the cone through its centre would lead to where the sun stands below the horizon (Fig. 142). The position of the Zodiacal Light changes with that of the sun and the alteration in the position of the Zodiac to the horizon. It generally rises in a very slanting line, like the beam of a very weak searchlight, excepting that its broader part rests on the horizon and the point is in the sky.

A Bridge of Light.—Constant careful observations have determined that the Zodiacal Light does not finish in the tip of the cone, but is continued in a very weak trail of light to the opposite side of the sky. Here it broadens out again, and, climatic circumstances permitting, a practised eye can not only see the light-cone in the west, but a dimmer second cone in the east as well, connected with the first by a faint luminous bridge. The first to see this was the great naturalist, A. von Humboldt, during his travels through the tropics.

Later, Brorsen discovered a brighter section in the fainter part of the Zodiacal Light, which is always found exactly in that part of the sky opposite the spot where the sun stands. This brighter light has received the name of

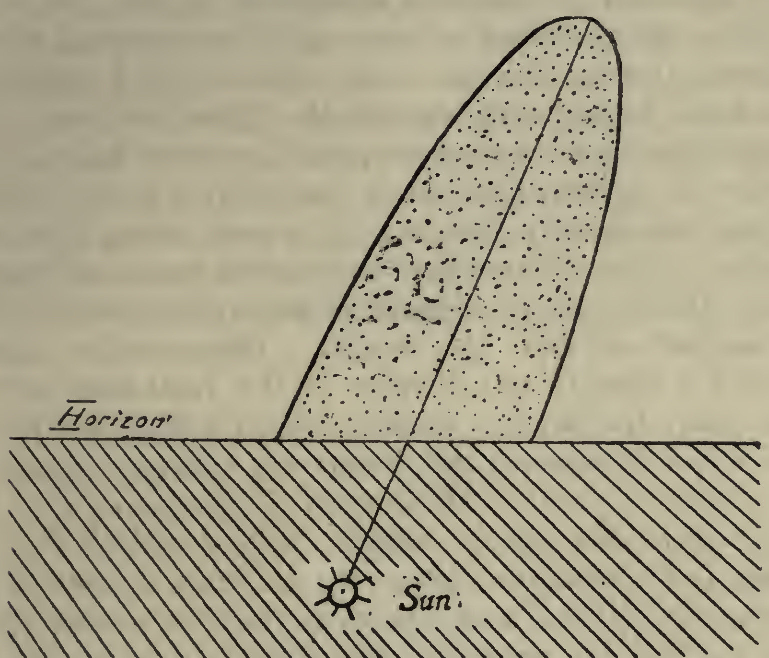


Fig. 142.—Relation of the Zodiacal Light to the Horizon and the Sun.

(*From a photograph taken in July, 1888, by O. Jesse, at Steglitz, near Berlin.*)

"Gegenschein," or "Counter-glow." All these discoveries served to do away with the idea that the Zodiacal Light is a plain, luminous trail originating from the sun, but marked it as a most complicated structure instead. In more southerly latitudes it sometimes appears as an arch of about forty full-moon diameters and spreads over the whole sky.

The light of this mysterious formation has been tested, and the polariscope, an instrument capable of showing whether a radiant body possesses light of its own, like the sun, or only reflects borrowed light, like the moon, revealed it to be a reflection of sunlight. The spectroscope gave the same answer. And now we arrive at the chief question: what this light really is, for it most decidedly is a corporeal structure, or rather emanates from such.

The Krakatoa Eruption and its Effect.—On May 20th, 1883, occurred the terrible eruption of the Krakatoa volcano in the Strait of Sunda, probably the greatest catastrophe the world has known within the memory of man. After almost a month of incessant eruptions, a part of the island sank into the sea amid a noise as of a thousand thunders combined; other islands were formed, and tremendous waves were dashed even against the American coast. Fifty thousand human lives were lost, and the ocean was so thickly strewn with ashes, brimstone, and corpses that even the steamers were hardly able to pick a path along this terrifying road. The air-pressure was traced even on European shores. When this paralysing disaster occurred, odd lights were noticed all over the world. Impenetrable darkness reigned for days in the vicinity of the Krakatoa isles, and farther away the sky for weeks took on a peculiar dull hue; the sun was blood-red and shone out through a mist. At other places the moon shimmered deep-green, with weird light effects, and many readers may recollect that their own sky for weeks burnt in a fiery red after sunset for hours at a stretch. All this was caused by the vast masses of ashes which the burning mountain had shot into the air for many weeks, and which had been carried by air-currents all over the earth, and partly descended in Europe in the shape of fine dust. As the atmosphere cleared by rains and storms, these appearances gradually vanished; but it then grew apparent that great condensations of the volcanic dust had taken place in the very highest atmospheric layers, forming themselves into remarkable clouds, which stood out brightly long after sunset, when all the sky was dark. This structure of "luminous nocturnal clouds" was visible for a period of ten years; and Jesse, of Berlin, made the clouds his special study. As they floated fifty miles above the earth, seven times higher than the highest ordinary clouds, they were caught and illuminated by the sun's rays long after it had itself set (Fig. 143).

Is Zodiacal Light a Solar Dust Belt?—I relate the history of the clouds caused by the volcanic eruption because their light was similar to that of the Zodiacal Light, which is probably caused by similar tiny corpuscles, atoms of dust, and perhaps of stone too, somewhat resembling meteor particles. Indeed, several observers have actually concluded that the Zodiacal Light is produced by a tremendous ring of dust surrounding the earth at a great distance, almost like the ring encircling Saturn, but not of so dense a nature. Others, among them Seeliger, believe the sun to be surrounded by a belt, or rather a disc, of the finest, thinnest cosmic dust, extending even farther than the earth's orbit, which, reflecting the sunlight, is seen by us as the Zodiacal Light. Professor Förster is of opinion that the light is caused by a structure which resembles a comet's tail, and is an appendage of the earth. However, the final pronouncement on this remarkable light has yet to be expressed.

CHAPTER XIII

MERCURY AND VENUS, THE SUN'S YOUNGEST CHILDREN

The Planet Family.—Like chickens around their mother hen, the planets cluster around the warmth-giving sun, for the sun is, in very truth, the mother of the planetary system, and the wandering stars are her children. We shall learn later that this is even truer than we imagine, since, according to our theories, the planets were once part of the sun, and were born of its body. So far as we are able to conclude, they evolved from masses of gas which the sun-ball, itself then gaseous, ejected millions of years ago, "in the beginning of the world." They are, therefore, all brothers and sisters, and possess many family traits in common. If these views of the origin of the solar system be correct, it must follow that the oldest planets are those which separated earliest from the bulk of the sun, and are farthest from it. So Neptune should be the oldest, Mercury the youngest, of the sun's progeny. At present we will confine ourselves to the two youngest-born of this gigantic family—Mercury and Venus.

Mercurial Statistics.—Mercury is only 36,041,200 miles distant from the sun. Fig. 118 shows how Mercury and the earth stand to the sun. An express train would take nearly 75 years to reach Mercury from the sun, but it would take almost 190 years before arriving at the earth from the sun. Mercury's year is a very short one, for it completes its circuit in 88 days. Its distance from the earth greatly varies; if Mercury be at point A (Fig. 119) of its orbit, and the earth at B, they will then be at their closest, being only 49,090,600 miles apart. If, however, the earth be at C, and Mercury at A, they will then be separated by 135,465,200 miles.

Difficulty of Observing Mercury.—Seen from the earth, Mercury is never far distant from the sun, and must always

Fig. 143.—Luminous Nocturnal Clouds.

Fig. 144.—Mercury.
(After G. V. Schiaparelli.)

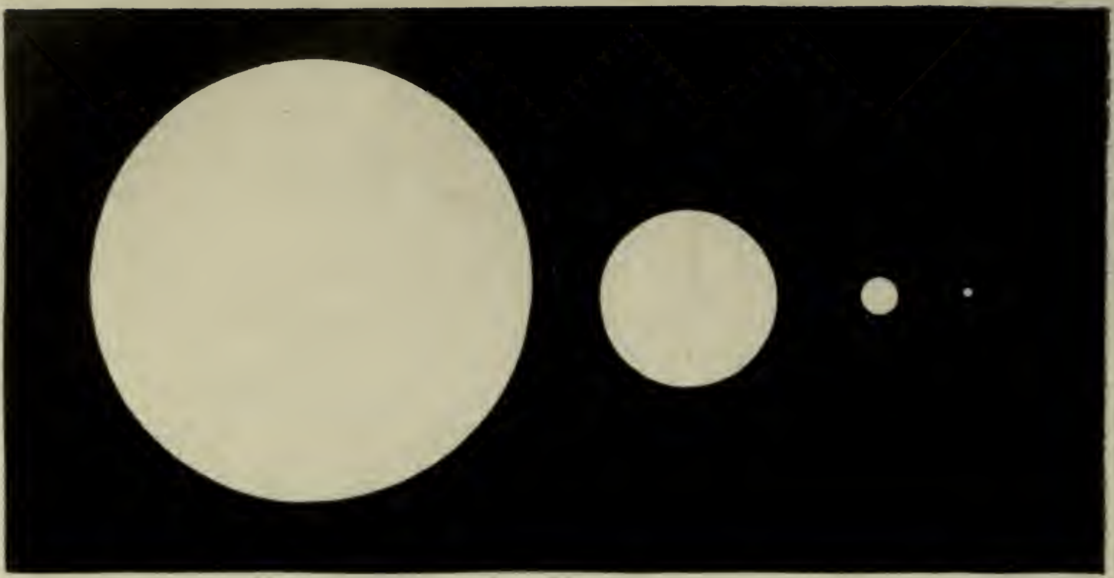


Fig. 145.—Diagram showing the size of the Sun's disc on Mercury (left), the Earth, Jupiter, and Neptune (right).

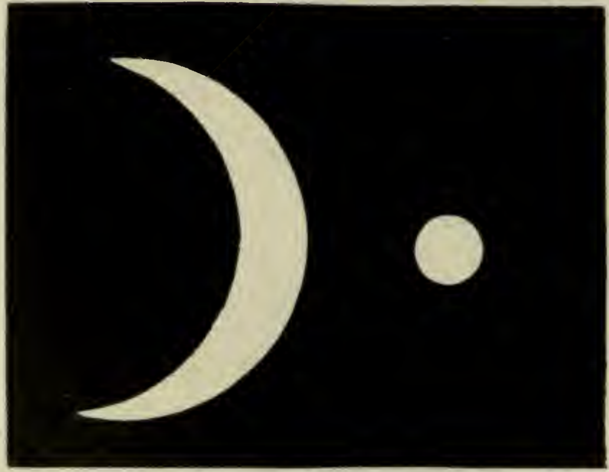


Fig. 146.—Diagram showing the size of Venus as a crescent and at full.

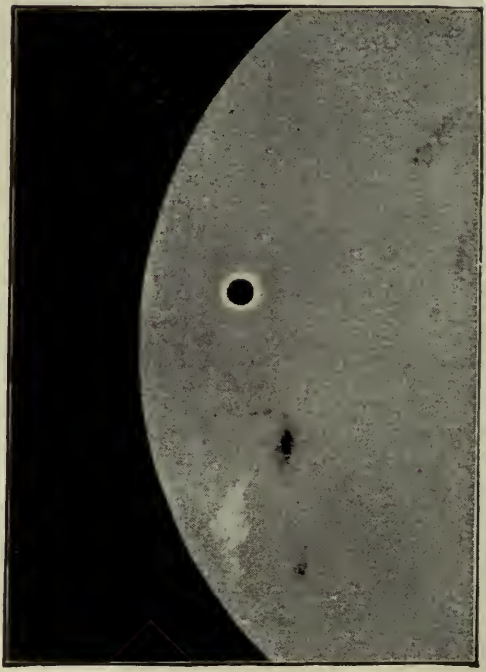


Fig. 147.—Transit of Venus.
(*After Harding.*)

be sought for in its neighbourhood; it is most difficult to locate without a precise knowledge of its position and a fixed telescope. That is why few people ever see it; and even astronomers search in vain for it without a table of its position. Copernicus, on his death-bed, is said to have lamented that he had never seen Mercury. It is only visible shortly before sunrise or after sunset, and then only in the vicinity of the solar rays, which overpower all other light. The star in itself is very radiant, and stands out prominently

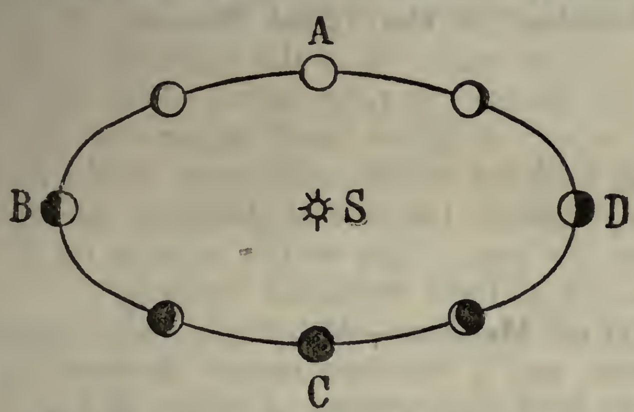


Fig. 148.—How the Phases of Mercury and Venus Originate.

during a total eclipse of the sun. In consequence of the difficulty of observing it, we know little of its surface conditions, much less, indeed, than of more remote planets. Even very good telescopes only show a few grey spots (Fig. 144). The planet presents the very same phases of light as the moon; it changes from a full disc to a more or less narrow crescent; at times its unillumined side is turned towards us, and it entirely disappears from our view.

Mercury Phases.—These are due to the fact that Mercury, like the earth, is dark in itself, and receives its light from the sun, so we can only see those parts that are illuminated by the sun. If we were to illuminate a globe in a dark room on one side only, and were to walk around it, we should reproduce, in a fashion, the phases of light shown by the moon and Mercury. Fig. 148 represents Mercury at different points in its orbit; S is the sun, and the earth, from which we watch the phases, would be at about the position of the reader's eyes. At A the planet is opposite the sun, and turns its fully-illuminated hemisphere towards us; it then appears in the telescope as a circular disc, just like a full moon. Wandering on to B, the right half only is lit up, and we see Mercury in the shape of a half-moon. Running towards C, the side turned towards the earth receives less and less light, and appears as a narrowing crescent until it becomes quite dark and invisible at C, when its bright half is turned towards the sun and its dark towards the earth. The contrary is the case on its progress from C to A by way of D.

The Smallest of the Great Planets.—Mercury is far smaller than the earth; it is the smallest of all the major planets. Its diameter is 2,993 miles, whilst that of the earth is 7,925.6 miles. It is not much larger than the moon, and only about half the earth's continents would find room on it. Twenty planets the size of Mercury would only make one sphere the size of the earth: objects on it weigh not quite one-half of their terrestrial weight.

Transits of Mercury.—Mercury's orbit is enclosed in that of the earth, and it therefore moves between the earth and sun. When both bodies stand as shown in Fig. 119—where S represents the sun, A Mercury, and B the earth—then Mercury, seen from the earth, is situated between the earth and sun, and passes in front of the sun, as the moon sometimes does at new moon. We know that the moon then occasions a solar eclipse; but Mercury, which is minute as compared with the sun, only appears as a small, dark, circular disc stationed in front of the sun. It then apparently passes across the sun, and this occurrence is called a transit. If the orbits of the earth and Mercury were in the same plane, a transit would happen every time the planet overtook the earth, that is, every 116 days. The moon, when new, generally passes above or below the solar disc, thereby evading an eclipse; and this is usually the case with Mercury, which but rarely projects itself on to the sun. The last transit took place on November 14th, 1907, but it was not well observed in northern regions, as the weather was extremely unfavourable. We may be able to witness this interesting phenomenon on November 7th, 1914.

The ancients knew nothing of these transits, as they are invisible to the naked eye. The sun's diameter equals

863,882 miles; that of Mercury but 2,993 miles. If they were both equally far away from us, Mercury would appear 288 times smaller in diameter on the solar disc than this itself is; but as the planet, at the time of its transit, is 41,633,800 miles closer to us than the sun, its diameter only appears 160 times smaller. Nevertheless, the difference in size is a formidable one, and if we took the sun to be a quarter of a yard in diameter, Mercury would not even be the size of a pin's head! The first to observe a Mercury transit was the physicist Gassendi. Kepler had calculated that the event

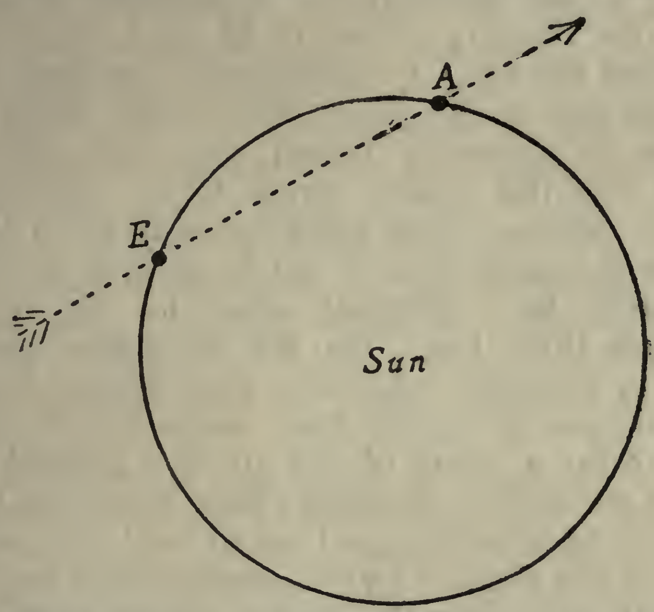


Fig. 149.—Transit of Mercury on November 14, 1907.

would take place on November 7th, 1631, and his prediction was correct. Gassendi witnessed it by darkening the whole of his room, only leaving a small hole in the shutter, through which the sun precipitated its image on to a white wall. Armed with a magnifying-glass, Gassendi examined the image to trace the tiny dark spot, Mercury. The dotted line in Fig. 149 traces the path the planet described across the sun during its transit on November 14th, 1907. All these events can be astronomically determined to a minute for many years in advance, and are most carefully studied with a view to ascertaining whether the motion of the planet shows any irregularities from which deductions could be made as to a disturbance of its orbit by a foreign body in the vicinity of the sun, a disturbance which might be due to a planet as yet undiscovered.

Perpetual Day and Night.—Seen through a telescope from another planet, the seas and continents of the earth stand out as dark and light patches, and their changes in position teach that the earth turns on its axis once in every 24 hours. By scrutinising the spots on the other planets in like manner, we can tell by their movement how long each body needs to complete a rotation, or, in other words, how long a day lasts on it. Observation of its spots suggests that Mercury rotates in 88 days, the time of its circuit round the sun. It unchangingly presents the same side to the sun, as the moon does to the earth, and the other side is constantly turned away from it. If we remember that this planet, owing to its close proximity to the sun, receives about eight times as much light and warmth as the earth does, it will be evident that Mercury would hardly be a pleasant abode for the inhabitants of the earth (Fig. 145). On the hemisphere perpetually turned away from the sun eternal night reigns, and on the other hemisphere a broiling heat, impossible for terrestrial life, with never a breath of cool air or a grateful shadow. Nor has a perceptible atmosphere been discovered by either telescope or spectroscope, and we probably do not err in designating this planet a barren, uninhabitable world. Perhaps scanty life is possible in the narrow border district around the globe where day and night, heat and cold, part company; and imagination may conjure up for us the fearful battles the planet-beings, if such exist, wage for the solitary inhabitable zone they call their home. But, as to the reality of this, science can tell us nothing, for it knows nothing.

Evening and Morning Stars.—Some years ago I had occasion to undertake a lengthy steamer voyage. It had rained hard during the day, but when night fell the sky cleared in the west, and a flaring star, beautiful Venus, suddenly shot out in all its wonderful radiance. Every eye was turned to the luminous body which arose from the dark like a symbol of good fortune. "The Evening Star!" said a man to his companion, who replied that, on a railway journey, she had once seen an equally bright star in the early morning hours, which must have been the Morning Star. A third person here interposed, declaring that they were both one and the same, for Evening and Morning Star were naught else but Venus. The first speaker expressed his disbelief in somewhat forcible terms, and, as he masked his ignorance by an outburst of temper, a heated controversy ensued, all on account of the pure and peaceful Venus.

The orbit of Venus, like that of Mercury, lies within the course described by the earth. Venus is also to be found in the vicinity of the sun, although it is almost as far away again as Mercury, namely 67,111,200 miles. Seen from the earth, Venus must always be sought for near the sun. Unlike Jupiter or Mars, Venus can never stand high in the sky at midnight or in opposition to the sun, for the courses those stars take around the sun enclose the earth's orbit, and if the orbits they describe round the sun were visible, they would be seen in the shape of rings embracing the whole of the heavens. We can, therefore, watch those stars wandering round the skies; but Venus and Mercury always remain in close attendance on the sun, sometimes on its right, sometimes on its left. When Venus is to the left of the sun, it stands above it at sunset, and therefore sets later; it is then seen in the west as the Evening Star. Hence, Venus stands lower than the sun at break of day and rises later, remaining invisible in the sun's dazzling light. When, however, Venus is on the right of the sun, it is beneath the sun at sunset, and sets earlier, being invisible at night. In the morning it rises before the sun and appears in the east as the Morning Star.

Radiant Venus.—Venus is the most radiant of all planets, its light being so powerful that it can sometimes be seen sparkling, like a tiny diamond, near the sun at midday; and it has inspired the poets of all ages and nations into songs of praise. Its light is so intense at times that it even throws a shadow. An experiment made after sunset in winter, when the sky is dark, and at an hour when Venus is in full power, will verify this; the shadow of a hand or any small object can be thrown on to a piece of white paper, provided no disturbing light is near.

Venus Phases.—Venus shows the same light-phases as Mercury (Fig. 148); it appears full, or crescentic, or, at times, when situated between sun and earth (at C), as invisible as the new moon. It might be supposed that Venus could be seen best when it turns its fully-illuminated side to the earth; but that is an error. It attains its highest radiance when it is seen as a crescent in the telescope, when only a small portion of the hemisphere turned on us is lit up. Fig. 146 shows the size of Venus in its various phases; it appears largest as a narrow crescent, and smallest as a full disc. This seeming contradiction is easily explained, for Venus is nearest to us when a crescent, and farthest away when fully illuminated. The earth in Fig. 148 must, as we postulated, occupy the position of the reader's eye, and when Venus shines as a crescent, either on the right or left of C, it is much closer than when situated, as a full disc, at A. It is able to approach us within 24,000,000 miles, nearer than any other of the eight major planets, and that is why it is so conspicuous an object. I remember a young visitor to the observatory who was able to recognise Venus in crescent shape repeatedly without instrumental aid. Travellers tell us that the Venus phases are often watched by the natives of Persia and India, where the atmosphere is exquisitely pure. This is almost impossible in Northern Europe, owing to the poor aerial conditions.

Transits of Venus.—It sometimes happens that Venus, standing between the earth and sun, passes across the sun, as Mercury does. Our neighbouring planet is then witnessed as a tiny dark disc on the glowing sun-globe. This passage, only seen in the telescope, is the transit of Venus, and for sundry reasons is of more importance to the astronomer than a Mercury transit, for, from its careful observation and the mathematical calculations resulting, the distance between the earth and sun, which is as yet not absolutely decided, can be more precisely determined. Observatories everywhere fit out expeditions which travel to the most suitable spots to witness this uncommon occurrence. The last took place on December 6th, 1882, and the phenomenon at the most occurs twice in a century. My readers are cordially invited to the next Venus transit on June 8th, 2004, at 9 a.m.

G.M.T. June 8, 5h 3m 13s first contact
11 24 32 last

Of the Sun's Distance from the Earth.—The passage of Venus in front of the sun resembles Fig. 147; but as it is very close to us, approaching to within 24,000,000 miles, observers stationed at two different points of the globe obtain divergent views of its position in front of the sun, as shown in Fig. 151. This fact materially assists in the calculation of the distance of the earth from the sun. Let E in Fig. 150 be the earth, V Venus, and S the sun. The observer, at point *a* on the earth, sees Venus stationed at *c* on the sun's disc, whilst the observer at *b*, at the same second, sees it

Fig. 150.—Diagram illustrating the measuring of the Sun's Distance during a Transit of Venus.

at *d*. Two large triangles are the result: *a* V *b* and *c* V *d*, both similar, as both form the same angle at V. In Chapter IX. we said that a parallax, the seeming change in position of an object when viewed from two different points, increases in size the nearer the object is to us and the farther apart the places from which it is regarded (Fig. 113). The difference in position which Venus seems to present on the sun to our two observers, the distance *c d* of Fig. 150, will appear the greater the farther apart the observers are on earth and the nearer Venus is to us. Certain relations therefore exist between the distance *a b* on the earth and the distance *c d* on the sun, and between the distance of Venus from the earth and its distance from the sun, which aid us in determining the distance of the sun from earth. A well-known geometrical law teaches that the distance of the two observers on earth, the line *a b*, is related to the line *c d* as the distance of the earth from Venus, *a* V, is to the distance from the sun, V *c*. If we know the distance of the two spectators on earth and the line *c d* on the sun, it is possible to find the distance of the sun from the earth.

The Black Drop.—It is easy enough to ascertain the distance between the two observers, and the expeditions sent out to the different quarters of the globe are entrusted with the task of exactly measuring the position of the Venus disc on the sun in order to find later the stretch *c d*. The moment Venus enters and leaves the solar disc receives particularly careful attention; but a remarkable appearance greatly interferes with this delicate work. If we lay the tips of two fingers lightly against each other, and hold them up to the light, we notice that an apparent tiny connection has become established; the fingers do not seem to lie directly on each other, but a small shadow forms a link between. A similar appearance arises when the edges of the sun and Venus touch during a transit. They do not meet actually, but Venus sends out a small bridge to the sun's edge, and the planet no longer appears as a circular disc, but as a pendent drop (Fig. 152). This, termed the "Black Drop," naturally increases the difficulty of a precise measurement of the exact moment of a contact. The Black Drop is due to the circumstance that dark bodies appear smaller on a light background and light ones larger on a dark background, both being combined in this case. From various observations of the transits of Venus the sun's distance has been computed at 92,340,000 miles.

Venus's Year and Day.—The size of the beautiful Morning and Evening Star almost equals that of the earth, for Venus is 7,438 miles in diameter. As it is so much nearer the sun than the earth is, its period of revolution is likewise shorter, and its year only lasts 224¾ days. We can state nothing with certainty regarding the length of a Venus day. It is quite possible the planet rotates on its axis once in about every 24 hours, but it is also possible that the like conditions exist as on Mercury, and that Venus rotates on its axis in the same time as it moves around the sun, and therefore always offers the same side to the sun.

As to the Surface of Venus.—Venus has an atmosphere, however. The telescope reveals a bright border of light encircling the entire planet during a transit (Fig. 147). This is its atmosphere, vividly illuminated by the sun's rays. Powerful instruments point out grey spots on the surface of the planet, and these are believed to be partly masses of clouds and partly land and water (Fig. 153). The exceptional

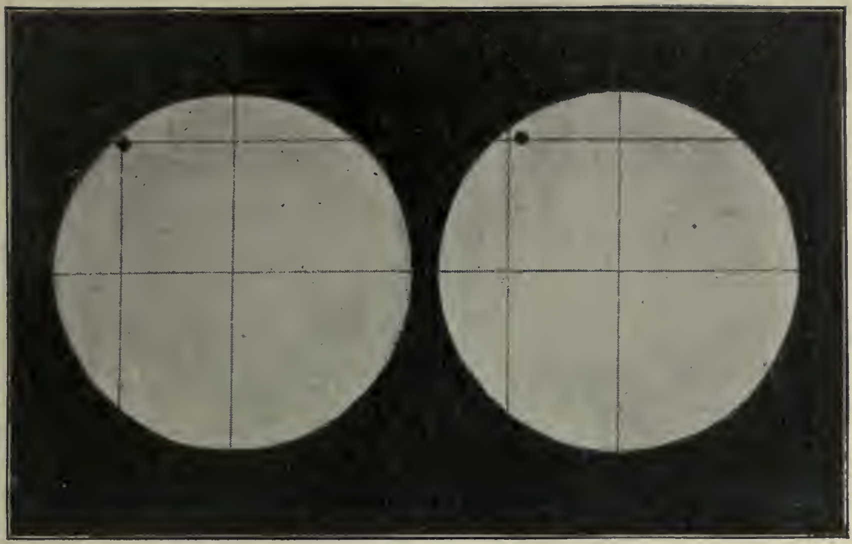


Fig. 151.—Venus in front of the Sun on December 8th, 1874.
Seen simultaneously by observers at Ispahan in Persia, and on the Auckland Islands.

Fig. 152.—The Black Drop.

Fig. 153.—Venus, according to the Author's observation.

Fig. 154.—Irregularities at the Light border of the Venus Sphere, which are supposed to be mountains.

Fig. 155.—The Earth and Moon in Space.

(From a drawing by the Author.)

brightness of the star renders its observation very difficult, and astronomers frequently prefer to watch it in broad daylight, when the general luminous state of the skies tones down what would otherwise be a strong glare in the telescope. White patches have been seen at the poles—probably masses of ice and snow—and bright spots of light, or, rather, frayed edges where day and night meet, lead us to suppose the existence of mountain ranges or single peaks (Fig. 154).

Northern Lights on Venus.—A phenomenon still awaiting satisfactory explanation is a weak glint of light in its non-illuminated regions, on the night side of the planet, which really ought to be of raven darkness. The well-known astronomer, M. Wilhelm Meyer, hazarded the interesting hypothesis that this might be produced by strong Northern lights on Venus.

Without a Satellite.—Neither Mercury nor Venus possesses a moon. At divers times astronomers professed to have seen a tiny star near Venus which they took to be its satellite, but this seems to have been an optical illusion. No mild moonlight beautifies the nights on those planets, but at the time Venus turns its dark side to the earth a star of magnificent radiance, outshining all others, sparkles in the Venus sky—the earth, which then presents its fully-illuminated hemisphere to its lovely neighbour. And who shall say that longing eyes on that far world do not gaze up to the earth-star, seeking a more perfect and more beautiful world in it, untroubled by the millions of tortured doubts which its beams carry into the starry regions! Perhaps, though, the millennium has already arrived in Venus—the age which all desire—and a united people glory in the gleam of the radiant earth, which, in verity, is so dark!

CHAPTER XIV

THE EARTH AS A STAR

The Earth in Space.—Although we may smile pityingly when we remember that our forefathers regarded our small terrestrial sphere as the *universe,* yet the idea is remarkable enough in all conscience that the earth, with its woods and forests, seas and lakes, mountains and hills, human beings and human works, is a star like all others, the third planet revolving around the sun. The earth a star in the sky—how odd it sounds, and yet how natural! To understand it we must part from the usual sense of "top" and "bottom," "up" and "down." There are no such things in space. The inhabitants of the Southern hemisphere—say, the Australians "down under" to the Briton—have the starry skies above them just as we, although they really (as our ancestors believed, who could not comprehend that the earth is a globe) "hang head downwards." As the moon shines in the sky for us on earth, so does the earth shine in the sky for a moon-man, and—seen from Mars, Venus, Jupiter, and the other planets—the earth is but a bright star, a planet, as they are for us, too (Fig. 155).

The Earth as seen from the Moon.—Now, let us endeavour to find out what the earth looks like when seen from other celestial bodies. This is not so very difficult, if we take the distance, conditions of light, etc., into consideration, and, above all, assume that we can look across to the earth from yonder stars, or that people similar to ourselves dwell on them.

Were the moon inhabited, the earth would be most interesting to its inhabitants. It floats in the shape of a mighty globe, or disc, in the black moon-sky, surrounded by a wealth of stars which not even the clearest of wintry nights reveals to us (Fig. 156). As the moon has no atmosphere, the azure of pure air is lacking in the daytime, too.

The sunlight is not reflected by the air, dust and water-vapour particles; and the sky remains entirely black, even when the sun is above the horizon, and the stars gleam forth in all their purity. The earth's disc is about thirteen times larger than that of the moon, and whilst the moon appears to us about the size of a plate 100 feet away, the moon-folk would see our earth about the size of a cart-wheel at a like distance. We can only see those parts of the lunar globe which are illuminated by the sun, and this holds good for the earth, too; for the earth, like the moon and planets, is in itself a dark ball of stone. The moon inhabitants would therefore see the earth as a crescent, in its quarters, as a full disc, and then not at all, and could promenade in the earthshine, while the poets and lovers raved of the mild light of the earth, as we on earth do of that of the moon. At the time we see the moon as a growing crescent, the earth would be visible to the lunarians as a declining one, and when we have new moon it would be "full earth" on the moon. The earth at this period illuminates the moon nights twelve times more brightly than the full moon those on earth. We on earth can even quite plainly see the light the moon receives from the earth. When the moon stands in the sky as a thin crescent, the other parts of its disc can be seen glimmering in a very faint grey light; that is the earth-shine on the night side of the moon (Fig. 157). It is brighter when the great desert plains of Africa and Asia are turned towards the moon, and fainter when the Pacific Ocean, whose water expanses reflect but little light, stands opposite the moon.

The configurations on the earth's surface could not be as easily discerned from the moon as we can see the grey patches on the moon, for our atmosphere would cast a misty veil over the outlines. The terrestrial oceans would appear of a greyish hue, and the land parts as light spots. The ice and snow masses at the Poles would stand out in a pure white; our forests would be visible in a greenish colour in summer, in a brownish tint in autumn, and grey in winter, and this would disclose a knowledge of the seasons to the people on the moon. Great banks of clouds must at times blot out whole districts of the earth, and it would be of intense interest to a meteorologist to be able to take a moon's-eye view of the movement of the terrestrial cloud formations.

Countries smaller than Iceland, or Scotland and Wales together, could not be recognised from the moon without aid, but armed with telescopes as good as ours, clear air being assumed, even the great pyramid of Cheops at the edge of the Egyptian desert would be visible as a tiny speck. (The huge instruments of the Lick and Yerkes observatories reveal craters of 180 to 220 yards in diameter on the moon.) On flattish ground an army corps could be plainly seen, whilst a large city like London would be a most conspicuous object, and its millions of lights would form a bright spot in the telescope of a moon astronomer.

As a Celestial Clock.—The earth would also discharge the functions of a large public never-stopping clock for the lunarians, as its diurnal motion must be plainly recognisable by the movement of the spots on its surface; and their position on the rotating terrestrial sphere would determine the time. But this celestial clock is only to be seen on one side of the moon, for the lunar body always presents the same front to the earth. The inhabitants of the moon's hemisphere which is turned away from us would have to take a long journey to see this immense star, constantly visible at their antipodes. How odd it would seem to us if the moon could only be seen in America!

As seen from Venus.—The earth would be a grateful subject of investigation for the moon folk, but the moon is our neighbour, and might almost be called a piece of the earth. If we were to wander out farther to the star which approaches us the closest of all the planets—to Venus—matters would be considerably different. Venus can come to within 24,000,000 miles of us, and the earth would be seen by the Venus inhabitants as a large star of a brilliancy unknown to our own sky. It might even be possible to recognise the round disc of the earth with the unaided eye, and the light of the earth should suffice to throw a small shadow of the objects on Venus on a clear night. Variations of brightness might also be witnessed, for when the earth's continents were turned towards Venus the light would be

Fig. 156.—Landscape on the Moon.

The stars are visible in the dark sky in daytime, as the Moon has no atmosphere.

(*From a drawing by the Author.*)

Fig. 157.—The "Ashen Light": Earthshine on the Moon.

Fig. 158.—Frederick William Bessel.

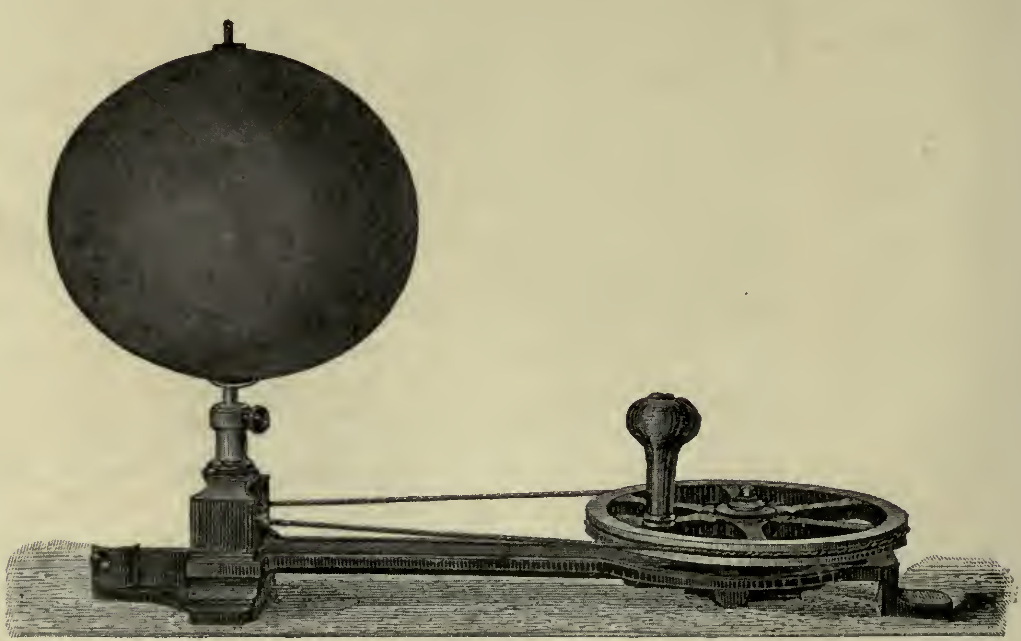


Fig. 159.—Rotation with Clay Globe, showing "Polar" flattening and "Equatorial" bulging.

stronger than when the water expanses confronted it. But that would be nearly all. Even with the unaided eye the moon would be a most conspicuous object, swinging from side to side of the earth like a pendulum, and a monster telescope would disclose continents, oceans, and white patches at the North and South Poles. All the finer details would remain hidden; the largest rivers could hardly be visible, the highest mountains might possibly be seen. The green shade spreading over the earth in summer would indicate that it was not barren; but of human beings, or the work of their hands and brains, there would be no trace.

The Earth in the Planet Skies.—Even less could be seen from Mars, which, at its nearest, is 37,000,000 miles away. Although the earth would still be a bright star, the power of its light would be considerably diminished. Telescopic research would point it out as a small spotted disc, with traces of clouds, ice, and snow.

Beheld still farther away, at giant Jupiter, the earth would dwindle to a tiny star, and the most powerful instruments could only show a dot or two on its surface. If all the forests of Europe were set on fire at one and the same time, this fearful conflagration would, in a Jupiter telescope, only wear the aspect of a tiny fleck of light, so insignificant that most probably no notice would be taken of it. The earth could not be seen at all from Saturn, 885,000,000 miles away, without telescopic aid. Viewed from there, it would be so close to the sun that it would appear to intermingle and vanish in the sun-rays. Supposing people exist on Saturn, if they possessed no telescopes of extreme power they would not even know of such a star as the earth; but if they did own instruments, and searched with great patience, they might be able to pick out our earth as a minute radiant dot—a wee, trembling spark, which yet was inhabited by millions upon millions of people, rent by untold woes, elated by countless joys.

Invisible beyond Saturn.—On Saturn's farther side the earth can no longer be seen; it has sunk in the solar sea of light, has disappeared in the sun's rays, and no telescope imaginable could reveal it to the inhabitants of Uranus or Neptune. Before we could reach the boundary of the solar system we should be already obliterated and unknown, just as we know naught of the earths of other suns.

Distance of the Earth from the Sun.—The earth revolves around the sun as its third planet, between the orbits of Venus and Mars. Its mean distance from the central luminary of the planetary system is 92,800,000 miles. When it is at perihelion, or nearest the sun, on December 31st, it is only 91,300,000 miles away; at aphelion, on July 1st, it is 94,300,000 miles distant. The earth completes its annual revolution in 365 days 5 hours 48 minutes 46 seconds, maintaining an average speed of 18½ miles per second.

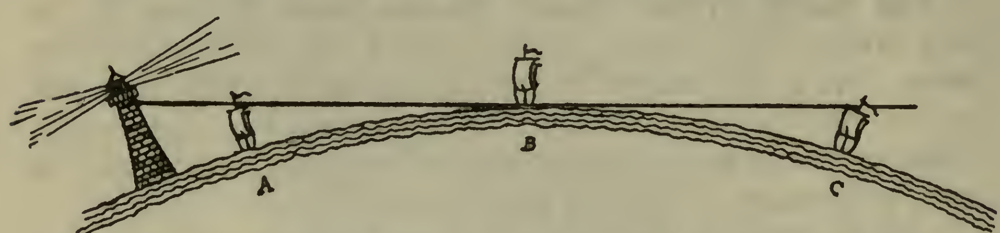


Fig. 160.—Diagram illustrating the Rotundity of the Earth's Surface.

The light drawn from the lighthouse is the spectator's horizon. The vessel is almost wholly hidden at A, for it has not come within view owing to the curvature; it is fully seen at B; and at C it has disappeared, again owing to the curvature.

Proofs that the Earth is a Sphere.—It has needed thousands and thousands of years for the inhabitants of this star to arrive at a clear understanding of its position in the universe, as well as of its size and shape. A great amount of trouble and brainwork was necessary before we recognised that we inhabited a spherical body. Even in the eighteenth century many could not imagine how it was possible to exist on a globe incessantly gyrating on its own axis. There are proofs enough of the globular shape of the earth. The curvature of the earth's surface is very noticeable on a voyage (Fig. 160), when the tallest points of a distant vessel, mountain, or lighthouse first appear on the horizon, and it is not until we have closely approached the object that we see its lower portions across the curvature of the earth. The circular shadow thrown by the earth on the moon during a lunar eclipse and frequent journeys around the earth have, together with many other proofs, put the statement that the earth is a sphere, similar to the other planets whose shape has been revealed to us by the telescope, outside the range of doubt.

How to Measure the Earth's Size.—Triangular measurements carried out on a grand scale by the scientific Commissions of different nations have determined the size of the earth. The first measurement of this kind was that of Eratosthenes, at Alexandria, in the third century B.C.; the circumference, he calculated, was 28,833 miles. An Arabian prince who lived in the ninth century had a large area measured off near Bagdad, and, basing on this, he gave the result as 25,600 miles. It is sufficient exactly to measure off a considerable distance, say in a northerly and southerly direction, to compute the size of the globe if we know the proportion which the measured distance bears to the whole. If we have measured off an area which we know to be the hundredth part of the earth's circumference, and find it to be 250 miles, obviously the whole must work out at 25,000 miles. A remarkable method of measurement was once effected by the French geometrician, Fernel, who, in 1525, drove from Paris to Amiens—the distance he intended to work on—and carefully counted the revolutions of the carriage wheels on the whole journey. Afterwards, he measured the size of the wheels, and, multiplying by this the number of the revolutions, he arrived at a total of 24,881 miles, which was very exact, considering his unique plan.

Modern science naturally works on far more precise lines, on trigonometrical principles, carrying out triangulations of the kind described in Chapter IX. The first to do this was the Frenchman Picard, who, in 1669, stated the circumference at 24,878 miles. In 1735 the French Government sent out two geodetic expeditions to Lapland and Peru, following this up by another from 1792 to 1808. The British Commission lasted almost fifty years, and finished its task in 1854. At the same time a Commission was at work in the East Indies, whilst the astronomer Struve undertook measurements in Russia, Sweden, and Norway from 1816 to 1850. The territory measured by the latter Commission covered a vast expanse, encompassing the fourteenth part of the earth's circumference, and reaching from Hammerfest, at the extreme point of Norway, to Ismail, on the Black Sea. The very precise investigations of Bessel (Fig. 158) were carried on in East Prussia from 1831 to 1834, and now the great task of earth surveying—which is to determine all deviations of the earth from a spherical shape as well—is conducted by the International Geodetic Association, founded in 1886, to which all the principal nations belong. According to Bessel, who based his calculations on the results of ten measurements, the earth has a diameter of 7,926.6 miles at the equator, and a circumference of 24,903 miles.

Flattening of the Earth.—These investigations ultimately proved that the earth is not an exact sphere, for different mileages result for an arc of one degree of the globe measured in different latitudes. The earth was found to be less curved in the northern regions than at the equator; to be slightly flattened at the poles. The diameter from pole to pole is less than the equatorial one, being 7,899.6 miles, or 27 miles less.

If a soft clay ball be quickly spun on a rotator around its own axis, it will rapidly assume a similar flattened shape; at the point where its revolution is the greatest, at the "equator," the matter slightly bulges out, and at the two ends of the axis, the "poles," the matter somewhat recedes, producing a deformation of the purely spherical body (Fig. 159). Matter invariably endeavours to withdraw from the axis of rotation, and at the time the earth was in a viscous condition this deformation arose from the cause mentioned. So we see that the earth is not a complete sphere, but a so-called "rotation-ellipsoid."

Other planets show a similar flattening, especially noticeable in the case of Jupiter; and, theoretically, it should appear on all globes rotating at a rapid rate. In proportion to the enormous size of the earth, however, these deviations are very small. The highest mountain in the world, Mount Everest, in the Himalaya, would only be as large as a pin's head on a globe 2¼ yards in diameter, and we should detect nothing of the flattening without an instrument, for the deviation from a spherical shape at the poles would hardly be as thick as a safety match! We may, therefore, legitimately call the earth a globe, for its variations from an absolute sphere are only perceptible after a series of most complicated measurements. Even metal balls, turned by a lathe, reveal similar flattening.

Weighing the Earth.—The earth has not only been measured, but weighed as well, although this assertion may at first appear incredible. Of course, it was not possible to put it on a pair of scales, so I will try to explain how this feat was accomplished.

How can the weight of any one object be determined without its being weighed? This is a simple matter if its size, or, rather, cubic capacity and density be known.

Let us suppose we have a big block of granite whose weight we desire to learn. If it be 10 feet each way—10 feet × 10 feet × 10 feet—its cubic contents will be 1,000 cubic feet. Now, one cubic foot of granite approximately weighs 162 lbs. avoirdupois, therefore our boulder of 1,000 cubic feet would weigh 162,000 lbs., or 72⅓ tons.

Without touching the block, we have arrived at a knowledge of its weight; and the weight of the earth could be decided in like fashion if a circumstance we shall immediately refer to did not prevent this. The earth has been precisely measured, and to-day we know its diameter to within 500 yards or so.

Every schoolboy knows how easy it is to calculate the cubic capacity of a globe when its diameter is known. Now, the equatorial diameter of the earth is 7,926.6 miles, its circumference 24,903 miles, and its cubic capacity, in round figures, 259,000,000,000 cubic miles. So we know the earth's cubic capacity, and if the earth consisted solely of sandstone or granite it would be as easy to arrive at its weight as it was to reckon our stone-block on paper, for if we weigh a certain amount of sandstone, and know how many cubic yards the earth contains, a very easy sum in multiplication will yield the result.

The earth does not consist of any one uniform material, but is composed of all sorts of minerals and stones, as well as a considerable amount of water. We know very little of the matter in the interior of the earth, for even our deepest mines are like tiny scratches on its surface. How could we decide the weight of the earth from all these totally different masses of material, whose quantities we do not even know? It would be an absolute impossibility, and accordingly other lines must be followed.

The Force of Attraction.—We know that all bodies fall to the earth in consequence of the attraction it exerts. This power of attraction is not a characteristic peculiar to the earth alone, but is possessed by the sun and moon and the other celestial bodies. In fact, every body, even the smallest, possesses an attractive power, be it a hill, a house, a stone, or even the pen I am writing with. The extent of the power alone varies. The larger, or, rather, the heavier, a body the greater the attraction it exerts on the surrounding bodies. A stone dropped out of the window is in reality attracted by the house, but the meagre force of the house is overpowered by the intensely greater one of the earth, so the stone does not fall against the house, but to the ground. Could we transplant our house into space, far away from the earth, the stone would fall to the house; with extreme slowness, however, for the force of gravity is an intensely weak one except where very large masses are concerned. If I know a certain body possesses an attractive force a thousand times less than that of the earth, I know that its weight will be proportionately less than that of the earth after making allowance for the difference of distance. Spheres attract as though their mass were all concentrated at their centre, and gravity diminishes as the square of the distance increases.

And now we can understand how the earth may be weighed. If we can determine in what degree a certain body —a small leaden ball, for instance—is attracted by a block of stone, and how much more by the earth, we can then immediately state the weight of the earth. Say the stone boulder weighs 1,000 cwts., if it attract the ball a thousand million times less powerfully than the earth, then the earth must be possessed of a thousand million times more power than the stone block multiplied by the square of the distance from the centre of the earth divided by the square of the distance from the centre of the block.

It is, of course, a very difficult proceeding to compare the attractive power of any terrestrial body with the tremendous forces of the earth, for even the most majestic mountain is but a grain of sand compared with the whole of our sphere; and yet these measurements have been made hundreds of times, with the help of extremely delicate and most complicated appliances.

Two English physicists, named Hutton and Maskelyne, in 1775, took advantage of the attraction exercised by the Scottish mountain Schiehallion on a plumb line to measure the density and weight of the earth. A plumb line, in its simplest shape, is a leaden weight hung upon a cord, which, under normal conditions, hangs absolutely perpendicularly when attracted by the earth, pointing towards its centre. The delicate methods employed by Hutton and Maskelyne showed that the mountain attracted the plumb line to a tiny degree from its perpendicular position. In Fig. 161 B represents the mountain, L the plumb line. If the hill's attractive force were not present, the line would hang perfectly straight, in the direction of L *a*. Influenced by the mountain, it hangs as shown by L *b*. The amount of this deviation was measured, and the mass, the weight of the mountain (of which the size and composition were known), was calculated. These investigations showed that the density of the earth must be 4.7—that is, the earth must be 4.7 times heavier than a ball of water of the same size as the earth.

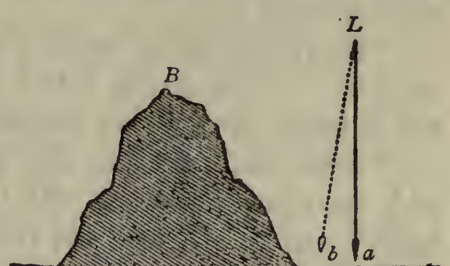


Fig. 161.—Attraction of a Plumb Line by a Mountain.

The mode of research resorted to by these two scientific men was not precise enough for modern requirements, and of recent years far more delicate measuring appliances have been devised to determine the earth's density. All the results varied between 5.4, 5.5, 5.6, and 5.7, but the outcome of the latest measurements sets the figure at 5.5, and a simple sum furnishes a total earth weight of 13,200,000,000,000,000,000,000,000 lbs.—a terrible figure, completely beyond us; and although it may not be correct to an ounce, yet on the whole it is a very fair statement of the weight of our earth.

The Golden Core.—It may be asked what benefit science derives from such knowledge. A whole series of important astronomical, physical, and geological questions is solved by the determination of the earth's weight or density. Here is a case in point. The stone masses of the earth's surface have a mean density of 2.7. As the density of the whole earth matter is 5.5, the material near the centre of the earth must be considerably denser, and it is surmised that the earth's deepest depths contain iron in enormous quantities.

The Earth's Axis.—A workman who had been attending to the fireplace in the study of Camille Flammarion, France's most popular astronomer, was greatly interested in a large globe of the world standing in the room, and after a while said, "I should like to ask you a question, sir. Is the earth really a great ball like this, and does it really turn on its axis, which, they told us in school, really doesn't exist at all?"

"Perfectly true," said Flammarion, setting the globe in motion. "The earth turns on its own axis, exactly as you see it here, once in 24 hours."

"Yes, sir," replied the man; "but there is a solid iron rod running through this thing. But I hear the earth hasn't one at all, and yet turns on it, and that's what I can't understand."

In order to convince his questioner, Flammarion undid the screws fastening the axis to the globe, and drew the rod out. He then took the sphere into his hand, and said, "Now, look here; we have taken away the iron axis, and I want to show you how the earth can rotate without a real axis. I shall throw the ball up into the air, and you will see it spin without the iron axis." Suiting the action to the word, the astronomer threw the globe into the air, but with so much energy that it flew with a bang into a corner of the ceiling, and on picking it up was found to have burst. Flammarion broke into a hearty laugh, in which the workman joined, but the latter could not help remarking, "You see, sir, there doesn't seem to be much virtue in an imaginary axis. I, for one, would rather trust to an iron one."

Proofs of the Earth's Rotation.—Many an educated person has held similar views to those of this simple workman, and a few decades ago a French physician said that "astronomers may assert a thousand times over that the earth rotates on its axis, like a duck on a spit; I, for one, will never credit it." Such people lack the faculty of imagination; they cannot picture to themselves that the earth can float in space, like the moon, and travel onwards, like a balloon driven by the wind, and yet turn round itself, just as we can at times see a balloon do. The axis on which the rotation takes place is a simple line. We call a given line, connecting the North Pole, earth centre, and the South Pole, the earth's axis. The very circumstance that the earth is flattened at the poles establishes its rotation beyond a doubt, for a non-rotating globe would not show any such flattening. It is absurd to suppose that the earth is immovable, and that the immeasurable army of stars, millions and millions of miles away, rotate around the stationary earth within 24 hours. The stars would have to possess an immense velocity to accomplish this at their vast distances. Moreover, the fixed stars would have to revolve just as quickly as the bodies nearest to us—sun, moon, and planets—for they are all back in their old places again after 24 hours.

Foucault's Experiment.—Many convincing proofs of the axial rotation of the earth can be made visible to all, with the help of the celebrated Foucault pendulum experiment. A pendulum hanging free possesses the peculiarity of unalterably retaining the direction of its swing. Hang a pendulum, which need be but a stone or weight fastened to a string, to a chandelier or gas-bracket, and set it in motion, and it will be found to retain its direction even though the chandelier or gas-bracket is carefully and uniformly turned round. If it at first swing from north to south, it will continue to do so, although the point from which it depends be turned in a circle. The French physicist, Léon Foucault, realised that this fact was of value in demonstrating the rotation of the earth on its axis. If swung at the Pole, the direction of the pendulum swing would always be the same, but as the earth turns on its axis, the ground would apparently run away from under the pendulum; it would seem to alter its direction, and deviate more and more from its original direction. As we recede from the Pole a similar apparent displacement of the plane of swing occurs, but the displacement becomes slower and slower until at the equator the displacement would vanish altogether. In 1851 Foucault erected a gigantic pendulum in the Panthéon at Paris, consisting of a metal thread about 7 yards in length, to which a pointer globe of 55 lbs. in weight was attached (Fig. 162). A dial was placed beneath it, the surface being divided to permit of the direction taken by the pendulum being clearly recognised. The giant pendulum needed eight seconds for every swing. A large number of scientists and others witnessed these interesting experiments. After the lapse of a very few minutes the pendulum veered westwards, away from its original direction, thereby proving the rotation of the earth on its axis from west to east. Foucault had previously marked out on the dial the spot which the point of the pendulum would have to reach after a certain time in accordance with the theory of the rotatory action of the earth, and his calculations were verified to the very second. This simple experiment has been frequently repeated, and should convince even the most hardened sceptic.

Sun Time and Star Time.—The time the earth takes to accomplish a rotation is observed and measured by the position of the celestial bodies. The sun stands highest at midday, being then in the south, and crosses the southern line or meridian at 12 o'clock. When, on the day following, it is again in the meridian, the earth must have completed one rotation. A "day" has passed—a period of time which we divide into 24 hours. We must not forget, however, that the sun does not stand motionless, but that it wanders around the whole skies once in the course of a year (in consequence of the motion of the earth around the sun). It daily draws nearer to the east. If it were to remain stationary it would pass the meridian after a lapse of 23 hours and 56 minutes, or four minutes earlier. So the earth must roll a little bit farther to catch up the moving sun. The fixed stars, which possess no motion of the kind, appear in the meridian after 23 hours and 56 minutes, and the astronomer differentiates between two kinds of time—solar day and star or sidereal day, solar and sidereal time. The earth travels more slowly around the sun in summer, when it is farther away, than in winter, when its pace quickens owing to its nearness to the sun. The sun, reflecting the motion of the

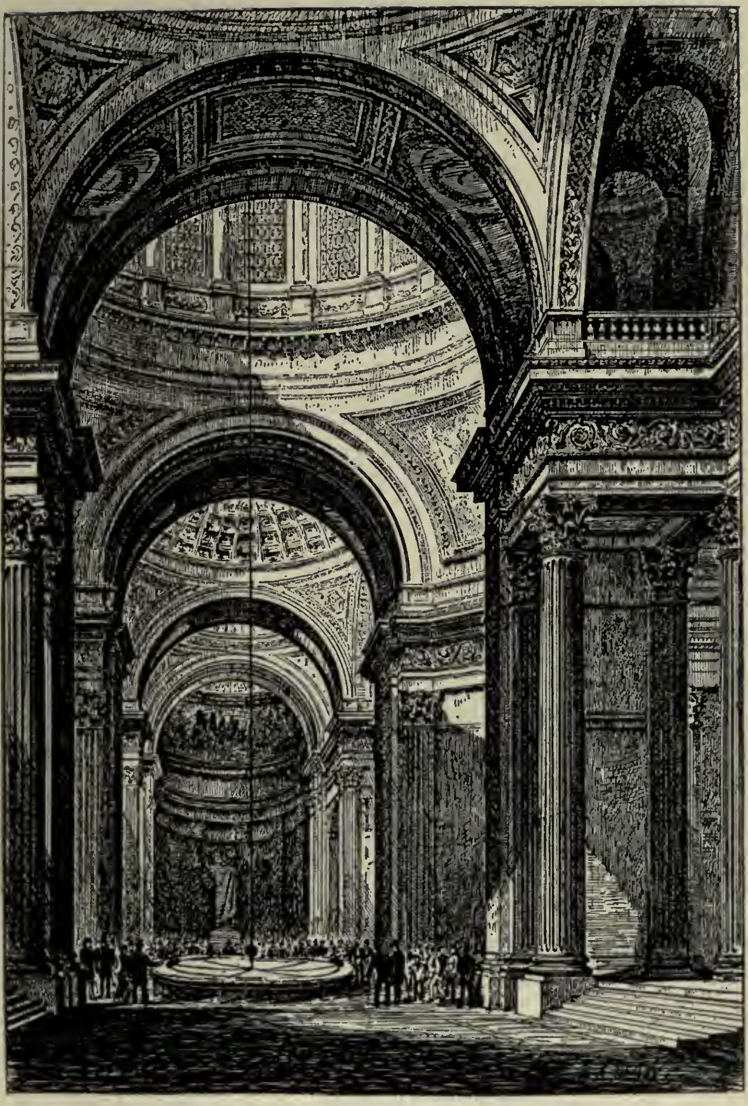


Fig. 162.—Foucault's Pendulum Experiment in the Panthéon, Paris.

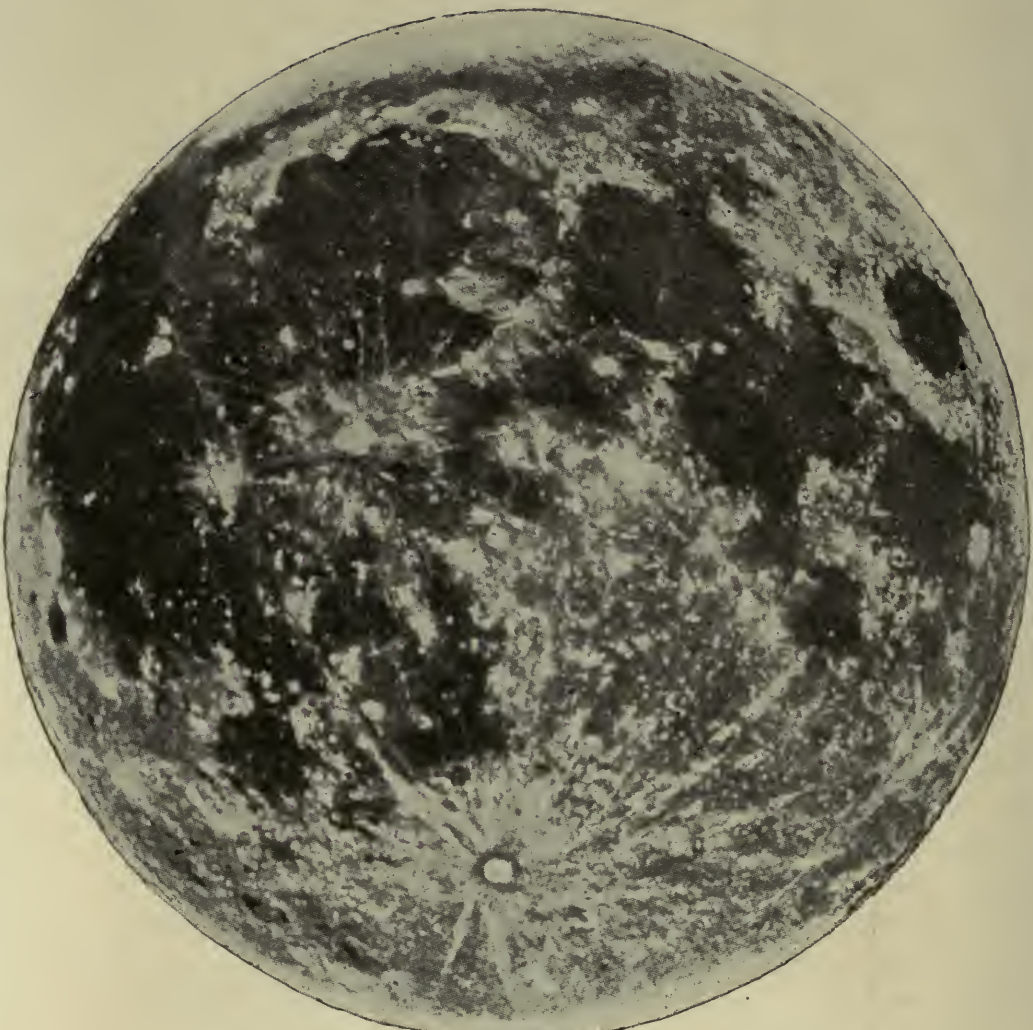


Fig. 163.—The Full Moon.

(From Nasmyth and Carpenter's "The Moon.")

earth, daily traverses shorter distances in summer and longer ones in winter. The diurnal motion of the sun is an irregular one, and the time between one meridian-passing and the next, the solar day, varies in the different seasons. So the sun is not a very trustworthy timekeeper, and it would hardly do to reckon according to the real solar time. Nor is this done; but time is calculated to what we may term an "imaginary sun," which completes its daily journey at a mean but strictly regular rate of speed. The sidereal time of the astronomer is an absolutely regular determination of time, such as he needs for his careful calculations and measurements. The fixed stars stand immovable for very considerable periods, and the earth's rotation time hardly varies perceptibly even in thousands of years.

Uniformity of the Earth's Motion.—The change from night to day, occasioned by the earth's rotation, is so unalteringly uniform that our most precise measuring instruments have not been able to discern even the slightest increase or decrease of the earth's rotation, or change in the day's length, for centuries past. The attractive powers of sun and moon are productive of high and low tides in the waters of the earth and, especially, of the tidal wave, which wanders through the oceans in a contrary direction to the rotation of the earth; and although these act as a drag on the axial rotation, yet calculations have proved that this counteraction can only have lengthened the day by about a twentieth part of a second since the birth of Christ—that is, if it has not been compensated by other influences. Our old nightwatchman, the moon, shows a slight irregularity in its motion around the earth, which has caused much racking of astronomical brains. In the course of a century it manages to arrive at a certain spot in the sky twenty seconds earlier than it should. It would almost appear, though, that this is hardly the moon's fault, but that of the clock by which we measure the motion of the moon. This clock is the earth itself, whose rotations create our time-determination of day, hour, minute, and second; and it would therefore seem as if the earth's rotation varies to a very slight degree.

High and Low Tides.—As the tides play an important part in this question, we must turn some attention to them.

Every sailor and dweller by the coast is familiar with the daily rise and fall of the ocean, an event of greatest interest to visitors to the seaside. It is the sun and moon, especially the latter, which cause this upheaval in the water-masses of the earth. Let E be the earth (Fig. 164) and M the moon, and, for easier comprehension, let us assume the earth to be totally surrounded by water. The moon exerts a strong influence on these masses of water. The solid mass of the earth is attracted as though it were all concentrated at the centre. The water at *a* is closer to the moon than is the centre of the earth, and is therefore more forcibly attracted, swelling up over the surface of the earth. On the other hand, the earth's centre, which is nearer the moon than the water at *b*, is more powerfully attracted, and here the water seems to lag behind the land and rise up in a billow. At the spots on the earth's surface turned towards the moon (*a*), and those exactly opposite them (*b*), there is high tide; the water-masses producing it are drawn from *c* and *d*, where there is low tide. At new moon, when sun and moon stand in the same spot of the heavens, and at full moon, when they are opposed to each other, they both act together on the water; the tides are then very strong, and are called spring tides. When the moon is in its first or last quarter, the sun stands sideways to it, at *c* or *d*, and

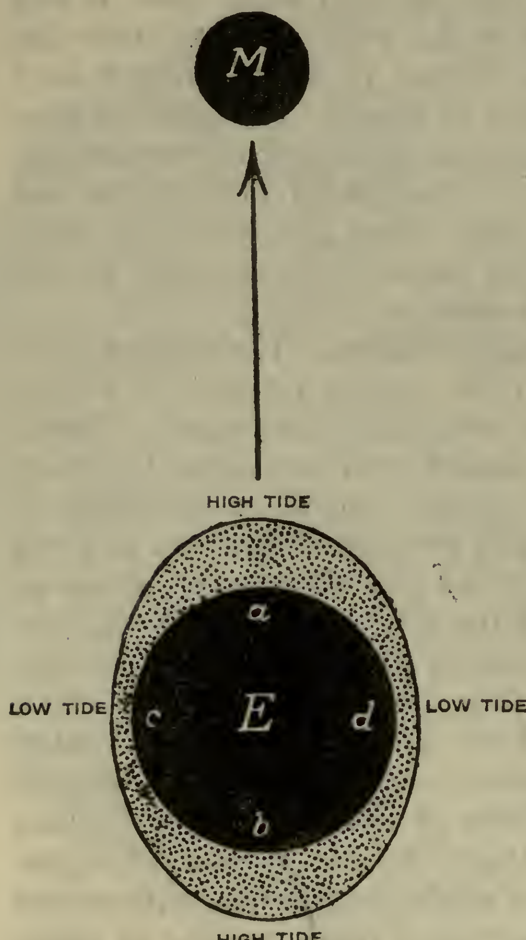


Fig. 164.—How High and Low Tides are Produced.

tries to call forth high tide where the moon tries to cause an ebb. The one counteracts the other to a certain degree; the water neither rises as high nor drops as low as the spring tides, and this is termed neap tide. These masses of water keeping step with the moon must act as a brake on the rotating terrestrial sphere, and this drag will become more noticeable in the course of thousands of years to produce a decrease in the rotatory speed of the earth.

Slowing of the Rotation.—Presumably the length of day has not always been that of the present time, nor will it always remain the same. There are grounds for assuming that many millions of years ago the earth turned on its axis in a period varying between ten and twelve hours, and that this velocity gradually slackened and will continue to decrease until, in due course, a day may become as long as a month is now, so that a fortnight of daylight will follow a fortnight of night. These are the conditions at present prevailing on the moon, and it is the moon that will cause a like condition on the earth. The moon rotates on its axis in the same time as it goes round the earth; we see its one side only, constantly see the same spots somewhat resembling a smiling countenance. Every spot on the moon enjoys a fortnight of day and a fortnight of night; and it was the earth which, in past ages, put a stop to the rotation of the moon by the force of its superior attraction. Mercury and Venus have also very probably lost their rotational movement.

The causes for the slackening of the earth's rotation are to be sought for principally in the attraction of the moon on the earth and the countless masses of meteors and shooting stars which daily fall to earth. According to Newton, about 10,000,000 meteors fall to the earth within 24 hours—or, rather, penetrate the earth's atmosphere, and evaporate. Enormous masses of meteor dust also fall, and all these things combined tend to increase the weight of the earth and influence its rotation accordingly, although the earth inhabitants will only become aware of this after the lapse of long epochs, and even then only through very delicate measurements.

These retarding elements are, however, opposed by a most significant phenomenon, which increases the rate of rotation. Ever since the birth of our planet from glowing matter, cooling processes have been going on, causing a contraction of the celestial sphere. The circumference of the earth shrinks owing to its contraction in cooling, and the smaller the sphere is the faster it will rotate and the days shorten. Calculations state that a decrease in heat of the entire globe for only the fiftieth part of a Celsius degree will produce a contraction of a little over 2.2 yards; the earth's diameter will grow smaller by this slight distance. But even this would mean a decrease of the 75th part of a second in the length of day.

All these influences, partly retarding, partly accelerating the earth's rotation, counterbalance each other, and therefore annul their single actions; but the slowing of day caused by the retarding influence of the daily tidal wave, due to the moon's attraction, must triumph in the end, and will at some remote period equalise day and month. In those future days the moon will remain stationary over a certain spot on the earth—neither rising nor setting—just as our earth, seen from the moon, always remains in the same position on the moon-sky, and is only visible on that half of the lunar globe turned towards us.

Displacement of the Earth's Axis.—Let us imagine the earth to have received a very violent blow, say, from a collision with another celestial body. The whole rotatory action would be rudely shaken; the axis would be moved from its present position and the terrestrial poles would therefore be altered—that is, other spots on the earth's surface would be our north and south poles, and the equatorial line would pass through totally different countries. An immense change would be experienced in our climatic conditions; open seas would take the place of the eternal ice barring the way to Arctic and Antarctic expeditions; countries hitherto possessing a warm clime would grow colder, others warmer; all the animal and plant world would undergo vast metamorphoses; the flow of the ocean would alter, and the whole earth attain a completely new aspect. And all this if the earth's axis were once to "burst its hinges." Can this really happen, and has it occurred in the innumerable millions of years since Dame Earth has waltzed around the sun? This query is related to the question whether the poles always occupied the same position and whether the tropics and the deserts always had the same burning climate.

It has been definitely determined that climates were different in earlier ages from those of to-day. From twelve to eighty thousand years ago the regions we now live in were completely buried in ice, leaving boulders and other glacial deposits as a reminder even to-day of the Glacial epoch. But it has also been determined by remains of animals and plants found beneath the ice that a warm temperature must once have prevailed far north. For a time it was believed that these changes were occasioned by purely local occurrences in the various districts, but later investigations have traced these alterations in temperature to more powerful and general agents. Signs of a former ice-bound state have been suspected in the torrid zone, near the equator. Tremendous upheavals of this kind on both hemispheres can only have been caused by an astronomical event in consequence of which the sun's radiation on the earth was totally changed. An increase of the eccentricity of the earth's orbit around the sun may have assisted in this, but a shift in the position of the earth's axis would have been far more powerful in calling these climatic changes into being.

Slight Variations of the Earth's Axis.—Small variations do really take place; the poles of the earth shift their position in a very slight measure. The astronomers Chandler and Küstner began researches on this point in 1885, and found that the stars suffered apparent slight variations in position which led to the determination of a variation in latitude of the terrestrial globe, or, to be quite precise, of the earth's axis, thereby causing an alteration in the position of the stars for us. This was a most valuable discovery, for all astronomical and geometrical measurements can only be absolutely trustworthy if the positions of the places on the earth suffer no change in their relation to those of the stars. Most careful observations were begun in different quarters of the globe to acquire a more intimate knowledge of these variations. Permanent stations have been erected at six places—in Japan, Sardinia, Pennsylvania, Turkestan, Ohio and California—and their results are forwarded to the Potsdam Observatory, which then draws its deductions from the material supplied. The displacement of the earth's axis is at present very small; from 1890 to 1900 the terrestrial North Pole was found to have described a spiral line around its mean position. The movement is rather irregular, and the maximum variation of the North Pole may be set at 17½ yards. How do these variations of the earth's axis originate? It can easily be explained in theory, since the axis of rotation in a globe floating independently must vary if the masses of matter in or on the globe alter their position. Such alterations constantly happen in or on the earth. The tremendous aerial depressions, the rivers which tear off great masses of earth and lodge them at their mouths, volcanic eruptions, earthquakes, all these serve to influence pole variations. Still greater displacements of matter, alterations in the position of entire districts and mountain ranges, remarkable transformations, must have taken place in past ages, when the inner forces of the earth burst their bounds and produced general reversals. The variations of the earth's axis must have been considerably larger in those days, and the terrestrial poles and the equator may have been situated quite differently from the positions they occupy at present. Perhaps mighty forests of ferns may have swayed in the wind where the Northern Lights break to-day.

CHAPTER XV

THE CIRCUIT OF THE YEAR

Annual Rejuvenation of the Earth.—The onward procession of the year, with its budding, blossoming, ripening, fading and dying, resembles our own little life. Every year we experience anew the fresh pulsating breath of spring, the spreading beauty of summer, the fruitful harvest of autumn, the icy sleep of winter, on which at length a joyous awakening follows, and the circuit is renewed. Nature has throbbed out its round for millions of years, setting every insignificant detail into motion to create a marvellous whole, embodying health, energy and beauty. Our old earth is annually rejuvenated, it appears every year in youthful and entrancing garb. The one half is constantly in energetic action whilst the other is at rest, and after the prescribed period has elapsed for the one, the other awakens to fresh activity.

And all this is due to the motion of the star on which we have our home around the sun, and especially to the fact, which at first hardly sounds very important, that the axis of the earth is not perpendicular to the orbit described by the earth round the sun, but is somewhat obliquely inclined instead.

The conditions to which the annual changes of seasons owe their existence are not very involved; we learnt of them in our school-days; but probably most of us have forgotten all about them, and we will therefore recount the cause of the seasons and the different climatic zones on our planet, as though we were setting forth something quite new.

Apparent Motion of the Sun.—We must constantly bear in mind that the earth is a sphere floating in space and revolving around the sun. To us the sun appears to wander in the sky, for after sunset we watch ever different constellations appear in the course of a year, during which time the sun has encircled the heavens and passed from one constellation to another. This is, however, only an apparent motion, similar to that of the bridge on which we stand gazing down at the water: it seems to travel onwards and not the water. Journeying in a train the telegraph poles and signals seem to dash past us while we stand still, but we know this to be an illusion, and that their action is only a reflection of the movement of the train. We therefore recognise the motion of the earth in space by the apparent

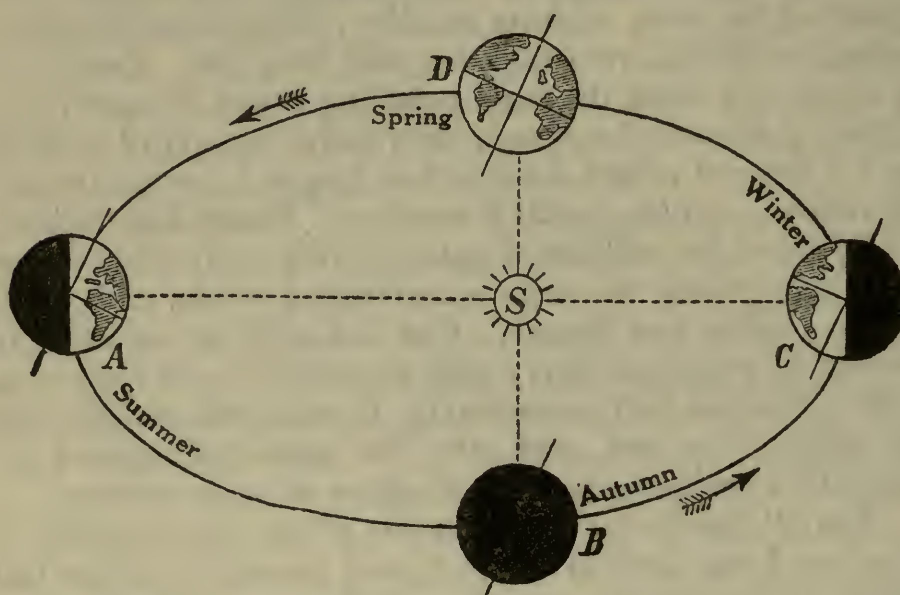


Fig. 165.—Annual Course of the Earth around the Sun.

motion of the sun, and careful study has imparted the knowledge that this motion of the sun is not uniform throughout the year. In winter the sun daily travels an apparently longer route than in summer. In June the sun traverses in a week a distance nearly thirteen times as long as a full moon's diameter; in December its course in the same time would be a full moon's diameter longer.

Irregular Speed of the Earth.—How does this irregular motion of the earth, reflected by the apparent motion of the sun, arise? Celestial bodies attract each other; the tremendous solar globe acts like a huge magnet on our little earth, and swings it around like a top. The nearer a piece of iron is to a magnet the stronger the attraction, and the closer the planets approach the sun the faster they have to move around it. The very circumstance that the earth sometimes hastens, sometimes slackens, proves that its orbit permits it at times to approach and at times to draw away from the sun. In summer the sun appears to us quite measurably smaller than in winter, a sure sign that the earth is closer to the sun in winter than in summer.

This is somewhat surprising, for it might be supposed that the closer we are to the source of heat the more warmth we should receive, and as it is not as warm in winter as in summer very special conditions must prevail to enforce an exception to the general rule. We will not enter into this at present, but will study the orbit of the earth (Fig. 165).

The Earth's Orbit.—The earth's orbit is practically a circular one, for its least diameter is only one part in 7,000 less than its greatest, which could not be discerned on the scale of the illustration A B C D. The sun, as we can see from this, is placed out of the centre by quite an appreciable amount, viz. 1½ million miles, or one-sixtieth of the distance, and the earth runs around the sun in the direction of the arrows, in a period of 365 days and 6 hours, which we call a year.

When the earth stands at A it is at aphelion, or the point farthest from the sun; it is then summer. At C it is at perihelion, or nearest to the sun, but it is then winter, and, though the sun is so much closer, snow and frost are supreme. We shall soon learn the reason for this. The earth is at A on June 21st, and then wanders on, and on September 23rd arrives at B, where A, S (sun), and B form a right angle. From there the planet passes to C, reaching it on December 21st, being diametrically opposed to A and in a right angle to B. The next station is D, which is reached on March 21st, when the earth is opposite to the autumn point; spring then sets in. Three months later the earth has completed its course, and arrives at its summer goal on June 21st.

A closer study of the two stretches B C D and D A B shows that the first (traversed by the earth in the winter six months) is decidedly shorter than the latter, and as the earth is stationed closer to the sun at the time and moves with increased speed, we must logically conclude that the winter must be shorter than the summer—and so it is, by exactly eight days.

The Earth's Debt to the Sun—Now let us return to the influence the sun has on the earth. It is the sun that renders our cold, rigid earth inhabitable and fertile; it illuminates and heats it at one and the same time. Whilst the day-side is being warmed by the sun, the night-side partly radiates the warmth received during the day into icy space, cooling off in the process.

Origin of the Zones.—How is it that, although the sun heats and illuminates the entire day-side, the districts near the equator are so much warmer than those near the terrestrial poles? How, in other words, do the different warmth zones arise—the torrid, temperate, and frigid? Although the question is easy to answer and these phenomena are simple in themselves, the question is generally solved in a very slipshod fashion, and the schoolboy who stated that "the poles are very cold because great masses of ice and snow lie there" has many a follower. In Fig. 166 the sun's rays strike the earth, surrounded by its atmospheric envelope (this is suggested by the dotted circle), from the left. All the sun's rays have first to pierce the earth's atmosphere before they reach its surface, and in doing so a quantity of their light and warmth, about 40 per cent., is absorbed by the air. Compare the rays striking the equator and entering the atmosphere at I with those at II, which reach the earth at Norway, and we shall find that the rays have a much shorter way to travel through the aerial strata at the equator than those at point II or III. The longer their passage through the atmosphere the more heat and light are extracted, and that is why the sun neither warms as well nor shines as brightly when low on the horizon, where its rays have to penetrate denser air-layers, as at midday, when it rides high in the sky. Now we know why the regions at the equator receive more heat than the northern and southern parts of the globe; it is all a matter of different absorption. This alone would account for the increased warmth at the equator, but there is another very important reason which we can explain best by a slight experiment.

Effect of Oblique and Perpendicular Rays.—Take a magnifying-glass and hold it in the sun till it throws a bright circular light on to a card held behind it. The paper grows hot and begins to scorch where the rays are focused. Repeat this, but hold the card at a slant to the plane of the glass. Instead of a round spot, an ellipse of light will appear, which being less bright and possessing less heat is unable to scorch the paper. The heat collected by the glass, if the card be held parallel to the plane of the glass, is

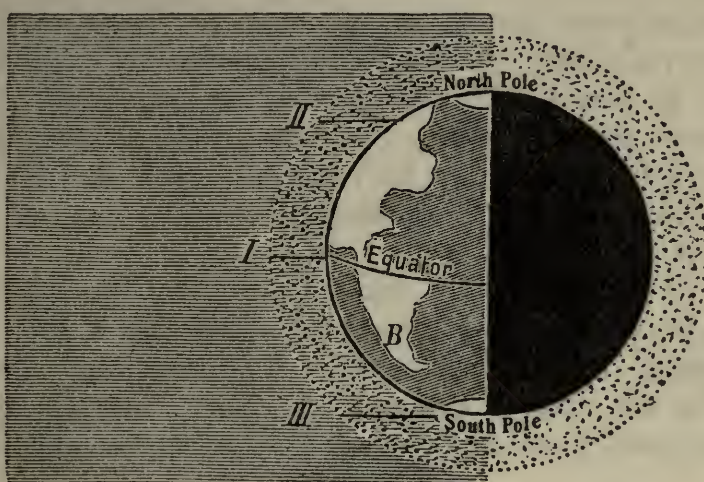


Fig. 166.—Illumination of the Earth by the Sun.

thrown on to one small spot only; if the paper be held slantingly, a much larger space has to be covered, and there is less heat for any one spot. It is very much the same with the rays striking the spherical earth. They meet the equator in a perpendicular line (at I), and are able to expend great warmth there. At the poles they strike the earth quite obliquely, and their influence is very slight. Everything is covered in ice, and huge icebergs make a most imposing show, whilst at the equator all the bewildering beauty of tropical vegetation has its being in dense green forests, and vast deserts breathe forth glowing heat.

Other things affect climatic conditions besides those we have sketched. High mountain ranges, which ward off storms, make a country hospitable that would otherwise have a rough clime; countries surrounded by water enjoy milder winters and less burning heat in summer, as the water counteracts both extremes of temperature to a certain degree.

How the Seasons Arise.—At the time of writing we are in the midst of winter; the snow is falling fast, and the frost has traced patterns on the window. The morning papers contain an account of terrible heat in South America, especially at Buenos Aires; of locust swarms entirely destroying the wheat- and corn-fields, already scorched by the sun's fierce glare. Buenos Aires is not very close to the equator, being situated in 35° S., about the spot marked B in Fig. 166. The temperature should equal that of Spain, a spell of preternaturally hot weather not being entirely excluded. If we were to travel still farther towards the South Pole, to the extreme point of South America, which is exactly as far away from the equator as Berlin, we should find everything in full blossom and midsummer reigning, whilst in Prussia Nature is in winter's toils. When it is summer in the north it is winter in the south—in short, the seasons are reversed in the two hemispheres on either side of the equator.

Obliquity of the Ecliptic.—This seasonal change is caused by the ecliptic (the sun's apparent orbit in the sky) being inclined towards the terrestrial equator. To put this astronomical sentence into plain English we need an illustration. We know that the earth revolves around the sun, and not the sun around the earth; nevertheless, we see the sun make a circuit of the skies within the course of a year. Now, let us imagine the earth to be stationary and the sun to revolve. The circle A B C D (Fig. 167) represents the celestial sphere with its stars; the earth is among them, the earth's axis being marked N S and the equator E E. The letters B F D H stand for the sun's apparent path during a year, the so-called ecliptic. It is distinctly shown that the ecliptic is not in the same plane

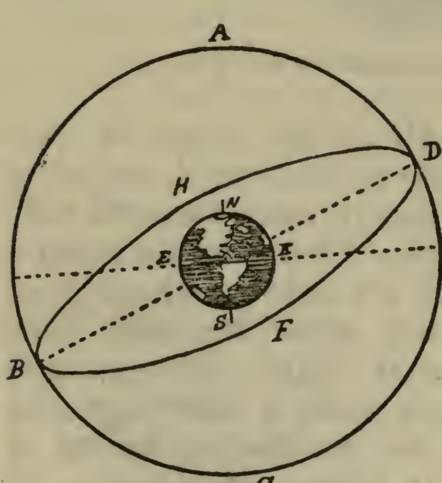


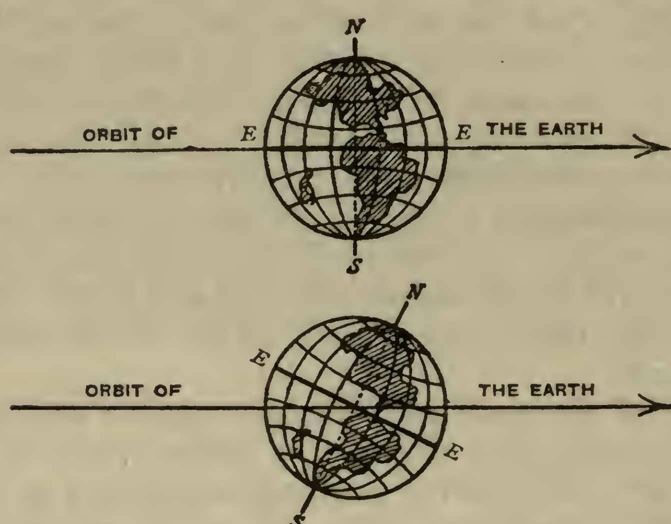
Fig. 167.—The Sun's Apparent Course round the Earth.

with the equator E E, but part of it lies above and part below the equatorial plane. When the sun is at D it stands above the equator, high in the sky for the northern hemisphere, and radiates a great amount of heat down on it; this causes our summer-time. Keeping in mind the fact that the earth rotates on its axis N S, the southern hemisphere must now have winter, as the sun is not high on the horizon for the places situated on it, and the South Pole, S, has no sun at all.

Long Days and Short.—We know now why the days are longer in summer. The sun rises very early in the north-east, sets late in the north-west, and stands very high at midday, describing a lengthy route through the skies, which takes up a great deal of time. Circumstances undergo an utter change when the sun arrives at B, six months later. Here it stands below the equator, and shines more powerfully on the southern hemisphere, which then rejoices in summer. Winter reigns in the north, where the sun stands low and has soon finished its daily rounds. In both intermediate positions, at H and F, the sun is neither above nor below the equator, but exactly in its plane, and both hemispheres receive a like amount of heat and light. It is then spring in the north and autumn in the south hemisphere, or vice versa.

March of the Seasons.—We have already explained that matters are somewhat different in reality, as it is not the sun that occupies different positions in relation to the earth in different seasons, but the earth, which exposes the one or the other hemisphere more or less fully to the influence of the sun. Please turn back to Fig. 165. The axis of the earth is obliquely inclined to its orbit, and this inclination always remains the same, as the four positions of the earth show. The earth, standing at A in summer, turns its northern hemisphere to the sun, when the North Pole is warmed and illuminated. As the inclination of the earth's axis is an unvarying one, it follows that the southern hemisphere must be turned to the sun after the lapse of six months, at C, when the South Pole has light and warmth, whilst the North Pole is cold and dark. Thus do the seasons develop and follow each other. The fact that the earth is nearer the sun during our winter is of little importance, for although the difference is one of three millions of miles, it is not enough to influence climatic conditions to a great degree. The northern summers are, however, appreciably cooler and the winters appreciably warmer through the difference in distance.

Speculations.—So we see that it is the inclination of the terrestrial axis that brings us dreary winter and gay summer. If the earth's axis were perpendicular to its orbit—in other words, were the ecliptic on a plane with the equator—there would be no change of seasons on our planet. The upper illustration in Figs. 168 and 169 shows a globe with an axis perpendicular to its orbit, which is in the same plane as the



Figs. 168-169.—Inclination of the Axes of the Earth.

equator. If these were the existing conditions, there would be neither winter nor summer. In reality the earth's equator and earth-orbit form an angle of 23½°, as shown in the lower illustration. Should the earth, one of these days, feel inclined to curtsey still more deeply to the sun, and tip its axis more forward, the differences in the seasons would be more sharply pronounced still. A slight alteration of the zones would set in, and different conditions reign on earth, involving a reversal of things in general for humanity, which is dependent for its welfare on climatic conditions. All this may have been once in ages past, for the discoveries mentioned in the last chapter (p. 169) prove the climates on earth to have been parcelled out differently in those days.

This chapter has taught us that a circumstance of apparent insignificance, such as the more or less oblique position of the rotation-axis of a planet, may be of the utmost importance and produce most far-reaching results, and that the whole habitability of a world is dependent on such seemingly trifling circumstances. Purely mechanical details may decide whether a star is destined to be the home of living beings of highest intelligence, or whether it is to form an abode for lower creatures only; or, lastly, whether it shall wander through the universe a barren, opaque globe.

CHAPTER XVI

THE MOON-WORLD

Tales the Moon Could Tell—When the pale moon rises above the dark tree-tops, and its mild light casts its silvery beams over the brown furze, the dreamy, poetical tales Andersen makes the moon tell in his "Picture Book Without Pictures" pass through our minds. What could it not relate, this trusty and true companion of ours, patron of lovers and poets, as it paces the selfsame path it has trod for millions of years? It knew our earth when it was a fiery, liquid ball; saw the oceans and continents arise on it, and beheld life blossom forth from wild chaos. Its mild refulgence broke on the masses of ice that covered the earth in the Glacial Age, when man, himself not far removed from an animal, sauntered forth, armed with a stone axe, to wage war on the beasts; it lit the desert for the Egyptians when they built their pyramids, and it looks down on the great cities of to-day, whose electric suns make its light pale, and in ages to come it will still accompany the earth when it shall once more have become a stony world, barren of all life.

What Telescopes Reveal.—The moon could tell us all this and much more, and it unfolds a long story to the astronomer who studies its pallid, wrinkled, crowsfooted features; and it tells, too, of the future of the earth, of the end of a world! Our giant telescopes permit us to scan this neighbouring world most intimately, as objects only about 160 yards in diameter are distinctly discernible in the shape of a dot, for the moon is very close to us in space, but 240,000 miles away, a distance an express train could cover in six months, and a cannon-ball, travelling at a uniform speed throughout, in ten days (Fig. 171). The light is the sole messenger that brings us news of the worlds afar. Its secrets have been wrested from it by the invention of telescopes, and we can now complacently turn our huge glasses on to the silent moon and search its rigid expanses. Such a view as it offers! A world of immense circular craters, deep gorges, wide plains, rigid peaks and summits sparkling in the sun, a chaos of light and shade, now dead and barren, but once, perchance, a world of green forests, billowing seas, and fleeting clouds. The moon is a Norway on a large scale. Mountain crowds on mountain, throwing deep shadows in the sunlight, shadows that help us in our determination of the objects on the moon. We know the moon to be an opaque body like the earth, illuminated by the sun. When the sun stands exactly opposite the moon, the whole

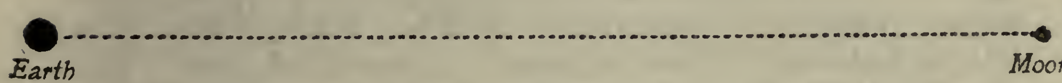


Fig. 170.—Diagram illustrating the Distance of the Moon from the Earth in Proportion to their Relative Size.

hemisphere turned towards us is illuminated, a state we term "full moon" (Fig. 163).

Full Moon.—At such times we cannot recognise much more than with the naked eye or an ordinary opera-glass. We can see, above all, the large dark spots on the surface, sometimes called the face of the "Man in the Moon." We know by the absence of shadows that they are wide plains, covered with a darker deposit than the mountainous regions. When the moon waxes or wanes, these plains are very distinct in the telescope. Our frontispiece reproduces a part of one of them, which the astronomers have named "Mare Tranquillitatis" ("the Sea of Calm"). It is surrounded on the right by hills, whilst various single craters, filled with black shadows, lie within its territory.

The full moon (Fig. 163) shows very bright districts, mountainous stretches which are specially conspicuous at the lunar south pole, where the sunlight throws several high peaks into bold relief. The reason why even powerful telescopes reveal so little at full moon is to be found in the fact that the sun and earth are in the same direction from the moon, so that all objects conceal their own shadows, the mountains casting no shadows, but only appearing as light spots, dots, and stretches, for we must not forget that we look down on all the features of the moon's surface—a consideration of great importance in scrutinising both the moon and its photographs. Full-moon time is generally deemed to be the most suitable for observation, and visitors to observatories are usually disappointed at the scantiness of details visible. The best time to gaze at the rugged mountain regions is when the moon is in its first or last quarter.

Lunar Oceans.—The astronomer has named those great grey plains on the moon, "Maria" ("Seas"). Fig. 171 shows their outlines as seen through a field-glass, and gives a list of their names as well. (A very interesting map of the moon, one of the oldest in existence, drawn up in the seventeenth century, is reproduced in Fig. 172.) There is a "Mare Imbrium" ("Sea of Rain"), "Mare Nubium" ("Sea of Clouds"), "Mare Serenitatis" ("Sea of Serenity"), "Oceanus Procellarum" ("Ocean of Storms"), and so on. These are not really seas and oceans in which mighty masses of water plough and churn, for there is no trace of water on the moon. It is, however, possible that these great plains are beds of former oceans, in which, millions of years ago, when the moon was a fruitful world, the waters rolled; they may, also, partly be deserts, similar to the Sahara. A most imposing sight is afforded us in our powerful telescopes by the craters rising upright out of the plains, as, for instance, the circular mountains, Archimedes, Aristyllus and Autolycus, in the western part of the "Mare Imbrium." (See Fig. 173, at the bottom, on the right.)

The Mountains in the Moon.—The surface of the moon takes on a very different aspect in the first or last quarter. It is then placed sidewards to the sun, so far as we are concerned, and only half of the hemisphere turned to us is illuminated. The sun's rays strike down obliquely, and all things near the centre of the disc throw a shadow. The moon appears as shown in Fig. 174, the photograph being taken during the first quarter; the light-dividing boundary is an irregular one, thousands of fine jags, edges, and blisters being noticeable. The mountains on the moon are very prominent, their walls and summits gleam in the sun, whilst their feet lie in the jet-black shadows which they cast

Fig. 171.—Chart of the Moon.

(*From observations by Beer, Mädler and Nasmyth.*)

1, Mare Crisium (Sea of Crises); 2, Mare Serenitatis (Serenity); 3, Mare Tranquillitatis (Calm); 4, Mare Fœcunditatis (Fertility); 5, Mare Nectaris (Nectar); 6, Mare Frigoris (Cold); 7, Mare Imbrium (Rain); 8, Oceanus Procellarum (Ocean of Storms); 9, Mare Nubium (Clouds); 10, Mare Humorum (Humours); 11, Apennines; 12, 13, The Circular Mountains Copernicus and Plato; 14, The Radiant Mountain Aristarchus; 15. The Circular Mountains Arzachel, Alphonso and Ptolemy; 16, Mount Theophilus; 17, Mount Tycho.

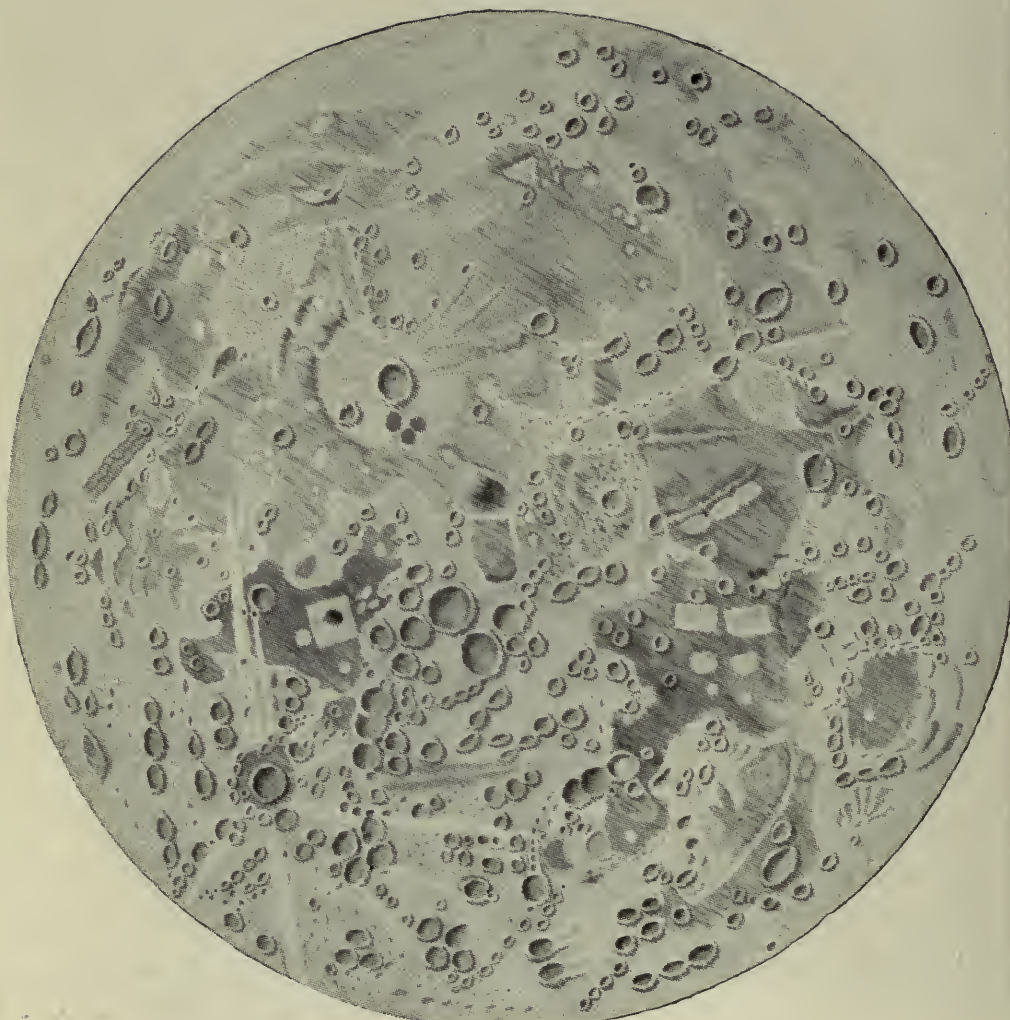


Fig. 172.—Chart of the Moon in 1671.

(Made by Cherubim d'Orléans.)

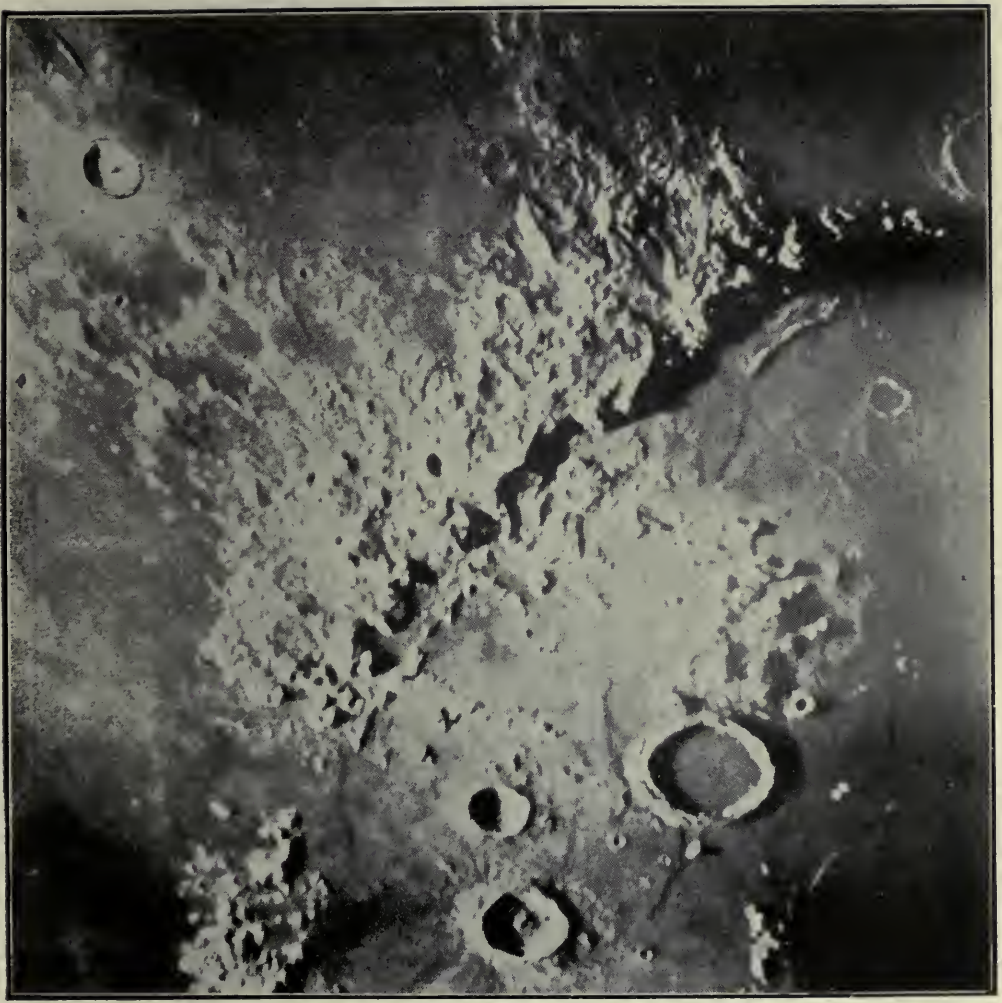


Fig. 173.—Mounts Archimedes, Aristyllus and Autolycus.

(After photographs by Loewy and Puisseux, Paris Observatory.)

Fig. 174.—The Moon at First Quarter.
(From a photograph by Loewy and Puisseux, Paris Observatory.)

over the valleys. A very good illustration of a typical moon-crater is found in Fig. 175; the circular walls enclose a deep valley, out of which a cone rears aloft. This mountain is called Gassendi. Black shadows, thrown by the walls, fall towards the right, the non-illuminated part of the moon. These are seen even better in Fig. 177, in which the whole interior is filled with the shadow thrown by the left wall, the cone alone rising out of the darkness. This comparatively small crater, Triesnecker by name, is large enough comfortably to stow away London and its suburbs in its interior. The steep mountain range adjoining the crater is very plainly visible.

Height of the Mountains.—The height of these mountains can be ascertained by astronomical instruments. The highest point on the moon is Mount Curtius (29,100 feet), running our own Mount Everest very close! The system of measurement is, however, different; on earth we measure from the sea level, on the moon from the surrounding plain. The shape of the crater walls can be determined by the shadows they cast. The circular mountain, Gassendi, throws very sharply defined shadows, resembling those of Gothic towers; its walls are therefore formed by tremendous crags, whose height has been set down at 7,620 feet.

Besides these isolated craters, there are long mountain ranges similar to the Alps and Cordilleras. Three circular forts, forming a triangle, are seen in Fig. 174, right at the top and close to the light-boundary. They are closed in by three mountain ranges extending around them almost in a semicircle. These are the Caucasus, Apennines and Alps. The Apennines are very distinct in Fig. 173, and some of the peaks reach the very respectable height of 12,000 and 15,000 feet.

How these Mountains Originated.—Geologists and astronomers have for years past attempted to arrive at a satisfactory decision as to the origin of these extraordinary circular moon-mountains. Fifty thousand are known to us to-day, not counting the hundreds of thousands of small craters hardly one hundred yards in diameter. If we were to visit the moon we should find its surface exactly to resemble that shown in Fig. 156, a typical moon landscape.

These circular formations, with or without a central cone, are to be seen everywhere.

How is it that all this has one and the same pattern? No definite answer can be given. There are but six such formations in all—and not even exactly similar—on earth. All these moon-mountains appear to arise from a certain state of conditions that must at one time have reigned on the moon. Our first idea, naturally, is that of volcanic forces. Masses of lava ejected from the interior of the moon may have formed these craters, similar to those of terrestrial volcanic mountains. This idea is set forth in Figs. 178 and 179, which show the development of a circular mountain, according to Nasmyth and Carpenter. These investigators believe the erupted masses to have been dashed out—with tremendous energy at first—falling to the ground in a wide circle around the mouth of the volcano, thus forming the ring wall (Fig. 178). As the forces lessened, the masses were shot up straight into the air, and, coming down near the mouth of the crater formed the central cone (Fig. 179). This theory does not explain all the characteristic features of a circular mountain, however. Another opinion has it that all these round walls were caused by the precipitation of heavy bodies on to the moon's surface; and there is much to be said for this view, for if a heavy body is dropped on to a pliable mass of matter a shape similar to that of a crater will arise. The author has experimented to this effect with a stone and mortar, the resulting artificial moon crater being shown in Fig. 176. And yet to accomplish it, it would have needed a perfect torrent of huge meteors, meteors of the size of celestial bodies and able to make holes 93 miles wide, as some of the craters measure quite this in diameter. We have to ask ourselves how it happened that the earth, floating so near to the moon, remained untouched by this terrific rain of celestial bodies, and we may as well confess that the origin of this lunar phenomenon still baffles us.

Radiant Hills.—The radiant mountains on the moon are an equal mystery; at the time of full moon five or six exceptionally bright spots, from which luminous streaks radiate in all directions for hundreds of miles, are con-

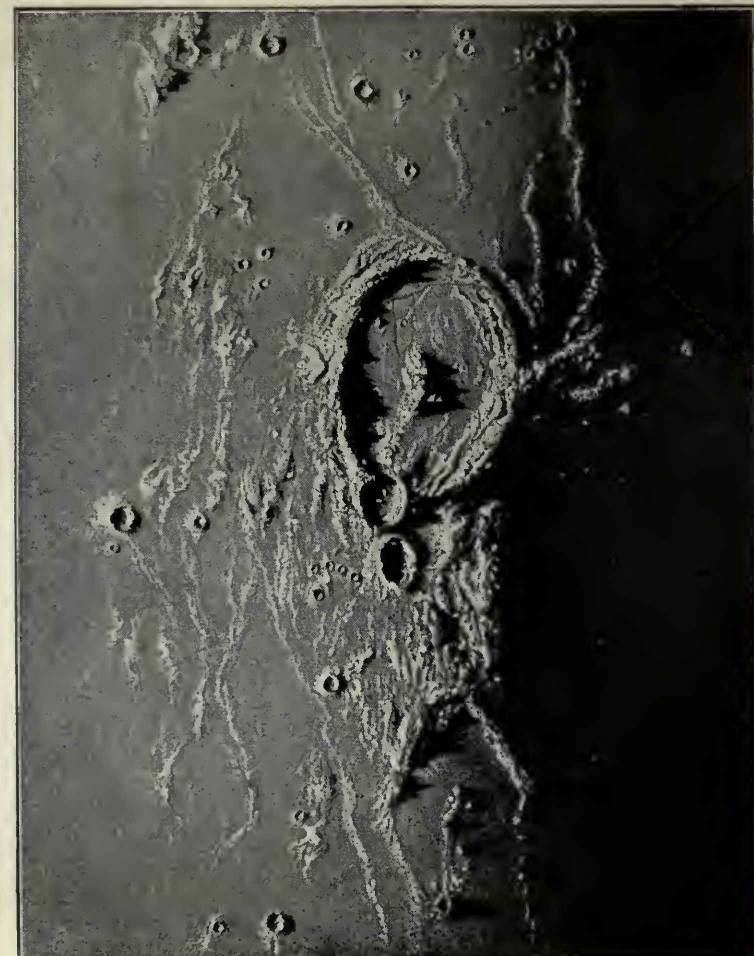


Fig. 175.—Mount Gassendi at Sunset.
(After a drawing.)

Fig. 176.—Artificial Moon Mountain, made by the Author by dashing a Stone into Mortar.

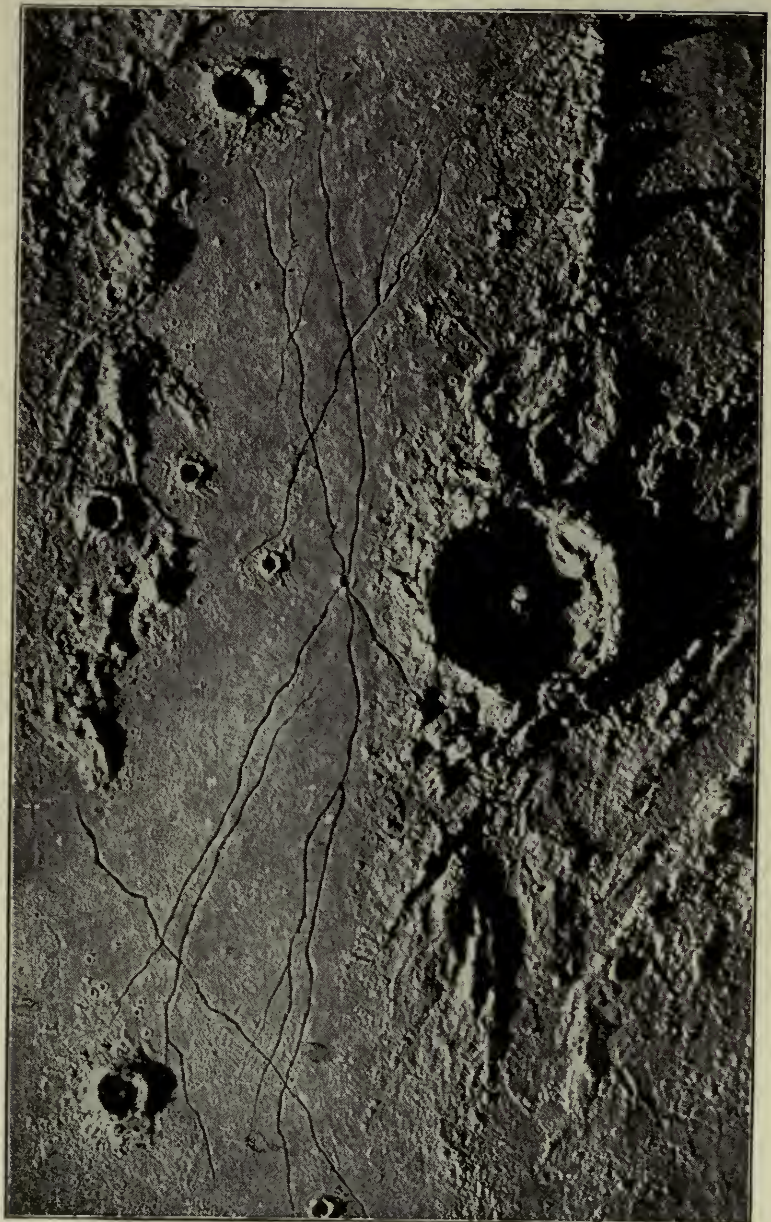


Fig. 177.—Cracks in the Surface of the Moon, near the Crater Triesnecker.

(From Nasmyth and Carpenter's "The Moon.")

spicuous. These rays are very noticeable in the case of the Tycho, Copernicus, and Kepler mountains. In our illustration (Fig. 171) one of these radiant mountains, Tycho, is very plainly visible; its rays extend over fully a third of the entire surface of the moon. The mountains emit so bright a light that they gleam out from the dark even when the moon is a narrow crescent, and the early astronomers believed them to be volcanoes in action.

Cracks.—Maybe they are tremendous clefts and cracks in the moon's surface that have been filled from beneath by glistening, glassy lava acting as a powerful reflector of light. Astronomers have listed a number of such cracks and ruts, looking like long, winding narrow lines, but reaching down for some distance. Cracks of this nature always arise when a stony crust begins to contract in the act of cooling, and every ball of clay or plaster of Paris will show similar features under similar conditions. These cracks are very noticeable in Fig. 177, near the Triesnecker crater. The interior of the Gassendi crater, that wonderful series of circular mountains near the light-border shown in Fig. 175, is filled with several such lines, and outside of it, too, a number of these cracks stretch out on all sides. I should like to call attention to the bright lines and dots rising out of the darkness on Gassendi's right; they are the summits of a chain of hills on which the sun is shining, whilst the valley is in utter darkness. Sunrise is in progress in this region.

An Effete World.—Crude black and white, glaring light and deepest darkness, are the tints on the moon; there are no half-tones, no grateful gradations from light to darkness, for the air which alone produces these shadings on earth is lacking on the moon. Neither water nor air, neither clouds nor wind, are encountered in this silent world. And where air and water, the two most important elements of life, are wanting, neither flora nor fauna can exist; no traces of vegetation have been discerned, and even if these had been quite insignificant, they would have been revealed to us by our gigantic telescopes. There is nothing to show that rational life once had its being on the moon. Although objects only a few hundred feet in diameter can be plainly seen, no discoveries have been made of buildings of any kind, neither collective nor single ruins of habitations. It has been argued that the former inhabitants may have had their homes in the large crater cavities, a supposition that is not impossible. It is, however, an utter impossibility for beings akin to man to exist on the moon to-day. As the daily aspect shows, the moon invariably turns the same side to us, and we see only its "countenance" with the spots. The moon does not possess a rotation in the same sense as the earth—it is almost as though it were connected to the earth by a solid axis. So far as the earth is concerned, it does not rotate on its axis. Matters would be different to a spectator stationed on the sun, for instance, who would be able to see all parts of the lunar globe within the course of a month. The moon rotates on its axis in the same period that it completes a revolution around the earth, so the solar day on the moon is equal to the time from full moon to full moon, 29 days and 12¾ hours. The sun beats down on every spot of the moon for a fortnight at a stretch, producing intense heat; the moon-night also lasts a fortnight, and with no sheltering atmosphere the surface freezes in the icy cold (Fig. 180).

Paradox and Perplexity.—Nevertheless, the moon should be most interesting to us. Its diameter, 2,159½ miles, is far smaller than the earth's (Fig. 155); the earth's surface is thirteen times larger than that of the moon, and it would take forty-nine moons to make a globe the size of our planet. The attraction of the moon on all objects is therefore far less than that of the earth; an article weighing twelve pounds here would only weigh two on the moon. One horse on the moon could do the work of six on earth, and the amount of muscular exertion necessary to jump over a chair on earth would carry the athlete a long distance on the moon. It would be impossible to light a fire on the moon, as there is neither air nor oxygen, and the moon may well be called the world of eternal silence. A cannon-ball might be let off next to us, and we should not even hear a sound, for the air which carries sound is lacking. The sun and stars do not beam and twinkle as on earth, where the air refracts and deflects their light. The sun stands on the black moon-sky as a circular ball of fire, and all the stars are visible even in broad

Fig. 178.—Early Stage of Lunar Volcano forming the Ring Wall.

(After Nasmyth and Carpenter.)

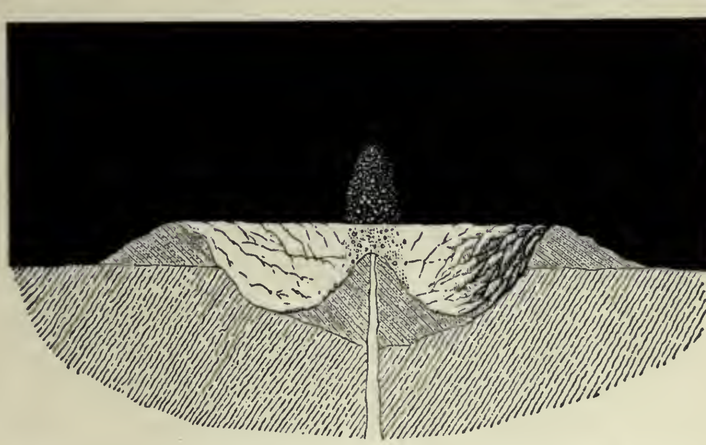


Fig. 179.—Later Stage of Lunar Volcano in Action, showing Formation of the Central Cone.

(After Nasmyth and Carpenter.)

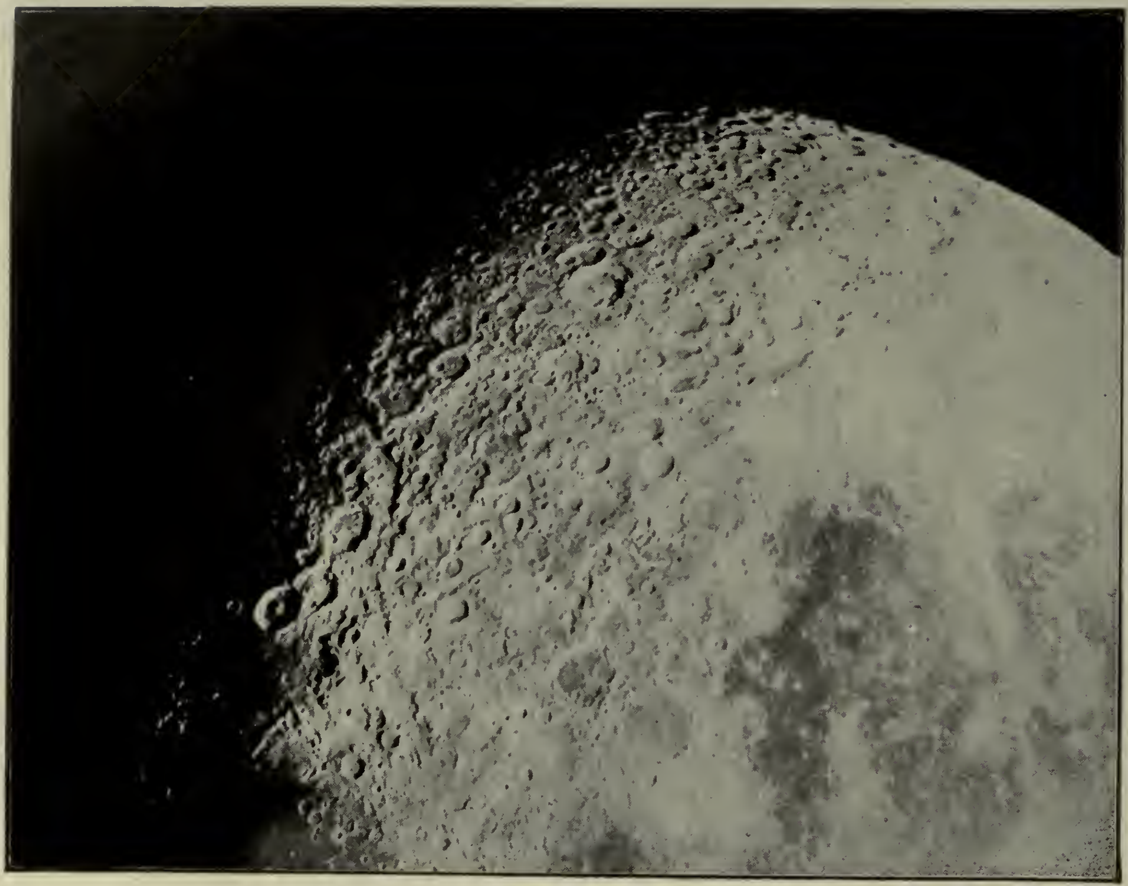


Fig. 180.—The South Pole of the Moon.
(After a photograph.)

Fig. 181.—Moon-Eclipse Ceremonies among the Peruvians.
(From Picart's "Cérémonies et Coutumes religieuses," 1723.)

daylight, close to the glaring sun, for there is no atmosphere to form a radiant veil (Fig. 156). The earth sends out a friendly mild light during the moon-night, and its comforting beam is even visible to us in the shape of a greyish light when our satellite appears in crescent shape (Fig. 157).

A Wandering Corpse.—The moon is a wandering corpse among the celestial bodies, and yet eminent lunar students, such as H. J. Klein, of Cologne, have been able to recognise alterations and changes in the appearance of various craters. The lunar globe is perhaps not entirely cooled off in its deepest recesses, and the pull and strain on its crust produce little deformities similar to those which the earth suffers by volcanic eruptions. The American astronomer, Pickering, declares that an inconsiderable amount of damp still lodges in the deep cavities of the circular mountains, ascending in mists when the sun rises and the districts in question rejoice in their lengthy morning. A delicate veil has been seen to pass over several craters, blurring their outlines until the mists are banished. But these discoveries have yet to be finally verified.

And What of the Earth?—No important changes or new formations which might be a clue to life in any shape have been brought to light. Wherever one may search this vast ruin of a world that possibly once may have borne pulsing life, there is never a trace of former work or higher intelligence, never the remains of structures bearing the impression of former civilisation to be found. There is no Pompeii on the moon! Was this world once the home of a culture developing on lines perfectly divergent from ours, or is it as a result of the gradual cessation of moisture that the last hundred thousand generations of a doomed world are able to live only in "subterranean" caves, homes and cities, their work being hidden from our prying eyes? Hundreds of questions crop up, countless ideas arise, and yet we know of no answer to them all, excepting that we could to-day see the work of human hands on earth very plainly if we were looking down from the moon. To-day! That is the crux of the question. What will have remained of all *our* work when, after a lapse of millions of years, the earth shall resemble the moon?

CHAPTER XVII

ECLIPSES AND PHASES OF THE MOON

Disaster to the Sun.—Once upon a time, according to an old Chinese chronicle, there lived at the Court of the Emperor Tshun-Khang two learned men named Hi and Ho, astronomers and astrologers, of whom we have already read (p. 75). They lived so well and merrily that they forgot the duties of their office and gave no heed to the course of the stars, bringing confusion into the reckoning of time. They even neglected to proclaim an eclipse of the sun, and the great event found the people entirely unprepared. Panic and terror reigned everywhere, as it was feared that the sun was blotted out for good. Even to-day vast numbers of Chinese firmly believe that at eclipse time a mighty dragon tries to swallow the sun. Notified of the forthcoming event by placards, the people rush into the streets and set up a terrific din with drums, whistles, trumpets, sticks and yells to scare away the monster and force it to yield up the victim it has devoured. The omission of Hi and Ho nearly cost the sun its life, and the anger of the Emperor may be better imagined than described. In true Chinese fashion, Hi and Ho had their heads, of which they had made so little use, laid in front of their feet, from which we may infer that the position of Imperial Astronomer was not exactly an enviable one. This interesting tale, which embodies the oldest mention of a solar eclipse, has been translated from the Chinese original contained in the "Tshu-king," one of the most ancient chronicles in existence, in which all the important occurrences of thousands of years have been recorded. The eclipse may have been the one of the early hours of October 22nd, 2137 B.C.

Superstitious Observances.—The idea that a terrible monster threatens the sun at a solar eclipse is spread among other races, and they also endeavour to frighten away the beast by uncanny noises. A representation of such a ceremony at a moon eclipse is shown in Fig. 181, where even poor dogs were thrashed to increase the din! It is easy to understand the state of fear and dread into which the ignorant people of ancient days and the uncivilised races of our own time are thrown by the sudden obscuration of the sun, the source of life and joy. All nature is affected by a total eclipse; the flowers close, the birds go to rest, and the animals in woods and fields seek refuge. The cattle in the meadows grow restless during the eclipse, and dogs set up long howls. In the eighteenth century solar eclipses were believed to have a baneful influence on terrestrial matters,

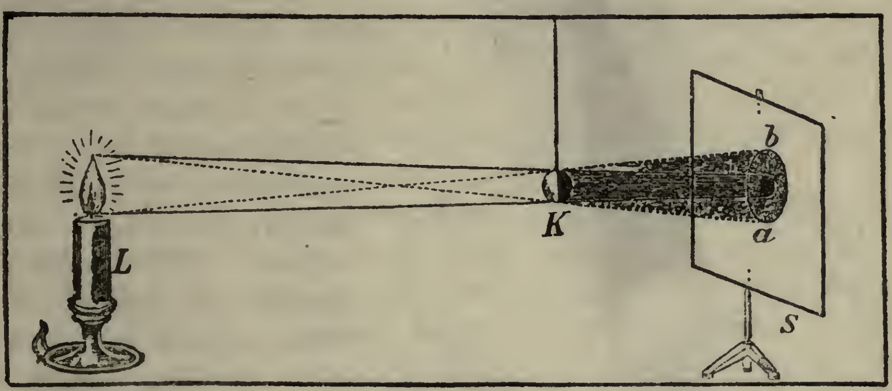


Fig. 182.—How the Shadow and Penumbra Arise.

and an English physician had all the wells in his district boarded up, to prevent them from being contaminated by the "poisonous mists" which, according to him, arose during an eclipse! So we need hardly sneer at the superstitions extant in China or India. There are some total eclipses where day turns into deepest night, and it is hardly possible to see farther than an arm's length; a pallid light, which seems to twine itself around the senses of man, at times casts a mysterious, almost ghastly, hue on everything around (Fig. 184). The remarkable corona mentioned in the chapter on the sun (p. 133) surrounds the dark lunar disc, obscuring the sun, and the stars stand out vividly in the day-time. As soon as the first sunbeam escapes the edge of the moon, the ghastliness vanishes, and we all breathe again.

Concerning Shadows.—We will now discuss the cause of sun and moon eclipses. Every dark body illuminated by a luminous one throws a shadow to its rear, and every non-luminous object must be obscured on entering this shadow. Earth and moon have no light of their own, receiving their light from the sun, and they both cast a shadow into space on the side turned away from the sun. When the moon enters the shadow of the earth an eclipse of the moon results; and when the earth enters the moon shadow it is obscured, as the moon then stands in front of the sun, thereby causing a solar eclipse. We all know a shadow to consist of a dark nucleus and a less dark border, which is called the penumbra. Fig. 182 shows how this arises: K (a ball), illuminated by L (a light), throws a shadow on the screen (S). A line, extended from the top of the flame to the bottom point of the ball, strikes the screen at *a*, and a line from the lowest part of the flame to the top of the ball strikes the screen at *b;* these form the penumbra (*a b*). Now draw a line from the top of the flame to that of the ball, and the bottom of the flame to the lowest point of the ball, and the core of the shadow, which is much darker and more sharply defined, will be found enclosed in these two lines,

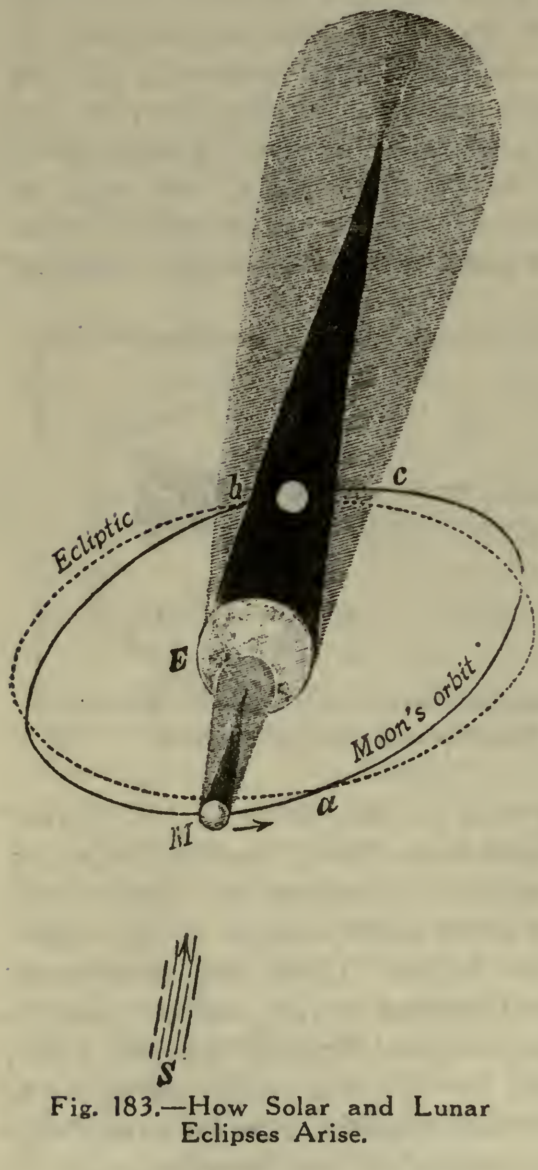


Fig. 183.—How Solar and Lunar Eclipses Arise.

resting in the interior of the penumbra. An eye in the shadow proper would see nothing of the light; in the penumbra it would see more the farther the eye was away from the nucleus, and outside of the shadow the light would remain totally undarkened.

How a Solar Eclipse is Caused.—At new moon the moon stands between the sun and the earth; generally, however, a little above or below the solar disc, which thereby escapes an eclipse. An eclipse only occurs when earth, moon and sun are in a straight line. If the orbits of the earth and moon were in the same plane, the moon, viewed from the earth, would have to pass in front of the sun at each new moon and cause its eclipse. The orbit of the moon, however, forms an angle of five degrees with that of the earth, the ecliptic, and only intersects the latter at two points, called the "nodes" of the moon's orbit. If our satellite is at or near a node at new moon, it will screen the sun, either partially or totally, from our view.

Fig. 183 shows the moon at M, quite close to node *a* of its orbit around E, the earth; the sun is far away at S. Illumined by the sun's rays, the moon casts a shadow to its rear, which is projected on to the earth, placed in the continuation of the line sun to moon. The dark cone of the actual shadow just grazes the southern hemisphere, where a total eclipse is witnessed, no part of the sun's disc being visible. As the cone-shadow only touches the earth with its extreme tip, and is very small, the eclipse is only total for an instant. The nucleus of the shadow is enclosed by a penumbra broadening the farther it is from the moon; at all places in its range a part of the sun can be seen, and therefore only a partial eclipse is experienced.

Length of the Moon's Shadow.—As the moon's orbit is somewhat elliptic, the earth not being in the centre, the distance of the moon from the earth varies, as follows:

Moon at greatest distance ...	252,000	miles.
Moon at average distance ...	238,876	,,
Moon nearest	225,760	,,

It also varies its distance from the sun, and the length of the shadow must, therefore, likewise vary. At its maximum its length is 238,000 miles; at the centre, 234,000; and minimum, 230,000 miles.

Various Kinds of Eclipse.—On comparing these figures, we soon realise that the moon-shadow cannot touch the earth when the moon is at the greatest distance. The cone either extends farther than the earth, or just touches it, or it does not reach the earth at all. When it extends farther, it is fairly broad where it touches the earth, and the eclipse would be a rather lengthy one, as the shadow can attain a breadth of 170 miles. If the shadow does not strike the earth, the moon appears smaller than the sun it is obscuring, and a glowing ring surrounds it on all sides. This is an annular, or ring, eclipse. An eclipse bears a very different aspect to observers in different parts of the globe, as it may be partial, total, or entirely invisible, according to where the observer stands. The rotation of the earth constantly brings other regions of the earth's surface within the passage of the eclipse, until the moon, crossing the solar disc from west to east, sets the latter at liberty once more (Fig. 185).

Duration of a Total Eclipse of the Sun.—A total eclipse of the sun can never last longer than 4 hours 38 minutes for the whole of the earth, and barely 8 minutes for any one spot on the equator. A solar eclipse not only permits science to verify the regularity of the movements of the earth and moon, but also gives rise to most interesting physical phenomena, which we discussed in Chapter XI.

Eclipse of the Moon.—The moon's action in obscuring the sun, and throwing millions of credulous human beings into a state of panic, does not pass without punishment. The earth revenges itself by blackening the moon's face and stealing the sunlight away from it. At full moon the moon is opposed to the sun, with the earth between them both. Should it then happen to be near its nodes, the shadow of the earth falls on it, and an eclipse of the moon is the result.

The eclipsed moon, in Fig. 183, is seen near node *b*, in the centre of the earth's shadow. Whereas a solar eclipse is seen under very different aspects by observers in different situations on the sunlit hemisphere (because the moon, being near to the earth, can be seen at different spots in the sky by

Fig. 184.—Total Eclipse of the Sun.

(After a drawing by M. Eiffler.)

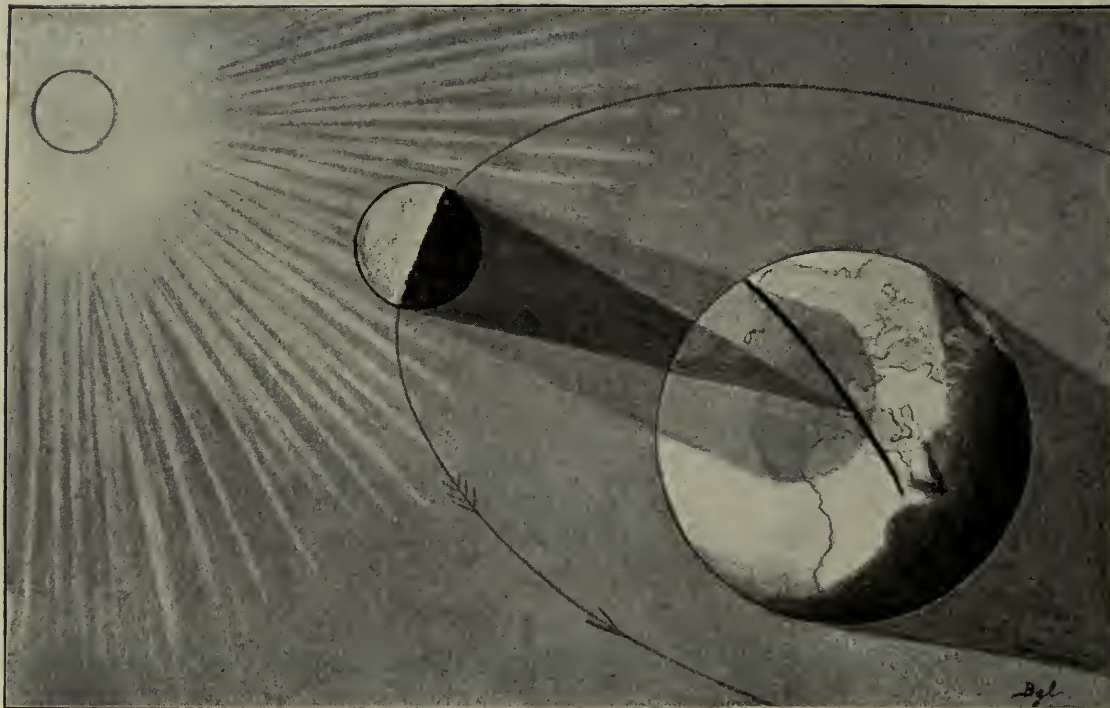


Fig. 185.—The Moon's Shadow on the Earth during a Total Eclipse of the Sun.

The black mark on the Earth points the way the shadow took.

(*From a reproduction by the Author.*)

Fig. 186.—Full-Moon Ceremonies among the Kaffirs.

(*From Picart's "Cérémonies et Coutumes religieuses," 1723.*)

observers stationed far away from each other), a moon eclipse always looks the same wherever the moon is visible at the time, as its surface is dark in itself. No other body stands in front of it, but the shadow of the terrestrial globe lies on the moon instead.

At *c* (Fig. 183) the moon enters the earth's penumbra, but the light diminution is so gradual that it needs instrumental aid to perceive it; the moon remains visible. As soon as it enters the actual shadow, a portion of its eastern edge immediately disappears. The earth's shadow being about 2⅔ times broader than the moon itself at its distance, a total eclipse easily occurs. It is as though a dark disc double the size of the moon passed over it, reducing the lunar surface to a crescent, and then entirely blotting it out. The darkened part of the moon is frequently noticed to emit a ruddy light; this coppery glow is caused by the refraction of the sun-rays that traverse the earth's atmosphere, and are bent into the shadow. After the moon has passed through the earth's shadow, it reappears on the east of it in crescent shape, and slowly grows into a disc once more. Should the moon only rise for any place on earth when about to leave the earth's shadow, the eclipse would only be a partial one there. Usually, a partial moon eclipse is understood to occur when the moon only partly enters the shadow, similar to a partial solar eclipse, which happens when the moon only covers a part of the sun's disc.

It frequently happens that a lunar eclipse takes place a fortnight after a solar one, or *vice versa*. This is explained by the fact that the moon needs a fortnight to travel from one node to another (*a* and *b* in Fig. 183).

Frequency of Eclipses.—Twenty-nine lunar eclipses occur in eighteen years, as against forty-two solar ones. To cause an eclipse of the sun, the moon does not need to be as close to its nodes as has to be the case with a lunar eclipse, which is, therefore, more uncommon. In spite of this, any one spot will experience more moon than sun eclipses, the proportion being three to one. At any selected spot two partial solar eclipses may be expected in a period of five years, and a total one about every three hundred years.

The Saros.—The nodes of the moon's orbit (*a* and *b*, Fig. 183) do not remain in the same position, but move back and constantly cross the earth's orbit at different points. The nodes complete a revolution in 18 years 219 days. There is a remarkable period called the Saros, somewhat less than this, consisting of 18 years 11 days, after which sun, moon, and node return to the same configuration; and eclipses are repeated under almost the same conditions, except that they occur 8 hours later in the day and the region of visibility moves 120 degrees westward on the earth's surface. This period was known to the ancients, who based their prediction of eclipses on this law. Of course, the announcements were not always exact, and many an eclipse must have found the star-gazers totally unprepared. So Hi and Ho were, perhaps, less guilty than it would appear, and if their Imperial master had known a little more about astronomy he would probably have acted less harshly!

Human Interest in Lunar Phases.—Sun and moon have been the centre of interest to people at all stages of the world's history, and barbarous races have always paid great attention to the variations of light presented by the moon, the diminution and growth of its disc. Everything possessed of motion and variety is apt to impress the human mind. The baby in the cradle, whose brain is just about to awaken, fixes its glance at the moving pendulum of a clock and clutches at things dangled in front of it. If the pendulum did not swing, the child would hardly notice it, nor would it grasp at a stationary article as eagerly as at a moving one. This, in some degree, is true of the adult as well. The circuit of the year, with its constant changes, never fails to interest us, and we eagerly await every phase of Nature's metamorphosis. A perpetual spring or winter would quickly deaden all interest. Perhaps this characteristic is of greater importance for our life and its institutions than we may believe; perhaps it is one of the secret levers that set so many social and political events in motion.

Kaffirs and Bushmen celebrate the new and full moon with peculiar ceremonies and important tribal assemblies (Fig. 186). With us it is the farmer who takes special in-interest in the different phases of the moon; but even people who do not direct too much attention to the heavens allow the varying contours of the moon to distract them for a few moments, at least. Whether they know the cause of these alterations is another matter. Even educated people have avowed the moon's phases to be due to the earth's keeping off of the sunlight from the moon; they believed that at the time the moon appears as a crescent or half-moon, the shadow of the earth covers up the other part! This would really result in an eclipse, as we have just learnt.

Let us furbish up our discarded school-knowledge and, firstly, consider the motions of sun, earth, and moon. Although the sun, the centre of our planetary system, possesses a proper motion as, accompanied by all its satellites, it travels towards the constellation Lyra at a rate of about 15 miles per second, we may imagine it to be at rest, as its motion is not perceptible in relation to the bodies encircling it. Our earth revolves around this fiery orb, in a somewhat elliptic path, at a mean distance of 92,800,000 miles, completing a circuit in 365 days 5 hours 19 minutes, accompanied by a trusty vassal, the moon, which completes a revolution in 27 days 7 hours $43^1/_5$ minutes, at a mean distance of 240,000 miles from the earth.

The Moon's Orbit.—It is not difficult to describe the earth's orbit, as it is an ellipse of very slight eccentricity; in considering the moon's orbit we may either refer to her path round the earth or that round the sun. The former is nearly an ellipse; the latter is an undulating curve moving from side to side of the earth's orbit. This is immediately realised on remembering that the earth, the central point of the moon's orbit, does not stand at rest, but itself tears through space. A dog running round and round his master does not actually complete a circle if his master moves on straight ahead. What is the moon's orbit really like? Its motion seemingly consists of its revolution around the earth, and their common course around the sun. If we remember that the earth journeys about 46,500,000 miles a month, that the moon not only has to keep up with the earth, but has to revolve around it as well in the same time, this being a distance of 1,500,000 miles, or about thirty-one times less than the earth's motion, we shall soon comprehend that the moon's whole motion is compounded of the two, and must therefore be an undulating line. A portion of this complicated course is shown in Fig. 187. The curve E E′ represents the path the earth takes in a month; the earth is seen at five points, accompanied by the smaller lunar globe, whose distance from the earth is correctly proportioned. At E the moon stands to the right of the earth, in the continuation of its orbit; a week later the earth is at F, the moon having described a curve of 90° around the earth's centre in this period, the dotted line E F denoting the real path taken by the moon. At the lapse of a fortnight our planet stands at G. The moon, which by now has half encircled the earth, enters that phase of its orbit lying between earth and sun, the latter being in the direction marked by the

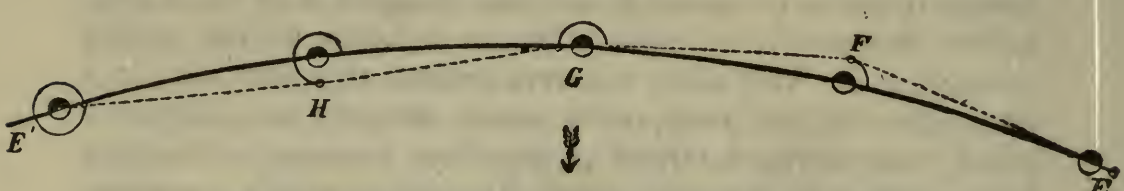


Fig. 187.—The Undulating Line of the Moon's Orbit.

arrow. At H the moon has completed three parts of its revolution, finishing at E′, where it again stands on the right of the earth, ready to begin all over again. The dotted line plainly shows the sinuous course of the moon.

How the Moon's Phases Arise.—We know earth and moon to be dark bodies, which would subside into utter darkness if a mighty hand were to reach up and extinguish the sun's flaming light. The mild glow with which the moon illuminates the dusky night is not at all its own, and it flaunts itself in foreign plumes, for this light is borrowed from the sun; and, in turn, the moon lends a part of its own borrowings to the earth. Of course, the illumination and appearance of any body alter if it, or its source of light, moves—a condition of affairs daily noticeable in the variation of phases or "lunation" of the moon.

We will study these phases by the help of a diagram. The moon being a globe illuminated from one side, one hemisphere has to remain in darkness whilst the other is lit up. Now, owing to the moon's motion, as we are not always exactly opposite the illuminated hemisphere (this is only the case at full moon), we do not always see the moon as an entirely illuminated disc. The moon (Fig. 188), A B C D E F, wanders around T, the earth, in the direction of the arrow, and the sun sends its beams from S on to those parts

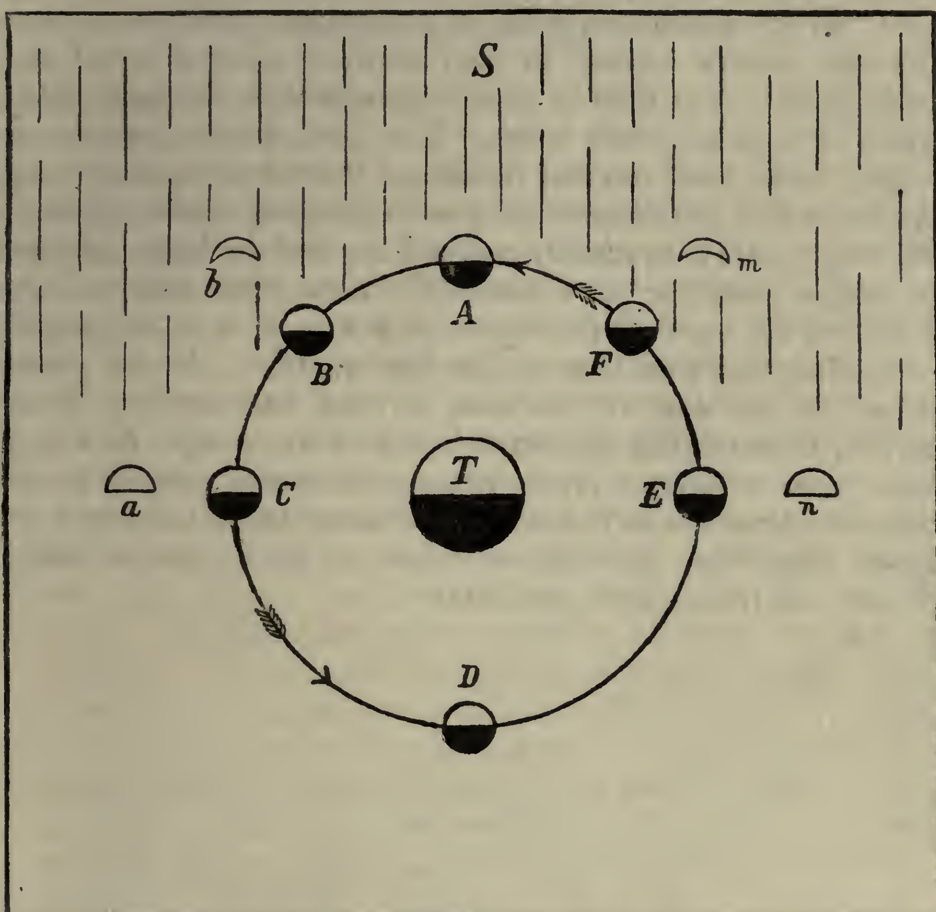


Fig. 188.—How the Phases of the Moon Arise.

of the earth and moon turned towards it. The moon is between the earth and sun, at A, and turns its dark side to the earth; at such times it is invisible, and we have new moon. Our satellite rises and sets with the sun, as both, seen from here, stand close to each other in the sky; the moon is then said to be in conjunction with the sun.

The moon then wanders on, reappearing to the left, or east, of the sun as a narrow crescent. We see a part of its illuminated sphere when at B, its shape then being that of *b* (the open part of the crescent is always turned away from the sun). When at C, half of each hemisphere is turned towards us, and we therefore see the semi-circle which we call the first quarter. The moon now rises and sets six hours after the sun, being 90° farther east and in "quadrature" to it. From this point it recedes more and more from the sun, slowly waxing in size, until, at D, it is a full disc once more. It is then in exact opposition to the sun, rising when it sets, and *vice versa*. The dark side is completely turned away from us; but full-moon time does not last long. At the end of two days we may see it growing visibly thinner; the bright side is gradually covered up, and the light vanishes in stages from the part constantly turned towards us. At E we can but see half the moon, as *n* shows; it is once again in quadrature, this time in its last quarter. As the moon is 90° to the west of the sun, it rises and sets six hours earlier, illuminating the small hours of morning. At F it is once more a narrow crescent (*m*), the horns turned in the opposite direction to those of the waxing moon; and at A we again experience new moon, when no trace can be found of our old friend and comforter.

CHAPTER XVIII

THE PLANET MARS—A SECOND EARTH

The End of a World.—A drop of water taken from the pond at the back of the house lies on the slide in the microscope. An immense activity is being displayed in this aqueous world; its inhabitants rush about wildly from north to south, never pausing for an instant. They are almost ridiculously minute and of wondrous shape; some look exactly like tiny outriggers, others are of a quaint wheel-shape, and the measuring apparatus attached to my microscope informs me that the largest among them is not even the twentieth part of a millimetre in length! There is quite an important island in one part of this world—a plant fibre, hardly recognisable to the eye—and the majority of the little folk seem to have made it their home. I wonder whether class distinctions are known here, too? At any rate, the "boats" hardly seem very cordially inclined towards the "wheels." I rear giant-like above this tiny world. If my finger were to pass over the plate, there would be an end to all the life and activity going on. If the infusoria in my drop of water are able to reason, they would certainly regard it as their universe, with endless voids across its borders, and they alone the masters of their world. Suddenly a disastrous alteration sets in. The water has begun to evaporate in the warm air of the room; the world is growing too small for its population, rushing madly towards the centre in a despairing attempt to save themselves from destruction. In another second all has vanished. The glass is dry on which a watery world existed an instant ago. A grey speck of dust alone remains on the slide. The end of a world!

Such it was for its inhabitants. We may smile at the interesting spectacle it offered, and yet many an object-lesson may be learnt from it. If our earth to-day were to crumble into dust, the astronomers on Sirius, or any other star (let us assume such learned men to exist to point our case), would never become aware of the catastrophe, for, as we have seen, the earth is invisible at those vast distances. We are still very much in the dark as to the real position of the earth in the universe, and the old theory that the earth is the "heart" of the universe crops up periodically. We can only compare such theorisers to the old Mother Duck in Andersen's fairy tale, who gravely explained to her ducklings that the world did not come to an end at the edge of the basket, but reached to behind the miller's garden.

Our instruments to-day show us 500,000,000 stars in the depths of space—500,000,000 suns similar to the one around which the earth revolves. A rough estimate sets the farthest at about 5,000 years of light away, and as light travels from the sun to us in 8¼ minutes, and needs 5,000 years, at an equal rate of speed, to fly through these immeasurable voids, we can faintly conceive the overpowering grandeur of the universe.

Earth Not the Only Peopled Star.—A "centralisation" craze of another kind has seized numbers of educated people. "Even though the earth be not the centre of the universe," they say, "it is, at any rate, the only spot in the universe peopled with intelligent, ay, even with living, beings." Refuge is even taken in the Book of Books to enforce this statement, and quotations, either wrongly understood or wrongly applied, are brought forth in its support. Nay, it is held to be un-Christian and blasphemous to imagine life to be existent elsewhere but on our planet, as though the Creator's omnipotence did not increase with the number of His inhabited worlds!

Life on Other Stars.—The question of the habitability or inhabitedness of the celestial bodies does not so much belong to the astronomical as to the philosophical branch of science, but astronomers are usually expected to tender an opinion. Everybody who pays some attention to the teachings of the universe and the deductions modern natural science has arrived at, will combat the idea that, of all the countless millions of astral bodies, the earth, an inferior satellite of the sun, alone has been chosen to fulfil all the necessary conditions of life. It is not only possible, but decidedly probable, that there are many other inhabited globes besides ours. Then comes a question of a totally different complexion: Have investigations yielded any proof that any other celestial body is inhabited; and have they shown conditions for the development of rational life upon it? This aspect of the matter appeals solely to astronomers, for the astronomer, or astrophysicist, alone can reach the conclusions necessary to a reasoned reply.

Life possesses forms innumerable: beings exist in air, water, and earth, in the icy polar regions, as well as the scorching desert sands, or even in boiling springs and pools. Some flourish in brightest sunshine, others shun all light. Human beings can stand a terrific amount of heat or cold, and explorers who have faced − 40° F. on a polar journey may, a few months later, expose themselves with immunity to 104° on a tropical expedition. A physiologist or zoologist could cite much more striking instances of life retained in beings of the highest standard of intelligence amid most extreme conditions. It would therefore be unscientific, not to say foolhardy, to say that no life could exist at a certain spot, because it is either too warm or too cold, too light or too dark, or has too thick or too thin an atmosphere. Nature has a thousand ways and means of moulding organic life according to external conditions.

Distance and Size of Mars.—Has science definitely named a world similarly inhabited to ours? The answer is in the negative, although we are about to talk of a star which, in the opinion of those who know it best, really is an inhabited world. There are times when a star of a bright red hue becomes noticeable, whose steady and tranquil light marks it as a planet. This is Mars, which is situated 46,500,000 miles farther from the sun than we are, or 140,000,000 miles in all, needing 686 days for one revolution around the sun, almost as long again as that of the earth.

Mars is a dark sphere dependent on the sun for light and warmth, and is considerably smaller than the earth (Fig. 189). Its diameter measures 4,191 miles, and it would take seven such globes to make one of ours. The size or, rather, mass, of a celestial body determines its power of gravitation, and as the mass of Mars is ten times less than that of the earth, all things on Mars must be proportionately lighter. If we were ever able to reach Mars we should find ourselves moving about with elfin gracefulness!

Mars Day.—An observer on the moon, looking at the earth, would perceive the terrestrial oceans and continents, in the guise of dark and light spots, apparently pass across the globe (owing to the earth's axial rotation) and return to their former positions within a period of 24¾ hours. This would give him a clue to the length of time needed by the earth to turn on its axis, which he would find to be 23 hours 56 minutes, after allowing for the moon's motion. On similar grounds observations of Mars have determined its rotation period to be 24 hours 37 minutes, so a Mars day is a trifle longer than a terrestrial one.

Best Time for Observation.—The relative position of the earth and Mars orbits permits Mars at times to approach within 35,000,000 miles of us; a cannon-ball would traverse this distance in four years. At other times 248,500,000 miles divide us—a twenty-nine-years' journey for the shot. Let us turn back to Fig. 119, where A is the earth, which, when Mars is at B, is at its nearest to us; when at C farthest away. Obviously, the nearer a celestial body is, the larger it appears, and the better it can be examined, so the astronomer has to wait for its approach to study it with success. The best time for observing Mars is when it is opposite to the sun, as it is then visible all night long. These "Mars Oppositions" are eagerly seized upon by astronomers of all nations, anxious for the opportunity of a closer investigation of this puzzling planet.

The Two Moons of Mars.—Two extremely minute satellites, discovered in 1877 by Professor Asaph Hall of Washington, accompany Mars. These, Phobos and Deimos by name, might have remained undetected if Mrs. Hall (p. 29) had not egged on her husband, who was weary of his fruitless search, to another attempt, which, happily, was crowned by success. And a couple of most interesting satellites they are, too. Phobos may be as much as thirty miles in diameter, and Deimos twelve; and a good pedestrian could walk around the latter in four or five hours, whilst

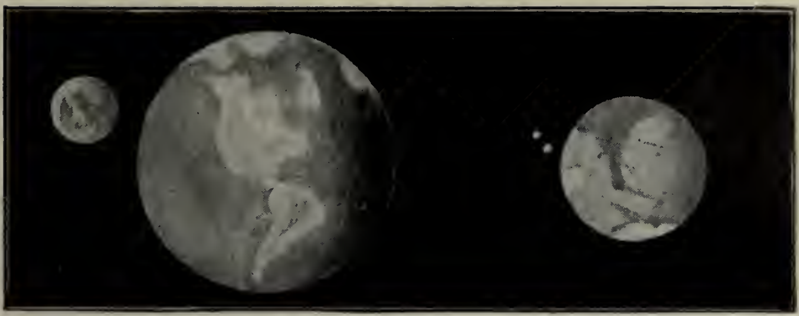


Fig. 189.—Sizes of the Moon, Earth and Mars Compared.
The Earth and Moon on the left, Mars and its two moons on the right.

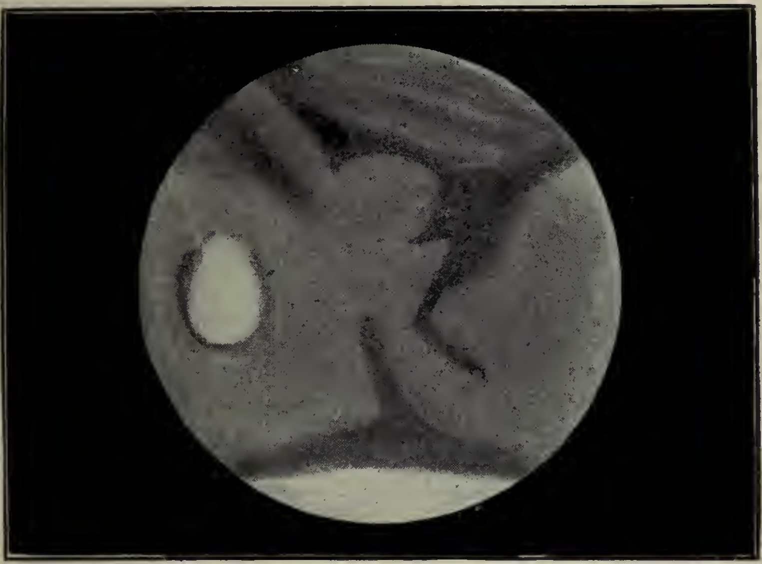


Fig. 190.—Mars.
(*From an observation by the Author on January 29th, 1899.*)

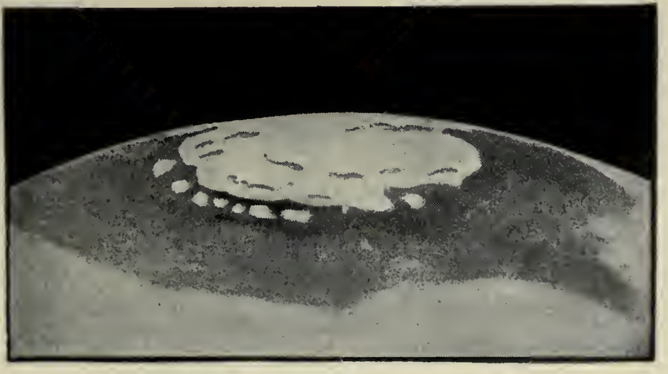


Fig. 191.—The South Pole of Mars in 1877.
(*After Green.*)

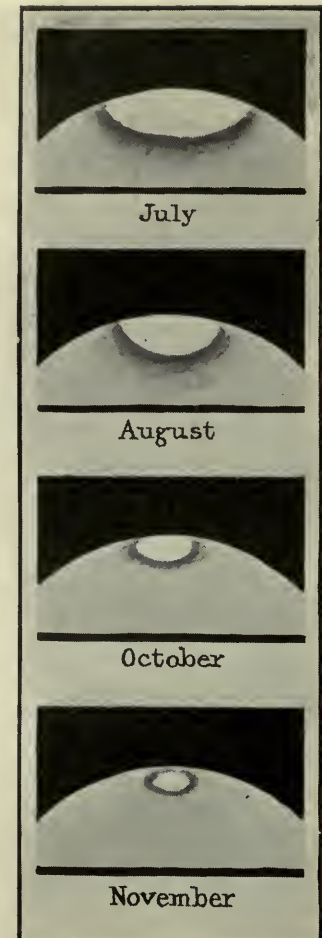


Fig. 192.—Alterations in the White Cap at the Mars South Pole in the Months of July to November, 1900.

(From observations by Flammarion.

Fig. 193.—Giovanni V. Schiaparelli.

a train would only take twenty minutes from the North to the South Pole. They are a wonderful testimony to the high degree of perfection to which the optician's art has attained.

One of these moons, Phobos, is only 3,700 miles from the surface of Mars, about the distance from London to New York, and it revolves so quickly around its planet that it rises and sets several times during the course of a Martian day for one and the same spot on Mars. Nevertheless, the Mars cities, if such there be, will hardly be able to economise their lighting bills on bright moon-lit nights (as ours delight in doing on earth) as the satellites will look smaller and less bright than our moon.

Mars's Polar Caps.—Searching Mars at a favourable time, greeny-grey patches are noticed standing out prominently on the ruddy disc. These are solid, unalterable structures always to be found in the same position—continents, oceans, and similar objects, as the engravings show—only it must be remembered that they are far more marked in the drawings than in even the best of telescopes. A very striking feature are the dead-white patches at each of the poles, called "caps." That at the South Pole is shown in Figs. 191, 192 and 199; that of the North in Fig. 190. (The astronomical telescope reverses all objects; the North Pole is to be seen at the bottom of the photograph, and the South Pole is at the top.)

Ice and Snow.—Mars turns its hemispheres alternately to the sun, like our earth, and it also rejoices in a change of seasons, which, however, last about as long again as ours do. When either pole is in its winter season, the cap is turned away from both sun and earth, and we see very little of it. The caps are chiefly visible in the spring and autumn seasons. In the spring a dark border surrounds the cap, growing larger and larger, and the white patch begins to dwindle in like proportion. On the other hemisphere, where autumn reigns, the patch has been seen to extend as the cold developed. Flammarion watched the South Pole cap dwindle during the months of July, August, September, October, and November, 1900, when summer came to that Mars hemisphere; the alteration is vividly illustrated in Fig. 192. What are these white caps, and what do they portend?

Careful research during a series of years has determined them to be great masses of ice and snow, water turned to crystal by the cold. Their colour, dependency on the seasons, appearance at the poles, and the very fact that they leave a dark border in melting, permit of no other explanation. Green had an excellent view of the melting of the South Pole cap in 1877, and he made the drawing reproduced in Fig. 191. Pickering, armed with a polariscope—an instrument registering certain changes of reflected sunlight—was able to declare, on the strength of observations at Arequipa, in Peru, that this dark border consists of water; whilst Barnard, of the Lick Observatory, and Lowell have frequently seen bright spots of light appear and vanish with lightning-like rapidity in the snowcaps, most probably arising from the reflection of the sun's light from great blocks of ice. The entire cap has been known to melt. Even the hottest of summers on earth cannot produce a like result at the terrestrial poles, where the tremendous masses of ice stand any amount of warmth with equanimity. As Mars is more remote from the sun, and favoured with far less heat than the earth is, the solution of this problem is beset with difficulties. Stoney, of Dublin, conceives it to be carbonic acid snow, which dissolves at an inferior degree of heat, but this theory is not very plausible.

White streaks and spots are sometimes seen in other parts of Mars as well. On January 30th, 1899, the writer observed the landscape called Elysium to be covered with white during the lapse of a few hours (Fig. 190, left edge), whilst it had previously been of a yellowish-ruddy tint. It would, however, be difficult to say whether this was a snow-fall.

The Atmosphere of Mars.—Mars undoubtedly has an atmosphere, as spectro-analytical examinations have proved, but it is considerably rarer than that of the earth, and a visit to Mars would probably find us in a somewhat short-winded condition. At spring-time, when the great snow masses begin to melt, clouds and atmospheric indistinctnesses are not an uncommon sight on Mars. Such evaporations are only the natural outcome of the great masses of water released about this time.

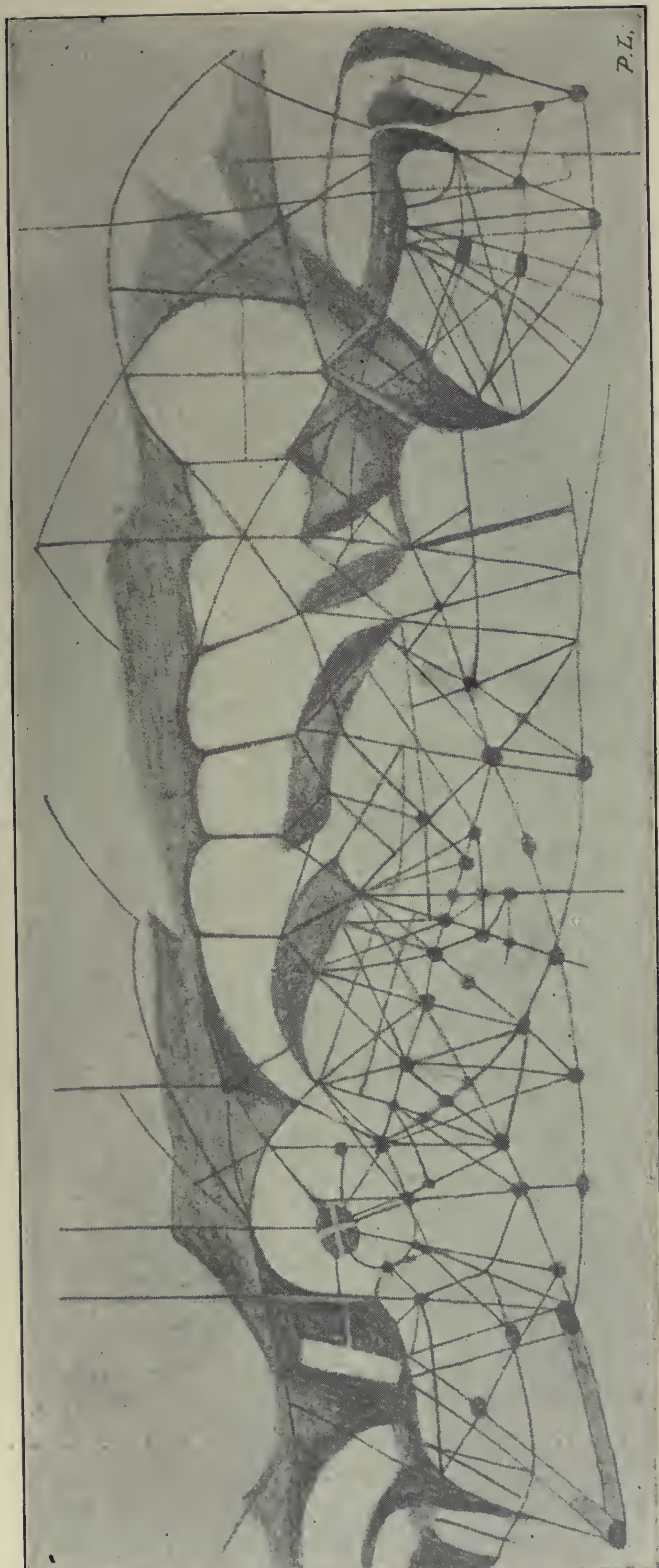


Fig. 194.—Map of Mars.

(Drawn by Percival Lowell.)

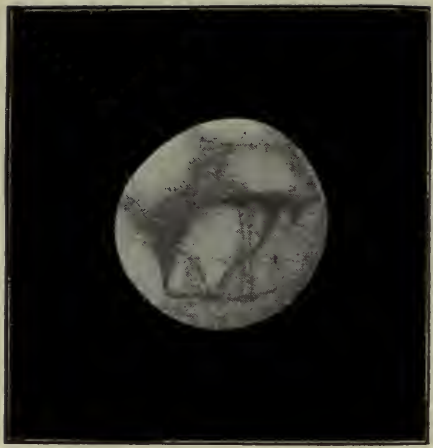


Fig. 195.—Mars.

(From a photograph by Lowell.)

On the original negative the planet's disc is only six millimetres in size.

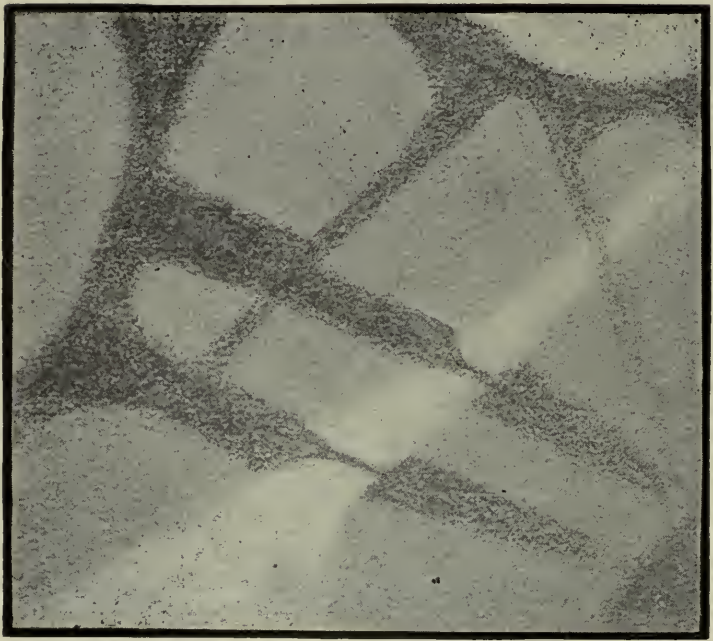


Fig. 196.—Mars Canals covered by a White Streak.

(From an observation by Schiaparelli.)

The Canals of Mars.—The most mysterious of all the Mars phenomena, however, is that delicate network of narrow, regular lines, first discovered by the Milan astronomer, Giovanni Schiaparelli* (Fig. 193), in 1877, and confirmed by the conscientious observations of Lowell, Douglas, Brenner, Pickering, Trouvelot, Antoniadi, Flammarion, and others. Hundreds of lines, apparently running along great circles, extend over the surface for several thousands of miles, meeting and intersecting at certain angles, and connecting the dark patches we take to be seas with each other. These lines are called "canals," and stand out boldly in Figs. 194 and 199. The former is a map of Mars, designed by the American astronomer Percival Lowell, the most eminent authority on Mars (Fig. 195). Fig. 194 is of astonishing richness in detail, disclosing a globe, with countries and oceans,† islands, seas, and "canals"; a world possessing day and night, clouds and Arctic regions; a world which furnishes eloquent proofs in support of the theory that an intelligent race may make its home amidst its wondrous network of canals. Nature by herself could not have brought forth this gigantic filament of lines. Look at the map of Mars—by the by, all Mars charts embody the same characteristics—and you will find a circular island, with a round sea in its centre. Straight lines, drawn at a certain angle, connect this lake with others and with the sea; another isle, at the top on the right, is cut up into an exact cross by these canals. At another point six or seven canals meet in star-fashion, with a dark, circular spot in the centre; farther on we discern an absolutely square island, cut into two equal triangles by a canal running from one corner to another. These markings were at first taken to be more or less of the nature of optical illusions, but their existence has been established by photography.

* Born at Piedmont in 1835; died at Milan in July, 1910.

† The majority of astronomers have abandoned the idea that the large dusky regions are oceans. They are generally considered to be regions covered with some form of vegetation, while the ruddy regions are sandy deserts. It is also by no means agreed that the canals are artificial. Their apparent regularity may be largely an optical illusion.

Theory as to the Use of the Canals.—Are these lines really canals filled with water and dug by human hands? Judging by all we know of Mars, water is rare there. Larger cloud formations are uncommon in its atmosphere, and the extensive coppery patches appear to be deserts where rain seldom falls. When the ice begins to melt, and the great water masses at the poles are released, plenty of the wet element, so necessary for vegetation and life in all shapes, is available. Tremendous floods would result, and the water turn to a curse instead of a blessing, if it were not by some means guided into safe channels. The same elementary laws are met with throughout the universe; the distant stars move according to the same laws as do the members of our solar system. The spectroscope has found the same substances in their light as we possess on earth; meteorites falling to earth contain minerals known to us, and we therefore hardly overstep the limits of possibility in claiming that the same laws govern the course of things on Mars as on earth. Under like conditions we, too, would throw back the onrushing water by great dams and irrigate arid areas by means of canals.

Vegetation Streaks.—The width of the Mars canals is stupendous, often attaining to seventy and more miles. It must have needed a race of giants to carry out this Titanic work. Observations on the part of Lowell and Douglas at the Flagstaff Observatory, Arizona, which chiefly deals with Mars investigations, seem to solve the mystery. They set forth the theory that the dark streaks are not the canals themselves, but the vegetation on their banks.

If Mars were inhabited, the Martians, armed with telescopes of an equal power to ours, would not be able to see the Nile. When, however, after an inundation of the Nile, each bank would be covered with vegetation for a considerable distance inland, this would indirectly aid them to trace the course of the river. The Arizona observers explain the Mars canal phenomenon in a like manner. This explanation is not far-fetched, and receives considerable support from an observation of Schiaparelli's. He once witnessed a white streak settling on a district intersected by canals (Fig. 196); it appeared to be an extensive fall of

Fig. 197.—Seasonable Changes observed in One and the Same District of Mars by E. E. Barnard with the Giant Telescope of the Lick Observatory.

Fig. 198.—The "Signal of the Martians" at the Edge of the Disc of Mars.

Fig. 199.—Mars showing the Parallel Canals.
(After an observation by G. V. Schiaparelli.)

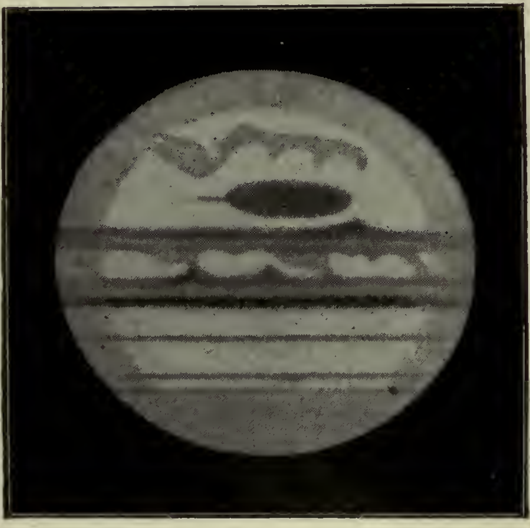


Fig. 200.—Jupiter with the Red Spot.
(After an observation by Lohse at Potsdam, on August 31, 1880.)

snow, and at the spots where the streak covered the "canals" they had grown quite narrow. According to the hypothesis just expounded, the parts not covered by the snow must have been the canals proper themselves, filled with water that dissolved the snow and made it invisible, whilst the vegetation on each side was naturally covered up, taking on a white hue. Lowell also determined that the canals are most conspicuous at the time the snow melts—that is, in spring or summer, which is a further proof in his favour; in autumn and winter they apparently fade away. The aspect of the Mars landscape undergoes a continuous change in accordance with the seasons (Fig. 197).

Oceans, Deserts, and Cultivated Land. — Large regions on Mars, formerly supposed to be oceans, are now known to change in colour with the progress of the seasons, being green in summer, and yellowish towards autumn. Observations have shown the canals to extend through certain of these dark stretches, which cannot possibly be oceans, but, as some investigators pronounced formerly, extensive areas covered with vegetation. Only two or three very dark patches are probably oceans, and most original methods have been resorted to definitely to determine this. The sun would be reflected in the Mars waters, and this reflection would be noticeable on earth in the shape of a tiny luminous dot in the telescope. If M (Fig. 201) were Mars, and the dark spot an ocean, then S, the sun, must mirror itself in the water, which would throw the rays back at a like angle to E, the earth. Such a reflection could only be seen in an ocean near the centre of the disc.

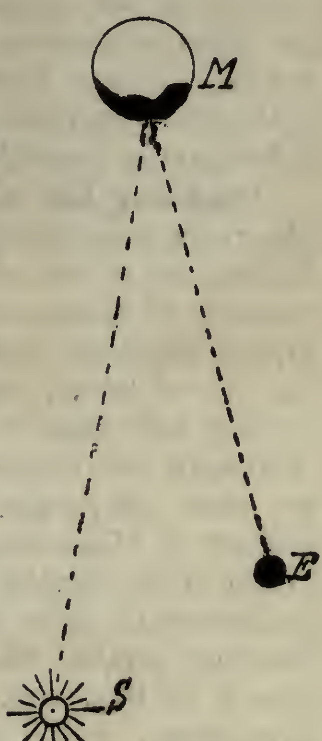


Fig. 201.—Reflection of the Sun in the Oceans of Mars.

"Messages" from Mars.—The patches of light which appeared at the edge of the Mars globe a few years ago, and caused such a sensation, were of a totally different nature. Some fantastically-minded person had given out that these lights were great signal-fires lit by the Martians to inform the earth inhabitants of their existence, and the newspapers throughout the world, especially those of France and America, declared it incumbent on the civilised races on earth immediately to reply to the signal. This spot of light is shown on a somewhat enlarged scale in Fig. 198. Nobody seemed to grasp that a whole huge forest would have to be set on fire to show as a sparkling dot of light in the Mars telescopes, and that the so-called "signal" could not have arisen from such a cause. We can only believe that the mysterious light was produced by very powerful reflections of sunlight on mountain tops or in the clouds.

Doubling the Canals.—Some of the best-known Mars observers are, however, of opinion that the planet is inhabited by a race of beings of whose existence the gigantic network of canals extending all over the sphere is a proof. Direct signs of their existence, such as signals, could, as far as we know, not be perceived on earth, unless those beings had mastery over natural forces unknown to us. Although we incline to the view that Mars *is* inhabited, we must not forget that many of the appearances on the surface of Mars are really inexplicable, such as the duplication of the canals Schiaparelli discovered in 1888. Canals thousands of miles in length suddenly split into two parts, running parallel like a railway track. Some of these are shown in Fig. 199. This phenomenon is counter to our hypotheses, which careful study alone can enable us to elucidate.

Astronomers on the Existence of Martians.—The extraordinary interest taken in the investigations of Mars by the general public was testified to when a sum of 100,000 francs was presented by a Parisian lady to the Academy of Science for communication with the Martians. Although the donor rather underrated the difficulties of interplanetary intercourse, her gift showed that folk were at last beginning to doubt the antiquated notion that the earth is the centre and *raison d'être* of the universe. Some of the greatest astronomers of modern times have issued positive pronouncements on the habitability of Mars. Schiaparelli asserts that the planet "is no desert of barren rock; it is alive! The statement that people exist on Mars may sound fantastic to some, but it is probably far less so than many another bold proclamation sent forth under the cover of science and debated at the universities." Lowell says that Mars "is most decidedly inhabited by a race of intelligent beings. This may meet with opposition from other astronomers whose observatories, not being so well placed, did not allow them to see all I have been able to recognise on the planet, but the future will bear out my statements." "We are forced to assume," remarks H. J. Klein, of Cologne, one of the most eminent German astronomers, "that Mars possesses a most highly civilised people, and that their culture is of older date than ours"; and Camille Flammarion voices the opinion: "To me no doubt exists that this planet is inhabited."

CHAPTER XIX

JUPITER AND SATURN, THE GIANTS OF THE SOLAR REALMS

When the Evening Shades Prevail.—Our conning-tower affords us an extensive view of the evening world below; the noise of day dies in the twilight, and tranquillity reigns with the departure of the sun. The presence of a large city in the distance is marked by a veil of vapour, through which a glimmer of light penetrates from a milky way formed by millions of electric suns.

No sound reaches us save that of a cart jogging along the road leading through the wood. Presently a dog begins to bark at the noise; but his angry yelping is finally drowned in the distance. We gaze down enthralled. A glowing, ruddy ball, shrouded in pale violet, arises phantom-like over the patch of willows; it is the moon. The silhouettes cast by the branches are still visible on the fiery disc as it ascends ever higher, throwing a pallid light into the darkness. A genial smile passes over it, as though the old, old moon were chuckling at the folly it has witnessed on our planet throughout all the grey ages.

Rising higher and higher above the misty horizon, the moon grows in radiance; its light brightens and clarifies until it falls to earth in a pure white trail, dancing in the pond and transforming the dusty road, winding in and out among the poplars, into a silvery band. The higher it ascends the more the stars, whose shepherd it is, fade; the smallest vanish first, then those of medium size, and the sky grows emptier and emptier, until the very brightest alone are left, the crown diamonds in the tiara of the heavens. Looking upwards from our tower, two stars fascinate us by their brilliancy, undimmed even by the radiance of the moon. They shine out steadily and peacefully, not flickering like the fixed stars around, which suffices to tell us that they are planets. They are almost opposite to the spot which the sun occupies below the horizon, and therefore are not to be enumerated among those planets always assembling close to the sun. They can be neither Venus nor Mercury, nor is Mars one of them, as their white light shows. We are here confronted by Jupiter and Saturn, the two largest planets of the solar system, travelling, at an inconceivable distance, around the sun on the other side of Mars. Jupiter is five times farther from the sun than our earth is, and Saturn almost ten times farther.

Jupiter, the Giant of the Planets.—Jupiter, the fifth planet, and largest of all the solar offspring (Figs. 118, 119), is 448,000,000 miles away from our central luminary, a distance it would take a cannon-ball about fifty years to traverse, while an express train, that travelled from the earth to the moon in six months, would be 950 years on the road from the sun to Jupiter. The planet is, at times, even still farther from the earth, attaining a distance of 536,500,000 miles; but it can also approach to within 365,000,000 miles of us, and then, at its highest radiance, is generally visible all night long, quite the contrary to Venus, which, although brighter in itself, is only seen at daybreak and dusk. Jupiter completes its orbit in 11 years 315 days, its year being, therefore, nearly twelve times as long as ours. The reason its light is nearly as bright as that shed by Venus, which is so vastly nearer to us, is explained by Jupiter's greatness. Fig. 3 illustrates this statement in a striking manner, showing Jupiter to be a small sun in size. Its kindred planets, all balanced out against Jupiter, would weigh three times less, and if we were to imagine its body to be hollow, we could stow 1,330 earths away in it. A steamer, journeying around the earth at its broadest, could accomplish the tour in 35 days without a break, but it would take a full year to circumnavigate Jupiter at its equator.

The Flattening at the Poles.—Jupiter is no exact sphere; nor is the earth for that matter, although its deviation from a spherical shape is very slight compared with that of Jupiter, where the flattening is far more conspicuous and more noticeable even in a medium telescope. Its diameter at the equator is 89,330 miles, that from pole to pole 5,600 miles less! If a soft putty ball be set into violent rotation, this flattening ensues, as we have already explained (Fig. 159). It is more pronounced the faster the globe rotates; and if a decided flattening is discovered in any celestial body, we may assume either that it turns very rapidly on its axis or that it once possessed a very fast rotation. This is the case with Jupiter, which rotates in a much shorter period than the earth, in 9 hours 55 minutes. If we had a day of this length on earth, the sun would only be above the horizon for five hours or so, and all conditions and matters would be considerably rearranged to fit in with the altered state of things. It is extremely questionable whether beings of our constitution would be able to stand so sudden a change from night to day. Stress of external conditions which, according to all we know of the evolution of living beings, is of determining influence on their organisation, may produce on other planets rational life of quite a different type from ours. The sun's diameter as seen on Jupiter is five times smaller than we see it (Fig. 145), and the light and warmth the planet receives are twenty-seven times inferior to that given to us. We might think that this would mean a very dim light, but it would in reality be quite considerably more than we receive on a cloudy day.

Jupiter's Enormous Cloud Belts.—We do not need to debate whether there are Jovians or no, for this giant planet is most decidedly not habitable, at least, not up to the present. Grey streaks encircling the globe will be shown even by a small telescope, and more powerful instruments prove these to be great masses of clouds floating in belts across the enormous globe, and marking the climatic zones on the planet (Figs. 200, 203). Nothing can be recognised of Jupiter's real surface, for the same reason that a mountaineer can see nothing of the villages in the valleys below, when dense cloud and mist formations hide them from his view.

The Constitution of Jupiter.—A thick, warm atmosphere, rich in aqueous vapours and in incessant motion, surrounds the planet, an atmosphere best compared to one of the notorious non-transparent London fogs. Of course, this comparison is only correct in its externals, for Jupiter's atmosphere arises from quite a different source, and possesses a high temperature. Close investigation into the question of the Jupiter atmosphere has shown these streaks generally to retain their shape and position, although the finer details are in a constant state of change, driven about by strong currents, which must be produced by great radiation of heat from the surface of the planet. This circumstance, together with others of a like nature, renders it practically certain that Jupiter does not possess a firm surface like that of the earth, but is still in a state of evolution, such as the earth passed through millions of years ago.

Centuries of Rain.—We may safely assume that Jupiter's surface is still in a hot, muddy, thickish liquid condition, and that the first thin layers of a firm crust are in course of formation around the once incandescent liquid sphere. The temperature in these top strata of the Jupiter atmosphere has probably sunk sufficiently to permit water-vapour to be condensed, which falls to the surface in torrents of rain, lasting for centuries in the phase the planet is at present passing through. The surface would, however, still be too hot to let the masses of water shape themselves into oceans, so they immediately evaporate, to begin all over again.

The Red Spot.—Close scrutiny of atmospheric detail on this planet permits us further to assume that the white and brighter shadings are the highest cloud-layers, the greyer ones being deeper down, and that very dark spots are rifts in the ocean of clouds, through which we can take a peep at Jupiter's real surface. The remarkable feature known as the red spot seems to confirm this. This phenomenon (which is seen in its usual oval shape in Fig. 200) first appeared in 1875, growing steadily deeper in hue until it formed the most prominent object on the disc of the planet. Powerful aerial disturbances were noticeable around it, a sign that unusual heat was being sent up from the surface. This, coupled with the colour of the spot, leads us to suppose it to have been the reflection of enormous heat; the surface had probably been rent asunder at this quarter by a kind of volcanic eruption, the fiery masses having flooded an extensive area. The hot currents sent up by them must have separated the clouds to some degree, the fiery glow flaring out from between the thick mists. The red spot was plainly visible for a quarter of a century. It was fully 21,749 miles in length at times.

Not Yet Adapted for Life.—All this shows us that Jupiter is as yet hardly fitted as an abode for organised life. The history of the universe, however, teaches us that every celestial body, the earth included, has passed through a metamorphosis of a like kind. Jupiter is a very youthful world, only a recently extinguished sun, and the hour has not come in which it will be called on to bear life.

Jupiter's Moons.—Equipped with a small pocket-telescope or good opera-glasses, several small stars can be sighted near Jupiter, its moons. There are eight in all, four of considerable dimensions and perceptible even with the inferior optical aids just mentioned (Fig. 203), and four so minute that they can only be traced by the most powerful instruments. The four larger moons were discovered in 1609 by Galileo, shortly after the invention of the telescope; whilst the four small ones are recent additions, due to photography and the giant instruments now in use.

The Larger Jovian Satellites.—The Jupiter satellites (we now refer to the four large moons) are most interesting structures. Apart from the magnificent aspect they present, revolving around their tremendous central planet and constantly changing their position to each other, they are also of unquestionable use to us. If their movements are studied for any length of time, one or the other will be seen passing in front of Jupiter, the sun casting its shadow on to the Jupiter disc (Fig. 204), exactly in the same manner as our moon throws a shadow on the earth during a solar eclipse.

Jupiter Eclipses.—This is analogous to a sun eclipse on Jupiter, for where the shadow of the Jupiter moon strikes the planet, the moon has to stand in front of the sun, obscuring it. At other times one of the satellites may be covered by Jupiter and vanish behind its disc. On passing behind Jupiter, the moon enters the immense shadow Jupiter throws into space, its light is cut off, and a lunar eclipse then occurs. Such solar and lunar eclipses are frequent on Jupiter, for there are moons in plenty, moving far faster around the planet than our moon moves around us; one moon completes its orbit in one day and eighteen and a half hours only!

Of Service to Travellers.—The Jupiter moon eclipses and transits, of which several often happen in a day, have been calculated in advance for many years; and in the astronomical annuals their position at a certain hour of every day is tabulated, as in Fig. 202. These remote celestial bodies are of distinct value to explorers when it is necessary to determine their bearings by the aid of astronomical calculations and instruments. One of the most popular methods of determining the geographical longitude is by observation

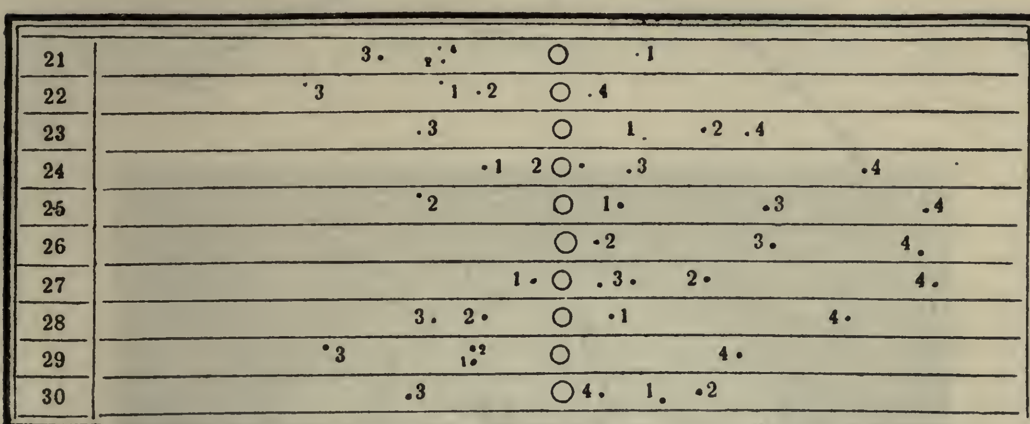


Fig. 202.—Position of the Jupiter Moons during a Period of Several Days. The small central circle is meant for Jupiter, and the dots marked 1, 2, 3, 4, are the major moons.

of the Jupiter moons. An explorer will, for instance, witness the eclipse of a Jupiter moon, decide its time, compare it with the eclipse times of the Nautical Almanac, find out the difference in time between his position and that of the observatory, and be finally enabled to determine his longitude. Science has thus a way of knitting the most unlikely subjects together to promote the interests of mankind. The eclipses are of little use to seamen, for the ship is seldom sufficiently steady to permit a telescope to be used powerful enough to observe the eclipse.

Jovian Moons and the Velocity of Light. — The Jupiter moons also supply an answer to the question concerning the rate at which light travels. We know it to journey with such velocity that we cannot follow its motion. A searchlight on a distant hill-top is seen for miles and miles at the very instant it flares out; an observer either one or ten miles away sees the light as soon as a person does who is situated next to the searcher. There is no distance on earth large enough to permit a difference in time to be determined between the flaring-up of the light and its sighting.* Only a

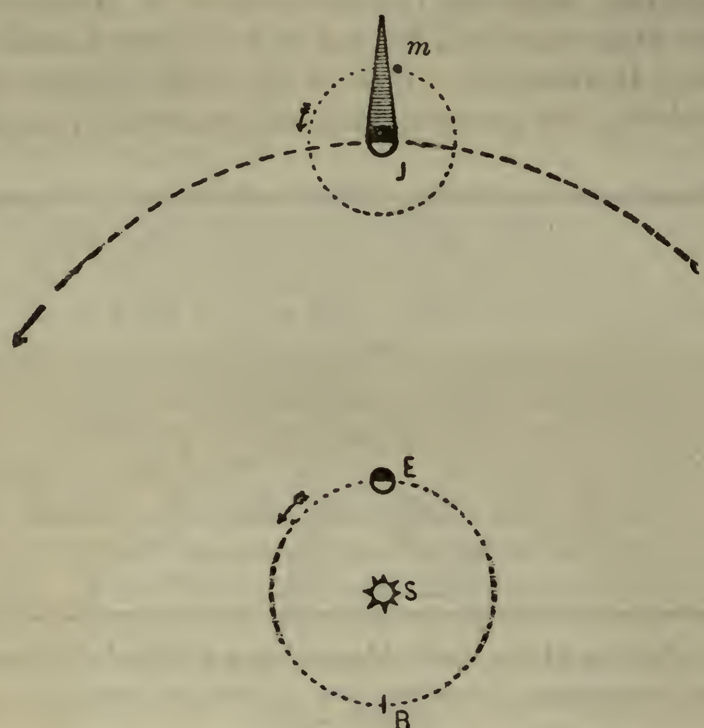


Fig. 203.—Measuring the Velocity of Light.

celestial occurrence could help to establish this knowledge; and in 1675 Olaf Römer made an interesting discovery to this end, whilst observing the Jupiter moons. He had been engaged in calculating the eclipse recurrences from day to day, and whilst they occurred promptly enough at first, they managed to lag 16½ minutes behind time at the end of six months. Due investigation showed Römer the cause of this disturbance; the earth wandered ever farther away from Jupiter during these six months on its journey around the sun, being 186,420,000 miles more distant than six months

* This does not apply to the method described above, by which the velocity of light is measured by the shift of the reflection in a rapidly revolving mirror.

Fig. 204.—Jupiter and its Four Major Moons.

(From a drawing by the Author.)

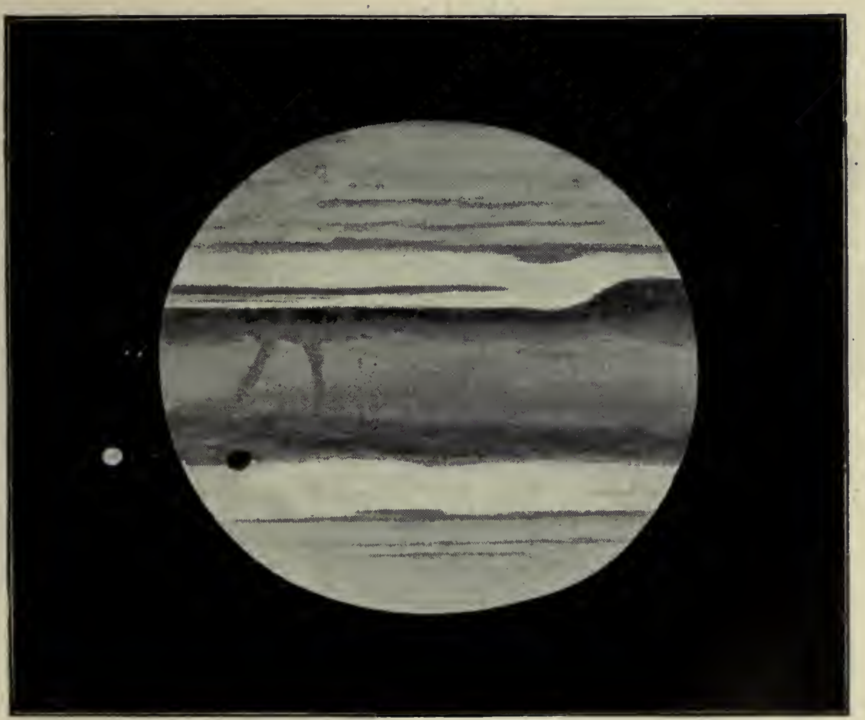


Fig. 205.—Jupiter.

(From an observation by the Author on May 16th, 1899, at 8.45 p.m.)

The black spot on the planet's disc is the shadow of the Jupiter Moon on the left.

Fig. 206.—The Planet Saturn.
(*After a drawing by E. E. Barnard.*)

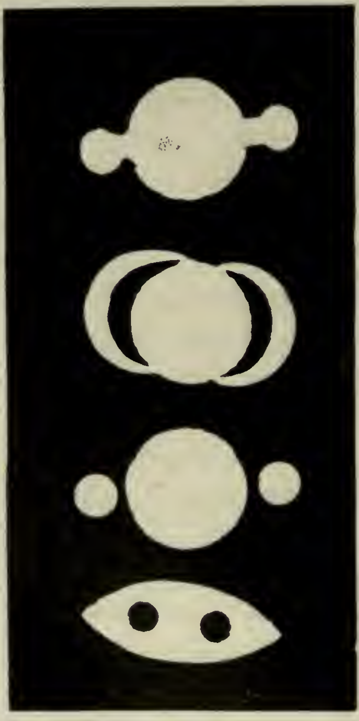


Fig. 207.—Saturn's Shape as it appeared to Astronomers soon after the Invention of the Telescope.

earlier, so the light-rays sent out by Jupiter had to travel 186,420,000 miles farther to bring us the news of the eclipses, a distance it took them exactly 16½ minutes to accomplish. Fig. 203 shows this very plainly, S being the sun, E the earth in its orbit, and J Jupiter casting a shadow to its rear, which a moon is about to enter at *m*, revolving around Jupiter in the course marked by the dots. When Römer began his calculations the earth stood at E, and six months later it was at B, divided from Jupiter by the entire diameter of its orbit (186,420,000 miles); so instead of the distance *m* to E, the stretch *m* to B had to be taken into consideration. As the rays of light needed sixteen minutes and forty seconds to travel the extra distance from E to B—186,420,000 miles—it followed that light had a velocity of 186,420 miles per second, a deduction confirmed by later physical experiments.

Jupiter's Realm.—The following data of the four large Jupiter moons are of interest:—

Moon.	*Diameter in Miles.*	*Distance from Jupiter's Centre.*	*Time of Revolution around Jupiter.*
1	2370	261,000	1 day, 18 hours, 27½ mins.
2	2141	416,000	3 days, 13 hours, 13¾ mins.
3	3600	663,000	7 days, 3 hours, 42½ mins.
4	2964	1,188,000	16 days, 16 hours, 32⅙ mins.

Excepting the second, which is about the size of our own moon, all the others are far larger than the earth's satellite. The newly-discovered ones are very much smaller; and the most distant among them, the eighth moon, is nearly 14,000,000 miles away from Jupiter, and takes about two years to complete a circuit. Jupiter's realm is a mighty one, and, with its eight satellites, is almost a solar system in itself.

Size and Distance of Saturn.—Turn we now to the other giant planet, Saturn. We still have a little way to go, as 400,000,000 miles separate the two. Saturn wanders around the sun in solitary grandeur at a distance of 885,500,000 miles. We have just ascertained the rate at which light travels; if the sun were suddenly wrenched from the sky, we should see its light for another eight minutes and twenty seconds, but on Saturn it would be visible for a full hour and a quarter, as it takes light this length of time to reach it from the sun.

The Old Man with Sickle and Hour-glass.—Saturn completes its circuit in 29½ years. The ancients, who looked upon it as the god of time, always portrayed it as an old, old man, with sickle and hour-glass. Its size is far superior to that of the earth, as it is 76,000 miles in diameter, the earth's being only 7,925½ miles. Saturn could be turned into 750 earths. Its shape deviates from the spherical even more than Jupiter's does, strongly tending towards an oval, as its polar diameter is 8,700 miles less than that of its equator. This must lead to remarkable differences in weight, for we know that on earth all objects are heavier at the poles than at the equator, and on Saturn the enormous flattening would result in great divergences between equatorial and polar weight.

Saturn's Ring.—Saturn seen in a telescope affords an extraordinary spectacle (Fig. 206). It frequently happens that people with but a smattering of astronomy, when shown the planet in a telescope, flatly refuse to believe that the weird object they behold is really the twinkling little star first pointed out to them in the sky. Nor is this surprising, for the aspect of Saturn is remarkable in the extreme. A most beautiful ring, of such perfection in shape that it might have been forged by a goldsmith, floats around the gigantic sphere.

Galileo Puzzled.—This wondrous formation is absolutely alone of its kind. Nothing has ever been discovered in the least resembling Saturn, unless we except a nebulous appearance in the very farthest depths of space whose outlines bear a slight likeness to those of Saturn. Our astronomical instruments easily permit us to recognise the peculiarities of Saturn; but if we hark back to Galileo's time, we can perfectly understand how greatly all astronomical observers must have been mystified by these astonishing planetary phenomena. On November 13th, 1610, Galileo wrote to an emissary of the Emperor of Austria: "Looking at Saturn with a telescope of more than thirtyfold magnification, it appears triple to me; the largest star stands in the centre, the other two lie on a level—one east, the other west—and appear to touch the centre star (Fig. 207). They seem like two servants assisting old Saturn to complete its journey, and do not budge."

Variations in the Aspect of Saturn's Ring.—As neither the earth nor Saturn always remains in the same position in space, the earth being above, below, or in the plane of the ring, it is but natural that the appearance of the structure should alter from year to year; in the course of a Saturnian year it is twice turned edgewise and twice opened out to its widest extent (Fig. 209). This further complicated the matter for the early astronomers. One of them pronounced Saturn to be a globe with two handles. Another believed a bar ran through the sphere (Fig. 207). Huygens ended the dispute once and for all in 1660 by conclusively proving that a thin, disconnected ring floated around the planet. According to the position of the observer, the ring may be seen in a more open or more closed condition (Figs. 210, 211). At times the earth and Saturn are in a position giving an edgewise view of the ring, which then appears as the thin line shown in Fig. 211. If the sun should then happen not to illuminate the sharp edge of the ring, the formation will be totally invisible.

A System of Rings.—In 1675 Cassini discovered the dark divisionary line in the ring seen on all our photographs, proving that it really consisted of two rings lying within each other. Five in all are known to us to-day, and it is very probable that there are numerous other divisions which our optical instruments are unable to reveal. The inner members of this system of rings are so fine and transparent that the limbs of Saturn can be clearly seen through this portion of the ring.

What does this most interesting structure consist of? Purely mathematical deductions show that the ring or rings cannot be a compact mass, as the laws of mechanics teach that such a mass would be dashed to atoms by the slightest disturbing action of another celestial body. The opinion that the ring consisted of countless small bodies, of a conglomeration of solid particles similar to meteorites, has been confirmed by spectroscopic investigation, and may be accepted as a certainty. The total diameter of the ring is

173,000 miles, or nearly twenty-one and a half times that of the earth. Its thickness is very slight, and computed at fifty-five miles; its breadth is placed at 40,400 miles.

Saturn's Nine Satellites.—Besides this unique companion, Saturn has a following of nine satellites—verily a world of marvels! What wondrous sights the sky must offer on that distant star, where eternal twilight reigns, where an immense arch divides the firmament, and nine moons constantly rise and set! Classified as to their distance from Saturn, the satellites are: Mimas, Enceladus, Tethys, Dione, Rhea, Titan, Hyperion, Iapetus, and Phœbe. A tenth moon (Themis), announced by W. H. Pickering, has not been completely verified. Fig. 208 gives an idea of their distances, illustrating the vast realm of Saturn in comparison with that of the earth and moon. The most distant Saturn satellite, Phœbe, is 8,000,000 miles away, and needs 546 days

Fig. 208.—Diagrammatic Representation of the Size of the Realm of Saturn.

The upper line shows the distances of the ten moons of Saturn from their planet, the lower the distance of the moon from the earth. The tenth moon of Saturn is thirty-four times farther away from the planet than is the terrestrial moon from the earth.

for its orbit, only appearing as full moon once every seventeen months! It would, however, be invisible to the naked eye as seen from the planet. Only eight satellites were known up to 1899, the remaining one or two having been quite recently discovered.

The Novelist and Saturn.—Saturn has been observed to show similar cloud formations to those of Jupiter, and its surface, too, appears to be far from solid. Bright spots, probably caused by powerful air-currents, have been seen in the dense atmosphere. By observing these spots, the rotation of Saturn was found to be almost as rapid as that of Jupiter, the length of a Saturn day being set at ten hours and fifteen minutes. Saturn is as far from being habitable as Jupiter. The sun sends to it one-ninetieth of the heat that it sends to the earth, and even its brightest day is very dim compared with ours. The fervid imagination of an English novelist peopled this remarkable planet with a race of giant newts,

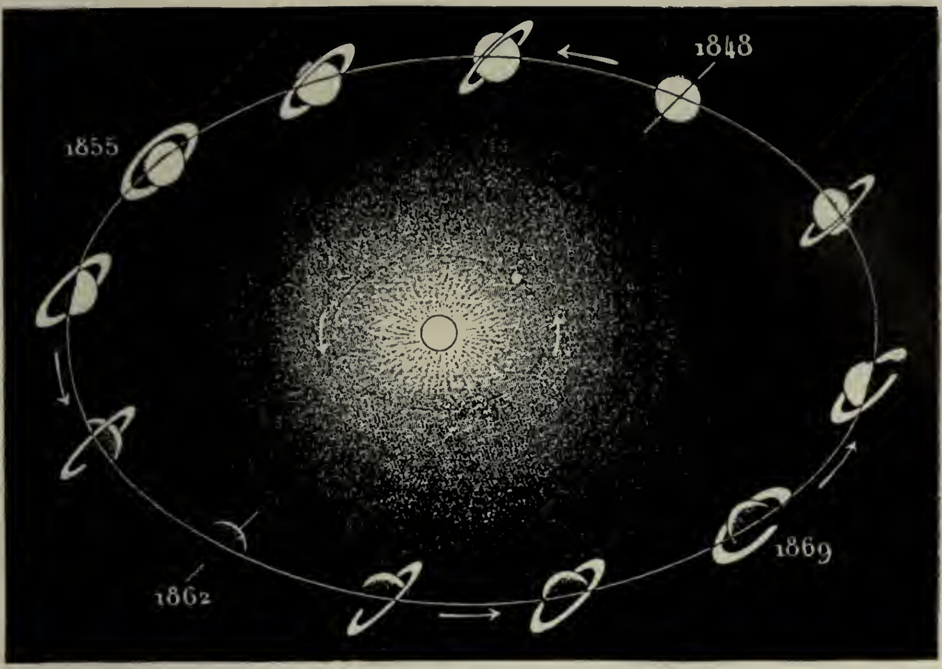


Fig. 209.—How the Phases of Saturn Arise.

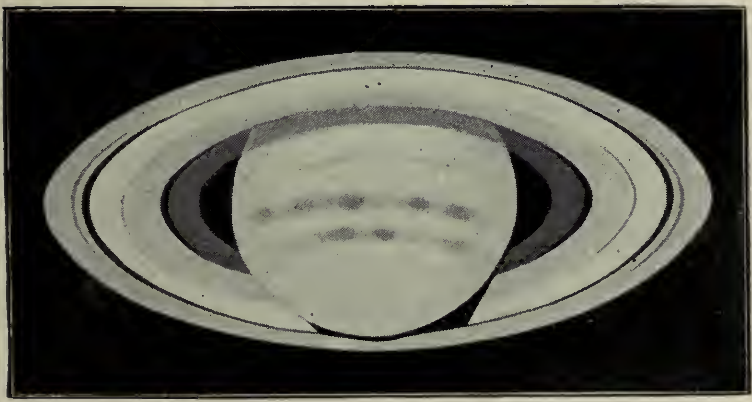


Fig. 210.—Saturn with very Open Ring.
(*As observed in June, 1898, by J. Rheden, Vienna*).
The shadow of the globe is visible on the ring.

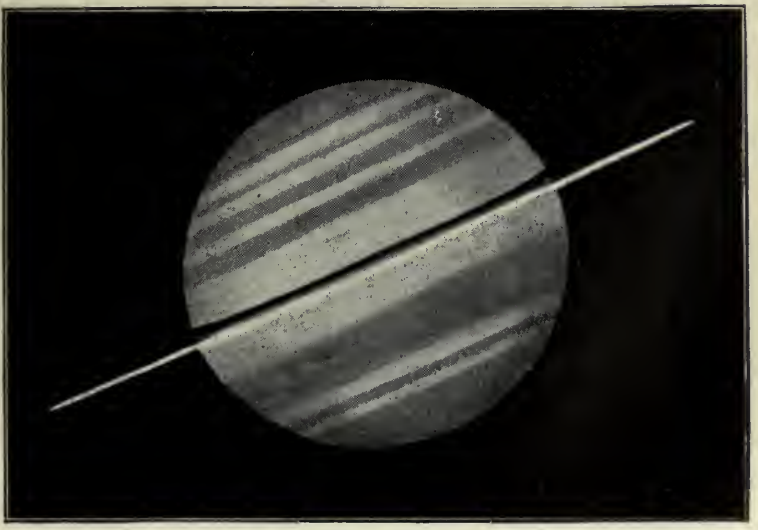


Fig. 211.—Saturn in 1908.
Only the edge of the ring is visible.

Fig. 212.—Design published in Celebration of the Discovery of Ceres by Piazzi.

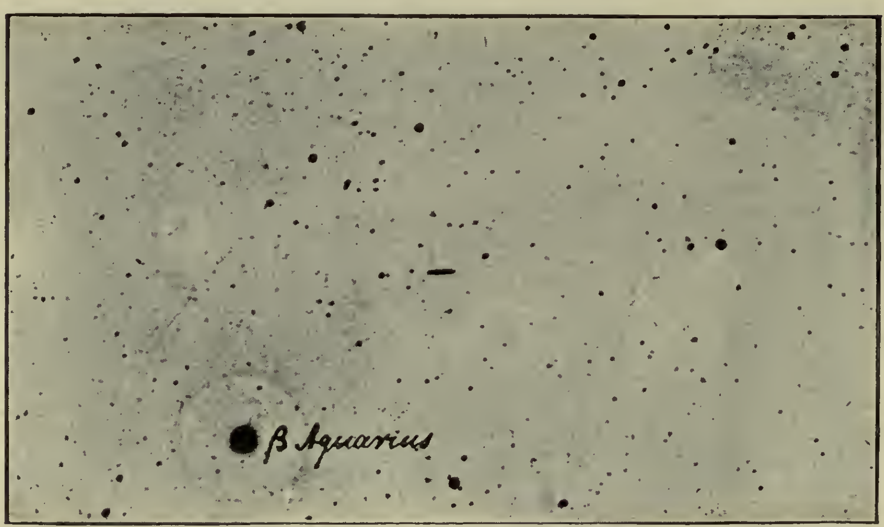


Fig. 213.—The Planetoid Eros.

Copy of the original plate on which Eros was discovered in 1898, by G. Witt of Berlin.)

The line in the middle of the plate is the planetoid.

Fig. 214.—The Size of Ceres compared with that of the Earth and Moon,

The Earth is on the left, the Moon in the middle, and Ceres on the right.

living in the depths of the thick, humid, aerial ocean, in everlasting greyness, and consumed with a longing for the sprite-like beings leading a brighter existence on the rings of the planet, where the atmosphere is admittedly very rare. This vivid piece of phantasy is a meet characterisation of the conditions prevailing in this remote province in the sun's empire, where the ruler divides his gifts so unequally among his subjects.

CHAPTER XX

LILLIPUTIAN WORLDS

"Gulliver's Travels."—Many years ago, when the multiplication table represented my greatest worry on earth; when philosophy, physics, astronomy, mathematics and all the rest of them were still undreamt of; when the slate, the primer, and the lunch-basket (this specially important) were my only instruments of learning, I possessed a book which was the most splendid work in all the world to me. Could I but read it to-day with the zest of those golden years! It was called "Gulliver's Travels," had a weirdly brilliant cover, with pictures of most remarkable hue, and was all about a man who journeyed to a country where the people were no larger than his finger. The name of the country was Lilliput, and the people were the Lilliputians. Later I was bitterly disappointed to learn that there was no such country on earth, but that there were people living on the stars, and that the Lilliputians most likely had their home on one of the "diamonds in the sky."

Conditions on Other Planets.—Since then I have learnt quite a lot of things about the stars, and have attempted to read their riddles, but, I must own, with very negative results; for we can state nothing with certainty as to whether they are inhabited or not, excepting that it is not improbable stars do exist able to serve as a home for rational beings akin to mankind. In fact, of all the millions of stars, there is, as we have already seen, but one of which it may be said that it is likely to be inhabited, and that is Mars.

One thing is very evident: the people on other celestial bodies will hardly be shaped as we are, since the conditions are so different from ours. The inhabitants of Mercury, which is so near to the sun, and where the light is about seven times as powerful as on earth, would have entirely different organs of sight from those on Neptune, the most distant planet of our solar system, where the sunlight is 900 times weaker than here. It is, however, hardly probable that creatures resembling human beings flourish on either planet.

An object weighing a pound on earth would weigh twenty-seven pounds on the sun, and but one-sixth of a pound on the moon.* Apart from the fact that the sun is a ball of fire, on which nothing organically constituted could exist, a being like man would break down altogether on it, as he would weigh about 4,408 pounds! It would be impossible even to raise an arm, not to mention taking a stroll. On the moon it would be just the reverse. The same person, whose terrestrial weight may be put at 165 pounds, would only weigh about 28 pounds there, and would be able to toss great blocks of stone about with ease, and jump yards high into the air. Running would be as easy as winking, for if we retained our present power, we should only weigh as much as a child.

Planetoids.—Such instances can be given in plenty, and are only meant to show that the inhabitants of other worlds would be adapted in organs, constitution and energy to their surroundings; for Nature, in her practical wisdom, takes physical conditions into consideration in her creation of organic life. On a planet 1,100 yards in diameter trees 150 yards high, such as grow in California, would not be found. Such tiny planets really do exist. Within recent years planets have been discovered but a mile and a half, a mile, nay, only several hundred yards in diameter. The smallest known at present is the planet which the late James E. Keeler, Director of the Lick Observatory, discovered in the summer of 1900; this is only about 550 yards across.

Gaps in the Solar System.—The interesting Lilliputian star to which I have been referring wanders around the sun, in the company of many others of like character, in the regions between Mars and Jupiter. Nothing was known of them until 1801, although astronomers had often been puzzled by the large gap in the solar system dividing these

* All these comparisons of weight on different worlds must be supposed to be made with a spring balance, not on a pair of scales, for in these the weights would change as much as the object weighed.

two planets (Fig. 118). Mercury is about 37,280,000 miles away from the sun, Venus 31,000,000 miles from Mercury; there are 24,856,000 miles between Venus and the earth, but 341,770,000 miles separate Mars and Jupiter! This broad, empty stretch in the solar system struck Kepler, and in his "Mysterium Cosmographicum," which appeared in 1596, he ventured the opinion that a hitherto undiscovered planet moved in this vacancy. "I am bold enough," he wrote, "to set a new planet between Mars and Jupiter!"

Bode's Law.—Later Bode showed that a singular relative proportion in distance, which can be expressed by a certain doubling of figures on a progressive scale, defined the distance of the planets from each other, and that according to this row of figures, known as Bode's Law, another planet should revolve between the orbits of Mars and Jupiter. At the end of the eighteenth century, astronomers were most industrious in looking for the new planet, and a society was formed, under the chairmanship of Zach, systematically to search the whole of the Zodiac, which they divided into twenty-four regions, each in charge of one astronomer.

The Romance of Ceres.—An Italian astronomer named Piazzi was at this time compiling a celestial catalogue at Palermo, entering all the stars he saw on his maps. On New Year's Day, 1801, he noticed an eighth-magnitude star in the constellation Taurus, wandering on slowly; it could only be a planet or a very remote comet. Without notifying his find to the astronomical world, Piazzi observed the star for several weeks, and was confirmed in his belief that he had hit upon an unknown planet. At last he published his discovery, but in the meantime the star had moved so close to the sun that it vanished in the solar radiance. The letters he had sent to well-known German astronomers were delayed by war; the star seemed utterly lost, and all idea of finding it again hopeless. Yet Gauss, the great mathematician, working from Piazzi's observations, was able to calculate its orbit, pronouncing it to be no other than the long-sought-for planet between Mars and Jupiter. Aided by these calculations, it was rediscovered by Olbers, strangely enough exactly a year later, on New Year's Day, 1802! The star was named Ceres (Fig. 212), and Olbers made it the subject of most careful study. On March 28th of the same year, another planet was discovered by him wandering in the same regions; this was named Pallas. In 1804 Harding found another small planet, Juno; and three years later Olbers was again favoured by fortune, finding a fourth planet in this group—Vesta, in the constellation Virgo.

Planet - Hunters.—The minuteness of these planets, that are but tiny stars many thousand times smaller than the other planets, promptly led to the hypothesis that they were fragments of a single large planet which had been shattered to pieces by some distant catastrophe. If that were the case, there would still have to be a large number of such tiny bodies in this region, and to trace them it became imperative to compile very precise celestial charts. This had the desired result, and led to a very great number being found. Some astronomers were so successful in this work that they were dubbed "planet-hunters." About 700 planetoids have been discovered in this group until now, Palisa, of Vienna, Charlois, of Nice, and, above all, Wolf, of Heidelberg, having found them by the dozen. It is most difficult to sort these grains of gold from among the desert dust of millions of small stars. Thus there might be hundreds of stars visible in the field of the telescope; their distances would have to be carefully measured at intervals to find a small planet hidden among them, a tiresome and tedious piece of work.

Photographing the Planetoids.—Photography is therefore called on to help. As the fixed stars stand still whilst the planets wander, the former are seen on the photographic plate in the shape of dots, whilst the moving planets show up as a line (Fig. 213). Numerous photographs are taken and carefully searched with magnifying-glasses for these short lines. Wolf has worked this procedure up into a fine art, and annually discovers a number of small planets.

Seven Hundred Asteroids.—These tiny celestial bodies encircling the sun between Mars and Jupiter are called asteroids, or planetoids—that is, small stars or planets. The chief group is between 186,000,000 and 373,000,000 miles away from the sun, and needs from two and a half to nine years to complete an orbit, the length of time being dependent on their distance from the sun. In Fig. 119

the asteroids are marked by a dotted ring. If all the 700 asteroids were welded together into one, this would even then be twenty times smaller than the earth. The largest of these Lilliputian worlds were naturally discovered first, being the most luminous. Ceres, Pallas, Juno, and Vesta are very much larger than the majority of the asteroids; but even Ceres, largest of them all, with a diameter of 478 miles, is but a very wee star compared with the earth. Fig. 214 represents the earth, the moon and Ceres in their exact proportions. As far as we know, all the larger bodies have been discovered, those recently found being but a few miles in diameter. It is not unlikely that the great mass of asteroids—possibly only fragments a few hundred yards or less in diameter—will always remain hidden from us, as no telescope or camera can ever possibly reveal them. Our forefathers, however, seemingly found the study of the heavens beyond their comprehension at times, if we may gather anything at all from the quaint woodcut of the sixteenth century shown in Fig. 215.

Origin of the Dwarf Planets.—The question how this gigantic swarm of miniature planets originated has not been definitely settled. We have already mentioned the hypothesis that a single planet, formerly revolving on the farther side of Mars, was shattered by a collision with another celestial body. We know, however, that marvellous orderliness reigns throughout the planetary system, and we cannot quite imagine what class of body caused so grave a disaster. Was it another planet suddenly appearing in the vicinity of the first? Was it a structure coming from the deepest depths of space and thrusting itself headlong into the solar system? In this case, the neighbouring planets would have been influenced to some degree, and at the very least an alteration of their motion must have been noticeable. It is far more likely that, at the period when the spheres evolved from gaseous masses, the matter in the space between Mars and Jupiter was disturbed in its condensation by some extraordinary event, and divided into little separate accumulations of matter, out of which many single small bodies were formed. On the other hand, certain peculiarities rather support the planet-fragment theory. Many of these stars have a remarkable variation in light which can only be explained on the supposition that they are irregularly-shaped bodies rotating on their axes, and presenting their larger and smaller sides to us in turn. For instance, a body of the shape shown in Fig. 216 must, if it turn on its axis and be illuminated by the sun, present varying degrees of radiance. When it is broad-

Fig. 215.—The Inhabitants of the Heavens.
(From a woodcut of the sixteenth century.)

side on (see on the left), it is visible to its fullest extent, and is at its brightest; but when the pointed side is turned towards us, it seems much smaller, and therefore less luminous. The light-variations of the asteroids are very regular; they last for a certain time, and repeat themselves at defined intervals; there is no doubt that they rotate on their axes during this period. A body which originated according to the laws of the universe is spherical in shape, as we see in the sun, planets, and moon, and the light-variations on these tiny planets entitle the theory that they are shapeless fragments to some respect.

Eros.—There is one among them invested with exceptional interest to astronomers. At first it was not classed with this group of planetoids, but was believed to be the first link of a chain of small bodies connecting earth and Mars. It was photographically discovered in 1898 by Witt, of Berlin, and named Eros (Fig. 213). Its main route is traversed in the space between the earth and Mars, and it approaches closer to us than all other celestial bodies, the moon excepted. It comes to within 13,670,800 miles, when it appears as a sixth- or seventh-magnitude star, although its diameter is only about thirty-one miles. When at its nearest, it would be visible to keen-eyed persons without instrumental aid. It will not make one of these near approaches till 1931. Its changes in light are very conspicuous, and lead us to suppose its rotation to take place in five hours and a half, besides showing us that it is irregular in shape. Eros is very important for astronomical calculations. Owing to its near approach, its distance from the earth can be measured with absolute precision, and this, in turn, helps to determine the solar distance more exactly. This discovery will probably render the very costly expeditions for the observation of the Venus transits, until now the most accurate basis for such calculations, unnecessary in future.

Possibility of Planetoids in other Regions.—This odd little planet may be no exception in the solar system; perhaps there are plenty of such asteroids outside the main group between Mars and Jupiter. Three were recently discovered coursing at the same distance from the sun as Jupiter. Some believe planets of this description to be present throughout the whole solar system, coursing between the orbits of the major planets, and it is further conjectured that the extremely minute Mars, Jupiter, and Saturn moons, which have only been discovered by the aid of the most powerful instruments, were formerly such small celestial bodies and penetrated the regions of the planets in question, and were held spellbound by their superior power of attraction. The small planets coursing independently around the sun became vassals themselves, satellites encircling the larger stars in moon-fashion.

The Smallest Worlds of All.—This, however, brings us to the realm of conjecture, to the smithy of hypothesis, where truth and fiction are so easily welded together to an apparently firm substance. Later we shall learn of the existence of still smaller bodies, splinters the size of a pebble roaming in their millions throughout the universe. Compared with them, the star discovered by Keeler is a veritable giant!

Our everyday definitions of size are at variance when Nature is drawn into discussion and we leave the safe limits of human measurements and surroundings. Millions of bacteria find a home on a pin's-head; and one of these minute celestial bodies, the size of a man's fist, might well be inhabited by such bacteria. The stone rushing through space would be a mighty world to them; and the human eye is too coarsely constructed to be able to grasp all the thousands of wondrous details a world of this description may contain.

CHAPTER XXI

AT THE FRONTIER OF THE SOLAR REALM

Saturn Once Deemed the Last of the Planets.—It has taken mankind thousands of years to explore our small earth, with the help of hardy, fearless pioneers, who penetrated into its fastnesses and laid them bare bit by bit, just as astronomers are endeavouring to do with the worlds above, reading the heavens word for word with the help of that greatest key of all—Science.

The ancients only knew of five planets—Mercury, Venus, Mars, Jupiter and Saturn—and for long ages Saturn was looked upon as the border-line of the solar realm, nobody even dreaming that there might be planets across its frontier. Sir Frederick William Herschel was the Columbus who discovered a new world, a new planet, and moved the boundary of the solar system 127,280,000 miles farther out. The new celestial body was just as far away again from the sun as the entire expanse of the then known solar system.

Discovery of Uranus.—On March 13th, 1781, Herschel was engaged in searching the sky for new objects, for comets and nebulæ, at the Bath Observatory, when shortly after ten o'clock he saw a small star in constellation Gemini, which, in its steady light, differed from the surrounding fixed

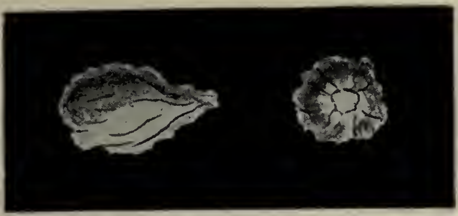


Fig. 216.—Variations in Size and Radiance of a Celestial Body of Irregular Shape.

Fig. 217.—Uranus and its Moons

Distances as correct relative scale.

Fig. 218.—Urbain Leverrier.

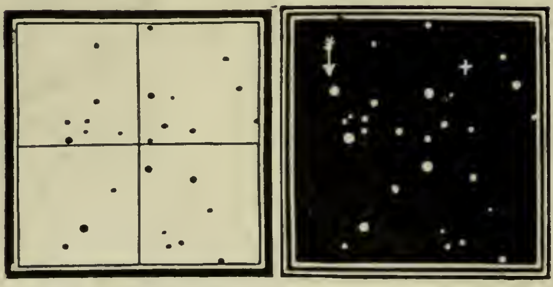


Fig. 219.—Chart of the Discovery of Neptune.

stars and was visible in the telescope as a tiny disc, fixed stars invariably appearing as dots. His attention was aroused, and his suspicions that it could not be a fixed star were confirmed when, after careful observation extending over several evenings, the star was found to have moved. At first he believed he had discovered a comet, which, at a very great distance, frequently resembles a small star. Herschel announced his discovery to the astronomical world, and all the telescopes in Europe were speedily turned on the interesting object; the mathematicians, above all the renowned Laplace, endeavoured to calculate its orbit, and both he and Lexell were soon able to state that the star did not move in a cometary orbit but must be a planet, revolving around the sun in an almost circular path, and therefore must have always belonged to the solar system, although it had remained hidden from human ken until then. Researches made in older star catalogues and charts, compiled by Flamsteed (in 1690) and Tobias Meyer (in 1756), disclosed the fact that these astronomers had seen and noted down the star, but they had assumed it to be one of the countless small fixed stars. Later the information was volunteered by a party of explorers that the star had been known as a planet to the natives of Tahiti for hundreds of years, and they had even given it a name. There is no reason to discredit this statement, for at its nearest approach the planet is recognisable to the naked eye as a sixth-magnitude star, and the pure air of the Polynesian zone may well have revealed it to the human gaze. Bode's proposal to name the new planet Uranus was accepted. In mythology Uranus was the father of Saturn, who was the father of Jupiter; so the name was very happily chosen and met with general approval.

Distance, Dimensions, and Periodicity of Uranus.—Uranus, revolving around the sun as its seventh planet (Figs. 118, 119), is 1,784 million miles away from it and needs 84 years and 7 days to complete its orbit. Its distance from earth varies between 1,608 and 1,960 million miles, according to the position of the earth in its orbit. Uranus has a diameter of more than 36,700 miles. The planet is decidedly smaller than Jupiter or Saturn, but nevertheless far larger than the earth (see Fig. 3); if the earth were stationed as far away as Uranus it would be only of the tenth magnitude. Even our powerful instruments fail to discover much on the surface of the planet, for the distance is too immense and its illumination by the sun too weak. Armed with the giant telescope of the Lick Observatory, Edward E. Barnard was repeatedly able to make out a broad grey angular streak; the Uranus world and its four satellites can be seen in a very powerful instrument when conditions are extremely favourable, as shown in Fig. 217. The spectroscope tells us that Uranus possesses a dense atmosphere resembling that of Jupiter and Saturn in many respects, and this is all we know of its surface conditions!

Moons of Uranus and their Motions.—Soon after Uranus was discovered Herschel found that two satellites accompany the planet on its long journey around the sun; they were named Titania and Oberon. In 1851 Lassell, of Liverpool, found two more with the aid of a huge reflecting telescope. Even the instruments of to-day only set forth these two very dim moons in an indistinct fashion, a proof that sharp eyes play a very important part in observation work. The satellites, 14th- and 16th-magnitude stars, were named Ariel and Umbriel. The distances of the four moons from their planet are on a scale proportionate to that of Fig. 217.

The Axis of Uranus.—The chief feature of the system of Uranus is the difference in the motion of these moons in their orbit from that of all the other planets and moons of the solar system. We have been taught that one direction generally prevails throughout the heavens—that running from west to east. The sun and all the planets rotate on their axes from west to east, as we can daily recognise so far as the earth is concerned. The planets revolve around the sun from west to east (see Fig. 119), and nearly all the satellites move around their own particular planet in a like direction.* The orbits of the planets nearly all lie in one plane. The prevailing conditions are best illustrated if sun, planets, and moons are imagined floating on a sheet of water set into circular motion by stirring, all the bodies moving in one and the same direction around the sun in the centre,

* The outermost moons of Jupiter and Saturn, the Neptune moon and all four Uranus moons are the exceptions to the rule.

and all of them, floating on the water, being in the same plane. This is not quite correct in reality, for there are certain small deviations to be reckoned with. The orbit of Venus is inclined about 3 degrees, that of Mercury by 7 degrees to that vast plane, but even including these deviations the solar system forms what I may call a gigantic, though thin, disc. The moons belonging to the various planets revolve around them (except in the case of the Earth, Neptune, and the outer moons of Jupiter and Saturn) almost exactly in the equatorial plane, and this occupies a most peculiar position in the case of Uranus, as a comparison

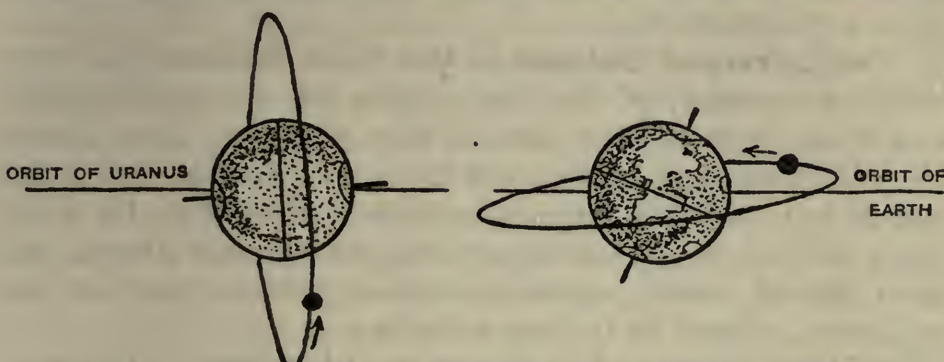


Fig. 220.—Comparison between the Movements of Uranus and the Earth.

with terrestrial conditions will show. Fig. 220 shows us the earth on the right, accompanied by the moon; the inclination of the earth's axis and the moon's orbit to the plane of the earth's orbit are shown at their correct angle. On the left are the orbit of Uranus and the orbit of its moons; the remarkable position of the axis of Uranus and the moons' orbits to the plane of the Uranus orbit will at once strike the beholder.

The Seasons of Uranus.—These peculiarities influence the seasons on Uranus. At every spot on the planet the sun would be seen in the zenith twice in the Uranian year, except within 8° of either pole, whilst on earth the sun can only stand in the zenith of a place within 23½° of the equator. When the North or South Pole of Uranus is turned towards the sun it has the sun for forty-two years above the horizon, and has forty-two years of day and sunshine, the other pole being plunged into a night of equal duration, for a Uranus year lasts for eighty-four of ours. If the imaginary inhabitants of the planet be as shortlived as we are, a person living in either polar region, born at the beginning of winter and dying at the age of forty, would never see daylight or the sun, but live in everlasting darkness like the pit-ponies in coal mines. The contrary would be the case with the summer-born, who would know of night and the stars only from hearsay. It must not be forgotten, though, that the sun, as seen from Uranus, is only a tiny point of intense radiance, appearing about 370 times smaller than we see it, so the difference between day and night would hardly be as great as described; darkness and cold are the main features of this remote world.

The Extremest Outpost in the Sun's Realm.—But even here the boundary of the solar system has not been reached, and if we were able to emulate that prince of liars, Baron Münchhausen, and fly through space on a cannon-ball at the rate of 550 yards per second, we should have to fly for 2,100 years from Uranus before arriving at another planet, the most distant known, namely, Neptune, which stands as the extremest outpost in the sun's realm.

Neptune discovered by Leverrier at his Desk.—If Uranus was discovered by accident, the existence of Neptune had been long known to astronomers before the faintest glimpse of the star had been seen. As soon as Uranus was found, calculations of its orbit were begun and its position determined for every day. It became plain after a short time that Uranus absolutely declined to fit in its movements with the tables prepared, for it appeared in a totally different spot from that calculated. The most eminent mathematicians of the day took the matter up and advanced the theory of another celestial body in those regions influencing Uranus in its motion. The Academy of Sciences at Göttingen finally issued a prize competition for the explanation of this deviation and an exact calculation of the motion of Uranus. The French astronomer Arago thereupon induced a young French mathematician, Urbain Leverrier (Fig. 218), who had formerly been a clerk in a tobacco depot, to investigate the matter. Leverrier began a most thorough series of calculations and, at the end of six months, laid the results before the Paris Academy. He proved that the irregularities could only arise from a planet as yet undiscovered, not situated between the sun and Uranus but on the far side of Uranus, since neither Saturn nor any other planet was influenced by its presence. The planet would also have to be very remote from Uranus, as the disturbance was but a slight one. According to the power of its attraction, shown by the deviation of Uranus from its calculated orbit, Leverrier determined the size and position of the star and the regions in which it would have to be sought for in the sky. On September 23rd, 1846, he communicated to Dr. Galle, of the Berlin Royal Observatory, the position in which the planet should be found, if his computations were correct. Galle discovered the new planet on the very same night in the shape of an eighth-magnitude star close to the spot indicated, only about twice the diameter of a full moon away from the point calculated by Leverrier. Comparisons were made with the help of an exceptionally good chart; Fig. 219 shows a portion of the map on the left and the sky on the right as seen by Galle in the telescope. All the stars marked on the chart are visible with the addition of a new one not on it and marked by a dart. This was the new planet; according to Leverrier it should have been seen at the spot designated by a cross. A young English astronomer, John Adams, mathematically located the new planet at the very same time as Leverrier, and quite independently, and is therefore entitled to an equal share of glory with Leverrier. His figures were in Airy's hands before those of Leverrier were published. Challis, at Cambridge, had actually seen the planet from Adams's figures before Galle had done so, but not having the new chart of the region which the Berlin astronomers had, he failed to distinguish it from a fixed star.

The discovery of the new planet, which received the name of Neptune, was an astounding feat. As Arago said, Leverrier had located a new celestial body with the point of his pen, determining its position while it was still concealed from view. Surely this should satisfy the most hardened sceptics who doubt the truth of astronomical computations and figures!

Neptune's Distance, Size and Year.—Neptune is 2,787 million miles away from the sun; a continuous train-journey would take 5,700 years to accomplish the distance from the earth, and a ray of light, travelling at a rate of 186,420 miles per second, which only needs one and a fourth second to fly from the earth to the moon, would be a good four hours on the way from the sun to Neptune. It takes Neptune 164 years and 280 days to complete its journey around the sun; and since its discovery it has finished little more than one-third of its orbit. The planet (see Fig. 3) is much larger than the earth, its diameter being, in round figures, 31,070 miles, and it would need nineteen earths to equal its mass. It also possesses a satellite, discovered by Lassell in 1846, and a very difficult object to observe; its discovery was effected by a powerful instrument in the clear atmosphere of Malta. This moon is of special interest as, like the satellites of Uranus, it diverges from the direction persisted in by the majority of members of the solar system, and encircles its planet from east to west. There is little to tell of the surface conditions on Neptune, for the best instruments only show the planet, which is wholly invisible to the unassisted eye, to be a small, weakly-illuminated disc, receiving but the 900th part of the heat and light in which the earth rejoices. It is the solar Siberia, and we can hardly imagine anything with the faintest resemblance to life existing in those regions of eternal cold and darkness.

Has the Limit of the Solar System been Reached?—With the discovery of Uranus and Neptune the borders of the solar system were extended from a round 936 million miles to 2,808,000,000 miles, and the universe as known by the ancients has grown to enormous dimensions. The question persists whether one or more planets may not yet exist beyond Neptune, of which we know nothing, and to discover which our optical means are as unfitted as were those of the ancients to disclose Uranus and Neptune. Neptune has only completed a fractional part of its orbit, so no conclusions can be arrived at as to any irregularities which might suggest the existence of another planet. Newcomb, and recently Lau, have devoted great attention to the subject, and both decided that there are no grounds for assuming the existence of another planet; there are equally no grounds against such an assumption.

TABLE OF STATISTICS OF THE MEMBERS OF THE SOLAR SYSTEM

Name and sign of the Planets.	Distance from Sun in millions of miles.	Time of revolution round the Sun.	Equatorial diameter in miles.	Mean speed of revolution per second.	Mass in proportion to the Earth (Earth=1)	Volume in proportion to the Earth (Earth=1).	Time of rotation.	Number of Satellites.
Mercury ☿	36	87·9 days	2,993	29½ miles	0·06	0·05	88 days (?)	0
Venus ♀	67	224·7 ,,	7,438	21⅗ ,,	0·78	0·97	225 ,, (?)	0
Earth ♁	92	365·25 ,,	7,926	18⅓ ,,	1·00	1·00	23 hrs. 56 mins. 0·4 sec.	1
Mars ♂	141	1 year 322 ,,	4,191	15 ,,	0·10	0·15	24 hrs. 37 mins. 23 secs.	2
Asteroids ①	180-397½	2·5—9 years	1-478	8⅗-13 ,,	—	—	(?)	—
Jupiter ♃	483	11 years 315 days	89,330½	8 ,,	309·8	1,279	9 hrs., 55 mins., 37 secs.	7
Saturn ♄	885	29 ,, 167 ,,	75,811	6 ,,	92	719	10 hrs., 14 mins., 24 secs.	10
Uranus ♅	1,779¾	84 ,, 7 ,,	36,787	4⅕ ,,	13·5	69	(?)	4
Neptune ♆	2,788	164 ,, 280 ,,	31,071	3½ ,,	16·4	54	(?)	1

	Distance from the Earth.	Revolution round the Earth.	Diameter.	Mass in proportion to the Earth (Earth=1).	Time of rotation.
Sun ☉	92 million miles	——	861,822 miles	323,000	25 days
Moon ☽	238,876 miles	27 days 7 hrs. 43⅕ m.	2,161½ ,,	0·0125	Equals time of revolution.

The Supposititious Vulcan.—It has been suspected that one or several small planets may revolve between the sun and Mercury, as Mercury's orbit shifts in a manner that can only be explained with difficulty otherwise. At one time a small planet was believed to have been located, and it was immediately named Vulcan. Several observers—among them, in 1859, a French physician named Lescarbault—thought they had seen the planet passing in front of the solar disc. Leverrier most carefully investigated all these claims, and was convinced that these various observations could not be verified, and the small star has not been seen again, despite the far better telescopes of the present day, more trained observation, and the fact that a careful watch has been kept for it at total solar eclipses, when Venus and Mercury stand out prominently in the vicinity of the sun, and Vulcan, too, ought to be visible. So the question of Vulcan's existence is practically decided in the negative.

The Pickaxe of Patience.—Neptune, running its wide course around the sun in the grey twilight of the infinite, marks the boundary of the solar realm. Yonder, across its orbit is barren, limitless space, only traversed by comets and meteors on their travels lasting tens of centuries. It is far, immeasurably far, to the next solar system; the neighbouring suns of our own sun shine out from such immensities that we can hardly realise them. The nearest sun is almost ten thousand times farther away from us than Neptune. Yet science does not despair and boldly ventures even into these depths armed with the pickaxe of patience and the spade of knowledge.

CHAPTER XXII

STARS THAT FALL FROM THE SKIES

King Edward's Letter-weight.—On the writing-table of King Edward VII. there stood, besides other costly objects, a plain piece of rock, a rough, unhewn stone about the size of a man's fist. "What a queer letter-weight for a king!" my readers may exclaim, and yet in its way this letter-weight was a costly article. Infinite trouble, terrible dangers and much science combined to place the stone on the monarch's desk. The leader of the Himalayan Exploration Commission chipped it off at the highest point reached on the mountain to which he gave his name, Everest, to hand it to his sovereign as a symbol of the conquest of the highest point on earth.*

The Stone in my Scarf-pin.—If the King could boast of having the highest point of the earth on his writing-table, I feel inclined to boast of a stone coming from much loftier realms than even the highest terrestrial mountain. I possess a black, insignificant pebble which might easily be taken for a bit of coal, and which by rights should find its place in the ash-bin instead of being mounted in gold as a scarf-pin. The tiny stone hails from regions never yet penetrated by man; its home is not found on high mountains, nor in ocean deeps, nor in dense jungles, nor in the interior of the earth. It does not belong to our planet at all. It was at one time more distant than the sun, moon, and all the planets. Perhaps millions of years ago it traversed the shining belt of the Milky Way; perhaps thousands of years ago it crossed the stars of the Great Bear, perhaps—perhaps! And then one fine day a radiant star appeared in its course through the voids of space and the little pebble was drawn within its circle of attraction. With ever-increasing

* The highest point reached by climbers is several thousands of feet below the actual summit of Everest.

rapidity it travelled towards that bright star we call the sun, and the nearer the pebble approached the larger the sun-star grew, until it loomed out as a huge ball of fire around which other balls revolved. Our stonelet rushed boldly on towards one of these globes; this became larger and larger, whirling clouds grew visible, then oceans and land, for it was our earth, and finally it dragged our pebble down towards it with tremendous velocity. It dashed down through the cloudy wrappers in a white-hot glow from its speedy journey, splintering into many pieces and falling to ground in sparklets. Then people who witnessed its fall cried out, "A meteor! a shooting star!" and rejoiced at the sight; whilst the more superstitious wished for something as they saw the body shoot along. But our little stone lay at peace after a pilgrimage, which may have lasted millions of years, through the nebulosities and past huge worlds which we see only as small stars, and lay embedded in grasses and flowers in a globe unknown to the depths it came from. It is one of these tiny splinters I wear in my scarf-pin, and it must be conceded that its past is an interesting one.

Stones from the Heavens.—A stone from the skies! How odd it sounds and how long it took to convince natural scientists that stones *did* fall to earth from the heavens! The chronicles from the very earliest times talk of "shooting stars," but the wise men of the eighteenth century were still far from placing the correct meaning on this familiar phenomenon. The falling of matter from the stellar regions, accompanied by fiery appearances, has been represented on an old Babylonian drawing, and we know that the holy stone of the Mohammedans in the Kaaba at Mecca is a meteoric stone that fell to earth from space. Diogenes tells of "stony stars that flew to earth in radiant trails," as, for instance, that of Aegospotamoi that fell in 476 B.C. Pliny mentions it and says the "star" was as large as a cart! References to meteoric stones can be found in the Bible, for in the Book of Joshua we read that "God sent large stones from heaven." The Greeks and Romans looked upon the pitching of stones on to earth as a little private amusement indulged in by the gods from time to time; several of these stones thrown down by the gods had temples erected to them. The "Stone of Diana" at Ephesus, the "Stone of the Sun-God" at Emesa in Syria, the stones at Thebes and Crete were meteorites that descended amid fire and thunder.

Showers of Meteorites.—There are accredited cases in the Middle Ages when "great fiery balls" were seen darting through the sky, from which a stone, or even a whole shower of stones, fell to earth amid thunderclaps. An event of this kind occurred in Saxony in 823, extending over an area including several villages, and doing a great deal of damage. Pater Benedict writes of another shower that took place at Narni, in Italy, in 921, and gave rise to a terrible panic. A great fall of masses of iron from a cloud in rapid motion happened at Meissen, in Saxony, on Whit Sunday, 1164. The stones are still religiously preserved in a number of cases, and mineralogical examination has demonstrated that these masses of stone and iron have a meteoric character. The remarkable shower of meteoric stones on November 7th, 1492, that descended at Ensisheim, in Alsace-Lorraine, at 11.30 A.M., was carefully noted by the chroniclers, and a piece of the stone that weighed three cwts. or so can still be seen in the village church. An account placed next to the stone states that the noise was deafening and was heard for many miles around. The meteorite fell into a cornfield, from which it was dug out, but not until a number of pieces had been hacked off by pilgrims. "But the learned men say they know not what it be, for it be supernatural for such a stone to fall out of the air, except it be a wondrous deed of God such as had never before been seen, or heard, or written of. As one found the stone, it lay half a man's height buried in the ground, and this be a token that it be God's will that it be found. And the noise was heard at Lucerne, at Pfullingen, and many other places so loud that the people feared the houses had fallen in."

Meteor Showers in Modern Times.—Meteor masses have fallen to earth in more recent days as well. The tremendous rain of stones at Aigle, in France, on April 26th, 1803, suddenly awakened the conviction in the majority of natural scientists that, instead of its being an atmospheric phenomenon, the occurrence was due to astronomical or cosmical reasons. This was at a time, however, when Chladni, the eminent physicist, had greatly impressed the world by his writings. Three thousand stones fell at Aigle, some of them weighing 16 to 18 lbs. Eye-witnesses plainly saw a small, dark cloud move rapidly along, which presently divided amidst a series of detonations as loud as the discharge of a cannon. A rattling noise followed, and then a shower of stones came pelting down. Other cases of still more recent date are: A fall of meteoric iron at Braunau, in Upper Austria, in 1847 (two pieces weighing about 80 lbs.); a shower of stones at Stannern, in Tyrol, in 1808; at Butsura, in India, on May 12th, 1861 (Fig. 221); on June 6th, 1866, at Knyahinga, in Hungary (a thousand stones of a total weight of 9 cwts.); a fall of meteors at Gnadenfrei, in Silesia, on May 17th, 1879; a rain of stones at New Concord, in Ohio, on May 1st, 1860 (thirty stones together weighing 132 lbs.); at Pultusk, in Poland, on January 30th, 1868; at Brescia, in Italy, on February 16th, 1883, when a meteor weighing 440 lbs. fell amid loud thunder-claps; a large iron meteorite, on March 27th, 1886, at Johnson's Creek, in Arkansas.

Panic in Madrid.—Wild excitement was caused by a meteoric shower at Madrid on February 10th, 1896, which an eye-witness describes as follows:—"This morning at exactly half-past nine, during beautifully sunny weather, a bluish glow of such power overspread the sky that even the sunlight was dimmed and people in the streets were dazzled. A minute and a half later a thunderous cracking was heard, as though thousands of cannons were being fired off simultaneously, and then followed a series of ever-lessening explosions. The earth quivered, buildings showed sudden rents, furniture was hurled about, and millions of window-panes were cracked. A terrible panic ensued, shrieks and cries of 'Terremoto! terremoto!' ['Earthquake!'] were heard on all sides, mingled with yells of 'Dinamita!' as others feared a revolution had broken out and that some Government building had been dashed into the air. But mankind was not to blame for the concussion; it was caused by a tremendous meteoric stone bursting over the city. The Madrid

Fig, 221.—Meteoric Stone of Butsura.

The watch illustrates the size of this stone.

Fig. 222.—Meteoric Stone found at Ovifak, Greenland.

Fig. 223.—Meteoric Stone, found by Peary, being conveyed to Brooklyn.

Fig. 224.—Meteoric Stone with "finger marks."

(Now in the Court Museum, Vienna

Observatory kept a careful watch on the appearance, and reported that, at the time stated above, a long, narrow streak of smoke drew near in the clear sky from south-west, moving in an east-north-easterly direction. The smoky trail, that had the shape of an extended ellipse, was perfectly white at its borders, but of a darker, ruddy hue in the centre. When the cloud was almost in the zenith, it exploded, and a shower of stones fell over Madrid and its environs. If the time elapsed between the flash and the detonation (a minute and a half) be taken as a basis, the explosion must have occurred at an altitude of about 18½ miles. The larger mass of the meteorite turned into dust and vapour, and was driven eastwards by the top layer of the air-currents. Four hours elapsed before the cloud entirely vanished from the east-north-easterly horizon. It is very difficult at present to attempt to determine the size of the celestial body until more definite details come to hand. The shower of stones resulting from the explosion of the meteorite seems to have fallen thickest in Vicálvaro, a spot quite close by, then in Vallecas and around the Madrid Hippodrome. Señor Cos and Señor Aguilar, of the Observatory here, picked up a particle of the meteorite on the road leading to Castellon; this had been seen to fall by several people. Don Pedro Esteban, an apothecary of Vallecas, was wounded on the forehead by a stone the size of a pea. Señor Soravilla was walking on the Castellana, busy reading his newspaper, when a fiery ball suddenly darted down from the sky and made a hole in the paper, scorching its edges; it then rolled on for about forty yards along the ground. The stone resembles a piece of sulphuric iron; it is of regular shape, and weighs about five and a third ounces." The reporter then went on to describe the many accidents due to shock that happened in Madrid and the neighbourhood.

Giant Meteorites.—Sometimes the blocks are enormous, at other times only tiny particles reach the earth in these meteoric showers; two of the largest masses of meteoric matter known are reproduced here. Fig. 222 represents a boulder of almost pure meteoric iron found by Nordenskjöld at Ovifak, Greenland, in 1870; it weighs close on 24½ tons. The stone shown in Fig. 223, of a like nature, was found by Peary in 1894 and conveyed to Brooklyn; it is about 3¾ yards in length and weighs nearly 37 tons.

Disputed Origin.—We have already seen that scientists, until the nineteenth century, could not accept the theory that these stones came from the skies. It was granted, as the utmost concession, that terrific gales might break off pieces of rock and carry them away, finally dashing them down to earth; volcanoes might also shoot stones into the air for some distance, but in every case a terrestrial origin was postulated. When the Paris Academy of Science received a report signed by three hundred eye-witnesses of a meteoric shower at Juillac, in Gascony, at 9 P.M. on July 24th, 1790, the learned corporation was shocked at such "muddled brains seriously believing that masses of stone could fall from the celestial regions."

Chladni's World Splinters.—At last a most eminent scientist, the German physicist Chladni, went thoroughly into the whole question, and in 1794 staked his reputation on the opinion that these structures originated in space. In a pamphlet that appeared in 1819 on "Fire Meteors and the Masses that Fall Down from Them," he drew a picture of the origin and nature of meteors that was exact in all its principal points. He wrote to this effect: "Besides the larger celestial bodies—the suns and planets—untold masses of small and most minute particles, which might be fragments of shattered celestial bodies, exist in the universe, but which far more probably have shaped themselves independently out of small collections of matter, just as the larger bodies were formed out of large masses. Ay, perhaps these tiny bodies constitute the remnants, the crumbs that remained over, when the large bodies were formed." Taking up the latter standpoint, Chladni named these minute bodies "world splinters." According to him, these splinters wander through space in all directions in countless millions, sometimes singly, sometimes in swarms. When they arrive within the circle of the earth's attraction, they are forced to rush to the larger sphere. Cold and dark in themselves, they grow heated and red-hot by the powerful friction with the earth's masses of air, through which they dart with tremendous velocity. If the intruders are very small or very distant, they do not give rise to any interesting sights; if, however, they are larger masses, penetrating deeply into the atmosphere of the earth and falling to its surface, a so-called ball of fire can be witnessed, sometimes even outshining the brightest of planets, and illuminating the night for an instant or so. These larger formations are called meteors. A part of the falling mass vaporises and glimmers away into fine, ashy dust in the air, but if it be of considerable size, larger portions fall to earth in the shape of meteoric stones or iron. These theories of the great physicist have been confirmed by later researches. Chladni also pointed out that comets must stand in a certain relation to shooting-stars and meteors, a view that was further established by the investigations of Schiaparelli, etc., in the middle of the nineteenth century.

Shooting - Stars and Fire Balls.—There is no generic difference between shooting-stars and meteors (balls of fire); the first are very tiny particles, entirely dissolving in the air and turning into gas and dust; the others are larger pieces, that do not vaporise as easily, and present most interesting light effusions in their fall. A radiant meteor in the act of explosion and surrounded by numerous shooting-stars is illustrated in Fig. 232. Careful scrutiny of shooting-stars has revealed the fact that some of them are possessed of a small tail, visible from five to twenty seconds after the body proper has died away. This tail consists of glowing ashes or dust that slowly evaporates and falls to the earth unnoticed. Researches have distinctly proved the continuous fall of dust from space; a greater part of meteoric matter consists of iron, and Nordenskjöld found traces of such incessant falls of iron dust on the untrodden snowfields of Greenland, where frequently the snow bore a rusty yellow hue from the action of the iron. Nordenskjöld had large quantities of snow melted, and in every case small heaps of iron dust remained. Occasionally the decks of ships in the Pacific or the South Sea, remote from land, are thickly covered every morning with ferruginous dust, although they had been swept at night; this dust is partly of a volcanic, but principally of a meteoric, origin. The author once attempted to catch meteoric iron dust by means of very powerful electromagnets placed in open spaces far away from traffic, with the poles rearing into the air. These attempts were not very successful, as a certain quantity of iron dust floats about emanating from factories, foundries, main traffic arteries, and so on. Nevertheless, a certain periodicity is noticeable if the mass of the magnetically-caught iron dust at stated times of the year be exactly determined, a periodicity in harmony with that of the regular recurrence of meteor showers, of which more anon.

Abundance of Meteors.—It is commonly supposed that the number of meteors entering the earth's atmosphere is inconsiderable; this is a great mistake. Given a clear view and pure air, an average of ten meteors or shooting-stars can be counted within an hour. But as a single observer can only see about the fourth part of the sky visible to him, an average of forty meteors per hour may be reckoned for any certain spot. Calculated for the whole of our earth, a total of 400,000 results for the hour; in twenty-four hours, therefore, about 10,000,000 meteors pierce our aerial strata. These must mostly be very minute particles, but still they may in time call forth certain changes on earth. According to M. W. Meyer, each one of these particles weighs 77 grains, which is a rather low estimate, and yet the weight of the earth must be increased by about 4,500 million pounds every century through this incessant fall of meteors. At the lapse of sundry thousands of years this increase of the earth's volume should act on the rotation of the sphere and cause a slight alteration in the length of day. Whether this influence will be counteracted by other agents is a different question.

Meteoric Dust.—As I have already stated, meteor fragments of all sizes whirl about in space; some are really gigantic, but, happily, there are so few of these that thousands of years may elapse before one falls to earth. Others are of the size of the boulders discovered by Peary and Nordenskjöld, and so on, down to the more usual little bodies visible as "shooting-stars." Some are even smaller, the size of peas or dust particles. We know as a fact that the earth at times meets large clouds of finest meteoric dust, slowly descending on it. Considerable showers of meteoric dust occurred in Scandinavia on May 3rd, 1892, the total weight being estimated at 500 tons. The shower of dust at Yeniseisk, in Siberia, in 1881, was of smaller dimensions. Exceptional interest was attached to the fall of dust in the thickly populated districts of South Italy on March 13th, 1813. Huge black clouds turned day into night, and the frightened people flocked to the churches for protection. Dust of a brick-red character fell in torrents, and in some places small meteorites were found later.

Iron and Stone Meteorites.—The constitution of these meteoric masses has been very closely investigated, and two principal groups set apart—iron meteorites and stone meteorites. These latter (Fig. 224) chiefly contain stone found on earth, such as chalk and clay, earth silicates, magnetite, olivine, chrome iron ore. Iron meteorites (Fig. 225) usually consist of about 90 per cent. of pure iron and 8 per cent. of nickel, with slight quantities of phosphorus, copper, silicon, and carbon. A special feature of iron meteorites are the so-called Widmannstetten figures (Fig. 226), which appear when a piece of the metal has been planed, polished, and treated with sulphuric acid. If meteoric stones be heated and the escaping gases examined, they will throw in the spectroscope similar lines to those of comet gases.

Of the Constitution of Meteors.—So we see that even these masses, coming from the farthest depths of the universe, contain substances found on earth, a fact fraught with great significance, as it sanctions the conclusion that the same laws operate throughout, and that creation, formation and development are in the main governed by the same principles.

Meteoric Finger-marks.—No organic traces have as yet been determined in meteoric stones. As already stated, the meteoric masses become glowing and luminous in penetrating the atmosphere of our earth. According to all we know, the temperature of the universe is an extremely low one, and may be set at 120° Celsius below zero. Meteorites, when broken into pieces, on touching ground have been found to be intensely cold inside. A black crust generally forms around the mass, owing to the sudden development of heat, and often bears marks similar to those produced by pressing the fingers into soft putty or plaster. Such "finger-marks" are plainly visible in the meteoric stone in Fig. 224, which belongs to the large and valuable meteorite collection of the Vienna Court Museum.

Speed of Meteors.—Before entering on an explanation of the incandescence of meteors, we have to consider their rate of motion and the altitude at which they first become visible. The speed at which they travel seems at first to differ greatly, but research has shown that these differences are only apparent, being occasioned by the proper motion of the earth. A train travelling at a rate of twenty yards per second towards a stationary train will naturally dash into it at the rate of twenty yards per second. If the other train is moving at fifteen yards per second on the same track and in the same direction, the first train will still run into it, but only at a velocity of five yards in the second. If, however, the second train were travelling at a fifteen-yard speed towards the twenty-yards train, the collision would take place at a speed of thirty-five yards per second. Our earth may be compared to the train in motion; it moves at a rate of about eighteen and a half miles per second. The motion of meteors in open space at our distance from the sun is probably, in most cases, about twenty-five miles per second. Those meteors that fly towards the earth from "the front" appear to meet our atmosphere (as the motion of earth and meteor combine for us) at a velocity of about forty-four miles a second. The meteors flying "behind the earth" and trying to enter the "back way" only enter the terrestrial atmosphere at a speed varying from six to twelve miles a second.

Courses of Meteors.—That is why some meteors describe such extraordinary curves in the sky. The author once noticed a group suddenly appearing high on the horizon, and apparently not running on at all, but standing perfectly still—in reality, it was moving straight towards the observer. It then slowly effected a queer, almost horizontal curve, and finally did not shoot downwards, but upwards, towards the zenith. Many meteors travel in zigzag and serpentine lines in the sky (Fig. 227), which are explained by the explosive forces during the incandescence of

Fig. 225.—Iron Meteorite with Polished Edges.

(Now in the Court Museum, Vienna.)

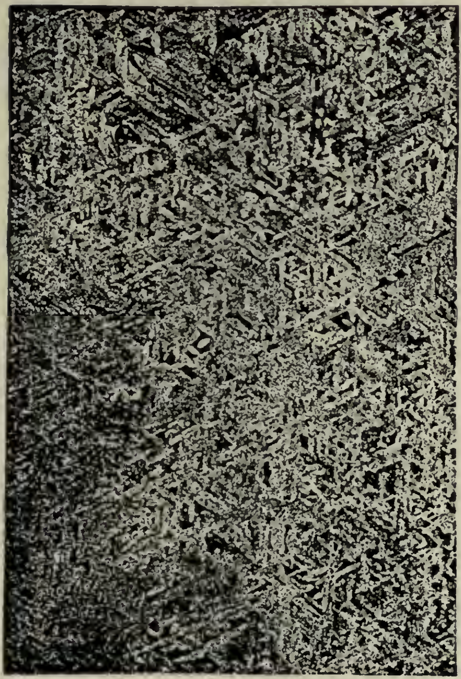


Fig. 226.—Widmannstetten Figures seen in Iron Meteorites.

Fig. 227.—Serpentine Path of a Meteor.

Fig. 228.—Flying Meteor.

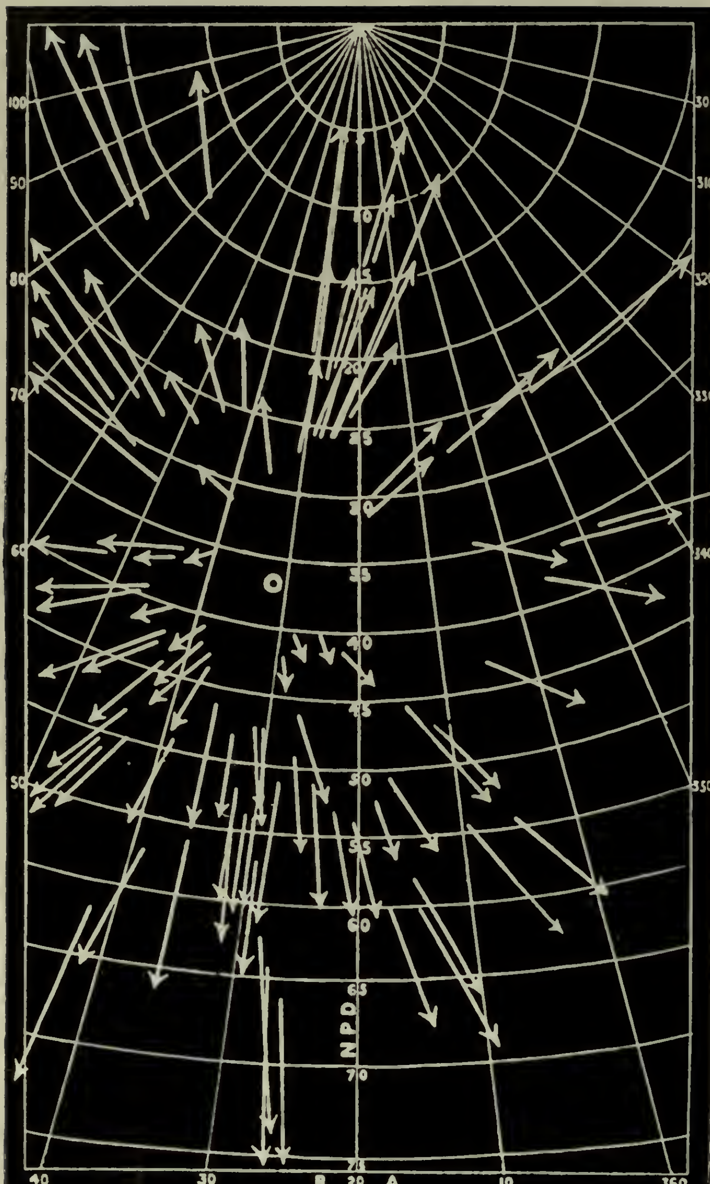


Fig. 229.—Radiant Point of the August Meteors.

Fig. 230.—Meteor Ring. (S, Sun.)

the meteor. Otherwise there is but little of interest in a meteor in flight (Figs. 228 and 53). The rapidity of its motion prevents observation in the telescope.

Height and Incandescence of Meteors.—The altitude at which shooting-stars and meteors are first noticeable has been very exactly determined. They generally flare out at seventy-four and a half to ninety-three miles above the earth, and die away at a height varying from fifty-six to sixty-eight miles. It used to be disputed whether our atmosphere could produce mechanic effects at such altitudes, fifty miles being set as the utmost limit; but the meteors themselves have taught us otherwise, as it is the resistance offered them by the air that forces them to radiate. Everyday things show us the resistance offered by the air to intruding matter. Recall our own schooldays, when the swish of the cane produced a state of great depression within us! The swish or whistle of a body flying or swung through the air is a result of air resistance. The faster the air is cut or compressed, the stronger the resistance. Most meteors enter the atmosphere of our planet at a velocity fifty to one hundred times greater than that of a shot. The aerial friction and the heat resulting from the air compression must therefore be very large, sufficient to set the small bodies into a glow. Added to this is another very important fact. It has been noticed for some time that the falling meteor masses do not strike the earth's surface with the terrific impact to be expected from their immense speed. Small meteoric stones have been found on a frozen sheet of water, whilst the force of a pistol-shot cracked the ice. Nor do the larger ones enter the soil as deeply as their velocity would lead us to believe.

Air Resistance and its Effects.—This is explained by the fact that meteors soon after entering our atmosphere almost completely lose their speed as a result of the air resistance they encounter. The air acts as a buffer to these bodies; a kind of air-cushion rapidly forms beneath the meteor, hampering, nay, almost entirely annulling its speed, and so the very fast motion possessed by the meteor is cut short not many seconds after it has entered the aerial strata of the earth. Of course, this enormous active force cannot be lost, although its action, hitherto one of progressive motion, has been retarded, for Nature's chief law is embodied in the doctrine of the conservation of energy. The retarded forward motion of the whole mass changes to molecular action —that is, the most minute particles of the meteorite are set into very fast vibratory movements, which induce a sudden and powerful rise of the stone's temperature. The stone grows white-hot, and the gases contained within come to an explosion, producing a flaring-out of sparks in the larger masses and the breaking away of numerous particles. At the instant a large meteor explodes (Fig. 232), it has reached stagnation point for the time being; henceforth the attractive forces of the earth alone act on it, and the meteor falls to earth with increasing speed, exactly like an ordinary body. It is quite easy to calculate the speed of its fall. Supposing the meteor to travel towards us at a rate of thirty-two miles per second until a distance of fifty and a half miles from the earth's surface is reached, these fifty and a half miles will be traversed under the influence of the earth's attraction. The meteor's speed, at first 0, is 10½ yards after the first second has passed. It will take 128 seconds to traverse the 50½ miles, the final rate being 1,373 yards per second—double the rapidity of a shot. This is not allowing for the resistance of the air, so a somewhat longer time for the fall and a lessened final speed are most probable.

Why most Meteors Fall in the Morning.—The fall of meteors is not equally numerous day and night. In the winter, when the dawn does not greatly influence the sky until about 6 A.M., few meteors are visible before "that hour o' night's dark arch the keystane," and gradually increase in number after midnight, until the highest total is seen towards four, five, and six o'clock in the morning. Let me explain the reason of this. Should it rain heavily when there is no wind, the rain will fall perpendicularly, and, if we stand without moving, beat down on all sides of our body, front, back, right and left with equal force. If we were to break into a run, we should catch more rain-drops with the front of our body than with the other sides, because we are rushing towards the falling drops. The front of a cannon-ball flying through a swarm of gnats will catch most insects on the side that first enters the swarm, and similarly the side of the terrestrial globe that heads through space must meet with most meteors, since it catches the greater part of them. Fig. 231 explains why this happens at 6 A.M. E represents the earth, and the curve A B a part of the earth's orbit, the arrow indicating the direction in which the earth

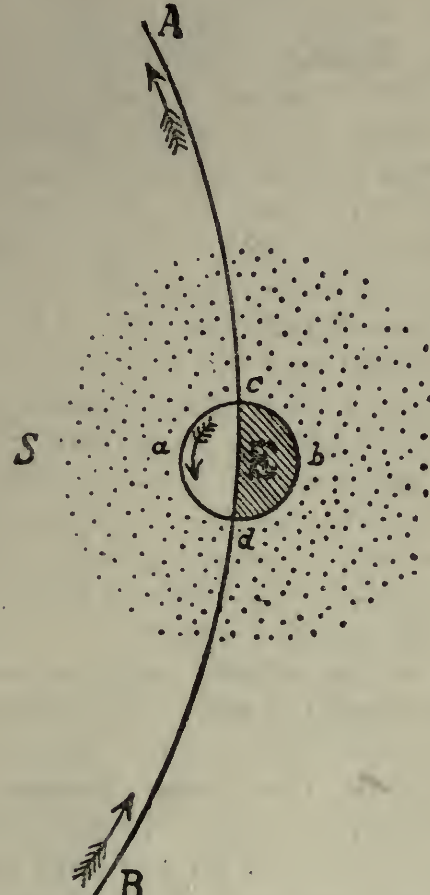


Fig. 231.—Diagram explaining the Frequency of Meteors in the Morning.

moves. The sun is far away in the direction marked S, and the hemisphere turned towards it is illuminated. The observer is imagined to be floating above the terrestrial North Pole; at point *a* it is 12 noon on earth, at point *b* midnight; at *c* it is 6 A.M. and at *d* 6 P.M. The spot where it is 6 A.M. lies on the "heading" portion of the earth in its orbit around the sun. Meteors fly towards the earth from all quarters; but as the earth's forehead encounters all those coming from the front, all the places situated there, and especially point *c* (6 A.M.), will witness the largest number. When, twelve hours later, this spot has arrived at *d* (6 P.M.), the smallest quantity of meteors will be visible, as this part of the globe is now protected against all meteors coming from the front, and only those travelling faster than the earth itself can strike it, coming from B.

Swarms on Certain Days.—The daily variation in meteor falls is explained, as we see, by the rotation and motion of the earth, but the extraordinary abundance of meteors on different days of the year is quite another matter. Far more meteors than usual fall in the nights from August 8th to 13th, November 10th to 14th, April 19th to 21st, November 26th to 28th, and on a few other dates. Should their trails then be carefully observed and set down on a stellar chart, the starting-point of all these meteors will be found in one and the same spot, whence they all appear to move (Fig. 229). This is called their radiant point; the radiant point of meteors falling on or about August 10th is in the constellation Perseus, and consequently these meteors are named Perseids. The meteors during the nights of November 10th to 14th radiate from the constellation Leo; therefore they are called Leonids. As the earth annually encounters these meteor swarms on the same dates, it proves them to wander around the sun in fixed orbits similar to that of our earth.

Meteor Rings in the Solar System.—The following points justify this hypothesis:—The earth every year arrives at a certain part of its orbit on a certain day. Let us take August 10th as an example. As it always encounters the Perseid meteors on this date, these would either have to remain perpetually stationary in the shape of a large cloud at this region of the earth's orbit, or form a huge ring (perhaps an ellipse), revolving around the sun. This latter conjecture alone is possible if we recollect that our whole solar system moves on in space, and that after a very few years' time our earth would have moved far away from a motionless cloud of meteors. Besides, the laws of celestial mechanics teach us that no body can remain immovable in our solar system; it must move around the sun in a

Fig. 232.—Shower of Meteors in the Mediterranean on November 27th, 1885.
(After a drawing by M. Eiffler.)

Fig. 233.—Facsimile of a Comet Broadside of 1580.

Fig. 234.—Appearance of a Comet of 1577.

(From an old print.)

circle, ellipse, parabola, or hyperbola. Immense meteor rings must therefore be in existence (Fig. 230), encircling the sun, and touching or intersecting the earth's orbit at different points. On the earth's reaching these points, "periodic" meteors become visible.

Enormous Showers of Meteors.—The meteor rings are not of equal thickness throughout, for sometimes, during the nights mentioned above, meteors in almost startling abundance occur, when all the world is attracted by the marvellous spectacle. The luminous sparks play about in the skies for hours, from 2,000 to 4,000 having been counted within sixty minutes. Fig. 232 shows us one of these periodic showers. On November 27th, 1872, 14,000 fell in Rome within five hours and a half, 7,700 at Göttingen within three hours, 900 in a quarter of an hour at Münster, and so on. Humboldt and Bonpland witnessed a meteor shower of exceptional beauty on November 12th, 1799, at Cumana, in South America; the date tells us it must have been the Leonid shower. Humboldt wrote: "Thousands of fiery balls and shooting-stars fell incessantly for hours. There was no piece of the sky the size of three diameters of the full moon that did not simply swarm with them throughout."

Native chronicles inform us of a similar occurrence on the same night in 1766, and it was calculated that another such phenomenon might be expected for 1833; this prediction was fulfilled, and the glorious spectacle was repeated in 1866 as well. The ring of the Leonid meteors must contain one especially dense spot (as indicated in Fig. 230) which touches the earth's orbit every thirty-three years. We may take it as granted that the whole Leonid ring completes its revolution around the sun once in every thirty-three years. Similar facts have been arrived at concerning the Perseids and other meteor rings. It is probable that this thick spot or nucleus consists of the main swarm, and that from it the meteors spread out over the whole ring, which will eventually attain uniform thickness.

Connections between Meteors and Comets.—Schiaparelli investigated the orbits of such swarms of meteors, and made the remarkable discovery that they move in precisely the same orbits as some of the well-known comets. The Perseid orbit is also that of the third comet of 1862, whilst the Leonids move in the orbit of Comet I of 1866. Other cometary orbits identical with those of meteor swarms are also known. This interesting discovery apparently solves the mystery of the comets. The nucleus of a comet would appear to consist of a vast cloud of meteor particles; the cloud appears to us in its entirety as a comet at the great distance it travels at, that is, as a more or less large radiant spot or a small luminous plane. The separate particles forming the nucleus of a comet in their millions are in reality so far apart that when the earth passes through the cloud they are seen as a shower of meteors. A comet's tail is of an entirely different consistency, but it seemingly develops from the nucleus. We shall return to this subject in the next chapter.

It is not unlikely that the meteor masses have not originated in our solar system, but come to us from the fixed-star regions. Entering the realms of our sun, these meteor-clouds or comets were in part forced to describe fixed routes around it. Thus meteoric stones are really comet fragments, pieces of those dreaded tailed stars that so often set the world a-tremble. After a pilgrimage lasting millions of years through the immensities of space, they come to their well-earned rest in the cabinets of our museums.

CHAPTER XXIII

COMETS AND THE FEAR THEY CAUSE

A Comet in the Middle Ages.—We are now going to hark back a few centuries. It is a fine spring evening, and the scene is laid before the city walls. The heavy iron gates ordinarily long closed at this hour have been left open for the last few days, by order of the High Council of the town, and all is agog to catch a glimpse of the horrid comet shape announced for this period. The City Fathers, with "wigs weel poothered as guid as when new," leaning on their tall, golden-headed canes, and accompanied by the swaggering figures of the officers of the municipal guard, have taken up their stand on a hillock, under a poplar tree. Close by are the men of letters, the physician and surgeon, the dominie, apothecary, and librarian. Master craftsmen and apprentices in their leather aprons and caps, women and children, burghers of all ranks stand about in little groups, the more respected pressing forward as far as they dare to where the council and the learned men congregate, in order to catch a word or two concerning the tailed star that has been hovering for days past in unequalled splendour above the town. Darkness gradually closes in, the stars begin to make a brave show, and now, a rustle passes over the waiting crowds, deep down on the horizon a bright trail darts into view. It rises higher and higher, grows longer and longer amid ever-increasing radiance, and, at last, when the tail has crossed half the sky, the head becomes visible, a brilliantly luminous star, dimming all others and even vying in radiance with the moon herself. The bellringer who first spied it tugs at the ropes, the tower bells peal out in long, clear tones. All eyes are riveted on the glorious appearance that seemingly captured all the heavens for itself. A curious group forms around the oldest inhabitant, an aged, white-haired man, who remembers the fearful plague of 1618, "which was caused by the giant-tailed star we saw that year," and who tells in quavering accents how the Black Sickness carried off whole families, how nobody dared to approach the hundreds of dead bodies lying about, and how the doors and windows of the stricken houses were bricked and boarded up and left alone with their awful contents. Cold shudders run down the spines of his listeners, watching the radiant "scourge of God" in fear and trembling.

Tales of Comet-caused Disasters.—The surgeon tells the learned gentry how, when one of the largest comets in the history of our earth was seen in 1577, there was a general dying of men and beasts, as the poisonous comet-vapours spoilt all the water in the wells, and withered the grass in the meadows. Then the apothecary remembers having read that during the appearance of the 1582 comet in Denmark, numbers of misshapen children of hideous aspect were born to whom the clergy refused the holy rite of baptism, and who were called "Comet Children." One of the magistrates —a level-headed, shrewd man, who has devoted some time to the study of the stars—does not believe that comets can influence human life and welfare, speaks of the immense distance which even these tailed stars, that seem to approach us so closely, are away from the earth, and says that it is impossible for their tail even to graze the earth, and that vapours could not descend from them. The oldest inhabitant, who in passing has caught a sentence or two of this refutation, chips in most emphatically with the assertion that he himself saw thick vapours coming from the comet of 1618 and resting for days on the surface of the earth; and, although the dominie pronounces them to have most probably been dense mists, the more timorous swallow the experience of the dotard rather than the wisdom of the learned man.

A Comet Placard.—The City Fathers have resolved meanwhile to print a "Comet Fly-leaf" (Fig. 233), which is to contain all that is known of comets, and in which the inhabitants of the town are to be exhorted to lead a modest and God-fearing life, and to recognise that the Lord had sent the threatening tail of this comet star as a warning that He is a jealous Lord, Who will punish all evil deeds with war and plague, with drought and barrenness, should the warning sign which He has sent forth be disregarded. A discussion arose on the coinage of a comet medal, to bear a view of the town on the one side, with the comet hovering in the air, and on the other the inscription :

"This star of dreadful deeds does tell—
Put faith in God and all is well."

The guardian at the gates blows a long blast on his horn, as a signal that the time has arrived for their closing, and the burghers obediently turn homewards, the City Fathers walking far behind at a lordly pace. Bad news has arrived from the capital: there are rumours of war between Sweden, France, and the Electorate. Surely the evil star above is but a foreboding of a long, desperate war. Troubled and harassed, the council pass through the iron gates that close behind them with a clang, and once more, before entering their homes, a last look is taken at the uncanny stranger above, which continues its course in majestic grandeur and calm.

This pen picture is a fairly exact account of the commotion and upset which prevailed everywhere when a comet came into sight in those days; and Figs. 233, 234 and 235 pictorially illustrate the horror and awe, or it might be merely the curiosity, which was aroused in the minds of simple folk two or three hundred years ago by the appearance of a comet in the heavens. Apart from a very few enlightened persons, the beauty of the unwonted spectacle presented by a brilliant comet went unnoticed, fear and trembling, anticipation of dire misfortune seizing the people during the whole duration of the comet's visit, to the exclusion of any other sensation.

Cometary Wickedness.—All the wickedness a comet was deemed capable of working is told by the chronicler Wolfgang Hildebrand in 1690:

"Whene'er a comet doth appear,
Come mishap, want, sorrow, and fear;
And never hath a comet's sheen
Without great evil yet been seen.
These dire ill-fortunes do ensue

When a comet appears to view—
Fever, sickness, plague, and death,
Hard times, need, and hunger's scathe,
Great heat, drought, and barren Nature,
War, murder, riots, fire, and slaughter,
Frost, cold, storm, and want of water;
For high folk death or humble lot;
Ill winds and earthquakes in many a spot.
Such mishaps everywhere arise
When comets course across the skies.
Repent we now in earnest prayer
God may ward off all harm and care."

Misfortunes occurring during the visit of a comet were set down to its baleful influence, and it was held responsible for the most divers happenings, such as are set forth in the following extracts from old chronicles:—"In 1668 a large comet star appeared, and there was a great dying of cats." It may be the cats would have died without the assistance of the comet, but it was handy to blame the unfortunate wanderer through space for this disaster. We read at another time that a "terrible comet came into view and everywhere cattle sickened and died." A Roman historian joyfully declares in 1538 that, "Fortunately the comet has not brought any ill-luck in its train this time, excepting that it happily (!) occasioned the birth of a two-headed calf in a village near Rome." As Mädler caustically remarks, at a time when there seemed to be a decided want of heads, a being with two must have caused an undoubted sensation!

Harbingers of Woe.—Comets were generally regarded as harbingers of evil, heralding war and plagues, and the death of kings, with which in those despotic days international and civil warfare were closely connected—days of deepest superstition, exorcisms, conjurations and witchcraft. In 1664 a Polish nobleman informed a friend that the "comet of the fifteenth instant is still to be seen, and the old star-gazer, Zorawski, has given out his opinion on the great changes and confusions that will arrive in case his Imperial Majesty does not, in his abounding grace and bounty, forget and forgive the misunderstanding hitherto existing." The same person, writing later from Vienna, says: "It has been newsed here from Spain that a monster has been discovered in the mountains of Castilia la Viega, said to be thirty feet long and four high, shaped half like a man, half like a crocodile and a satyr, with horns,

Fig. 235.—Facsimile of an Old Woodcut of the Comet of 1528, symbolising War and Murder.

with a comet and four letters. . . . Special messages received from Grätz tell of a splendid dagger which was seen there in the sky in broad daylight on April 24th." Fear acted on the imagination of the people to such an extent that all sorts of shapes were given to comets; they were frequently drawn resembling swords, daggers and dragons surrounded by horrible creations (Fig. 235).

Another extract from a mediæval chronicle recounts that: "Early in July, 1223, a so-called comet star was seen, a sign of a disturbance of the kingdom; King Philip lay sick at Mantua at the time, and died on July 14, 1223." The Paris Museum contains a comet medal struck in 1619; it shows, on one side, thousands of people kneeling on the ground, addressing supplications to the Almighty, whilst a comet floats above them; the words, "God grant that this comet teach us a betterment of our lives, 1619," are inscribed on the other.

Precautionary Measures.—All possible precautions were taken to rob these wicked comets of their harm. Days of general repentance were set apart in 1665 by Duke Eberhard of Würtemberg "on account of the doleful comet star, so that our Lord God may not chastise us with the punishments He intends for us." When the French entered burning Moscow in 1812 a teacher who had remained behind informed them that a catastrophe had been long predicted, "as a comet had shone out most horridly over the city"! As far back as 371 B.C. the inundation of the towns of Helice and Bura was said to be the act of a comet, and an English physician as late as the middle of the nineteenth century had all the wells in his district covered up, to save the water from being contaminated by the poisonous exhalations from a comet. In 1829 a surgeon named Forster wrote to the effect that "it is an undoubted fact that since the commencement of our time-reckoning those years in which many comets appeared were the most unhealthy—in healthy times larger comets have never been seen."

Fears of a Cometary Collision with the Earth.—Latterly this kind of childish superstition has died out, and in its stead the fear of a collision between the earth and the comet has sprung up, frequently almost verging on a panic. The idea gradually spread that comets did not move in fixed unalterable paths, but that these things, which differ so much in appearance from ordinary well-behaved stars, were naught but celestial vagabonds, ruffians seeking trouble and picking quarrels with all decent members of the stellar family. But, as in most terrestrial countries, law and order

Fig. 236.—Donati's Comet at its greatest radiance (October, 1858).
(From a drawing by M. Eiffler.)

Fig. 237.—The Giant Comet of 1843.

(From a drawing by M. Eiffler.)

must reign in Urania's immense realm, if it is to continue to exist.

The World's "Whipping-Boys."—Our present-day instruments point out more than 500,000,000 stars in the skies. Innumerable comets traverse the universe, and, if everything were not regulated according to inexorable law, the stars and starlets would be free to roam about at their own sweet will. Everlasting hustling and jostling would result, ending in a general upheaval, and it would take Dame Nature all her time to put things shipshape again. We know that the stars have run their lawful courses for thousands, nay millions of years, and that collisions between celestial bodies, of which mankind has so unreasoning a dread, are almost totally impossible. The comets are the "whipping-boys" of the world, and accordingly much mischief, of which they are innocent, has been set down to their account. On the whole, they are such harmless, timid, nay even poor-minded things, that I must say a few words on their behalf, and tell the story of their remarkable existence, and show that, still partly wrapped in mystery, they are the most interesting celestial bodies we know of.

Donati's Comet.—It would seem as though comets consistently shun those quarters of the solar system in which mother earth revels, for since 1882, when the last conspicuous comet aroused admiration, few large really brilliant and prominent comets, visible to the naked eye, have appeared. There have been the great southern comet of 1901, the daylight comet of 1910, and Halley's comet in 1910. Older folk may recollect the wondrous beauty of Donati's comet,* which rendered the sky during September and October of 1858 so imposing a sight. People rushed to the open to see the mighty comet and its long, beautifully curved tail (Fig. 236).

The Comet's Tail.—The chief feature of a comet is its tail, and this imparts to it its magnificent aspect, besides being the cause of much racking of brains in astronomical, or rather astrophysical circles; it remains an unsolved problem even to this day. Comet tails can be enormous in length. The tail of Donati's comet was, at its fullest development, larger than the whole constellation Ursa Major;

* Comets are usually named after their discoverers.

the comet itself was then 62,000,000 miles away from the earth, and its tail extended over a distance of 52,819,000 miles.

The Giant Comet of 1843.—The giant comet of 1843 (Fig. 237) was even larger. Long and narrow in shape, it stretched over the whole of the sky like the ray emitted by a huge search-light. Even when its head was buried below the horizon, the tip of its tail was straight above the heads of the admiring crowds collected everywhere on the Northern hemisphere to watch the fiery rod, in which many saw a symbol of God's wrath. This immense comet had a tail 155 million miles in length; what this really means will be more comprehensible if we remember that the earth is only 92½ million miles distant from the sun.

Number of Comets.—But such very grand comets are most uncommon; the general degeneration so loudly complained of on earth seems to have extended to comets as well, for those of the last few decades were rather feeble affairs. One or two small comets (Fig. 238) are nearly always in the sky, for the number of these structures is exceptionally large, close on 900 comets having been seen within historical times, while twenty are known to be constant members of the solar system.

Telescopic Comets.—The comets of the last few years were generally so-called telescopic comets—*i.e.* only visible in the telescope—and solely interesting to the astronomer, who quietly traced and, if possible, photographed their movements in his observatory. Such photographs are seen in Figs. 239 and 240, the latter offering a somewhat extraordinary aspect and demanding an explanation. The light of such telescopic comets is so weak that instantaneous photography is utterly out of the question, and the plates have to be exposed for at least an hour or so to obtain a good picture. During this time the comet has moved on beneath the stars, and the photographic apparatus attached to the telescope has had to be turned by clockwork at a rate corresponding to the celestial motion of the comet to enable the latter to act unchangingly on one and the same spot of the plate. The stars meanwhile have remained stationary, but as the apparatus was moved they do not

Fig. 238.—A Small Comet.
(From a photograph.)

Fig. 239.—Perrine's Comet on October 29th, 1902.
(From a photograph taken at Lick Observatory)

Fig. 240.—Telescopic Comet (Perrine's, 1902).
(From a photograph taken by I. Roberts.)

Fig. 241.—Head of Coggia's Comet (1874).

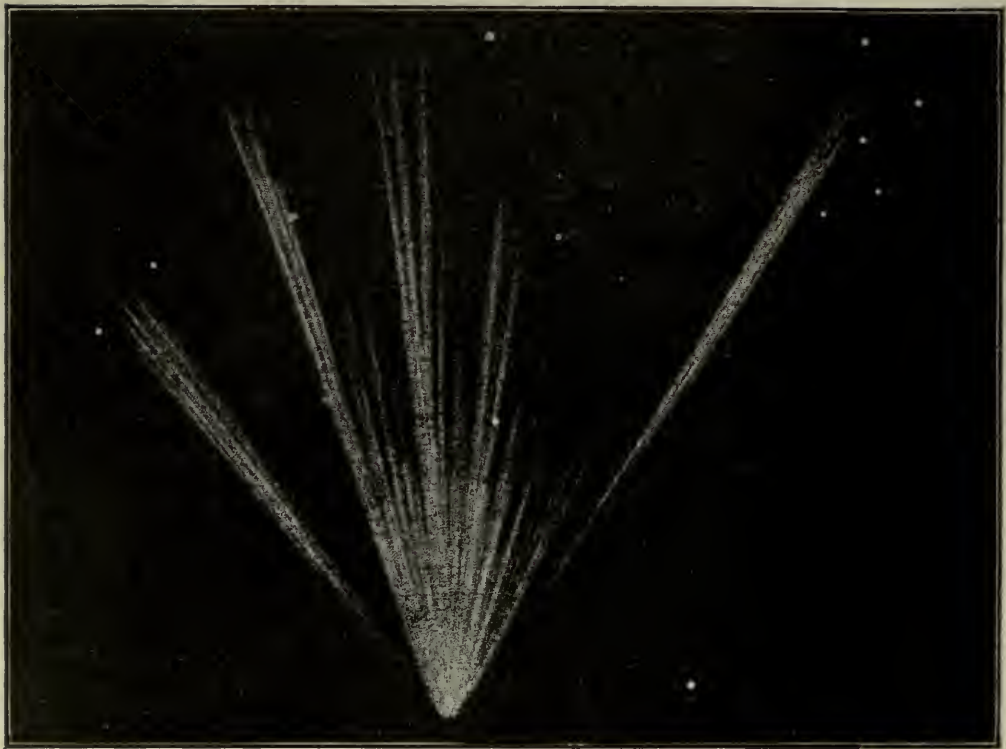


Fig. 242.—Five-tailed Comet of 1861.

(From a drawing by M. G. Williams.)

Fig. 243.—Spectrum of a Comet.

By way of comparison the spectrum of carbon is shown above it.

show as sharply-defined dots, but as lines instead, just as the flame of a street lantern would take the shape of a line if the camera were moved on in a straight direction during the act of photographing. The telescopic comet in Fig. 239 possesses a decided tail; tailless comets are not unknown; indeed, the tail of comets only begins to form on approaching the sun. All comets, even the very largest, are, when discovered—that is, when still immeasurably far away—only small dim clouds of light, which an experienced eye alone can sight and differentiate by their motion from the nebulæ which they resemble, but which are of quite another nature. A very remote comet like an undefined nebulous patch, and without a firmly outlined tail, is seen in Fig. 240.

The Three Parts of a Comet.—A comet is divided into three principal parts:—(1) The "nucleus," a bright, almost star-like patch of light, surrounded by (2) a less radiant vaporous envelope, the "coma," which together form the head of the comet, and (3) the tail, which joins on to the head. Fig. 241 illustrates the head of Coggia's comet.

Changes and Transformations on Approaching the Sun.—The closer a comet (whose discovery and position in the sky are immediately telegraphed to all observatories, so that astronomers may pursue its every movement) approaches the sun (and the earth, too), the more its entire formation changes. All kinds of alterations take place in its head, alterations which, for the most part, still remain a mystery. The sun, or rather the energy emanating from it, is the cause of these transformations, which principally relate to the nucleus, for the matter forming the tail and the beauteous nebulous envelope is sent forth from the nucleus.

Matter Constituting Comet Tails.—The tail invariably forms itself on that side of the comet turned away from the sun, and always remains in this position, no matter what movements the comet carries out (Fig. 244). Smaller comets, or such whose orbit does not lead them close to the sun, are not very conspicuous objects. Sometimes, however, these bodies approach so near to the sun that they almost graze its surface, as, for instance, the comet of 1882; and, if they are large comets into the bargain, a gigantic tail develops like those possessed by the 1843 comet and Donati's comet. Comets have been known to own several tails, five (Fig. 242) and seven having been counted. Donati's comet also had a second tail, as closer inspection of the illustration (Fig. 236) will show. This comet allowed the development of its tail to be observed in all its various stages. The closer the comet moved towards the sun the more intense the emanations from the nucleus grew, at first surrounding it in the shape of semi-circular ribbons of light (similar to those around the nucleus of Coggia's comet), and then rapidly extending to form a tail. The extent of these emanations may be best judged from the fact that within forty-eight hours a bridge of light about 9,000 miles in length poured from the nucleus of Donati's comet.

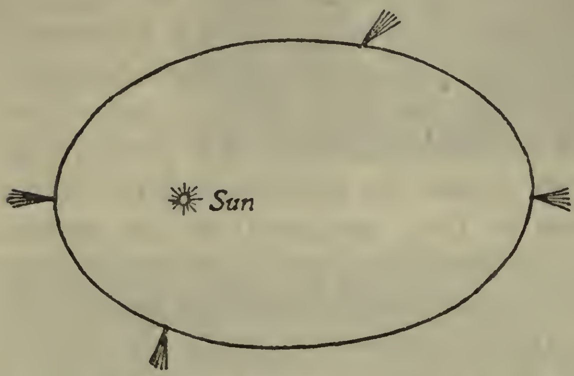


Fig. 244.—The Tail of a Comet is always turned away from the Sun.

Minute investigation of comet tails has shown them to consist of almost incredibly fine thin matter. We have already mentioned their extent, but even the tiniest stars obscured by a cirrus cloud shine out through the tail of a passing comet, which has a thickness of many millions of miles; so the matter forming the tail must be of such fineness that, despite this circumstance, it yet remains as transparent as glass. We know of no gas of like fineness; our own air, for instance, would be absolutely non-transparent in such masses, and the matter composing the tail must be far, far thinner than the terrestrial atmosphere.

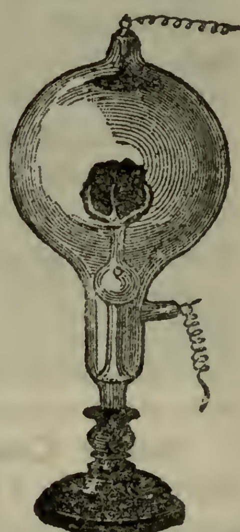


Fig. 245.—Cathode Rays Tube.

It is very difficult to express an opinion of the matter composing the comet's tail, as, on the one hand, it presents several purely physical features and, on the other, is seemingly a weightless, bodiless something (Fig. 243). It were best to class it with the weirdly beautiful Northern Lights, and with the lighting of the air in the cathode-ray tubes through which an electric current is sent (Fig. 245). Scientists know that the matter forming the tail, which always keeps on the side away from the sun, is repulsed by the sun, and this almost makes it a certainty that electrical forces are at work. Observations have fully proved that the sun sends forth electrical forces.

Development of Comet Tails.—The development of comet tails may be presumed to be as follows :—The nucleus of the comet consists of solid masses of stone and metal, as we shall very shortly see; it is surrounded by a gaseous envelope, the coma, which the spectroscope has revealed to consist of carbo-hydrogen gases. On the comet approaching the sun, the rise in temperature forces increasing quantities of gas from the nucleus, spreading over a space gradually lengthening. On the principle that two bodies loaded with equal electricity repulse each other, the gases under the influence of the sun's action must be driven in a direction opposite to the sun. Electricity most decidedly is produced by the rapid expulsion of gas from the nucleus, and it is not at all unlikely that the radiance of the comet's tail is of an electrical nature. The influence of the sun turns the nucleus, so to say, into a cathode—the pole in the airless glass-tube from which the mysterious cathode light (the "cathode rays") emanates—and in so doing produces the luminosity of the tail.

The Comet's Lack of Density.—The lack of density of comet matter is verified by another important circumstance. We know that all bodies in space attract each other; the sun attracts the earth and the earth the sun. As the sun is more powerful than the earth, possessing far more matter, the latter is dependent in all its movements on the sun. The moon, on the other hand, having less mass than the earth, is subservient to it. If a body of greater mass than the sun were suddenly to appear in our solar system the earth would in all probability (presuming the strange body approached as closely as the sun does to the earth to-day) forsake the sun to follow the new and more powerful star. Comets have come extremely close to the earth on frequent occasions, but none has ever influenced it even to the least degree. When in 1770 Lexell's comet approached quite close to us, it was computed that, if its mass equalled that of only the 5,000th part of the earth's, it would so disturb the motion of the earth as to shorten the year by two seconds. Not the slightest disturbance was noticed; but, on the other hand, Jupiter, into whose realm the comet unwisely ventured, pitched the celestial vagabond entirely out of its course. Bodies of such slight mass cannot be very formidable, and this fact alone stamps the general fear in which comets were held as perfectly groundless. How would it be, though, if a comet were not only to approach the earth, but to collide with it? Before replying we will find out how comets move in space.

Comet Orbits and their Motion in Space.—We have learnt of the existence of periodic comets, returning at predicted intervals. The orbit of one of these is shown in Fig. 117, and we can list twenty such to-day, all observed during various reappearances. They move around the sun in fixed orbits, differing however in shape from planetary orbits. Whilst the latter closely resemble a circle, the orbits of comets are generally elongated ellipses, or parabolas and hyperbolas (Fig. 246).

The position of several cometary orbits to that of our earth is illustrated in Fig. 247, where S is the sun, E the earth in its almost circular orbit around the sun. The whole orbits pursued by Encke's and Biela's comets are visible, but those of Halley's and Olbers' comets are far more drawn out. Each planet circles round the sun without much variation in its distance from it, but the orbit of comets, as a closer examination of Fig. 117 shows, varies enormously. Halley's comet, which returns every 76½ years, is at perihelion only 54,000,000 miles away, but at aphelion its distance increases to more than 3,100,000,000 miles (Fig. 248). Still more astonishing is the orbit of the comet of 1680, which approaches the sun within 150,000 miles and recedes unto 80,000,000,000 miles! At perihelion it travels at a velocity of 341 miles per second, and at aphelion at only four yards per second. This remarkable traveller journeys forth into endless space, and needs some 9,000 years to complete a revolution.

There are comets that never again return to our solar system after they have once paid us a visit amid great pomp and splendour, like some illustrious foreign potentate, the

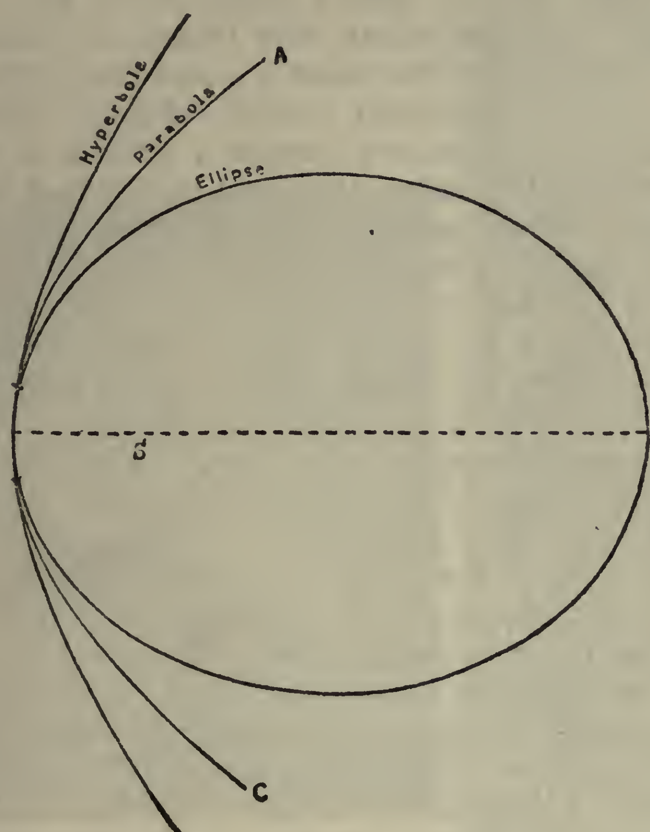


Fig. 246.—Ellipse, Parabola and Hyperbola.

cynosure of all eyes. They then journey away into the infinite void of space, where the suns are milestones and finger-posts which the wanderer meets with but once in millions of years. These stellar bodies are never beheld again; their orbits are open curves which the mathematician terms parabolas and hyperbolas, whose two branches diverge ever farther from each other (Fig. 246).

Halley's Comet.—One of the most interesting of all periodic comets is the one named after the English astronomer, Edmund Halley, who, in calculating the orbits of various comets in 1705, came to the conclusion that a comet of 1531, a comet of 1607, and a comet of 1682 must have described very nearly the same course. The idea was suggested that it might be one and the same body which completed its orbit around the sun once every seventy years or so. He worked out its next period, and predicted its return for 1758, the first time a reappearance had ever been prophesied His calculations were revised by Clairault and Madame Lepaute, and the comet's return determined for the spring of 1759. A peasant named Palitzsch, who was an ardent student of astronomy, caught a glimpse of the comet near Dresden in December, 1758, and in March of the following year it reached perihelion as predicted. Later it was discovered that the comet had been seen at every return since the year 87 B.C., and that its return at the expiration of every seventy-six years or thereabouts had been chronicled by various archivists. It appeared to time in the autumn of 1835 (Figs. 249, 250), and its next visit was calculated by Pontecaulant for the spring of 1910, when it arrived punctually. It reached perihelion on April 19th, after being visible in the telescope from the previous autumn. On May 18th it came so close to the earth that in all likelihood we stood within the tail of the comet. Although it was not a very conspicuous object, appearing as a faint nebulous cloud, yet a splendid view of it was obtained in the fields and open spaces far away from any disturbing artificial light, the object being clearly visible without external aid (Fig. 250A). Fig. 251 shows the oldest pictorial representation of Halley's Comet from the Bayeux Tapestry. On the right King Harold is represented deploring his defeat at Hastings and attributing it to the presence of the "evil comet," at which, on the left, several people are gazing.

Meeting of Earth and Comets in the Earth's Orbit.—Among the comets wandering around the sun in fixed orbits are some whose courses touch that of the earth at a certain point. If earth and comet were to arrive at this point at the same time, a collision would be unavoidable, as there would be nobody present to attend to the "points." The earth would very properly insist on its priority, and that the younger of the two must turn out; the comet, however, like all comets, extremely scatter-brained, knows no considera-

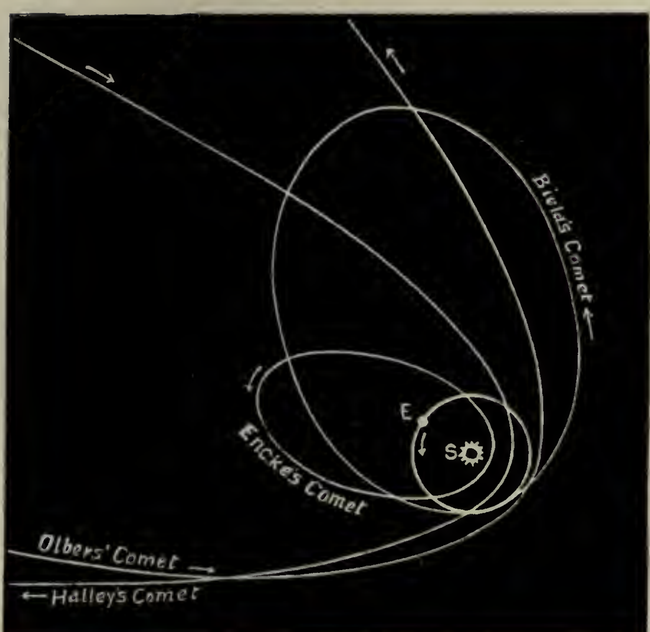


Fig. 247.—Position of the Orbits of several Comets relatively to that of the Earth.

Fig. 248.—Orbits of Halley's Comet and of the Earth.

Fig. 249.—Halley's Comet in 1835, seen by the naked eye.

(*After Sir John Herschel.*)

Fig. 250.—Details of the Head of Halley's Comet of 1835.

(*After Sir John Herschel.*)

Fig. 250a.—Halley's Comet, as seen at Madrid, 1910.

Fig. 251.—Oldest representation of Halley's Comet.

(*From the Bayeux Tapestry.*)

tion, but owing to its extremely small mass it is unlikely that any serious mischief would result. There would doubtless be a thick rain of meteors, which might cause some casualties, but every inhabitant of the earth learns at a very early date that his life is run at his own risk. The above conditions really do exist in a few cases. Biela's comet approached the earth's orbit within a distance of two earth diameters, the tail extending far past it. The return of the comet was predicted for 1832, when general fear prevailed that it would mean the destruction of the earth. In the universal panic the fact was entirely overlooked that, although the orbits of both bodies may approach each other very closely, this does not invariably mean that they must reach the point in question at one and the same time. As it happened, the comet passed the "junction" on October 29th, 1832, and the earth arrived on November 30th. The earth has frequently encountered the tails of comets; for instance, in 1861, when it met the tail of the June comet. Nothing happened, excepting a delicate misty gleam in the sky and a number of shining shooting-stars.

Latest research, especially on the part of Schiaparelli, has established the fact that we meet with comets or the fragments of former comets several times a year, particularly on those August and November nights mentioned in the previous chapter.

Biela's Comet and its End.—Biela's comet, said to be fraught with untold danger for our earth, greatly assisted in establishing these decisions. It completes its circuit in six years and three-quarters, and has reappeared several times, true to the dates appointed for it. A most remarkable feature was noticed on its return in 1845; the comet appeared to be visibly ailing. It drew itself out more and more, and at the end of December of that year it suddenly divided in two parts, which proceeded singly through space (Fig. 254). When it put in a punctual appearance in 1852 the two parts had drawn still farther away from each other, a space of over one and a half million miles separating them. It should have come again in 1859 and 1866, but it stayed away and was given up for good. Nevertheless, it was believed that if it were still in existence it might be seen again in October, 1872, and all the telescopes in the world began to search for it, but in vain. But on November 27th, 1885, the day on which (as explained) the earth reached that point of its orbit intersected by the cometary orbit, a wondrous phenomenon occurred. A shower of meteors, numbering many millions and of great brilliancy, was witnessed, lasting for many hours. It was immediately surmised that Biela's comet and this swarm were identical, and a few days later the Madras Observatory informed us that this fleeing clouds of meteors, through which the earth had passed, had been observed on the opposite part of the heavens in the shape of small comets.

Connection between Comets and Meteors.—As Biela's comet presented itself on November 27th, 1885, in the guise of a meteor swarm, once more we are led to the final conclusion, strengthened by the results of investigations made with other comets, that a comet is naught but a huge conglomeration of minute meteor matter, particles of shooting-stars, and these in turn are, as we know, stones and minerals, as a visit to our museums will teach us, stones that fall to earth from space, as we discussed in Chapter XXII. Only the nucleus can consist of such, however, the tail being formed out of layers of the thinnest of gas. According to Schiaparelli, a cloud of meteoric stones, such as the nucleus of a comet is composed of, must in time disintegrate and strew itself over the whole orbit, forming, in so doing, a meteor ring like the one shown in Fig. 230. This ring will be thickened in one place, where the former nucleus of the comet rests. Every comet is apparently destined for destruction; and should the earth happen to pass through a point of the cometary orbit at a favourable time, a beauteous meteor shower is all we shall finally behold. If it traverse the thick part of the meteor ring, the showers will be particularly magnificent. This occurs at regular intervals. Every thirty-three and a quarter years the earth meets the nucleus of the meteor ring whose showers we annually witness from November 10th to 14th, the Leonids. So once in every thirty-three and a quarter years shooting-stars are especially numerous during these nights.

So far from justifying the alarm and dismay that they excite, comets are very delicately constituted, and much shorter-lived than is a steady-going planet. The earth passes through their tails like a cannon-ball through a cloud of smoke. In 1857 and 1873 a terrible panic ensued on the return of a comet being announced; and even Halley's harmless comet in 1910 gave rise to an exhibition of nervousness, hardly in keeping with the advance of science. Let us hope that the next time a large comet shall appear in our sky—which it may have visited many thousands of years ago, when totally different races and grades of civilisation reigned—the expectation of witnessing so interesting an astronomical spectacle will predominate to the exclusion of all unworthy sentiments.

CHAPTER XXIV

HOW TO FIND ONE'S WAY IN THE SKIES

An Open Book with Golden Letters.—The starry sky has often been likened to an open book in which the stars formed the golden lettering—a pretty and apt comparison indeed. To all who have mastered the art of reading this book a wondrous tale of world-creation and world-end is unfolded, but unfortunately only few are able to decipher the starry hieroglyphics, and even these few cannot always put the proper construction on what they have read. Really, everybody ought to study this marvellous book, even though they acquire little more than a knowledge of the alphabet, how to spell out the titles of the chapters, and thus at any rate learn the nature of the contents.

Before entering on a description of the constellations, and telling how best to find them and the easiest way to commit them to memory, we will take a general survey of the heavens. This may not be very interesting at first, but it is imperative.

Terrestrial and Celestial Spheres.—Every child knows that the earth is not the centre of the universe, and that the latter is not a huge hollow globe. It appears to be one, for the sky everywhere seems a vast hollowed dome of which but the one half is visible, the other being hidden by the earth itself. Our earth apparently floats in the centre of the hollow globe. The fact that all this is but apparent is of no importance just at present; indeed, it were better for the sake of easier comprehension to imagine it really the case, and we will retain this belief for the moment.

This apparent state is shown in Fig. 252; the large outer circle represents the celestial sphere in which the earth floats. Now, we have in our imagination covered the earth with a fine network dividing it into numerous degrees, as any ordinary globe of the earth will show. The astronomers have drawn a like network on the celestial sphere, dividing the heavens into different zones, readily to determine the position of the stars, just as the geographer can immediately find any spot on earth when he knows its longitude and latitude.

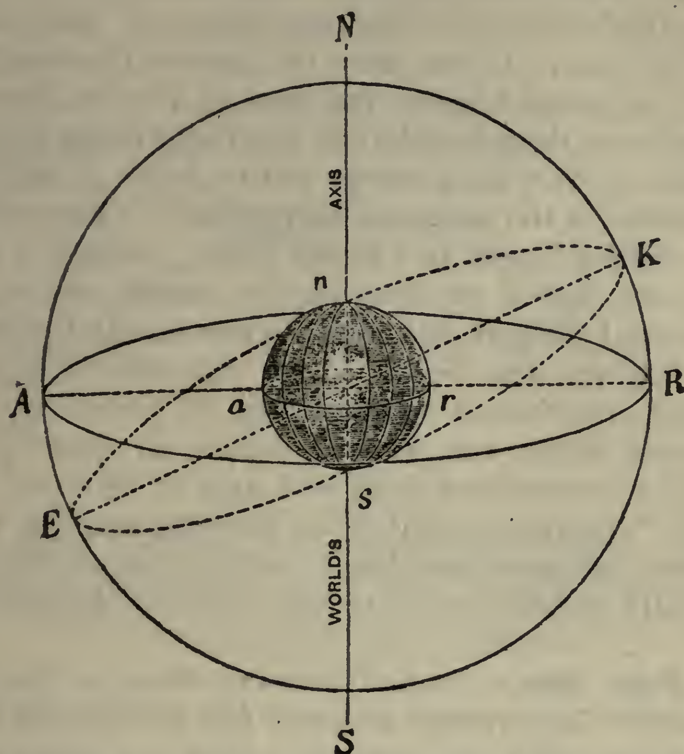


Fig. 252.—Circles and Lines on the Terrestrial and Celestial Spheres.

The Poles and Equator of the Earth and Heavens.—It is clear that the network of degrees on earth can be continued to the skies, for if we imagine the circumference of the earth in the diagram to be extended to that of the celestial sphere, the same lines will be found there as on the terrestrial globe. Points *n* and *s* on earth are the terrestrial North and South Poles, and the corresponding spots N and S on the celestial globe the North and South Poles of the heavens. The circle *a r* on earth is the equator, the letters A R in the sky the celestial equator.

The Ecliptic.—The dotted circle E K, whose plane forms an angle of 23½° to the plane of the celestial equator, is the apparent path the sun pursues in the sky in the course of a year. We call this orbit the ecliptic, and know it to be only the reflection of the orbit the earth really describes around the sun.

The Celestial Axis.—The line marked *n s* is the earth's axis; its two ends, the North and South Poles of the earth, only rotate around themselves, whilst all other places on the earth's surface carry out larger or smaller circles around the axis. If we were to observe the evening sky carefully, we should notice the stars to rise in the east and set in the west; there is only one fixed spot in the sky around which all the other stars rotate, so to speak. A similar condition obtains in the southern hemisphere. These two points are the celestial North and South Poles, marked N and S in the diagram, and if we continue the earth's axis *n s* right to the celestial globe it will meet the two celestial poles. The terrestrial North and South Poles, the earth's centre, and the celestial North and South Poles, all lie in one straight line around which the whole celestial structure seems to turn. This tremendous shaft and axis of rotation, the line N S of our diagram, is called the celestial axis; in reality it is only the continuation of the terrestrial axis, for the rotation of the earth deludes us into crediting the sky with a like motion.

The Pole Star.—To find our way about in the sky it is of the utmost importance to know the position of this axis in connection with the spot at which we happen to be. Polaris, the Pole Star, is stationed at N, the celestial North Pole. We must now imagine the northern end of the terrestrial axis to point straight at the Pole Star, and that if the axis really were a solid bar and had received a sound blow on its southern end, forcing it right out of the earth, it would fly at and strike this star. In short, the Pole Star stands in the continuation of the terrestrial axis. People who have travelled a great deal will have noticed that the Pole Star stands at varying altitudes above the horizon, seen from different parts of the globe. At the terrestrial North Pole the star would be exactly above our heads, at the zenith; the farther we wander away from the North Pole the more it sinks, and at the equator it lies on the horizon.

Geographical Latitude.—The height of the Pole Star in the sky informs us of geographical latitude; we know it to touch the horizon at the equator where its height is 0°, and we have already learnt the geographical latitude at the equator to be 0°. At the North Pole the Pole Star stands at an elevation of 90°; the geographical latitude is likewise 90°. The altitude of the celestial pole above the horizon equals the geographical latitude of the point of observation.*

Armed with this knowledge we can decide the position of our own dwelling-place. Take Berlin as an example of

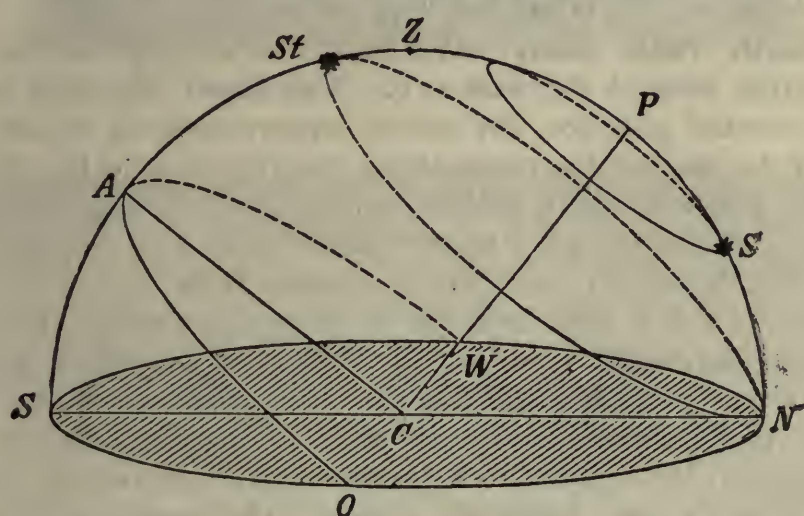


Fig. 253.—Positions of the most important Celestial Points.

how this is worked. The shaded lines of Fig. 253 mark the horizontal plane of Berlin, and we are stationed at C; Z is the zenith above us, N the north and S the south point of the horizon. As Berlin is 52½° N. latitude, the height of the Pole is 52½°; the celestial North Pole is therefore stationed the same number of degrees above the northern horizontal point N. The sky rises up above our horizontal plane like a huge halved globe, and we can determine the altitude of the Pole with instrumental aid and the help of our diagram. Point P is 52½° above N; this point must therefore be the celestial North Pole, and the straight line P C is the world's axis. The lines P C and N C form an angle of 52½° at C.

* As the Pole Star is not stationed exactly at the North Pole, but 1⅛° away, it is at a certain time 1⅛° lower than the celestial North Pole and twelve hours later 1⅛° higher, as it revolves around it once in 24 hours.

The Celestial Equator.—After having established the position of the celestial North Pole and the world's axis so far as our point of observation is concerned, we must now discover that of the celestial equator. The plane of the celestial equator forms a right angle with the world's axis, as is perceptible in Fig. 252. In Fig. 253 we have to draw a line from C of the world's axis leading rectangularly towards the sky, thus forming the line C A. To our vision the semicircle O A W is that part of the celestial equator above the horizon; the other half lies below it.

North Polar Stars.—We must now imagine all the stars to circle around the axis C P. The closer the stars are to the celestial pole (or, for easier comprehension, to the Pole Star) the smaller the circles they describe around the world's axis. Thus S only describes a very small circle, S*t* a larger one, and the stars on the celestial equator the largest one of all. Now, all stars farther away from P, the celestial pole, than the star marked S*t* do not complete their full course above the horizon, as the circle described by this star already touches the horizon at its lowest point. Stars of a North Polar distance of more than 52½° do not perform their entire revolution above the horizon of Berlin. All other stars, however, remain perpetually above the horizon and are termed North Polar Stars. Of course, these vary according to the latitude of the place of observation, but all stars are reckoned to belong to this circle of perpetual apparition whose polar distance is at the utmost as great as the latitude of the place. For Berlin the amount is 52½°, for Stockholm 59⅓°, for Madrid only 40⅓°, and so on. At the North Pole all visible stars, *i.e.* all stars north of the celestial equator, belong to this circle, but at the equator the circle has ceased to exist; the latitude here is one of 0°, and the North Polar distance would therefore have to be 0°; not even the Pole Star belongs to the North Polar stars seen from here!

A Map of the Northern Constellations.—To show how the circle of perpetual apparition differs for various places, I have prepared a map of the northern constellations divided up into circles (Fig. 255). The outermost circle marked with the figure 5 encloses the constellations seen at St.

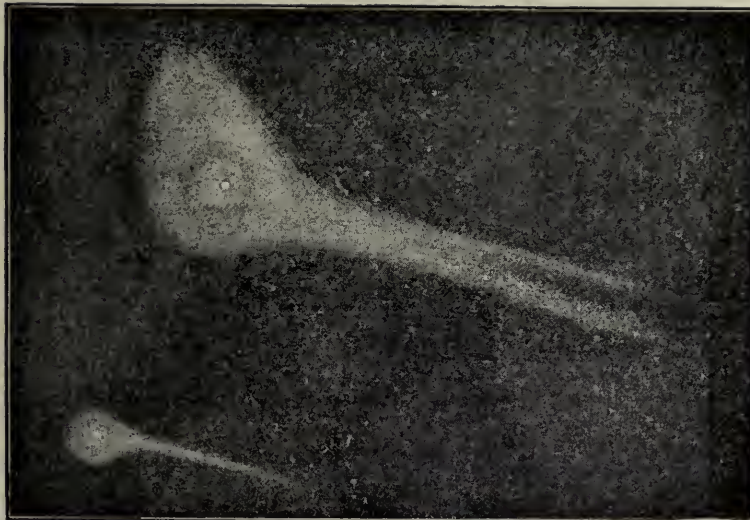


Fig. 252.—The Divided Biela's Comet at its return in 1846.

(*After Struve.*)

Fig. 255.—Chart of the Northern Constellations.

(*From a drawing by the Author.*)

Fig. 256.—Part of a Star Map of 1660.

(*After Andreae Cellarius.*)

Petersburg, 60° N.; all the stars, from the Pole Star down to the Heavenly Twins, are above the horizon the whole of the year for the Russian capital. Circle 4 holds good for Berlin; No. 3 contains the North Polar stars, as seen at Paris; and No. 2 those seen at Rome. Gibraltar, 36° N., only enjoys the aspect of a very few stars; those of circle 1, and the central ring, within which only four stars are visible to the naked eye, contains all the northern stars seen at places of 10° N., Cameroon, for instance.

How many Stars can you See at Once?—Now that we know where and in what altitude to look for the celestial pole, the Pole Star and the celestial equator, we can turn our attention to the constellations themselves. The number of stars visible to the unassisted eye is generally set at far too high a figure. Ask whom you may how many stars are visible on a very clear night, and you can always reckon on "Millions!" "Countless!" "Hundreds of thousands!" for a reply. In reality a normal eye can only see at the very utmost 3,500 stars at one and the same time. If all the stars seen by a keen eye on the whole of the heavens, north and south, were to be counted, the figure may be doubled. A person of normal sight can therefore see, on an exceptionally clear night, about 7,000 stars. This number probably errs on the excessive side, and many observers pronounce the number to range from 5,500 to 6,000.

Magnitude of Stars.—Stars are divided into magnitudes according to their radiance; stars of the first magnitude are the brightest, but astronomers have to work with stars of the sixteenth and even the twentieth magnitude. Even the gigantic American telescopes go no farther than the sixteenth- and seventeenth-magnitude stars, those of the twentieth being recognisable only by means of photographic charts. The smallest stars visible to the naked eye belong to the sixth magnitude. According to Argelander, the heavens contain 20 first-magnitude stars, 65 second-, 190 third-, 425 fourth-, 1,100 fifth-, and 3,200 sixth-magnitude stars. Only about four-fifths of the entire heavens are visible in North latitude 53°, and we shall soon learn that with a knowledge of the stars belonging to the first, second and third magnitudes, one may find one's way about in the starry realms; those of the fourth may be included in very exceptional cases. So we have to deal with only 300 stars, and as these are grouped in constellations, it will be advisable to learn them by heart. It is not so complicated a matter as it might at first sight appear to find one's bearings in the starry realms.

Charts of the Constellations.—Attempts were frequently made in olden times to obtain a better view of the fixed-star army by joining conspicuously bright stars and groupings together by lines. The resulting figures, in which fancy affected to trace the outlines of animals, fishes and gods, were easily remembered, and acted as a celestial guide. It would seem as though the Chaldees first gave names to the twelve constellations forming the Zodiac, through which the sun wanders in the course of a year, calling them Aries, Taurus, Gemini, etc.; other constellations were named in the sixth century B.C. by the Greeks. It needs a decided effort of the imagination to discover the resemblance to a bull in this, to a maiden in that, or to Hercules in the other constellation, and on the old star charts the stars themselves are quite secondary considerations, elaboration in drawing being far more important, as a part of the old map reproduced here will show (Fig. 256). Such pictorial representations are now ignored; the celestial charts used by the scientific astronomer pay no heed to them, containing besides the stars themselves only a carefully-drawn network of degrees, determining the position of the stars in the sky according to the "right ascension" and "declination," corresponding to longitudes and latitudes on earth (Fig. 54). The statement "right ascension, 5 hours 49 minutes 58 seconds, North declination, 7° 23.4′," helps the astronomer to ascertain immediately the star in question, which in this case is the beautiful principal star Betelgeuze in constellation Orion.

The Northern Constellations.—The following is a list of the constellations visible in northern latitudes, some of the best known being shown in our illustrations: 1, Andromeda; 2, Aries (the Ram); 3, Auriga (the Waggoner); 4, Bootes (the Herdsman); 5, Camelopardalis (the

Giraffe); 6, Cancer (the Crab); 7, Canes Venatici (the Greyhounds); 8, Canis Minor (the Little Dog); 9, Cepheus; 10, Coma Berenice (Hair of Berenice); 11, Corona Borealis (the Northern Crown); 12, Cygnus (the Swan); 13, Delphinus (the Dolphin); 14, Draco (the Dragon); 15, Gemini (the Twins); 16, Hercules; 17, Cassiopeia; 18, Leo Major (the Great Lion); 19, Leo Minor; 20, Lynx; 21, Lyra; 22, Pegasus (the Flying Horse); 23, Perseus; 24, Pisces (the Fishes); 25, Serpens (the Serpent); 26, Taurus (the Bull); 27, Ursa Major (the Great Bear); 28, Ursa Minor; 29, Vulpecula (the Little Fox).

The Constellations on the Celestial Equator.—The constellations which stand partly on the northern and partly on the southern horizon are: 30, Aquila (the Eagle); 31, Cetus (the Whale); 32, Hydra (the Water Serpent); 33, Monoceros (the Unicorn); 34, Ophiuchus (the Serpent-Bearer); 35, Orion; 36, Sextans (the Sextant) ; 37, Virgo (the Virgin).

The Constellations in the Southern Hemisphere Visible in Northern Latitudes.—To dwellers in the northern hemisphere certain constellations of the southern hemisphere are visible, namely: 38, Aquarius (the Water-Carrier); 39, Argo Navis (the Ship Argus); 40, Canis Major (the Great Dog); 41, Capricornus (the Goat); 42, Columba (the Dove); 43, Corvus (the Raven); 44, Crater (the Beaker); 45, Eridanus (the River Eridanus); 46, Lepus (the Hare); 47, Libra (the Balance); 48, Pisces Australis (the Southern Fish); 49, Sagittarius (the Archer); 50, Scorpio (the Scorpion); 51, Sculptor; 52, Scutum Sobiescii (the Shield of Sobieski).

Separately named Conspicuous Stars.—Very conspicuous stars of a constellation have received separate names. An interesting little cluster of stars belonging to the constellation Taurus, consisting of seven or eight stars standing close to each other and visible to the naked eye, has been dubbed "Pleiades," or "Seven Stars"; the three stars standing in a straight line in Orion are frequently called "Jacob's Staff," and so on.

The Zodiac.—It is advisable to commit to memory the names of the Zodiac constellations through which the sun wanders in its apparent annual motion around the sky.

This yearly orbit is called the ecliptic, and the twelve ecliptic or zodiacal constellations are : Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricornus, Aquarius and Pisces. Fig. 257 shows the date on which the sun stands in the different constellations. When, for instance, the sun stands in the sign of the Goat on February 1st, neither this nor the neighbouring constellations are visible, because they are in the sky at day-time; but of this more anon.

Star Nomenclature.—In order the better to distinguish the different stars of any one constellation, they have been designated with the letters of the Greek alphabet, the most radiant star being marked with the first letter, the second brightest with the second, and so on. It is hardly necessary to know all these markings unless a thorough study of the sky is desired; but it will be useful to set forth a few which are frequently found in astronomical reports. But first of all I will write down the small (*i.e.* not capital) letters of the Greek alphabet :—

α	*Alpha*	ι	*Iota*	ρ	*Rho*
β	*Beta*	κ	*Kappa*	σ	*Sigma*
γ	*Gamma*	λ	*Lambda*	τ	*Tau*
δ	*Delta*	μ	*Mu*	υ	*Upsilon*
ε	*Epsilon*	ν	*Nu*	φ	*Phi*
ζ	*Zeta*	ξ	*Xi*	χ	*Chi*
η	*Eta*	ο	*Omicron*	ψ	*Psi*
θ	*Theta*	π	*Pi*	ω	*Omega*

The constellation Cassiopeia is shown with the stars marked as above in Fig. 258; it contains many other stars, but the most conspicuous only are set down here, as they alone strike the eye, and it is a grave mistake to note down too many insignificant stars on popular maps, as they only tend to confuse the student. These principal stars in Cassiopeia form a somewhat drawn-out W; the three brightest are marked Alpha, Beta, Gamma, the two following Delta, Epsilon, and the smallest star, a fourth-magnitude one, has been designated Kappa. The stars are called according to their lettering; the one on the extreme right is "Beta Cassiopeiæ," the lowest "Alpha

Fig. 257.—Signs of the Zodiac.

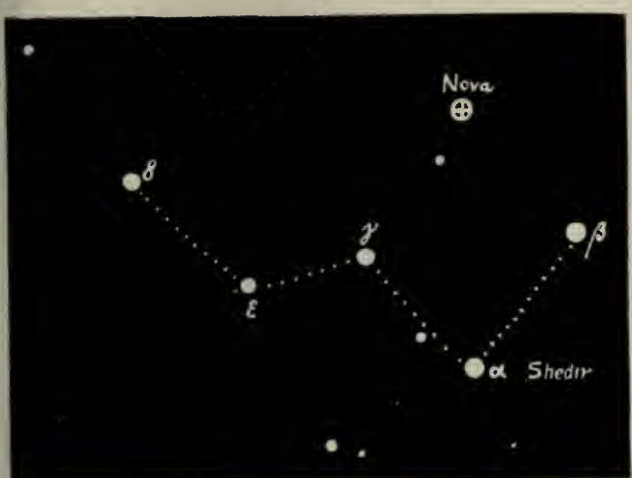


Fig. 258.—The Constellation Cassiopeia.

Fig. 259.—The Constellations Ursa Major and Ursa Minor.

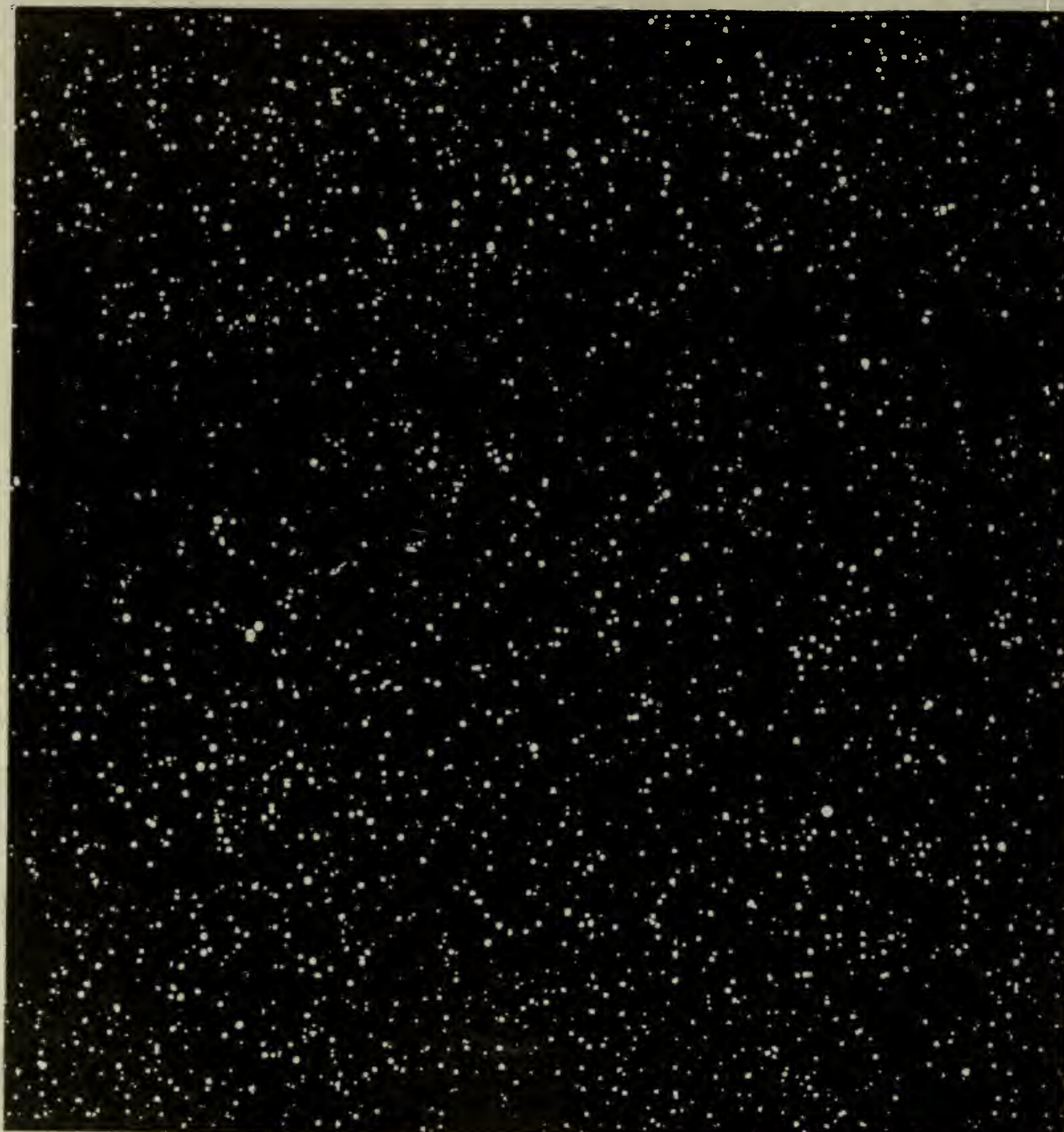


Fig. 260.—Portion of the Constellation Cygnus (the Swan) as seen through the telescope.

Cassiopeiæ." This star has an additional name "Shedir," which it received when the Greek lettering had not yet been introduced into astronomical work, and which, like the majority of the others, is of Arabian origin. Nearly all the more radiant stars have separate names, and it is as well to commit them to memory, as they are often used without any further designation. A list of the most important names follows:

Albireo is the name of star β in Cygnus; Aldebaran = α in Taurus; Algol = β in Perseus; Alcor is the name of an interesting little star in the Great Bear; Arcturus = α in Bootes; Altair = α in Aquila; Bellatrix = γ in Orion; Deneb = α in Cygnus; Betelgeuze = α in Orion; Denebola = β in Leo; Capella = α in Auriga; Gemma = α in Corona; Castor = α in Gemini; Mizar = ζ in Ursa Major; Pollux = β in Gemini; Regulus = α in Leo; Rigal = β in Orion; Shedir = α in Cassiopeia; Sirius = α in Canis Major; Spica = α in Virgo; Vega = α in Lyra.

A Star Atlas.—We have now learnt all that it is necessary to know to enable us to find our whereabouts in the heavens, and may begin to look up the positions of the constellations and their chief stars. The student would find a suitable star atlas of great assistance. A series of small charts which will help him to ascertain the position of the different stars will be found at the end of this volume.

To View the Midnight Sky.—Those who wish for a comprehensive view of the constellations and the principal radiant stars must choose a spot from which the whole of the sky is visible. No artificial light of a disturbing quality must be close by; streets in large cities are out of the question, as there even the brightest stars are dimmed or screened from sight. Poor townfolk who never have a chance of leaving their homes have a very slight acquaintance with the beauties of the heavens, and some of the oldest inhabitants may not even remember ever seeing a star. It is necessary, first of all, that a suitable standpoint should be chosen, a field or hill being best. The sky must be clear and dark, as the presence of bright moonlight obscures stars even of the fourth magnitude. The only outfit really required is a good handy chart (if possible one containing only stars of first to fifth magnitudes), and a pocket lantern with which to examine the map.

How to Find the Constellations.—In order to identify the stars and constellations it is necessary, first, to find the objects marked on the chart, which should be as perfect a copy of the heavens as possible. This may appear very easy, but is often fraught with difficulties. I will, therefore, give a few hints how best to attain this end.

How to Pick out the Circumpolar Stars.—First of all, learn the names and find the positions of those stars always visible and contained in the circle of perpetual apparition mentioned earlier in this chapter. They are all stars not too far away from the celestial pole, near Polaris, or the Pole Star. It has already been explained how this star is found. We now start from this known point in our search for the unknown. The best-known star in our regions is Ursa Major, the Great Bear. Even people not on bowing terms with the goddess Urania can point out this constellation. It is shown, as generally seen, in the lower part of Fig. 259; it contains a great number of other stars, several being marked on Charts I to IV. (*See* pp. 343 to 346.) The seven principal stars are there joined by dotted lines, forming a characteristic figure easily found in the sky. If all constellations are imagined as joined by such lines, it will be far easier to commit them to memory. All our charts are marked in this manner, and the figures which the stars suggest can be readily identified. Now let us look up other stars, aided by the old and trusty method of alignment, in which we connect known and unknown stars by means of straight lines. Extend the lines connecting stars α and β of the Great Bear for about five times this distance, and we shall strike the Pole Star (Fig. 259), the chief star of the constellation Ursa Minor. This configuration resembles the Great Bear to some degree, only on a much smaller scale. A glimpse at the star atlas will help in finding these two groups and thereby laying the foundation for further work.

Draco, the Dragon, is found at once (*see* Chart II), as its tail winds in between the Great and the Little Bear, and its three-cornered head is easily recognised in these star-impoverished regions. Below its head and rather farther away from the Pole Star is Hercules, a somewhat extended constellation not very strongly marked, with a cluster of faint stars. Lyra, standing close to Hercules in an easterly direction, is a most conspicuous object, with its first-magnitude fixed star Vega shining with a whitish-blue radiance. The striking shape of Corona Borealis, on the other (the western) side of Hercules, cannot be overlooked, and joining its semicircle is Bootes, with Arcturus glowing with a powerful ruddy hue. The region between Bootes and the Great Bear is rather poor in stars, only two radiant third-magnitude stars being found there and forming the small constellation Canes Venatici. If a straight line be drawn from the end tail star of the Great Bear to the Pole Star and continued for about as far again, it will end in the beautiful constellation Cassiopeia, easily recognisable by its W shape. Exactly between Cassiopeïa and the Dragon's Head is Cepheus, consisting only of third-magnitude stars. On Cassiopeia's other side lies Perseus, with its remarkable star Algol, or the "Demon," which is a variable star, shining as a second- and a fourth-magnitude star during a period of 2 days and 21 hours. Observers must not be led astray by these light-variations. It is of the second magnitude most of the time.

A straight line drawn from the Dragon's Head across the Pole Star leads to a radiant star belonging to the first magnitude; it is just as far off on the other side of Polaris as the Dragon's Head is on this. It is Capella in Auriga (the Waggoner), whose nearest neighbours are the Twins, with those bright objects Castor and Pollux.

Our Charts and their Use.—These are the most important of the circumpolar stars, or at any rate the constellations which are visible during the greater part of the year, and which have to be known. It is far more difficult to remember the constellations of the celestial equator and the zodiac, as they disappear periodically for months. Here a revolving adjustable chart showing the position of the stars for every day in the year is of the utmost value, as it will indicate the stars above and below the horizon at the time. The four charts at the end of this book suffice for all ordinary purposes, as they represent the aspect of the sky at the chief seasons of the year and at a suitable time. Chart I (p. 343) is dated for January 1st, 8 P.M.; the stars are in like position on December 1st at 10 P.M., and on February 1st, 6 P.M. Chart II (p. 344) is for April 1st, 9 P.M., March 1st, 11 P.M., and May 1st, 7 P.M. Chart III (p. 345) is for July 1st, 10 P.M., August 1st, 8 P.M., and June 1st, 12 P.M. Chart IV (p. 346) is for October 1st, 9 P.M., September 1st, 11 P.M., and November 1st, 7 P.M. Places situated more to the east or west will have to calculate the time according to their position; some may be an hour or half an hour ahead, others the same period behind the time given. But the charts will be found generally applicable.

Novices are often confused by planets accidentally visible at the time, which cannot be marked down on the charts as they constantly change their position. Very luminous planets, such as Venus and Jupiter, can hardly be mistaken for fixed stars; but this is not an uncommon error with Mars and Saturn, which are at times very weak in light. The planets are distinguished from the fixed stars by their tranquil light. In very doubtful cases it is best to look in the almanac and see whether a planet is marked down in the constellation in question.

All details that might lead to confusion are left out of our charts, nor are the names of the constellations set down, as this would prevent an easy general view. The names can soon be ascertained by the aid of the numerals. It must be borne in mind that the centre of the charts corresponds to the zenith. Perseus on Chart I is therefore almost at the zenith. The semicircle on all the charts stands for that part of the celestial equator above the horizon at the time. A comparison of all the four charts (which in their entirety trace the annual circuit of the stars in the evening skies) shows the different equatorial and zodiacal constellations for the different seasons. The straight line running from the most southerly to the most northerly point of the horizon, through zenith and north pole, is the meridian line, and the stars on that part of the meridian lying between the pole and the southern horizontal point are at the point of culmination—that is, they are at their highest above the horizon. On Chart I, for instance, Algol is passing across the meridian.

Now a word as to the use of the charts. Hold the chart in such wise that the point of the edge corresponding to the part of the sky under observation is at the bottom and turned in the direction marked on the margin. If the constellations near the northern horizon are under observation, the stars have to be brought into line with the corresponding objects in the sky. The relative position of the celestial equator and the horizon at different parts of the globe has been fully set out, and a careful study of the last few pages will, in conjunction with the star atlas and my sundry hints, help the reader to find stars and constellations. Practice will make perfect here as elsewhere.

CHAPTER XXV

THE FIXED STARS

A Plethora of Suns.—Suns, innumerable suns, myriads of suns! Suns and solar systems without number! Space is filled with them, and no telescope is powerful enough to point their boundary, for, even behind the most distant twinkling star, we know that unknown suns dwell in unknown space. And if an Ahasuerus of the universe were to fly on for millions of years, past the shimmering girdle of the Milky Way, consisting of billions of tiny stars, he still would not reach the end of the gleam and the glitter. Ever new suns, new galaxies and new stretches of infinity!

What is a Fixed Star?—Those far-off suns that nightly crowd the skies are called fixed stars. Though "fixed stars" really mean immovable stars, this term is not quite correct, for these objects do move on, although at a far slower rate than the planets, only travelling a very small way in many centuries. The phrase dates back to the times when the suns were believed to be golden nails or lights fixed firmly to the crystal dome of the heavens. We stated in the preceding chapter that the number of stars visible to the naked eye is greatly overrated. A normal eye, we said, can count from 6,500 to 7,000 stars in the whole of the sky, in the northern and southern terrestrial hemispheres, and this is the maximum.

Grading the Stars.—The astronomer, as we have learnt, classifies the stars according to their brilliance. We know of stars of from one to twenty magnitudes, but only those up to the sixth magnitude are visible to the naked eye. There are only twenty stars of the first magnitude, that is, the very bright ones we see gleaming as soon as darkness sets in; on the other hand, there are 3,200 stars of the sixth magnitude, and with decrease in size the number of stars grows. Our stellar catalogues mark about 14,000 of the seventh magnitude, and 60,000 of the eighth magnitude. There are more than 250,000 stars of the ninth magnitude, and so on to numbers that are positively overwhelming. Herschel attempted to determine the stars visible in his giant refractors and set the figure at 20,000,000. Modern instruments permit us to compute the number at 50,000,000, and even this falls short of the actual myriads. Infinity cannot be explored.

Other Solar Systems than Ours.—How wonderful that these solar armies consist of bodies similar to our sun, that our sun is but a fixed star like the others! How immeasurable is the grandeur and sublimity of the universe! A faint inkling of the endlessness of space is imparted by this knowledge, for it is most probable that these suns form the centres of solar systems, that there are millions and millions of solar systems like ours, whose expanse we deemed so formidable, and many millions of planets, of whose inhabitedness it is impossible to say anything with certainty.

Apparent Size and Distance of Various Stars.—The apparent size of the stars has little to do with their real size. A very bright star like Sirius, which shines with such brilliancy in wintry nights, may be far smaller than any star of the tenth or even sixteenth magnitude, only visible as a dot in the telescope. The distance of the stars alone decides this, and is of great importance. Researches have revealed that the real average size of the fixed stars does not vary greatly, and we may truthfully state that, on the whole, the size of these suns resembles that of our own sun, although some are vastly larger and some vastly smaller. Fixed stars, whose distance is known and whose size can be calculated, have verified this statement. In any case, the difference in size vanishes in proportion to the difference in distance, and it can be generally accepted as a fact that the fainter stars are the more distant.

The Region of the Unthinkable.—The most gigantic telescope is of as little use in gazing at the fixed stars as an opera-glass would be to a Briton in searching for America. They are so very remote that our instruments, which reveal such numbers of fine details on nearer stars, are absolutely powerless; the fixed stars may appear a little more or a little less radiant, but they remain mere dots scintillating like glittering diamonds. All astronomical measurements fail here. The distance of the earth from the sun dwindles into nothingness in comparison, and the nearest of these millions of stars, our sun's neighbour, is, as already stated, so far away that we can hardly express it in miles, for the huge figure would convey no meaning. This nearest star is Alpha Centauri, a bright luminary only visible in the southern hemisphere, and when I tell you that careful calculations have fixed its distance at 25,300,000,000,000 miles from the earth, this leaves us just as wise as before. Such distances, as we have already said (p. 8), have to be reckoned according to a different method—years of light. Light travels at an incredible velocity and dashes through 186,420 miles in a single second, coming from moon to earth in 1¼ second. The distance light wanders in a whole year is called a year of light. As a year comprises 31,536,000 seconds, and light travels at the rate stated, the mileage of any star can be calculated if its light needs a year to reach our earth.

Not one of these stars, however, is within this radius, for even Alpha Centauri is 4⅓ years of light away. Its distance is best illustrated by the following example. Imagine the earth no farther from the sun than one eye is from the other. and the dividing distance of 92,800,000 miles has dwindled to the distance our eyes are apart, even then Alpha Centauri, on a like scale, would be 11¼ miles away. And yet this is our next-door neighbour among the fixed stars!

Stars whose Last Rays have not yet reached us.—The smallest fixed stars visible in our telescopes are believed to be tremendous distances away. The tiny dots which in their millions form our Milky Way probably are 4,000 to 5,000 years of light away from us; ay, there may well be stars no longer emitting light but which are still visible to us, as their last rays have not yet reached us. If the beams emanating from the earth could be analysed in the Milky Way, the earth would be seen in the state it was about 4,000 years ago, as, despite its speed, the light could only now arrive there, and we in turn witness these stars in the light they shed 4,000 years ago. Plainly, no calculation of the distance of these farthest suns can be made; estimates have to take the place of measurements, based on the fact that the apparent radiance of the fixed stars permits a computation of their distance from our solar system. Stars farther than 50 years of light are outside the bounds of measurement, therefore but few stars are near enough for their distance to be stated with anything approaching exactness.

Measurements of Fixed Stars.—The first measurement of a fixed star was undertaken by Bessel in 1838. After a period of almost two years, in which measurements of the apparent motion of 61 Cygni (a fifth-magnitude star in the constellation Cygnus, Fig. 260) were carried on, he set down its distance at 11 years of light; later efforts with more precise instruments put it at 6⅓ years. Radiant Sirius is so far away that its light needs 8 years of light to reach us, Arcturus in Bootes is 90, Vega in Lyra 39, and the Pole Star 60 years of light away. And yet all are wanderers steering their course near to ours in space! It is quite within the bounds of reason that some of these brighter neighbouring stars and our sun form a little stellar family of their own, wandering in company through the universe.

The Crowding of Stars in the Constellations is only Apparent.—The stars we unite in constellations are only apparently near to each other, only apparently form a connecting figure, and are in reality separated by vast spaces, standing partly behind, partly in front of each other, our perspective alone giving them their familiar aspect in the sky. Some dart hither, others thither, no bond unites them, and at the lapse of millions of years the whole cluster will have fallen apart and new configurations be formed. This is strikingly illustrated in Fig. 261, where the central figure shows us the Great Bear in its present shape; the arrows point the direction of the different stars. Some of them travel through space in a straight line and single file; others do not belong to this little swarm of suns, but go their own way, in divergent directions, either standing far ahead or to the rear of the others. The constellation must have had a totally different aspect in former times, and thousands of years hence it will once again have completely changed.

This future alteration is set forth in the bottom figure, and will be the result of the stars' proper motion. In Fig. 262 we are shown the constellation Orion, the most beautiful in the sky, in its present grouping as well as how our descendants will see it 75,000 years later. If we could suddenly burst in on such a constellation the vast space between the separate stars would appal us; nothing would be seen of any connecting link. The skies would bear an aspect similar to the one we are familiar with, only here and there specially radiant stars would be noticeable—those forming the constellation. It is most probable that the sun, the fixed star to which the earth is attached as a satellite, wanders on jointly with other bright stars nearer to us. Seen from the planet of a very remote sun, our central luminary would undoubtedly form a constellation together with other fixed stars. This would vary according to the direction of the imagined planet; but the sun's nearer neighbours, Sirius, Alpha Centauri, etc., would in any case appear close to it.

Fixed Stars by no means Fixed.—So the stars, seemingly so tranquil, so eternally immovable, utterly belie their appearance. They are not at all hammered fast into the crystalline celestial dome, but, on the contrary, shoot through space at a fearsome rate. And yet we see them in almost the same condition as Hipparchus saw them when he compiled the first star catalogue 150 years B.C., and as the Egyptians saw them while building their pyramids long centuries ago. If a Pharaoh were suddenly to appear among us, after a sleep lasting thousands of years, he would not find any great changes in the sky; he would see the well-known constellations gleaming as of yore, when he shed power and glory around him. Nevertheless, we know for a certainty that the stars fly through space faster than anything set into action by human force, thousands of times faster than the fastest of bullets.

The Velocity of the Stars.—It was left to present-day astronomy and its delicate instruments to determine and measure the distance of the stars. How tiny the apparent displacement of the fixed stars is, despite their rapid flight, is shown by the fact that the star possessed of the greatest speed (a small star in the constellation Ursa Major) moves

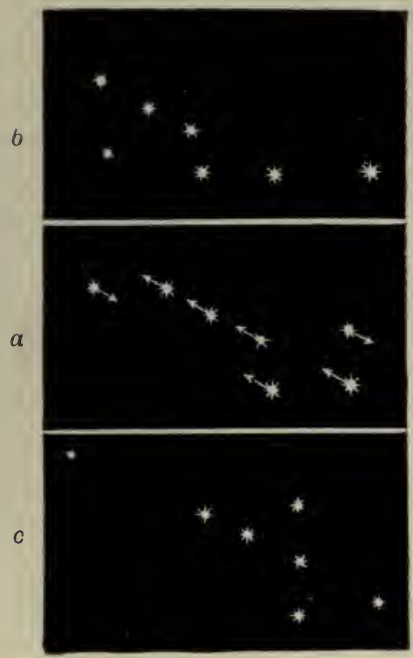


Fig. 261.—The Great Bear: in its present shape (*a*); as it was 10,000 years ago (*b*); and will be 10,000 years hence (*c*).

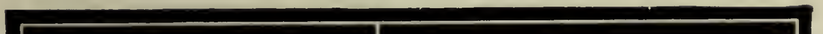


Fig. 262.—The Constellation Orion as it is to-day (left) and as it will be 75,000 years hence (right).

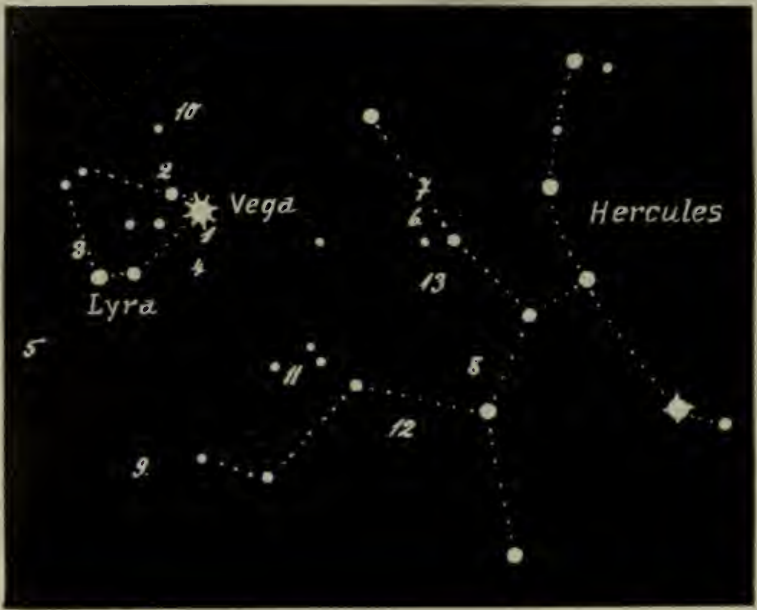


Fig. 263.—The Constellations Lyra and Hercules, towards which our whole Solar System rushes. (*After Kobold.*)

The numbers show the end of the journey according to different observers: 1, Newcomb; 2, Porter; 3, Porter (later); 4, Stumpe; 5, Bakhuyzen; 6, O. Struve; 7, Mädler; 8, Argelander; 9, Campbell; 10, Voss; 11, Kobold; 12, Dunkin 13, Galloway.

Fig. 264.—The Pleiades (seen with the naked eye).

Fig. 265.—The Pleiades (seen in the telescope).

on a third of the diameter of the full moon in the course of a century, and this forms an exception to the rest in its rapidity. The stars nearer our solar system naturally show a faster rate of motion than others farther away. A railway train apparently moves the faster the closer we are to it, whilst seen from afar it appears to crawl along. Alpha Centauri, the nearest fixed star, travels the sixth part of a full-moon diameter in a century; Arcturus in Bootes an eighth, and radiant Sirius but a fifteenth in the same period.

Motion of Stars.—On the distance of a star being determined and its apparent speed calculated, it is not difficult to ascertain its real motion and turn it into miles; and a very high velocity generally results. The small star in Ursa Major we mentioned above covers 185 miles per second, this being at a rate six hundred times faster than a cannon-ball flies. Shedir in Cassiopeia traverses 110½ miles per second, Pollux in the Twins 33 miles, Aldebaran in Taurus 32⅓, Vega in Lyra 16¾, and Sirius 11 miles per second.

Receding and Approaching Stars. — Of course, it was a very difficult matter to determine the velocity of a star moving straight on towards us or receding in a straight line, as no change in position either to the left or to the right relative to the other stars could be determined. It is almost as if we stood on the railway and beheld a train a long distance away; it is hard to decide whether it is stationary, or advancing to or receding from us, and its direction can only be determined after a short interval, when it either looms out larger or grows smaller to the eye. Mankind would have had to wait for many thousands of years to recognise the motion of a star from its increase or decrease of size. Other means had to be evolved to determine whether such fixed stars possessed a progressive or regressive motion; this problem was solved by Christian Doppler, and is described in Chapter VI. Stars dart through space in all directions, some approach, others travel away from us; Sirius, Vega, and Arcturus are included among those coming towards us, whilst Aldebaran, Pollux and the principal stars in Orion constantly add to the space dividing them from our solar system.

Real and Apparent Stellar Motion.—Our sun is a fixed star like all others, and this fact leads us to assume that it, too, is not stationary, but floats on in the limitless ocean of the universe like the rest, carrying its planets with it. The motion of the solar system can only be ascertained by the motion of the stars and is reflected in it, figuratively speaking. When walking along an avenue of trees those in front appear to move farther apart the nearer we approach them, whilst those behind us seem in receding to move closer together. In similar fashion the stars in those regions towards which the solar system advances should increase their distance from each other, and those in the opposite direction should move closer together. Of course, this is not really so simple as set forth here, for we have learnt that these stars themselves move on in the most divergent directions. The astronomer has therefore to differentiate between the real and the apparent stellar motion to determine the real motion of the solar system as compared with its apparent one. The most varying means have been enlisted to elucidate this question, and it was eventually ascertained that the solar system moves on towards constellation Lyra or its neighbour, Hercules; Fig. 263 shows the regions under discussion, the end-points of our solar journey according to different astronomers being marked by figures. Newcomb argued that the sun is travelling almost towards Lyra's principal star Vega.

The Sun of all Suns.—All the members of our solar system revolve and group themselves around its gigantic central luminary, the sun, and it is therefore well within the bounds of possibility that all these countless suns we call fixed stars in turn encircle a mutual central point. It was formerly firmly believed that a tremendous star, *the* sun of all suns, formed the centre of the fixed-star system, and a careful watch was kept for this central sun. Nearly everybody is acquainted with that small and interesting group of stars known as the Pleiades, which presents itself to the naked eye as a cluster of six or eight stars standing close together (Figs. 264, 265). Mädler believed his investigations to justify his publishing the statement that this cluster formed the central point of the fixed stars, and that the brightest star of the Pleiades, Alcyone, was the long-sought-for central sun. Further research has proved this to be erroneous; nothing is known to-day of the central body of this mass of suns, and the central point of all the fixed-star orbits may possibly be an empty space; it is not at all necessary for a gigantic star or constellation to be placed there. Similar to the motion of two celestial bodies around an incorporeal point lying between them in space, their mutual centre of gravity, the army of fixed stars may quite well revolve around such a matterless centre of gravity.

Stars in their Mad Career.—So we learn that the stars, our sun included, which seemed so firmly anchored in the heavens, whirl about in all directions in space, like leaves in the autumn winds, like dust driven about by a storm. If we were able to condense time and space, turn thousands of years into seconds and millions of miles into inches, we should see the stars careering about wildly in chaotic madness. Well-known constellations would suddenly alter their appearance, stars would dash away into space never to return, others start up out of depths never pierced by human eye—the whole stellar army is, in short, in as restless a condition as the corpuscles pulsing in their millions in our veins.

Why do the Stars Flicker?—Poets in all ages have rhapsodised over the sheen and glitter of the stars and compared them to eyes gazing down benignly from hallowed heights on the people below. This glitter and flickering are especially noticeable on clear wintry nights, when the stars stand out more prominently from the dark background of the skies, and it is generally believed that this is the most appropriate time for observation. Working astronomers know better, for on the nights when they scintillate most the stars are not at all clearly visible in the telescope, for their amiable twinkling is a sign of strong aerial disturbances greatly blurring and distorting their images. It is almost impossible to see any finer details on such nights.

Scintillation.—This glitter and flickering are astronomically termed "scintillation." Closely observed, the stars will be seen constantly to vary in brightness and wave to and fro like a candle exposed to a draught; further, they are noticed to change their colour like a diamond on which the light plays, they shine forth in all the hues of the rainbow. All this is due to stellar light having, before reaching our eye, to travel through the restless terrestrial atmosphere which is one of varying density. Were this aerial envelope lacking, the stars would shine out in majestic peacefulness; on the moon, for instance, where there is no atmosphere, they must be entirely free from scintillation. A decrease of scintillation is noticeable on high mountain-tops, and this is why stars low on the horizon, where their light has to travel farther through the air than at the zenith, flicker more powerfully than those standing high in the sky.

Anybody who has lain in a meadow on a very hot summer's day and looked across at a neighbouring village will have noticed how blurred the outlines of the houses appeared; they seemed to vibrate gently like the pebbles in a stream when the water is slightly disturbed. The hot currents of air arising from the ground and mixing with those of lesser heat lying above them cause whirls in the air, spirals and air-waves representing aerial layers of various density. Similar to the difference of refraction in lenses of different thickness, aerial layers of varying density refract the light differently, and the outlines of objects seen through such strata appear blurred and distorted; these effects can often be observed when workmen light their stoves in the street. Our atmosphere is more or less in constant motion. Aeronautics and aviation have established the existence of currents of varying power, direction and temperature at different altitudes. We can clearly understand that the fine sheaf of light rays emitted by the stars must be constantly deflected and refracted in these layers and thus call forth the impression of flickering stars.

Why does Starlight seem Rainbow-coloured?—How does it happen that stellar light, generally of a white hue, shines in all the colours of the rainbow? White light is, as we know, a combination of all the rainbow-colours—red, orange, yellow, green, blue and violet—simultaneously striking our eye. White starlight also consists of these colours. As long as the rays can travel together the light remains white, but as soon as a hindrance arises—should they have to pass through glass, water, aerial layers, or strike planes of a certain formation—they part company and proceed singly, forming the coloured bundle which a prism shows.

In penetrating and passing through our atmosphere the white stellar light is torn into its elementary colours. The rays arrive within our range of vision more or less separated, proportionate to the aerial density and motion. Now they may be together, in the following instant they may reach us consecutively, immediately afterwards they may be jumbled up once more; so starlight simply has to appear in ever-changing colour and brightness to us. The scintillation is especially marked if there are strong aerial disturbances or if a change of weather is imminent. Their powerful flickering has been taken from times immemorial as a sure sign of a break in the weather.

How we tell a Planet from a Fixed Star.—The stars would hardly scintillate if they were not such minute spots of light. If they were ever such tiny discs the sparkle would cease, for, in a planet, the dots of light forming the whole would in their entirety compensate the disturbances suffered by its single components. That is why the planets neither flicker nor sparkle; their light is tranquil and steady, and their radiance more subdued. All this assists us in recognising a planet from the fixed stars. Revolving around the sun planets are comparatively close to us and appear as small discs, so that, as explained above, no scintillation can occur. During exceptionally strong currents of air they may occasionally show a very slight flickering, but this is most uncommon. The fixed stars are so immeasurably far away from us that, although they are in themselves hundreds and thousands of times larger than the planets, they appear only as dots of light whose diameter cannot be measured. It is a remarkable fact that they appear smaller in a telescope, and a stranger looking at a fixed star through the telescope for the first time is always disappointed by its minuteness. An opera-glass would be of little use to us in gazing at an object ten miles away, and, from a like cause, even the best astronomical telescope cannot bring the fixed stars—suns floating at such inconceivable remoteness—near enough for us to see them even as the tiniest of discs. And if, in spite of this obstacle, the astronomer includes these stars in the field of his researches, armed with instruments of even greater power, the reasons for such investigations are to be sought for elsewhere.

Why is a Star Ray-shaped?—Some time ago Holtz, of Greifswald, inquired into the cause of the stars appearing as "stars"—that is, in the ray-like shape ✶ we term a "star," for all stars are fiery globes similar to the sun. The question may appear simple, but it is the very reverse; and it still remains to be seen how far Holtz's explanations are correct. We have already said that a star appears smaller in a good telescope than when seen with the naked eye. This is due to the fact that the construction of the optic lens does not reproduce the star in the retina as the tiny dot it really is, but as a small disc instead. The different fibres and lines of the retina covered by the star-disc are of varying sensitiveness according to Holtz, the less sensitive parts not accepting the light at all. Bright lines alternate with dark ones on the disc, as retained by the eye, thereby forming a star-shape as we know it.

Double and Compound Stars.—Although their vast remoteness does not permit our telescopes intimately to portray the fixed stars, the sharp, clear outlines given of them reveal all that was otherwise hidden by the dispersing ray-like light, and in concentrating the light they have rendered most minute stars visible to us. This enabled the remarkable discovery to be made that stars, seemingly possessing no striking features at all when seen without aid, in reality consisted of several stars, perhaps two or three. They are termed double, triple, and so forth, according to the number clustered together. Frequently their nearness is only apparent, as they are sometimes divided by distances such as separate Sirius and the sun; we are under an optical illusion in these cases, whilst they may be looked on as impostors among compound stars, time and their lack of characteristic movements alone revealing the fact that they stand in no relation to each other.

On a clear night a small star may be recognised in the

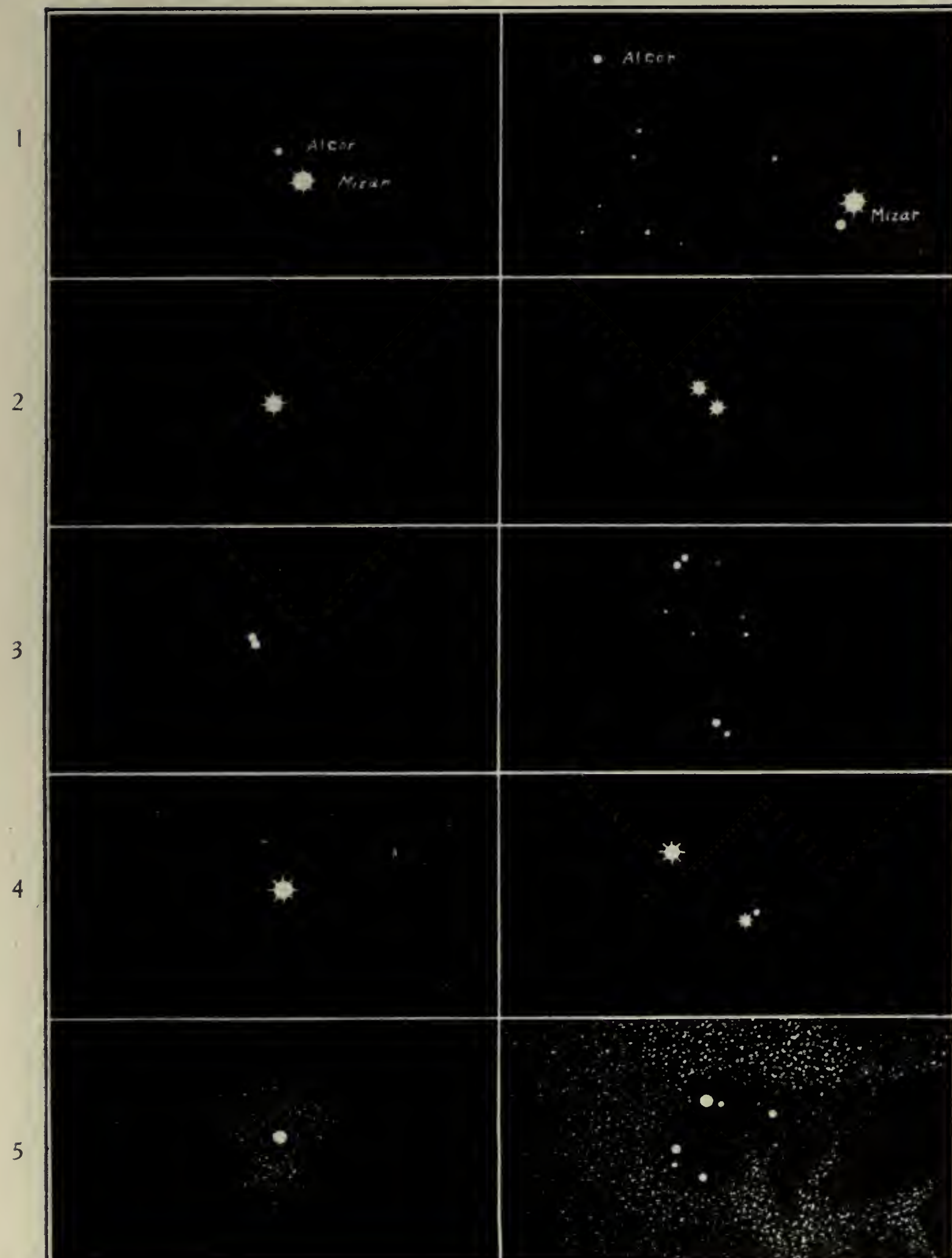


Fig. 266.—Chart of Compound Stars, as seen with the naked eye (on the left), and in the telescope (on the right). (*By the Author.*)

1. Mizar in Ursa Major; a small star, Alcor, can be seen without aid, next to Mizar. The telescope shows Mizar to be double itself and several small stars to be situated between Mizar and Alcor. 2. Castor in Gemini. The telescope shows two equally large white radiant stars separated by the 320th part of a full-moon's diameter. 3. The fourfold star in Lyra, seen by the naked eye, has a long shape. An opera glass shows it to be double; a good telescope reveals each star to be again duplicated. The space between the stars nearest to each other is only the 750th part of a full-moon's diameter. 4. The threefold star Alamak in Andromeda. The brightest is orange, the medium-sized one is blue, and the smallest white. The space between the two smallest is only about the 2000th part of a full-moon's diameter. 5. The sixfold star, the so-called Trapezium, in the interior of the great Orion nebula.

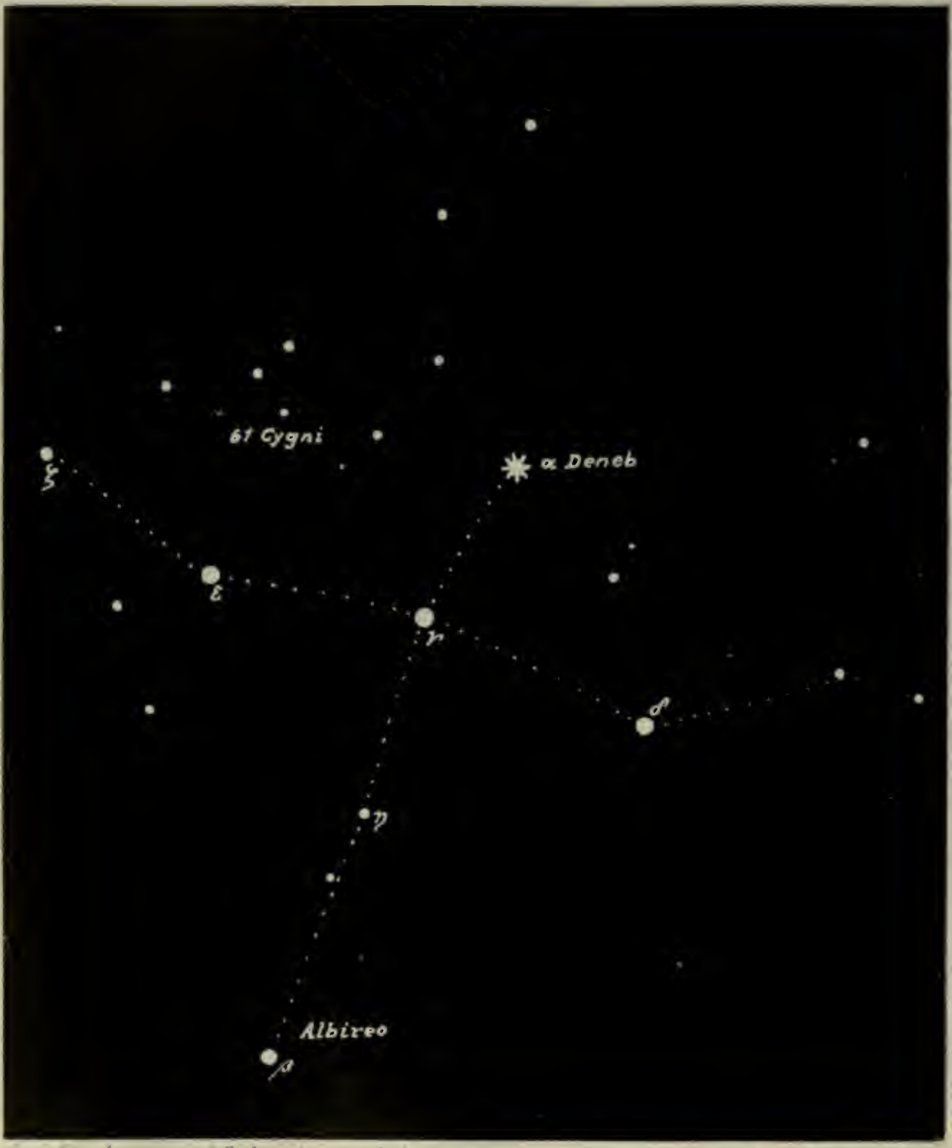


Fig. 267.—The Constellation Cygnus with the compound star Albireo and 61 Cygni, a neighbour of our Solar System.

constellation Ursa Major close to a larger one (Fig. 259); the larger one is named Mizar, and its tiny companion Alcor. The finding of Alcor was a favourite test of sight among the Arabians. Their apparent distance from each other is about a third of the full-moon's diameter, so this might be looked upon as a compound star; but even an ordinary telescope shows Mizar to have a companion, a fifth-magnitude star almost fifty times nearer than Alcor. So Mizar really is a compound star (Fig. 266). These two stars, large and small, are close to each other in space (although divided by many millions of miles)—two suns belonging to one another and travelling jointly through the voids—sister suns mutually revolving around the centre of gravity situated between them. The period of revolution of many of these stars is known; some circuits, as seen from earth, appear to lead one star past the other, and that is why even the best instruments at times show these compound stars in single shape, both only reappearing to view after the lapse of years, when they have moved on a proportionate distance in their orbit, slowly increasing the dividing stretch to its maximum. Zeta Hercules was seen as a double star by Herschel in 1782; nothing was visible of the duplication in 1795, and it was only remarked again as late as 1826 by Struve, when the companion star had moved considerably away from its principal. The time of circuit only lasts a few years with some stars and centuries with others. A period of revolution of 996 years has been computed for the radiant compound star Castor in the constellation Gemini, consisting of two equally bright bodies of like size. The distance some stars are apart is often very inconsiderable, and the multiplication only noticeable in the most powerful instruments. Compounds only the 18,000th part of a full-moon's diameter apart are classed among the closest of sister suns catalogued!

There are several threefold and fourfold stars; an eightfold star has been discovered in the constellation Lepus, and Burnham even mentions a sixteenfold one. This would mean a whole cluster of suns, a stellar family. Some of these compound stars are illustrated in Fig. 266; on the right they are shown as seen in the telescope, and on the left by the naked eye. More than 10,000 such compound stars have been discovered up to the present time.

Stars of Varied Hues.—It is interesting to note that stars situated close to each other usually possess perfectly different colourings, and this can be verified by a glance through a hand telescope or field-glass. There is a very beautiful compound star of this kind in constellation Cygnus (Fig. 267). It is named Albireo, and forms the lowest point of the somewhat irregular cross. Next to the principal star, one of third magnitude, is a fifth-magnitude star; the large star is orange in colour, the smaller one has a greenish-blue fire. The threefold star Gamma Andromedæ owns to a golden, a blue and a white star, the rays of the latter being faintly tinged with violet. A compound star formed of a deep red and a blue star is found in the constellation Argo Navis; a certain star in Ursa Major shows violet and yellowy-white colours; a star in Hercules yellow and green.

Most remarkable light contrasts should be witnessed on a planet belonging to one of these compound stars; the inhabitants would see two suns in their sky, one of large dimensions, the other smaller; one perhaps red, the other green. The rising of the red sun would shed a magic light over all this world where everything would be veiled in a roseate hue, and, according to the well-known law of Optics, the shadows would take on the complementary colour and be green. The time for the setting of the red sun draws near when the green sun begins to rise in the east; the rays of both intermingle, colouring the sky red and green in patches, whilst in the middle an odd leaden-grey light ensues. The red sun sinks to rest like a vanishing ruby; the green sun looms on the horizon as a huge emerald; the red lights turn to green and throw ruddy shadows. Red and green twilights would be known, people would reckon according to red and green hours, and painters and fashion-artists achieve colour compositions undreamt of even in our wildest flights of colour fancy. If a third sun had to be taken into consideration, a white or violet one, the world would have a kaleidoscopic effect—nay, there may even, according to the orbits described by such suns in the heavens of our fancy planet, be countries of the red, green and white sun, where one or other colour may predominate as a result of the higher position of that particular sun.

Variable Stars.—Compound stars furnish us with absolutely no information about the constitution of these distant suns, but a certain category of stars does exist whose characteristic features permit us a deep insight into the conditions prevailing on the fixed stars. These are the so-called "variable" stars—that is, stars changing their light, their radiance. They burn with a more or less bright light at certain periods; the variations in light are perfectly regular in some cases, and in others quite uncontrollable, apparently following no fixed rule. Usually such variable stars shine for weeks and months with uniform brightness, when suddenly their radiance seems to decrease; they grow steadily darker during a few days or hours, as the case may be, until they reach their minimum, occasionally, to the unassisted eye, entirely vanishing, and then slowly recovering until they regain their former brightness, and the period returns for a repetition of the process of transformation. Thousands of such variable stars are known to-day, and they have afforded most valuable data as to the nature of these suns.

Some of these variable stars have carried out their changes for decades, perhaps for countless centuries, at most regular intervals, and the very minute and hour of their maximum radiance have been calculated for months and years ahead. There is a star in the southern hemisphere in constellation Cetus named Mira (the Wonderful) that attracted widespread attention as far back as the fifteenth century. When full its light is that of a first-magnitude star, growing fainter and fainter, until it totally fades after about three months, remaining, however, clearly visible in the telescope. After a period of five months it reappears as a faint dot, gaining in strength, until, after another three months, it gleams out at full brightness once more. The most conspicuous example of another type of variable star is Algol in Perseus (Fig. 268), which is very regular in its variations. For about two days and a half it vies with the stars of Ursa Major in radiance, and then dwindles in a period of four and a half hours to the insignificant star it remains for eighteen minutes, when it gradually returns to its first condition, its whole period only lasting 2 days and 21 hours.

Cause of Variable Light.—Numerous theories have been advanced as to the cause of these regular variations of light. Our sun is at times covered with gigantic dark patches, which some scientists pronounce to be the first signs of its approaching old age, products of the cooling processes which are again dissolved by the heat. It is possible that there are suns already partly covered over by cinders and partly by glowing masses. Bearing in mind that these distant suns rotate on their axes just as our own sun does, it is only reasonable that a semi-extinguished sun will at times turn its dark-spotted surface to us, whilst at others the incandescent parts will become visible, producing the impression of a variation in light. This is the cause of the variation in many stars of irregular period, but is hardly likely to be the case in very precisely acting variables, since we cannot suppose that the cinder patches keep their position and extension unchangingly for any length of time.

The surmise that these regular stars are encircled by a dark body thrusting itself at regular intervals between us and the distant sun, and thereby partially eclipsing it, would be a full explanation of this regularity, as the period in which one star revolves around another suffers no alterations for very many years. The exceptional regularity with which the light variation occurs on Algol led to the statement that the remote Algol sun was encircled by a second less radiant sun producing these obscurations. This explanation was backed up by the discovery that such a body does form a compound star with Algol, and it has even been possible to determine the size and orbits of both. It may appear somewhat difficult to understand how the existence of such dark * stars is ascertained, as light alone

* It has now been ascertained that the companion of Algol is not really dark, but gives several times as much light as our sun. It is, however, relatively dark compared with Algol.

can bring us news of the conditions in space; if a fixed star no longer emits light it is beyond the power of all optical instruments in the world to find it. Astronomers cannot catch a direct glimpse of a dark body, but the influence it exercises on other radiant stars is noticed, and from such disturbances the presence of an invisible dark body is presumed.

Dark Stars.—It is only within reason to accept the existence of such dark stars in the heavens as a fact. As there are different ages of mankind on earth, why should there not be brightly radiant "young" stars, paling suns on the downward path, and effete, extinguished ones in the millions of worlds above? Science teaches that our earth was once a sun, a bright star revolving around its great central orb, the sun, as it does to-day. The small sun sent out its heat into icy space, gradually cooling in so doing, until a crust formed around it, choking its radiance; the sun was killed, and the planet, the home of thousandfold life, was born in the same hour.

The great sun, however, still shines down on the planet whose development it witnessed from the earliest beginnings, as it will for millions of years to come. Its cooling process is a much slower one, as its gigantic body can find room for 1,750,000 such terrestrial spheres as ours, and it is only in accordance with the laws of Nature for the smaller globe to grow cold at a more rapid rate than the larger one. A time will come when, in the perpetual circle of creation and decay, the last glowing field of the sun will be encrusted in dark, hot cinders. The number of æons that must elapse before this shall occur is a secondary matter to science, but not at all so to the inhabitants of our earth and the other planets of the solar realm.

As our sun is only one of a million of fixed stars visible in the depths of the universe, must we not conclude that there are many extinguished, effete suns in the voids of space if our hypothesis be correct? Now, has astronomy been privileged to demonstrate the existence of such suns, or have proofs to that effect not been adduced?

How we Learn of the Existence of the Dark Stars.—We cannot ourselves see these dark stars, but they thrust themselves on our notice by the power of attraction they exercise on other stars near by. We have learnt that there are numerous compound stars in space, and that these manifold suns revolve around a common centre of gravity. Our delicate instruments have very exactly determined the motions of such stars in their orbits. Motions of like nature are frequently noticeable in stars that are perfectly isolated and showing no companion in the telescope, and yet such a comrade must be present, for the attraction it exercises on the visible star betrays its presence. These would be compound stars with one radiant and one dark member, the latter making its existence indirectly felt. It is known that in several cases of variable stars a dark body pushes itself in front of the radiant one and eclipses it for a short time; this is undoubtedly also a dark star.

Vogel and Scheiner, the astrophysicists of Potsdam, were able to prove in 1889, aided by the spectroscope, that, on Doppler's laws, Algol shows revolution in an orbit, and they determined that a large dark celestial body standing close by forces Algol to the backward and forward movements in which it indulges. The distance between the two is estimated at 3,218,852 miles, and the dark companion should about equal our sun in size, having a diameter of 826,462 miles, whilst it moves at a rate of 55¼ miles per second round the centre point of the system.

Algol is not the only star possessing a dark companion on its endless voyage through space, and although the number of stars in respect of which astronomy has determined the existence of such mates is yet small, the presence of these bodies has been established beyond all dispute. Moreover, it must be remembered that the existence of these non-radiant bodies can only be determined by means of stars situated relatively close to us, where the orbit which both describe around the centric point of their system appears comparatively large. It is not a difficult task to follow the movements of some radiant and dark stars in their orbits. The position of the fixed stars has been ascertained to about a ten-thousandth part of the diameter of a full moon. Protracted investigations have elicited the fact that several stars

Fig. 268.—The Constellation Perseus with the variable star Algol and the position of Nova in 1901.

Fig. 269.—Tycho Brahe observing the New Star in Cassiopeia.
(From Flammarion's "Astronomie populaire.")

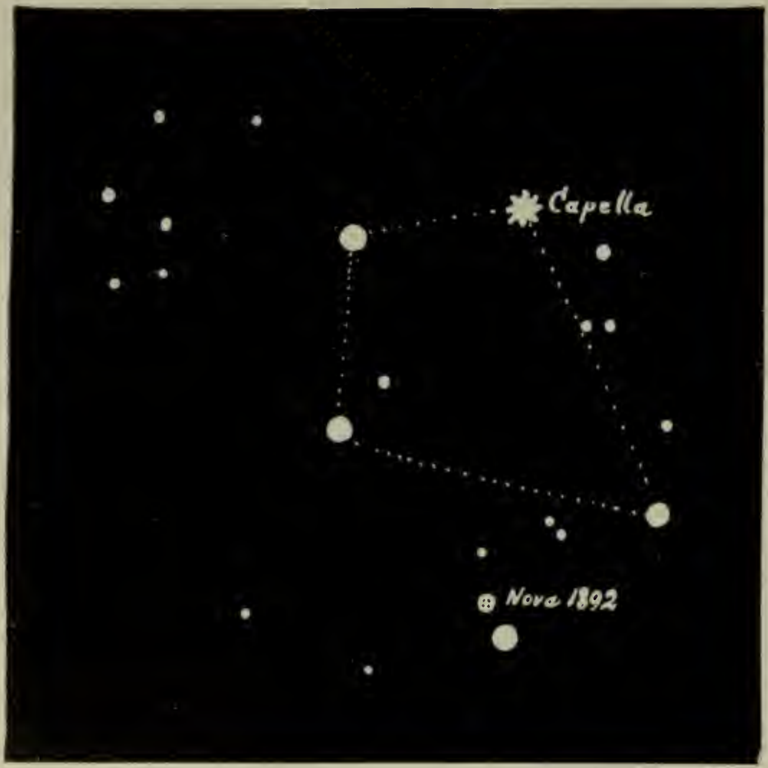


Fig. 270.—The Constellation Auriga.

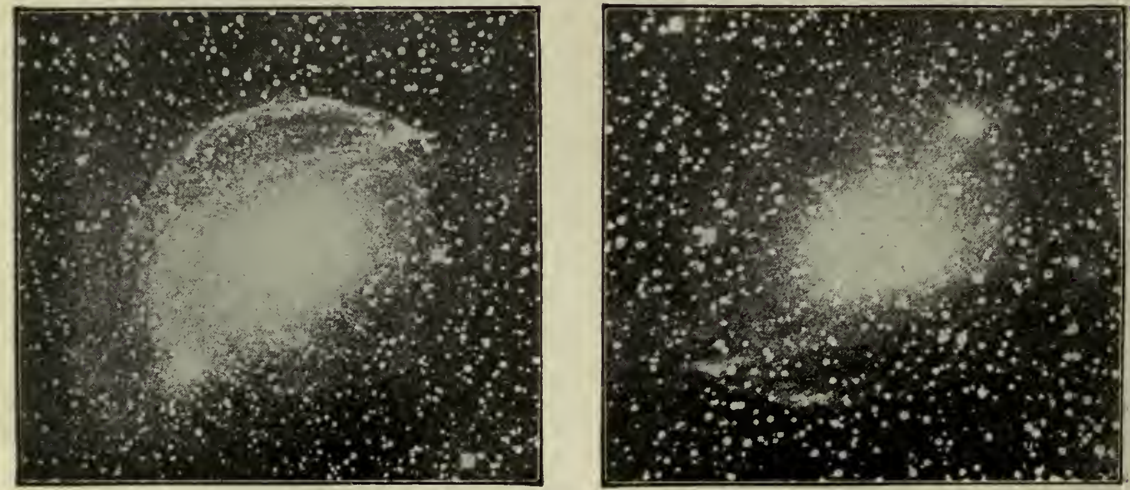


Fig. 271.—Two views of the Nebula surrounding the New Star in Perseus.
(*From photographs by G. W. Ritchey, November, 1901.*)

—among them Sirius, in Canis Major, and Procyon, in Canis Minor—move around their mean positions in a small orbit, movements that can only be explained by assuming each to be accompanied by another celestial body. When Peters of Königsberg calculated the orbital conditions of Sirius and its invisible companion, he came to the conclusion that Sirius completed a revolution around the centre of its system once every 50 years. Later the Sirius companion was revealed in a very powerful telescope as a minute star not yet totally extinguished; its discovery was an absolute proof of the correctness of the hypothesis. Procyon's companion has now been found, and is still fainter than that of Sirius.

World Catastrophes.—There probably also are companionless dark suns which cannot be betrayed by any irregularity in the motion of another star, as they stand alone, and will therefore remain hidden from us to all eternity. And yet there is a possibility that some extraordinary occurrence may one day reveal the existence of these deceased worlds, tossed about like wrecks in the vast ocean of space. Although things in the great universal system are controlled in a remarkably orderly manner, and collisions in the stellar regions are rare, yet an event of this kind does occur sometimes. When an extinguished sun strikes another celestial body, both immediately become visible; the two, meeting at an inconceivably high velocity, burst into a bright glow at the impact, and the dark sun blazes out in sudden radiance.

The Tychonic Nova.—Light, Infinity's messenger, has informed us of such events often enough. When, on November 11th, 1572, Tycho Brahe crossed the courtyard of his observatory, he suddenly noticed in Cassiopeia a star of exceptional brightness never hitherto seen (Fig. 269). This remarkable appearance was visible even by day; it stood as motionless as all the others, and only faded away seventeen months later, in March, 1574. Since then no trace of it has ever been found. This is not an isolated case, as in recent times "Novæ," the designation given to such new stars, have not been infrequent.

New Stars.—Old chronicles often relate the unexpected appearance of unknown bright stars. A star that suddenly appeared in the constellation Scorpion in 123 B.C. was the cause of the compilation of a star catalogue by Hipparchus to aid him in following other such interesting events. Chinese annals tell of a radiant fixed star near Alpha Centauri coming into view on December 10th, 172, and lasting eight months; according to the above source of information, it sparkled in five colours. Old Greek historians mention a star in 389 that was stationed close to Altair in Aquila and was said to resemble Venus in beauty; it paled after a period of three weeks. The old Arabian astronomers, Haly and Giafar ben Mohammed, observed a new star in the Scorpion in 827, which was said to possess a like degree of radiance as the moon when in its first quarter. We further learn of a star first sighted in Aries, in May, 1006; it was of gigantic size and flickered like a flame. New stars appeared in 1012, 1203, 1230 and 1260, and to these must be added the "Tychonic Nova" in Cassiopeia of 1572, whose position is marked on the chart in Fig. 258. A pupil of Kepler's discovered a new star in Ophiuchus on October 10th, in 1605, described as "brighter than Jupiter, but not so bright as Venus." Kepler wrote a treatise on it. The star possessed a very powerful scintillation and changed its colour. Its radiance died away very gradually, and it vanished for good in 1605. A "Nova" that appeared in Ophiuchus in 1848 was first observed by Hind of London; it paled extremely slowly, and can still be seen as a tiny dot of light. A second-magnitude star was discovered in Corona Borealis by Birmingham, at Tuam in Ireland, during the night of May 12th to 13th, in 1866. Two hours before the Irishman sighted the star, Schmidt, engaged in lunar research at Athens, had accidentally scoured the identical regions without finding the faintest trace of any new body. Later it was ascertained that Argelander, at the end of the 'fifties, had already inscribed the Nova in his catalogue as a tiny tenth-magnitude star. It is visible as a very insignificant object in the Corona.

The Flaring-out of New Stars.—The stars appearing in Cygnus in 1876, in Andromeda in 1885, and in Auriga in 1891 were subjected to most searching investigations. Not only were their light variations and decrease of radiance carefully booked, but the spectroscope was also set into action to determine the conditions causing their sudden radiance. The Nova last mentioned, whose position is shown in Fig. 270, was discovered by the Rev. Mr. Anderson, of Edinburgh, on January 23rd, 1892. American astronomers afterwards ascertained that the star had been seen on photographs of those regions at an earlier date. Unlike other new stars, it did not flare up suddenly into maximum brightness, but steadily grew in radiance. Its later behaviour was of the utmost interest and importance. After it had faded away a circular luminous nebula appeared, bright in its central portions and gradually fading into space. This nebula was visible for months, permitting a very detailed investigation. Until then the theory had been general that the flaring-out of new stars was produced by a collision between two extinguished stars, which were once again set into a bright glow by the astounding impact. The opinion had also been held that, as a result of a close approach to another solar system and the power of attraction exercised by a second sun, incandescent matter probably burst forth from the interior of a celestial body already partially crusted over, setting the extinguished object in new radiance for a short time.

The strange deductions drawn from a protracted observation of the luminous nebula of the Nova forced a different interpretation upon us. Exactly similar conditions were observable in the new star—the celebrated Nova Persei—which appeared in 1901. This was also discovered by the amateur astronomer, Mr. Anderson, its birth-date being February 21st. The celestial regions in which it was found had, oddly enough, been photographed the day before, and not a trace of the star was to be seen on the plates. The star flamed out quite suddenly, and at first possessed the brightness of a third-magnitude star, speedily attaining that of one of the first magnitude. Its radiance began to wane on February 23rd, and to-day only very powerful telescopes indeed show it as a tiny twelfth-magnitude star. Its most extraordinary feature was the formation of huge clouds of vapour around the star, seemingly in a very turbulent condition. The spectroscope had ere this shown two different bodies to be stationed in the region where the new star blazed out; the spectrum of the one was that of a star surrounded by an atmosphere chiefly containing calcium vapour, that of the other having all the characteristics of glowing gases. The rate at which the stars moved was measured on Doppler's lines, and it was found that the star moved away from us at a rate of 11 miles per second, whilst the gaseous masses came towards us at a speed of 435 miles per second, a velocity such as had never before been known. This nebula, its alterations and motion, is seen in Fig. 271; it apparently winds itself in curves and spirals around the dying sun. Fig. 272 represents the mists clinging around the star, according to a drawing by Professor Ritchey, of the Yerkes Observatory.

Explanation of the Nebulae around the New Stars in Auriga and Perseus.—A new field of research was opened out by these extensive luminous nebulæ seen around the new stars in Auriga and Perseus. Professor Seeliger of Munich has apparently found the proper explanation of these remarkable occurrences. There was no collision between two suns, but a dead sun, or maybe an entire solar system, must have penetrated into one of the huge clouds of cosmic nebulæ, cosmic dust floating everywhere in space and visible by telescopic and photographic means. It is always easier to hit a large target than a small one, and a sun wandering through spacial immensities will much sooner strike a mass of nebulæ spreading over a space large enough to contain innumerable thousands of solar systems than it will strike a single solitary star. The exceptionally fine and vibrating matter of which nebulæ consist would rush on to the trespassing sun with tremendous speed, bursting into a glow as a result of the sudden motion of the single particles and condensation of the mass. The sudden stoppage of a rapidly moving body turns the retarded progressive energy into a motion of all the minute particles or molecules composing the body, and this general motion results in a generation of heat. We witness this best in the heat radiating from a cannon-ball on striking a steel plate. Progress is suddenly stopped and turned into circular molecular action. It will be recollected that meteors in piercing our atmosphere become white-hot when their rapid flight is suddenly thwarted by air-resistance, thereby producing a high degree of warmth in the component mineral particles.

End of Solar Systems.—Perhaps whole planetary systems perish in these primal catastrophes; perhaps terrible events, such as the bursting into flame of earths similar to ours, are concealed within the flaring-out and light variations of these new and interesting stars. We may console ourselves with the thought that, even if this were the case, the disaster must have happened ages ago. Nova Persei of 1901 is a star comparatively close to us; Bergstrand's investigations show it to be about 130 years of light away, so in reality it did not first appear in 1901, but in 1770 instead. Our sympathy may in some cases be about 1,000 years too late, light having had to travel about this length of time to acquaint us with the disaster. And in a few months perhaps no trace will be left to remind us of the last of a world.

Who knows but that the meteorites occasionally falling to earth are fragments of such awful collisions, coming within the radius of the terrestrial atmosphere after a pilgrimage of thousands of years? I wonder what they really *could* tell us! And yet what does a collision of this nature signify in the infinity of the universe where the scale of all happenings is so gigantic! The myriads of stars wander on without rest to an unknown goal, and who can say whether our own sun, tearing through space with incredible velocity, is not rushing on to a catastrophe such as the sudden bursting of other suns into luminosity betokens?

There are a number of things not yet fully understood in these calamities which occur so very far away, yet it would appear as though the radiance of the star itself were of short duration. Nova Persei at first burnt in a pure, white light which later turned to yellow, and finally, according to the rate at which its radiance decreased, to red, showing the very same phases as a piece of glowing coal taken from the grate.

The Colour and Age of Stars.—The different colours in the light of the stars allow us to arrive at a knowledge of the age and energy of these distant suns. A star shining in a pure white or a bluish light, like Sirius, is at its highest power, a youth among the heavenly bodies. The yellow stars, to which our own sun and Altair, the chief star in Aquila, belong, have passed their prime, and stars burning red like Betelgeuze in Orion, conspicuous by its ruddy glow, are nearing their old age. Red stars frequently show irregular fluctuations in their light, the chief number of variable stars recruiting from them, so it is hardly presumptuous to assume that cooling processes are going on on their surface, that perhaps the first cinder stretches are in the act of formation, gradually spreading out to lay themselves as a firm stony crust around the extinguished celestial sun after its demise.

The difference of star colours is very pronounced in the spectroscope (*see* Fig. 273, which shows the spectra of various stars). The number, position and aspect of the lines depend upon the temperature, density, and pressure of the stellar atmosphere. Age and temperature of the stars can be determined from their spectra. Stars whose spectrum is long and bright at the violet end are younger and hotter than those whose spectrum is only sharply defined in its red, green and yellow portions. Very juvenile stars show traces of a hydrogen atmosphere, metal vapours are found in older ones, and the aged red stars possess various chemical combinations only possible in a rapidly-sinking temperature. Cinder stretches, the foundation of the stony envelope which will finally enwrap the whole dead sun, appear; its light changes; the star is marked down as doomed. One day it will have completely died away, and have to be crossed off the chart—a sun gone to its death and with it perhaps organic life on many planets revolving around it and dependent on it for existence.

The immense army of the fixed stars has taught us that they, apparently eternal, apparently anchored for ever in the depths of space, are equally subject to change, to the perpetual growth and decay throughout Nature, as all else is; that they, too, wither and fade, like the flowers of the field. They dash through space's vast expanse at a tremendous speed, whirl madly about like dust scattered by the wind, rise and fall, glitter and glow, like the spark the smith strikes out of the iron. Æsthetically-minded persons may

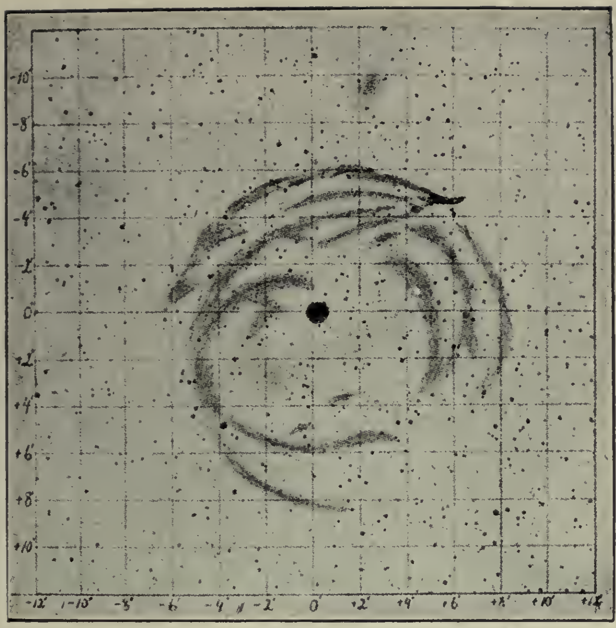


Fig. 272.—The Nebula round the New Star in Perseus.

(From a drawing by G. W. Ritchey, September 20th, 1901.)

Fig. 273.—Spectra of different Fixed Stars.

The second lowest is that of the Sun.

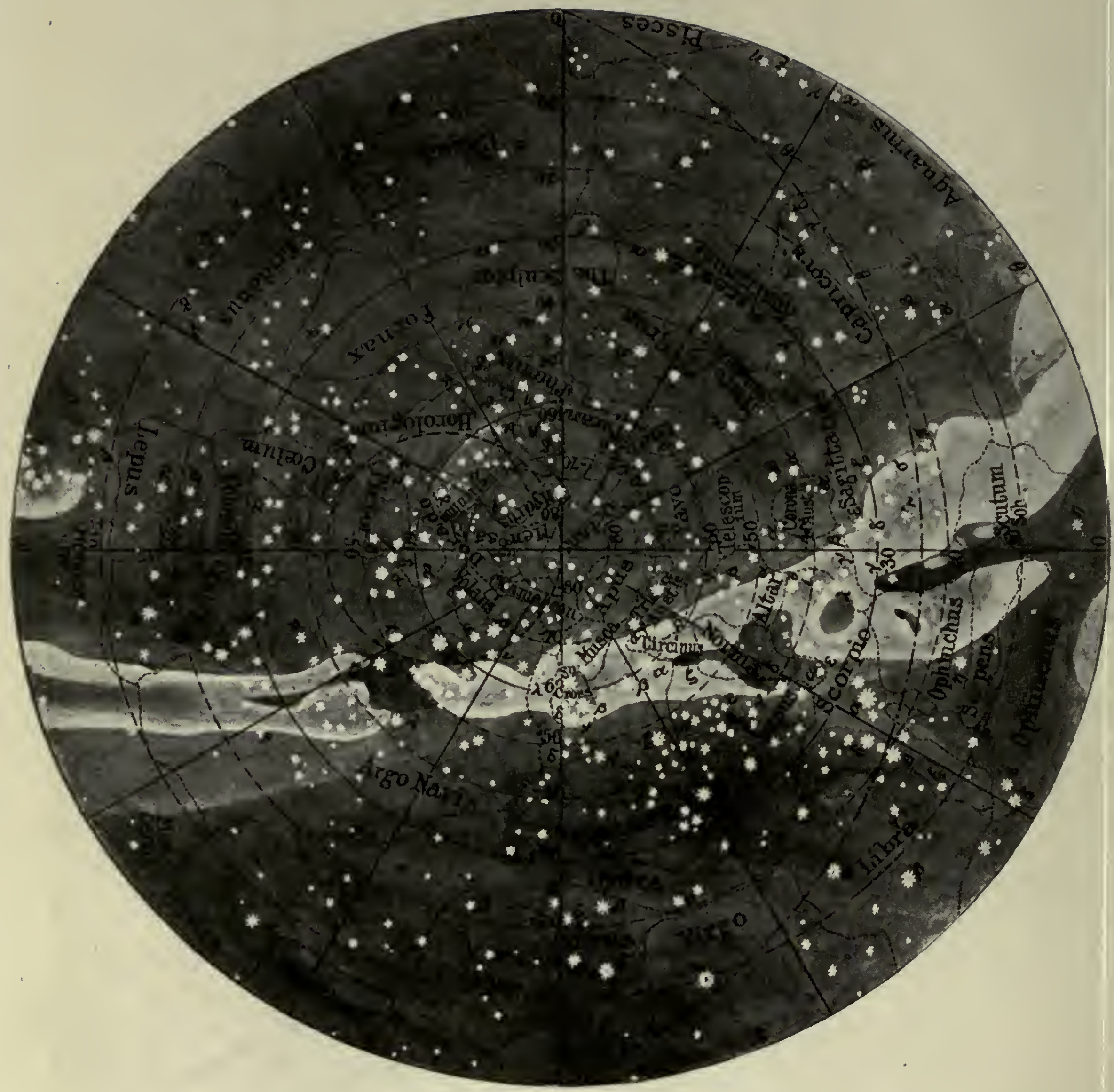


Fig. 274.—The Milky Way in the Southern Hemisphere of the Sky.

regret that man in his everlasting quest for knowledge has destroyed this apparent eternity, and that the skies no longer represent the restful pole in the flight of apparitions. Science cannot heed such remonstrances in its attempts to penetrate the most puzzling paths of this bewildering labyrinth, constantly recognising the new obstacles cropping up in its way. It has attained to dazzling heights in its collection of new facts and new matter, but nevertheless cannot spell out even a letter of the great First Cause of all things, of the *raison d'être* of all these seemingly reasonless changes in the swarms of solar systems, and stands absolutely helpless when confronted by this mighty and insurmountable barrier.

CHAPTER XXVI

THE MILKY WAY

The Rainbow's Sister.—A great luminous band spans the celestial dome in a bold vast arch, an arch which the ancient Mexicans aptly termed the "sister of the rainbow." This delicate ribbon of light winds like a misty, gleaming veil in and out among the radiant stars and starlets, and when, on clear wintry evenings, the dark skies seem to extend without a limit and the heavenly lights stand out like diamonds on a velvety background, this mighty belt of light glitters in enhanced radiance, as if composed of millions and millions of the tiniest sparklets. It is the Milky Way. The fable runs that Hercules, when a giant baby and drinking at the breast of Alcmena, spilt a drop of milk which ran down into the skies, spreading farther and farther, its trail forming the Milky Way. Theophrastus declared the gleaming ring to be the place where the two celestial spheres were joined together, and other wise men of ancient times believed it to be the route of the sun-chariot, the Milky Way being the hollows which the wheels had worn in their journey lasting thousands of years. They had an easy, offhand method of explaining the universe and its immeasurable glories in those distant times! To-day we know this radiance to be due to the presence of millions of stars, millions of suns floating in space vast distances off. Democritus, however, a philosopher who lived five hundred years before the Christian era, shrewdly surmised that the Milky Way consisted of endless numbers of small stars, but it was left to Galileo and his telescope to justify this supposition by announcing its truth.

Aspect and Nature of the Milky Way. — The gigantic radiant girdle extends across both northern and southern hemispheres, encompassing the whole stellar dome. It does not possess a uniform brightness, as a glimpse at

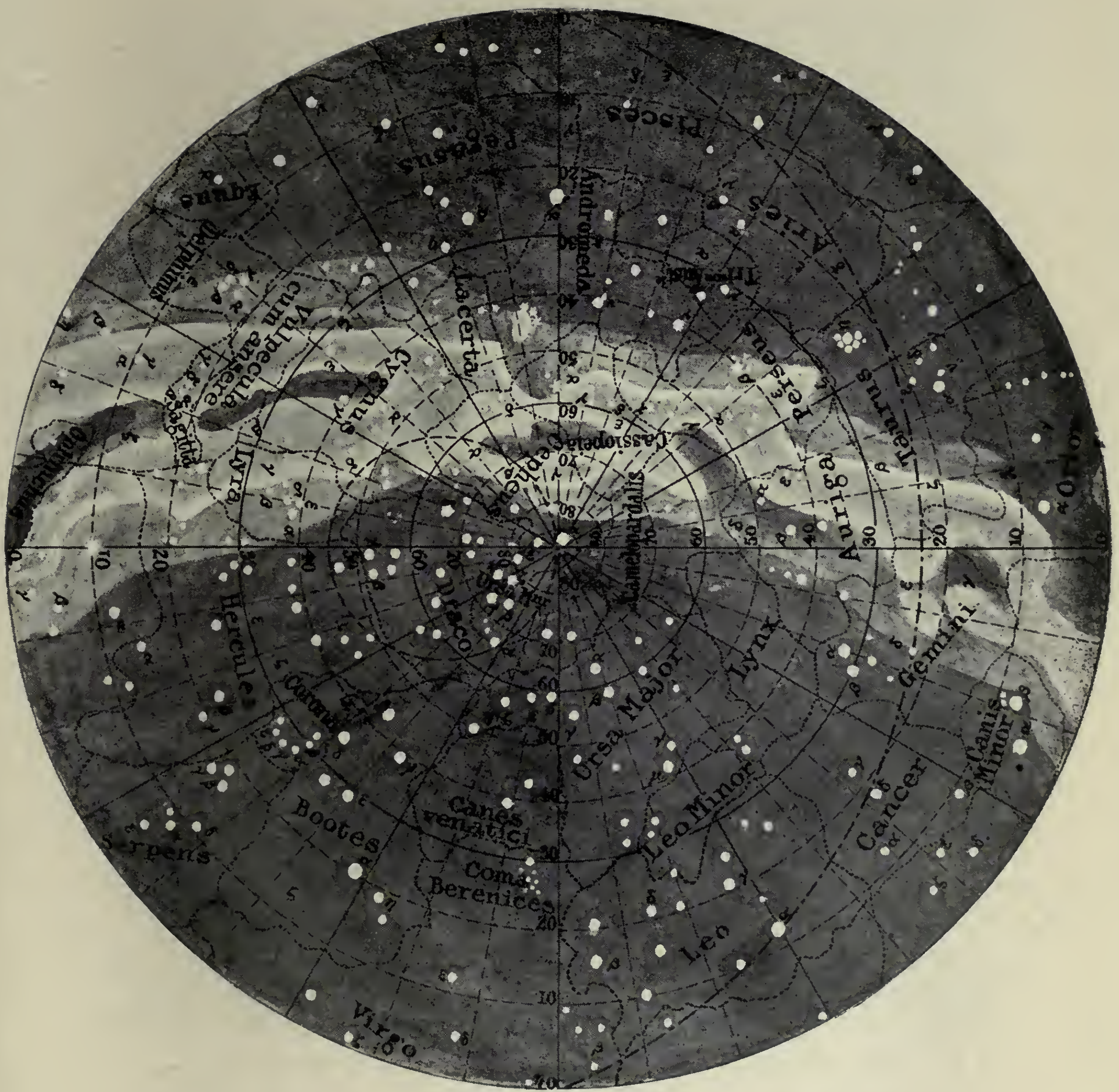


Fig. 275.—The Milky Way in the Northern Hemisphere of the Sky.

Fig. 276.—Portion of the Milky Way in the Constellation Cygnus.

(From a photograph by E. E. Barnard, Lick Observatory.)

Figs. 274 and 275, which illustrate the Milky Way in both parts of the globe, will show; nor is it a structure of ordinary ring-like shape, as it branches forth into divisions and ramifications, although the entire formation is generally termed a belt.

The brightest parts of the Milky Way in the northern hemisphere are situated in constellation Cygnus (Fig. 276). Suns crowd and throng together in inseparable numbers, impossible for the eye to retain. The parts of the Milky Way passing through the constellations Scorpio and Sagittarius (Fig. 277) in the southern hemisphere are even richer in stars. There are, however, stretches almost entirely without stars, resembling holes torn in Urania's gleaming veil. The Southern Cross, one of the most beautiful of constellations, has a barren patch, aptly nicknamed the "Sack of Coals," owing to its almost utter lack of light. A similar spot is found in the centre of the Milky Way stretch in Ophiuchus (Fig. 280). The width of the Milky Way varies greatly, but its most interesting feature is the great bifurcation beginning in the constellation Cygnus and reaching to Centaurus in the southern hemisphere.

Intricacy of its Structure.—It is hardly surprising that this striking and beautiful belt of light attracted special attention at all ages. Astronomers have devoted years to the investigation of the galaxy. Herschel, Heiss and, later, Plassmann and the Dutch astronomer Easton, above all, have rendered invaluable help in explaining the Milky Way. The last-named, probably the most eminent Milky Way specialist, declares it to be a remarkably intricate structure. He has compiled a list of about one hundred and fifty breaks in continuity, concentrations and ramifications in the starry belt. On looking at it on a clear winter's night, when there is no moon to deaden its finer details, numerous conspicuous features are very noticeable. The light shed by the Milky Way is principally caused by very minute stars of tenth- or eleventh-magnitude, and so on; their number amounts to many millions. Observing these vast clouds of light in a powerful telescope, or looking at the countless number of dots of light on photographs of the Milky Way, the fact is forced home that it far surpasses human power to enter into details of these crowds of suns, whose abundance almost disheartens astronomers. We can only receive an idea of the whole formation and its chief features, even these alone affording us a tremendous field of activity.

Distance of the Milky Way from Earth.—As the Milky Way generally appears of uniform brightness, we are led to suppose that our solar system is not very far distant from the centre of this huge starry ring. From this we infer the angle at which we view the whole stupendous structure. Moreover, the fact that, as seen from earth, the Milky Way does not pass through the centre of the skies and does not form a "greatest circle," proves that our solar system must be situated somewhat outside the belt, above its plane. Then, too, the stars of the Milky Way are much farther away from us than the stars which we can see in the other celestial regions outside the trend of the galaxy, and which appear on an average far larger and brighter than the bodies forming the Milky Way. Estimates of their distance, based on the light-power of the stars, have shown the most distant stars outside the Milky Way to be only about half as far away as those on its borders. Light has to travel from 4,000 to 5,000 years to come to us from the galactic stars, and the diameter of this sun-belt would therefore be nearly 10,000 years of light. Let us remember, in connection with this calculation, that our nearest fixed star Alpha Centauri is 4⅓ years of light away from us, or about 250,000 times farther than the sun, and that this distance seemed ungraspable to us. The above distance of the Milky Way is the lowest of all computations. According to M. Wilhelm Meyer, the dividing space may be set down at 10,000 years of light, and the diameter would then be increased to 20,000.

Position of Our Solar System to the Milky Way.—If we were to attempt to draw a picture of the whole collection of stars, based on the relative position of our solar system to the belt of the Milky Way, the effect would be as shown in Fig. 278. We should, first of all, see the great girdle of Milky Way stars, above whose plane, towards top and bottom, and partly filling the centre as well, are the stars outside the galaxy we notice in the skies. Our own sun

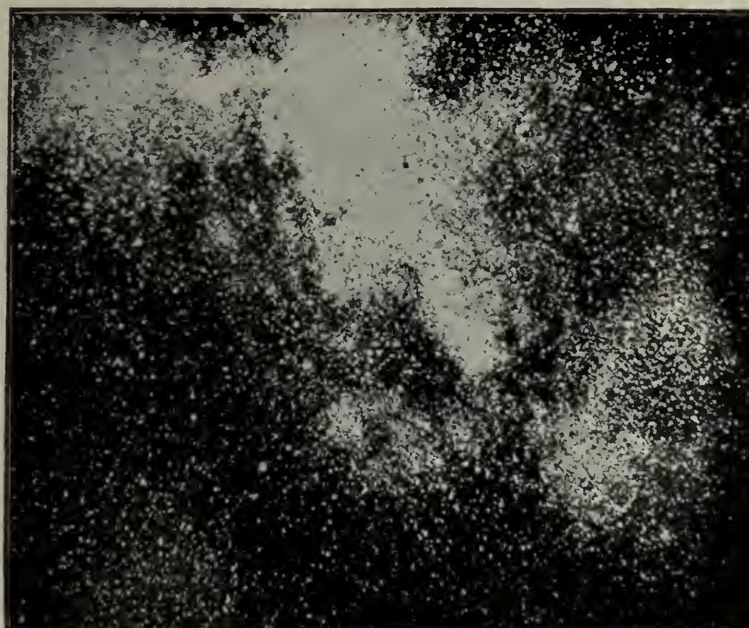


Fig. 277.—Part of the Milky Way in the Constellation Sagittarius.

Fig. 278.—Supposed shape of the Milky Way System seen from a great distance and from above.

Fig. 279.—Supposed shape of the Milky Way System seen from a great distance and from the side.

Fig. 280.—Part of the Milky Way in the Constellation Ophiuchus.

In the centre is the starless patch called the "Sack of Coals."

(From a photograph taken by the Yerkes Observatory after an exposure of 4½ hours.)

belongs to these stars; its position in the Figure is marked S. If we could take wing and soar high into space above the whole structure and then look down on it, we should see it as shown in Fig. 279.

The Fringe of the Vast Archipelago of Stars.—The more we know in detail about the Milky Way, the more certain it becomes that we have to deal with a lens-shaped body, formed of millions of stars and comprising all those visible to us. The whole huge congeries of fixed stars to which our sun belongs forms a starry isle in space, a flat, round, lentil-shaped entirety, of which the Milky Way is the border, and the whole structure seen, say from the side, would probably possess a shape resembling that of the object represented in Fig. 282, a body which can be seen standing

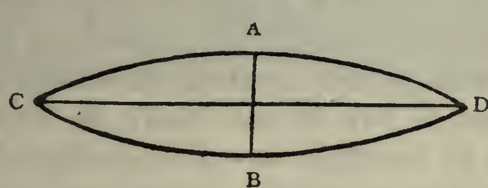


Fig. 281.—Diagram to explain the distribution of Stars in the Milky Way.

at an immeasurable distance away, and which may also be a similar island of stars far beyond the Milky Way, another and still more remote Milky Way system! The starry lentil is formed of suns in the same fashion as a glass lens consists of countless millions of tiny parts, called glass molecules. If we were to imagine an incredibly tiny being with reasoning powers to have taken up its abode on a molecule in a glass lens, stationed about the centre of the lens, it would see the molecules scattered about inside the lens in the same way as we see the stars of our stellar system. In the direction marked A and B in the diagram (Fig. 281) far fewer molecules would be seen floating about the glass lens than in the direction C D, the edge of the lens. Our imaginary molecular resident would therefore see the edge of the lens as a dense ring of glass molecules, a molecular Milky Way, and outside of its trails, at A and B, far fewer molecules would meet its eye, similar to the sparse scattering of stars outside the Milky Way belt in the sky.

Andromeda Nebula.—We have just pointed out that there are structures in the depths of space greatly resembling the galaxy in shape, if we take into consideration the fact that we see these bodies partly from above, partly from the side. One of these luminous isles of the heavens, the celebrated Andromeda nebula, is photographed in Fig. 282; it is faintly visible, even to an unassisted eye, in the shape of a tiny, dim, elliptic cloud in Andromeda. It consists of a huge conglomeration of stars mixed with the nebulous matter to which we will refer in the next chapter. This Andromeda nebula apparently has a flat lenticular shape; we see it very much from the side, and to us it apparently has the form of an ellipse. The annular nebula in Lyra (Fig. 292) resembles our Milky Way system even more closely in shape; it is not a conglomeration of stars, however, but a cosmic nebulous mass from which stars and suns will probably be evolved at some future period. Various features of the Milky Way, its bifurcations, arms and curls seem to hint that the great girdle is but the central twist of an enormous winding spiral, and that the matter from which this gigantic host of stars was formed was once possessed of a whirling motion, such as is exhibited by the "spiral nebulæ," of which a fine specimen is shown in Fig. 283.

Are there Milky Ways beyond Our Own?—There are objects enough in space whose shape offers a certain justification of our speculations on the Milky Way formation, although its more intimate details are totally unknown to us. A pertinent query arises: Are these luminous islands which so greatly resemble our Milky Way in form and appearance other Milky Ways beyond our own, or are they smaller Milky Way structures still inside its mighty confines? Only measurements can answer this question. If it be definitely proved that bodies such as the Andromeda nebula are no farther away than the Milky Way stars, or that they are even closer to us, then the theory of Milky Ways outside our stellar system must be abandoned as baseless. Latterly several of these brighter islands have been examined as to their distance, and it is believed that they will be shown to be nearer to us than the stars of our

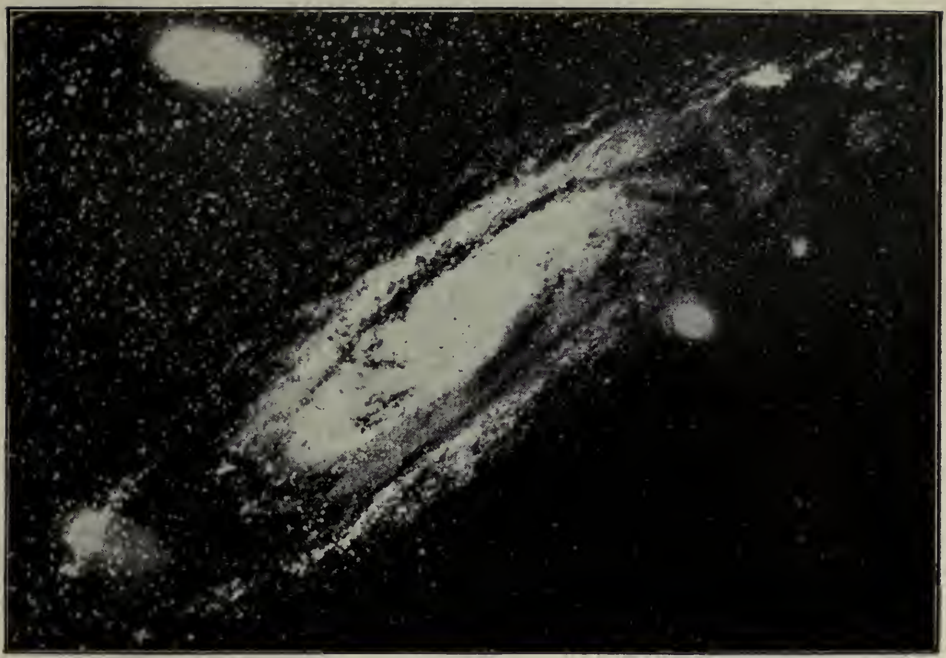


Fig. 282.—The Great Nebula in the Constellation Andromeda.
(From a photograph by G. W. Ritchey, Yerkes Observatory.)

Fig. 283.—The Spiral Nebula in the Constellation Canes Venatici.
(From a photograph by G. W. Ritchey.)

Fig. 285.—Cluster of Stars in the Constellation Centaurus.

(*After a photograph.*)

Fig. 284.—Cluster of Stars in the Constellation Cancer.

(*After a drawing by Lord Rosse.*)

Fig. 286.—Cluster of Stars in the Constellation Toucan.

(*After a drawing by Lord Rosse.*)

Milky Way. We must not forget, however, that such measurements are very uncertain, owing to the vast remoteness of the objects under observation, and it were well not to trust deductions too implicitly as yet. In any case, the Andromeda nebula is a most extensive formation; its apparent length is about four times the diameter of the full moon. Countless stars and large masses of nebulæ fill this expanse, and we are almost persuaded to regard the nebula as a body equal to our own stellar system and lying outside of its borders.

The Border of the Universe.—Some astronomers are of opinion that the Milky Way is the limit of the visible universe, and that our instruments do not permit us to look farther than this bounded space. They believe that a vast space, empty to our senses, lies on the farther side of the Milky Way, and only beyond this immense region could there be any new Milky Way systems floating in the infinity of the universe. Great voids separate the different suns from each other, and therefore farther voids, proportionately larger, must divide the various Milky Way systems; and it is questionable whether the rays of light emanating from these unimaginable depths are able to penetrate to us, and whether on their journeyings, lasting thousands of centuries, through the ether of space the rays are not so weakened as finally to perish from sight. This perhaps may explain why our knowledge will never be able to extend farther than the Milky Way, and no human eye will ever be able to see the starry isles beyond its borders. But, like Columbus, who with outstretched hand pointed the direction in which lay a new world as yet unseen by mortal eye, we, too, dare to point at Milky Ways beyond our own!

Knowledge Grows from More to More.—Knowledge of the universe is ever being added to. The earth, which was once thought to be the only world, has dropped to but a single unit; we know many such worlds to revolve around the sun and, with it, form the solar system. We know that there are millions of such solar systems, that they, too, are, so to say, separate bodies, which in their numbers form the Milky Way system. And this knowledge helps us to conclude that this gigantic collection of suns is, in turn, but a single structure, and that the universe may contain many such clouds of suns. We have long ago left all human measurements, comparisons, and feelings far behind, and, faced by these infinite possibilities, a sense of bewilderment seizes us and we feel like a babe lost in the wood. We realise our minuteness in these immeasurable crowds of systems, and, despite all research, all pains and all success, we may compare ourselves to a child gazing with lively curiosity at the "works" of a complicated clock, and seeing nothing but blinking bits and wheels moving inexplicably and ceaselessly up and down and to and fro.

CHAPTER XXVII

THE COSMIC NEBULÆ AND THE EVOLUTION OF THE WORLDS

Luminous Clouds in Space.—As the telescope carries us through the starry skies on a clear wintry night, world upon world flashes across our vision and, when our large glass eye moves only one-tenth part of a degree, we have wandered several million miles farther in the universe. Comets near and far flit by, planets surrounded by masses of clouds and encircled by tiny moons float slowly past, and then come suns, huge and flaring, or tiny as a small diamond, whilst every now and again a shooting-star leaves a bright trail of light in the sky. Then in our field of vision appears a small misty cloud, looking like a faint chalk mark on a black slate, undefined, weak of light, only perceptible to an untired eye, a new stellar object such as we had not hitherto noticed. Our glass eye is not powerful enough to reproduce it sufficiently sharply, and we have to fit in a different eye-piece to obtain a more distinct view of this luminous cloud. And then we find the apparently nebulous mass to be an immense collection of stars, a cloud consisting of many thousands of suns, a "star cluster" like those in the constellations Cancer, Centaurus and Toucan (Figs. 284, 285, 286). The stronger eye-piece reveals them plainly like diamonds resting on a velvet bed; thousands of suns and probably thousands of earths, too.

Star Clusters.—Their clustering is only apparent, for in reality wide empty regions divide the single suns, and it is only in consequence of their immense distance from us that they seem so densely packed. The smaller clusters, such as the well-known Pleiades (Figs. 264, 265), are the connecting links between the compound stars and the stellar mass now under discussion. These dense clusters are apparently Milky Way systems on a smaller scale, the mass of matter from which they were evolved being smaller than that from which the Milky Way system was formed. It is almost impossible to say positively what is the remoteness of these structures. We cannot even do more than conjecture whether these numerous clusters are inside of the galactic belt—parts of it which have been torn away—or whether they are situated outside its borders; this last theory, however, appears far more probable for many reasons.

Cosmic Nebulae.—It has required patience to dissect these radiant clouds into stars, as they really seemed to be nebulæ (for instance, the notable Cancer nebula, Fig. 284), gaseous masses without a solid body; and we shall learn almost immediately that the universe contains immense quantities of glowing gases called nebulæ, which play a most important part in the cosmos. The spectroscope, as we have learnt, informs us whether the light under observation is emitted by an incandescent solid, liquid, or gaseous body, and, long ere telescopic observation of several of these luminous clouds had singled out the various tiny stars, it had definitely proved the light to emanate from fixed stars, and not from gaseous masses. There are cases, however, in which the gas spectrum is seen together with the fixed-star spectrum in these celestial objects, so some star clusters must still contain wide expanses of nebulæ of gaseous matter. On the other hand, we know of nebulæ which already contain stars, whilst the chief mass of matter has not yet condensed to stellar bodies. The celebrated Andromeda nebula is a structure of this type (Fig. 282). Furthermore, there are also thousands of dim clouds, as yet innocent of stars, which possess a purely gas spectrum, and which are tremendous banks of cosmic nebulæ, some being of perfectly enormous extent.

Size and Distance of the Nebulae.—The Andromeda nebula spreads over a region about thirty-two times as large as the solar disc; the brightest parts of the Orion nebula alone are at least twenty times the size of the sun, and Wolf of Heidelberg has discovered nebulæ which reach through a large part of a constellation, as, for instance, the America nebula in Cygnus, which received this name owing to its shape, but which is very far from extending over the

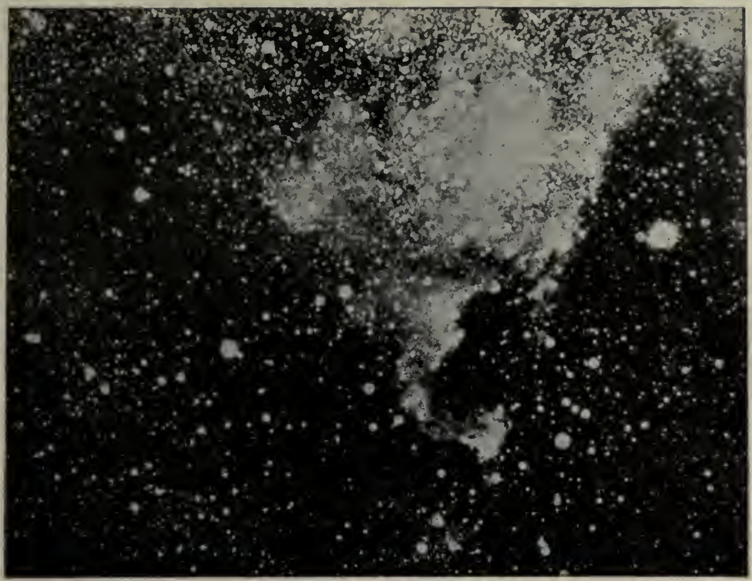


Fig. 287.—The America Nebula in the Constellation Cygnus.
(From a photograph by Professor Wolf, Heidelberg.)

Fig. 288.—The Great Nebula in Orion.
(From a photograph by Professor Scheiner, Potsdam)

Fig. 289.—Finer details of the Great Orion Nebula.

(From a photograph by G. W. Ritchey, Yerkes Observatory.)

whole of Cygnus (Fig. 287). Even if the Andromeda nebula were not farther away than the most radiant and nearest fixed stars, it would cover an expanse two hundred times as large as the diameter of our whole solar system; Neptune's huge orbit, comprising 5,600,000,000 miles could find a home two hundred times over in the spacious dimensions of the nebula! It is totally impossible, however, for nebulæ to be as near to us as we have just assumed. Although we have not arrived at any definite knowledge of their distance, I incline to agree with the frequently combated hypothesis that the large nebular masses are beyond the Milky Way, that they are themselves Milky Ways, or parts of Milky Ways, similar to our own. We still have a few words to say on the subject of the real nebulæ, these vast and extremely thin clouds of gas, and the *rôle* they play in Nature's workshops. If our theory be correct, they are a most important factor in the cosmic doctrine, as they are worlds in the making, the substance out of which entire swarms of worlds are gradually created.

Shapes of Nebulae.—Nebulæ take very different shapes. We have observed turbulent, shapeless clouds as well as those in which the matter has been formed and forced into position by the pressure of rotating and attractive forces. Human life, even of whole generations, is far too short to trace greater developments in the nebulæ. Hundreds of centuries must elapse before the evanescent matter, following the eternal, inexorable laws that prevail throughout the whole of space, can group itself in suchwise that any alteration, any progress in the prevailing conditions can become noticeable. Nevertheless, the logical sequence of discoveries made in the many thousands of nebulous shapes compels the conclusion that these chaotic, formless clouds of mist slowly turn to nebulæ of a certain kind, striving towards the attainment of a definite end, influenced therein by the energies mentioned above, that here, as everywhere else in Nature, evolution is at work shaping the primitive material into higher forms. Such shapeless beginnings are seen in Fig. 287 and also in the Orion nebula, one of the brightest and most beautiful specimens of nebulosity in the sky (Fig. 288), which seems as yet to be quite in the "rough," although closer examinations have traced the beginning of spiral-shaped curves and twists in it, too (Fig. 289).

Spiral Nebulae.—M. W. Meyer, says that it is possible to trace the outlines of the movements which nebular matter follows if we watch the changes which tobacco smoke passes through in an undisturbed atmosphere. Just as the small clouds of smoke hovering in the air of a room may form into spirals around a central nucleus, impelled thereto by slight currents of air, so the matter in those distant nebulous clouds also tends to assume a spiral structure. The nebula in Canes Venatici (Fig. 290) plainly shows us the moving powers at work. The matter winds itself in serpentine lines around the central core of the nucleus, the tip of the most extreme curve having a second nucleus, which seems to have at some indefinite period penetrated the nebulous mass and set it in motion. The nebula in the constellation Coma Berenices (Fig. 291) must also be classed with the spirals; we see this edgeways on, and so it takes a spindle shape to our vision. The great nebula in Andromeda—which, by the way, partly consists of stars, and in which the nebulous matter is in the act of condensation to stellar bodies—also shows spiral-shaped structures. The annular nebula in Lyra (Fig. 292) possesses exceptionally interesting features, as the weaker spirals are apparently invisible, and only the chief turns can be seen; there is a star-like condensation of matter in the centre. Fig. 293 represents a remarkable twisted nebula cloud in Cygnus.

Planetary Nebulae.—We also know of nebulæ which are of a completely circular shape, and have been named planetary nebulæ (Fig. 294), as a superficial observation in the telescope shows them to have the aspect of a planet's disc. In these cases the nebulous matter (planetary nebulæ apparently are always of smaller size) is already in a state of powerful condensation towards the formation of a sun, and very often the centre of such an object is of star-like radiance.

Nebulous Stars.—Moreover, stars have been found in the skies that are a connecting link between nebulæ and the finished product—stars surrounded by a nebulous ring—and we hardly err in regarding this as the last traces of the

Fig. 290.—The Spiral Nebula in the Constellation Canes Venatici.

(From a photograph by G. W. Ritchey, Yerkes Observatory.)

Fig. 291.—Spiral Nebula in the Constellation Coma Berenice, which, thus seen from the side, seems spindle-shaped.

Fig. 292.—Annular Nebula in the Constellation Lyra.

(From a photograph by the Papal Observatory, Rome.)

Fig. 293.—Remarkable Twisted Nebula Cloud in Cygnus.

(From a photograph by G. W. Ritchey, Yerkes Observatory.)

Fig. 294.—Planetary Nebulæ.

gaseous matter from which the star originally sprang. Such nebulous stars are to be found in Orion and in the stars forming the small Pleiades group.

The Spectrum of Nebulae.—The determination of the constitution and condition of nebulous matter is of great importance, as it would seem that we are here confronted by the substance from which the celestial bodies are evolved. Spectroscopical investigations have proved that the matter forming the nebulæ is of a very simple composition, without any complicated chemical elements. The spectrum of stars, consisting as it does of thousands of lines (Fig. 273), leads us to assume the presence of an extremely large number of chemical elements on them, whilst the spectrum of nebulæ (Fig. 295) only throws up four bright lines, of which two are produced by hydrogen and the third indicates carbon. The fourth line proceeds from some unknown matter, probably not met with on earth in that condition. So we see that at any rate the chemical composition of nebulous matter is very simple, and if the stars really do shape themselves from nebulæ, and if the nebulæ really do represent the elementary matter of the suns—and there is no reason to doubt this—then the numerous chemicals present in the sun and other stars, and particularly in our earth, which is a celestial body like all others, must originate later, when alterations of temperature, the condensation of nebulous matter and other forces have compelled the tiniest particles of nebulous substances to enter into different positions.

The Primitive Element.—It has long been surmised that the many elements we know, such as hydrogen, oxygen, gold, iron, magnesium, and so on, although it is impossible for us to decompose them chemically, are only different forms of one single great primitive element, the universal element on which the whole world-structure is reared. Perhaps the nebulæ to some degree contain or even embody this primal element; the simple chemical constitution of these gigantic clouds of gas brings this assumption well within the bounds of possibility.

Nature's Workshop.—Perhaps we may be really on the track of one of the mysteries of Nature in following up this clue; perhaps we have actually been permitted to take a peep into Nature's workshop where the celestial bodies, whole clusters of suns, are moulded and fashioned without ceasing. And does all that our terrestrial globe calls its own—its countries and oceans, its fiery depths and airy cloud strata, its masses of ice and snow, its countless forms of animal and plant life, its human beings and the marvellous creations of their hands and brains—does it all lead us back only to tossing and heaving masses of gas which millions of years ago slowly floated through the immensities of space?

The Kant-Laplace Theory of the Origin of the Solar System.—Is it possible that all that surrounds us on earth was, untold ages ago, dissolved in one enormous, inconceivably huge cloud of gas? The idea that the celestial bodies, especially our solar system, originated from gaseous clouds was expressed long before we possessed a clear knowledge of the composition of nebulæ. Swedenborg, famed for his spiritual researches, set up a kind of nebular hypothesis in 1734, and Thomas Wright, of Durham, defended his doctrine. It was, however, left to the illustrious Kant (Fig. 297) and the no less illustrious Laplace (Fig. 298) to promulgate what is generally known as the Kant-Laplace hypothesis and work out the theory of cosmogony, especially of the origin of our solar system, which still occupies the foremost position among theories on the subject. The two *savants* differ in many respects, but it is customary to couple their views. According to Kant, the space now occupied by our whole solar system was once filled with an exceptionally thin gas. The matter, which later formed the sun with its planets and moons, was spread out with extreme tenuity over this entire space and was possessed of a very slow rotatory motion. Kant attempted to offer an explanation of the origin of this motion. Laplace, however, did not venture on the question, which is one of extraordinary difficulty and was not solved by Kant either, the Frenchman accepting the rotation of the great nebular masses as something that had existed from the very beginning. Both stated that the gas masses had a flat, circular shape, resembling that of a lens, and that they gradually contracted, the greater force of attraction exerted by the inner masses on the outer ones

Fig. 295.—Spectrum of a Nebula.

Fig. 296.—Development of the Solar System on the Kant-Laplace Theory.

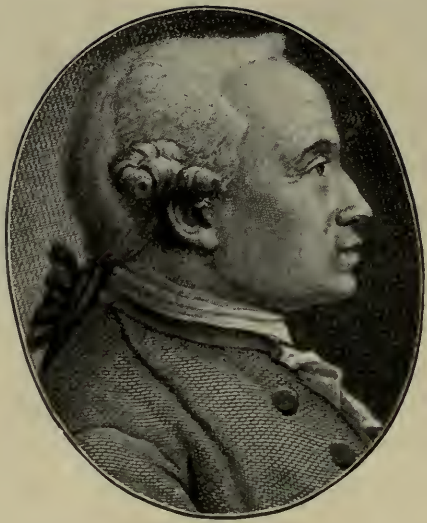


Fig. 297.—Immanuel Kant.

Fig. 298.—Pierre Simon Laplace.

causing the matter to contract in the centre, the nucleus of the entire masses, from which the sun was finally evolved. Kant pronounced a condensation of matter also to have taken place on the outside of the central mass, around which all else revolved, and others at intervals within it, and from these separate collections of matter the planets were formed, all revolving around the central body, the sun, in the same direction which it took; we know this to be really the case. The smaller accumulations that collected inside the gaseous globes, from which the planets originated, went to shape the moons of these planets; these, too, being compelled to encircle their planets in the direction in which the planets themselves rotated on their axis. With a few exceptions this argument is correct. Kant also elucidated why the outer planets (Jupiter, Saturn, Uranus and Neptune) had to be larger than the inner ones (Mercury, Venus, Earth and Mars), and further demonstrated that, as really is the case, the planets nearer the sun must be of denser constitution than the others.

Laplace, who published his hypothesis of the origin of the world forty years later, in 1796, assumed the presence of the glowing solar ball rotating on its axis as an indisputable fact from the beginning. But, according to him, the globe was at that time surrounded by an enormous atmosphere, a layer of gas which spread out much farther than the space taken up by the most remote planet of our solar system to-day. The temperature of the immense globe gradually sank, the matter contracted into a smaller space, and, in obedience to physical laws, the rotatory speed of the ball had rapidly to increase, so much so that the outermost gaseous layers tore away, as we may perceive must happen with very rapidly rotating bodies. In time whole rings of gas were thrown off from the sun's bulk (Fig. 296), reminding us of spiral nebulæ, for instance, that in Canes Venatici (Fig. 290). These rings fell asunder, the matter of each contracting around one somewhat denser point in the belt, its nucleus, and thus a globe, a planet, was gradually evolved which courses around the sun to-day in the orbit which the ring originally took. On the same principle on which the rings destined for planets were ejected from the solar globe, rings of gas were thrown off from the planet balls, later forming their moons.

Certain Difficulties in the Nebular Hypothesis.—It is not necessary to go farther into the history of the transformation of a volatile gaseous planetary ball into a glowing gaseous and an incandescent liquid ball, as a result of increasing condensation, finally, in cooling down more and more, to be turned into an incandescent solid body on which a dark firm crust of ashes was formed. Here we are only interested in the very earliest beginnings of a solar system, and it cannot be denied that Kant and Laplace raised their world-theory on extremely simple foundations. It is this very simplicity that renders their hypothesis so acceptable, since it offers an explanation of a whole series of phenomena peculiar to the different members of our planetary system. Take, for instance, the uniform motion of the bodies from west to east. No better theory has been presented than the Kant-Laplace hypothesis, although recent astronomical discoveries have disclosed grave errors which cannot be reconciled with the existing conditions. Apart from a great many other points that cannot be set forth without mathematical treatment of physical laws, we may take as an example of erroneous views the reverse rotatory motion of Uranus on its axis, and the orbits of the four Uranus satellites around their planet which, as we saw (Figs. 217, 220), run counter to the general motion prevailing in space. The Neptune moon and the newly discovered outer satellites of Jupiter and Saturn also possess this contrary motion, which can by no means be explained on the theories put forward by Kant and Laplace. As an explanation of these irregularities it has been assumed that foreign bodies with a motion different from that of the members of the planetary system penetrated the matter from which the solar system was evolved, forcing a part of it into subjection to themselves. According, however, to recent researches, these retrograde satellites may be explained as follows: When a planet existed as a nebulous ring, the inner portion, being nearer the central mass, would revolve more quickly (as we see in Saturn's ring). The hypothesis of Laplace is sometimes stated as if a nebula could rotate as a rigid body, which is, of course, absurd. It is easy to see that a planet formed from such a ring would start with a retrograde rotation. According to W. H. Pickering and Stratton, its outer moons were born at this epoch; subsequently solar tides inverted the planet, giving it a direct rotation, and its nearer moons were born after this occurred. Owing to the great distance of Uranus and Neptune, the solar tides were too feeble to invert them, and their retrograde rotation and satellite revolution persist. If it be true that Mercury and Venus always turn the same face to the sun, this must likewise be ascribed to the effect of the solar tides, which have acted as a brake.

Moulton and Chamberlin's Hypothesis. — Another cosmic hypothesis deserving of attention is that advanced by Moulton and Chamberlin, although it does not go back to the very first beginnings of the formation of the universe,

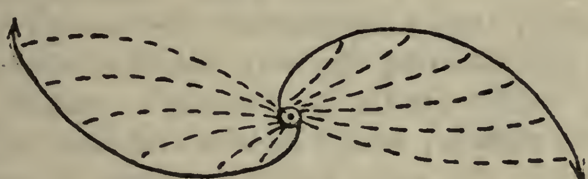


Fig. 299.—How a two-winged Spiral Nebula originated, according to Moulton-Chamberlin.

which it was Kant's ambition to explain. They imagine that, millions of years ago, a foreign sun once approached our own. This close approach produced a tidal action on our sun—that is, the attractive forces of the second sun brought about tremendous eruptions and outbreaks from the interior of our sun at two opposite points, thereby causing a two-armed spiral nebula to develop (Fig. 299) in whose centre our sun stood as a central point (we know that several such spiral nebulæ do exist in the universal system). The matter of which this spiral nebula consisted must have been unequally divided and there must have been certain collective masses of matter which revolved around the central nucleus. The planets were evolved from the larger accumulations, and the moons from smaller masses that had gathered near to the planets. Several characteristic features of our solar system which the Kant-Laplace laws do not explain at all, or only on very far-fetched grounds, are made more comprehensible by this hypothesis.

Arrhenius on the Evolution of the World.—The theories advanced by the Swedish physicist, Svante Arrhenius, on the origin of the universal system are singular and most instructive. He also tries to convince us that there will be no end, no final cessation of motion in the universe, such as Clausius regarded as a positive, an irrevocable issue. Clausius believed that the heat now communicated from warmer bodies to colder and productive of energy, will at some future period be uniformly distributed throughout the universe, without any difference whatever, and that in consequence of this general uniformity the world will be wrapped in dense rigidity. Svante Arrhenius, on the other hand, lays great stress on an eternal, never-ceasing circulatory motion of the universe, which turns nebulosities into suns and suns again into nebulosities; the energy given forth by the suns and assuring the very life, the very existence of the universe would gradually decrease in power, whilst the energy of the nebulæ, which absorb and suck up the forces emanating from the suns would increase in proportionate measure. Later the nebulosities would reissue the matter to the suns in process of development. It was Arrhenius who uttered the opinion that the thousands of nebulous patches in space are collective points for immense clouds of meteoric stone and dust particles journeying through the universe. The resistance which they encounter in the masses of nebulæ stops them and they are caught up in them. Thus ever more matter is brought together from all parts in the gaseous clouds of the nebulæ, especially the tremendous masses of very fine dust particles radiated and ejected by the suns. All these substances contract in the nebulæ to form smaller stars, with which larger suns, which perhaps died ages ago, collide when penetrating the wide expanses of nebulosity in their pilgrimage through space, their motion being retarded by the constant resistance they meet with. Even effete stars, according to Arrhenius, still retain so high a temperature in their internal regions that the matter, bursting forth through violent collision with the nebulæ, behaves exactly as explosive substances behave and sets everything around into a whirling action. After an event of this character a so-called "new" star is seen suddenly to flare out, as already described. The erupted masses of gas bursting from the new star spread out in a whirling motion through the nebulæ, thus producing a spiral nebulous shape. The delicate masses of matter would at a later period condense to a central body again, a newly-formed sun, whilst other portions of matter collect around different outside centres to form the planets. The planetary system thus evolved may after long ages, during which its sun has probably entered on the stage of cooling, pierce another patch of nebulæ, and here the regeneration of the dead group of celestial bodies would immediately begin.

A daring series of ideas these! Science endeavours by all the means in its power to determine the beginnings of the universe, the evolution of suns and earths out of chaos. It cannot affirm, it must demonstrate: hence the simple method of saying that all this was achieved by the Creator "in the beginning" is not for it. So men fall back on speculation, and one hypothesis stands until a more plausible one dislodges it, for theories, after all, possess only a conditional value. Hypotheses come and go, are being constantly set up and broken down, but the veil shrouding Nature's greatest mysteries is impenetrable and eternal, and no human hand will ever raise it.

CHAPTER XXVIII

THE STARS AND THEIR HISTORY

A Mountain Walk.—We trudged across the snowy mountain in the starlight; the sun had early sunk below the horizon like a burning ship of weird shape, with fluttering grey cloud-sails, in the ice and snow sea of the wide plain. A dull ruddy glow rested on the white wintry pall, and then it, too, died away and a strange violet light suffused earth and sky. The pines rose gaunt and black on the darkening heights and stillness crept over the woods. The twilight quickly vanished and the stars shone out bright and pure in the clear mountain air.

And we walked along over the crisp, crunching snow, the forester and I. The red flame of his lantern danced ahead, and every now and again a twig cracked and fell in the wood. The old man at my side, his beard frosted over with the hoar of age and winter, held forth on this and that, told how he was born on these heights where he had played as a child and how he hoped to die there, too. Suddenly he clutched my arm as we stepped out of a clearing and saw the plain extending far beneath us and the star-strewn heavens above, and pointed to Sirius burning like a pure and radiant flame in such beauty as I had never before seen it. "That," he said, "is my favourite star! I saw it and loved it as a child; I have grown old and grey, but it has ever remained the same, and so shall it be long after I have passed to rest. Is it eternal? Has it always existed? You should know, for you have studied the stars. Tell me all about it, for it has been my lifelong companion; but it is more fortunate than I, whose course will soon be run."

Did my sturdy old friend need consolation? Was he really envious of the brilliant star, flaming in the firmament in eternal youth? Who knows! So whilst we trudged over the snow I told him of the life of the stars.

Man's Life as a Measure.—How is it that man measures everything around him by the span of his own short existence? I remember how sad it made me as a child to find that a cockchafer had such a very short life—only a few paltry weeks. And yet, within the period which, to our thinking, is so short, the little brown insect experiences everything that determines man's own outer existence. If such a being were able to think and had a conception of time, it most probably would also measure everything by its own term of life and regard man, who experiences no changes in those few weeks, to be eternal, for in the life of a cockchafer a day is of the same importance as a year, or several years, to man. Still, a May-beetle is an absolute Methuselah compared with a May-fly, which only experiences one solitary sunrise and for which life's merry round of birth, youth, life and death passes with a bewildering swiftness. Compared with it, our May-beetle enjoys a very lengthy lease. Man, who grows to be 25,000 times as old as the insect would, to its comprehension, appear as eternal and immutable as are the stars above to us. We, in turn, gaze with awe-stricken admiration on the giant trees of California which have passed their two thousandth anniversary and which existed before the Nazarene walked on earth expounding the sublime truths of His gospel.

Eternal Unrest.—But of what value are single years, nay, tens of centuries, in the endless flow of eternity? Turn centuries into seconds, stellar distances into arms' lengths, celestial bodies into particles of dust, and a universe would arise before us in the shape it might assume to a being capable of existing for millions of years, a giant creature peering as closely into the universe as we look into the whirl of specks of dust dancing in the sunbeams through the room. Similarly, we might behold the stars, which to us never seem to alter their positions or to possess any motion at all, rush wildly to and fro in ceaseless turmoil; we might see some of them vanish into utter darkness, others suddenly arise from nothingness—a stream of worlds in eternal unrest, in constant motion.

Short-lived and Long-lived Stars.—It is the same with the aspect of the stars as with their motion. All the manifold alterations they pass through are lost on "short-lived" man, and science alone can determine the conditions that prevail in the heavens. But the venerable faith in the everlastingness of the stars fell when the clear searchlight of truth was turned on it. Stars of the most varying constitution have been discovered and we are now possessed of a more intimate insight into their history, which teaches us that there are young and old stars, stars in the making, stars in fullest vigour, and stars that are dying a lingering death; just as a forest contains trees of all ages, from the most delicate sapling to the decayed and worn-out giant.

A Stellar Cycle.—The beginning and the end of a star's life history are both lost in the mists of the unknown, as is so often the case in scientific research. We can say nothing of either, as we know nothing of either, for all our knowledge is but piecework patiently put together. The opinion that those gigantic clouds of gas which we perceive floating far away in space represent the substance from which the stars are evolved, gains an ever firmer hold on scientific circles. We cannot with certainty determine the nature of the matter composing these masses of nebulæ, but we do know that hydrogen gas plays a very important part in their constitution, and this leads us to assume that we are here confronted with universal matter in its most simple form.

Nature's forces and Nature's laws are carried out on the same principles in those remote gaseous clouds as with us on earth. The gaseous substances condense more and more, occupying an ever smaller space in their contraction. On the condensation of the nebulous masses reaching a certain stage, the matter gradually attains a higher degree of luminosity, and a spherical, more lucid globe of gas takes the place of the once dim and shapeless cloud. We know such gaseous globes exist in space; they are stars in the making, suns in being.

Birth of a Star.—And one of these days—perhaps when millions of years have lapsed, for centuries only possess the value of fleeting seconds in the life-history of a star—the moment will arrive in the increasing contraction of the gaseous globe and the rise in temperature connected with it, when a radiant sun, blazing out hotly through space, will be evolved from the ball of gas that only shone out dimly compared with the finished star. The gaseous masses are in powerful condensation and at full glow. A star has been born; it launches forth on its solar career, leaving the dimness of its former embryonic condition far behind. The youthful star blazes out in a strong bluish-white light, and these white stars, to which Sirius also belongs, mark the period of youth in the life of a sun. Gradually, infinitely slowly, the temperature of the young sun begins to sink under the influence exerted by the iciness of universal space; the sun turns to a yellowish hue like that of our own sun, which has, alas! left its youth far behind. All these phases, which we can perceive in one single second in the bright spark flying in a white-hot glow from the anvil of a smith, mark the career of a star in the course of enormously long periods. Its light first turns to yellow, then to orange, to a reddish tint and finally to a paling red like that of an expiring coal. The astronomer has listed many such yellow and red objects, the red ones, as we have seen (pp. 307-8), being wasting, aged stars doomed to a near death.

The Upper Crust.—The topmost stratum of these stars, which is principally exposed to the onslaught of the iciness in space, slowly turns into an incandescent liquid condition. Its substances combine and unite themselves to those masses of magma, which, still in motion, later form the first dark petrified crust enclosing the sun. Thus the first hard cinders are finally produced, the earliest parts of a firm surface, for a long, long time destined to float about on the glowing masses, until they remain victorious in the struggle for supremacy; the variable light emitted by numerous red stars proves, as we have elsewhere learned, that regions of solid dark surface are already in course of formation. The time is then not far distant when the doomed stars die away completely. A star fades out of sight, and disappears from our gaze; its light has departed and it floats through space as a dark opaque globe. The presence of dark stars of this nature in the skies has been recognised, and astronomy has scored a veritable triumph over countless difficulties and obstacles in having in many cases been able to determine their existence, position and orbit.

Extinct Stars.—Our earth and moon and all the other planets of our solar system are naught else but such extinguished stars, which have all passed through the phases of evolution we have briefly described. The terrestrial globe would be a dead, lifeless ball of stone if it had not had its home in the proximity of a luminous star, the sun, which provides it with light and heat, and is the mainspring of its life and energy.

When the Sun Goes Out.—Nevertheless, our sun will in its turn at some future period have to pass through this dread metamorphosis, changing into a lightless, icy, rocky sphere, running the course of destiny marked out for it as for all its kindred. Then our earth, on which all life will have disappeared when the heat supplied by the great furnace above finally abates, will wander through the immensities of space as a dead world. Whether the duration of the sun will be 2,000 million years, as a French *savant* has calculated, or whether the number of years, which we may look on as the death-day of the whole family of celestial bodies we call our solar system, will be twice or thrice as long, is of no moment to our contemplation, which teaches but the one great fact that the instant must come when the sun's heat shall finally and absolutely depart, an event that will mean the inevitable death of the whole planetary system.

We have in these few words described the entire life-story of a star, have watched the gaseous ball develop through condensation from nebulous matter, have learnt of its increase of radiance, of the gradual absorption of its light and warmth through its incessant radiation into icy space, and of the solid, cold, stony layer, the dark crust, that formed around the dead sun.

The Star's Atmosphere.—After the temperature of the star has sunk to a certain point, permitting of a combination of its various chemical elements, an atmosphere begins to form, and the celestial globe is surrounded by an aerial envelope, at first of extreme density and non-transparency, which offers resistance to the rays of celestial bodies, but which, with increasing refrigeration and the subsequent depression of the different elements, ultimately becomes transparent and clear. When the temperature of this gaseous envelope has, for instance, sunk below − 148 degrees F. the hydrogen and oxygen contained in it will unite to produce water; water will then pour down from the atmosphere in torrents of rain lasting for centuries, and, beating down on to the hot top crust of the dead star, will at first hiss and evaporate, but nevertheless fall without ceasing.

Oceans, Mountains and Valleys are Formed.—Thus the great primitive oceans are slowly created to fulfil their gigantic task. They gnaw and wash out the rocks against which their waves break tirelessly, tear off layers of the stone which have been reduced to a muddy state by the work of long epochs, separate them into single pieces and deposit them in other spots in the shape of fine sand, thus forming the loose earthy strata on which life is later to strike root. And the cooling processes continue steadily, here straining the stony crust of the star, there squeezing it together, until pleats form in some places and accumulations gather in others to sink down in hollow cavities, until mountains rise and valleys spread out. The skin of a dried-up apple forms into pleats and wrinkles, for it has grown too loose for the withered core, and the stony skin of a celestial body, the solid crust composed of the upper rigid masses of the ocean of heat, is forced in like manner to wrinkle and contract when the core of the star shrivels. These pleats and wrinkles in the skin of the celestial body, these accumulations and furrows, are the hills and valleys, the vast troughs in which the waters of the oceans gather, the gigantic mountain ranges around whose summits the clouds float. Air, water, wind, cold and heat, batten on the rocks of the mountains, wear them down, carry them to the valleys in the guise of dust, sand, mud and pebbles, fill up the deeps, beat down whole hills and form the fruitful plains on which Flora can establish her many-hued realm, if the other gods be kind. In the earliest days of a planet's existence the glowing interior often breaks through the crust, volcanic hills form, large clouds of lava are thrown up and the once radiant sun more and more acquires the exterior of an "earth-star."

The Conditions Essential to Primal Life.—The star when in this condition will soon be ready to bear organic life should a sun, a celestial body sending forth warmth and light, be stationed in its proximity. Without this aid, the star would never reach this the highest and most important stage of all and become a sustainer of life, perhaps of reasoning beings.

This shows the vital significance of the fact whether an extinguished star shall enter into connection with a still luminous radiant sun or not. If it wander alone through the universe, without receiving light and heat from elsewhere, it will remain a dead, rigid giant, but if it should form a double star together with another yet radiant sun, then life may develop on it in an equal measure, as on the planets revolving around the sun.

But What is Life?—Life! Here begins the greatest wonder that we are confronted with in Nature's everlasting round—here is the dark barrier we have not yet been able to surmount. What is life? How did and how does the first trace of life arise on a heavenly body? We have followed the evolution of the stars from their primal matter, and seen them rise and fade away; we know that a dark, firm crust surrounds the dead globe and have learnt how seas and lands, hills and valleys were formed. We contemplated the lifeless, non-organic masses at work; the dead stone, the eternally restless water, the whirling gases and the destructive fire in their seemingly aimless, inharmonious though gigantic action. But a vast interval parts these lifeless objects, the result of a certain disposition of primal matter, from living beings possessed of highly developed organisms. How impossible to bridge the gulf between the lifeless stone and the animate being, even of the very lowest rank among Nature's creatures, which, nourishing itself and procreating new life, fights for its existence!

These two great provinces in the kingdom of Nature, the organic and non-organic, are so totally different in all their phases that we cannot trace any connecting link between them; they stand in such opposition to each other that a human being, from his very earliest youth, as long as his brain is yet unable to classify the things around him, will instinctively mete out an utterly different treatment to these two extremes.

Protoplasm.—We know that living beings have, in the course of many millions of years, passed through an evolution leading them from the most primitive of all forms to ever higher and more complex standards. The older the rocky layers of the earth's crust that we examine the simpler are the animal and plant formations, and the least complicated and the lowest of all organic creation are shapeless lumps of protoplasm,* without special organs or firm outlines —simply a glutinous mass. We may watch such a being part in two, separate into several bodies as soon as it has arrived at a size that perhaps no longer serves the end of the whole, and from the one lump of gluten two have been developed—an infinitely simplified act of procreation and birth. And the newly created exactly resembles the original, having neither back nor front, neither head nor body, *sans* organs of motion, digestion, procreation and sense. A living substance! And yet this most primitive of all living beings contains a something not recognisable in our microscopes, not resolvable in chemical analysis, not explicable by all our brain-power, a something that distinguishes it from any one dead or artificially created lump of gluten and stamps it as the living thing it is. We can well understand how some scientists ever and again return to the hypothesis that there must be a separate "energy of life" innate in all that is alive in the world and animating it; an argument from which modern science departs more and more, explaining the function of life as an intricate combination of chemical and physical forces such as are met with everywhere even in "dead" Nature.

How, then, does Life Arise?—Did life arise from death? Can the organic be created from the non-organic, or does the hand of the Omnipotent, the Creator of the universe, make its workings undeniably felt? Thousands of questions rush in on us, impossible to answer at the present stage, perhaps never answerable at all! It helps us nothing to be informed by some that life *may* have travelled to us from other celestial bodies, that life in its lowest shape, germs of all kinds, floating in the atmosphere of a celestial body and arriving at a very great height, *may* have been driven out into space, finally to land on the surface of another world and there rise to further and higher developments. This does

* Protoplasm chiefly consists of albumen.

not help us to elucidate the great problem by a single iota, and we still ponder the origin of life, whether it may have had its source on a Sirius planet or on a star of the Milky Way.

Should the external conditions be favourable, life can develop to higher and nobler forms, finally incorporated in a being who—as on our own earth—is able to conquer and rule the star on which he dwells, able to send out his thoughts farther than his own celestial body, ay, than the whole of the universe. Life is, however, thoroughly dependent on external circumstances; should the sun which supplies the star-bearing life with warmth and light slowly begin to decrease in vigour, life—as we have already said—will be gradually crippled in its growth and ultimately perish, despite all the intelligence which the highly-developed humanity of such a world could set into action in an endeavour to maintain life by artificial means. Judged from a human standpoint the celestial body has then played out the rôle assigned to it; in future it can only travel about the universe, a rigid, cold, dead, ghostlike wreck of its old self.

The End of the World.—On such deductions it is only rational to assume that at some future age all the stars, all the countless millions of suns that fill the universe will be extinguished, even if millions of years, too many for our brains to comprehend, must pass before such a climax is reached. This would mean the stagnation-point, the end of the world in the very widest sense of the phrase. No star would gleam in space's immeasurable voids, no planet be inhabited any longer, not a single eye be present to behold this everlasting night of Infinity.

Resurrection in Space.—The very circumstance that nothing of the kind has been noticed until now, that countless suns still gleam and glitter in the skies must give reason to pause. If the world be a finite, a created "whole" that has its limitations and once had a beginning, then it must own to an ultimate end, must come to a standstill like clockwork that has run down. If, however, it be eternal, be infinite, both as to time and space, then there will at some period be a resurrection in space, when all the extinguished suns will awaken to fresh life, to new radiance. Present philosophical and physiological speculations seem to lead to the conclusion that the universe is in truth an eternal, infinite structure (if the word "structure" may be applied to the whole, the All-comprising, the All-being) in which nothing ever dies or is lost, but where everything strives in ever higher and ascending circles to attain ever more perfect and more purposeful forms. Newer cosmogonic and astronomical researches have determined that these perished stars collide with other dark stars in their pilgrimage through space (this meeting most probably occurring in the great clouds of nebulosity which float about everywhere in the universe and in which celestial bodies of all kinds are apparently trapped like insects in a spider's web) and that a new world is born from the collision of two worlds dashing into each other with terrific force. The motion of the two globes, which is stopped with such alarming suddenness by their impact, is turned into heat, and the two worlds are dashed by this violence into a state of highest incandescence; they glow and radiate and change into glowing gases, luminous nebulæ, in which all the atoms have been set into most violent action. We have frequently witnessed these phases in the so called "new stars" that suddenly dart up on the horizon; these are suns that have undergone their resurrection.

Nature's Everlasting Round.—From a nebulous globe back to a nebulous globe! The circle has closed, has returned unto itself. In this resurrection the energy, the mass and the power of two great bodies have been united, beginning a new round of life with new and higher forces. And we ask ourselves whether we, too, shall experience a like resurrection to a higher standard of life.

Matter is Indestructible.—The deeds of the single unit are transient; the largest sun in the heavens is destined for destruction; but nothing is ever lost in the universe, not even the most minute particle in the awful working of the worlds. Everything, though it may seem to us to have passed without leaving a solitary trace, lives on for ever —atoms and forces, thoughts and deeds, all are eternal. Thoughts and deeds are tied down to matter, they are probably but certain expressions of the matter composing the brain and the body of man, and matter as such is indestructible. It is imperishable wholly and entirely, be it where it may, even in the farthest depths of the universe, where none of our telescopes can penetrate, with which we can deal in supposition only. It changes its shape, it frees itself from its fetters when man, animal, star, or flower "dies," but it persists to all eternity, linking itself to other chains, living on for ever in perpetuity. It is only the form that can be killed, for neither the energy nor the substance can perish!

The Seeker after Truth.—Man, the little god of this earth, tied down to the small star which infinite Nature gave him for an abode, storms forth into immeasurable stellar space with his thoughts; ponders and questions the Why and the Wherefore, the Whence and the Whither, the beginning and end of all that is, and tries to comprehend, to embrace and to explain the whole universe with its myriad of suns in the narrow space of his brain-chambers. Here rests the great contradiction that we despairingly study in a silent hour, when the turmoil of a working day has given place to quiet meditation. This small human being, so utterly unable to fulfil the duties of a good steward—as he was destined to be by Nature, with its great and harmonious developments—to his own possession, the earth, who has waged a narrow-minded and gory war with himself and his kin for thousands of years, who sighs beneath hundreds of self-created wrongs, and who, at the end of his limited span, shakes his weary head at life's shortcomings and awaits the day when he, too, will turn to dust, man, in all his incompetence and incompleteness, clutches longingly at the stars and desires to grasp them, using all his reasoning powers to excogitate their beginning and end. There is something almost terribly grand, tragic and pathetic in this quest of knowledge, so deeply ingrained in the inhabitants of our earth that they do not shrink even from the most sublime of all; but it renders it doubly difficult to understand why humanity is not more logical in using the wider views it has gained in the investigation of Nature and its workings towards beautifying and elevating its own little circle; why, recognising how insignificant and short human life is, it does not steer its own destiny towards greater and loftier ends and turn the earth into a Garden of

Eden, consecrated to all that is true, lovely and of good report.

Limitations of Human Knowledge.—And considering the inadequacy of human argument and action, we may well ask ourselves whether the picture of the universe mankind has painted for itself is a correct one, whether man's brain-powers suffice to comprehend and explain the great entirety as it should be. The profoundest philosophers of all ages have occupied themselves with this problem, have put the brake of criticism on to human thoughts and ideas. The thought, never far distant, again comes to us that the human brain, in itself an incredibly minute particle of universal matter, itself something that has been created and developed, is hardly in a position to conceive the infinite world in all its heights and depths.

The Brain and the Senses.—We know of a dark cave, secured against the outer world, in which an aged man lives, a quiet thinker, who has set himself the task of solving and elucidating all that happens in the outer world. Five messengers visit him in his retirement, bringing him accounts of all that goes on in the world, and from their reports the philosopher builds up his image of the world and explains all its thousands of intricate proceedings. We soon recognise that he can only construct a proper likeness of the universe if his messengers supply him with absolutely correct accounts, if they report the entire truth, if they do not lead him astray, and do not withhold important facts from his knowledge. He, in turn, will only be able to construct an exact picture of the universe from the accounts with which his five messengers supply him, if he possesses wisdom enough to assimilate all the mental nourishment brought to him, and cleverly to combine it into a whole.

This parable is not a difficult one to solve. The philosopher in the cave is the brain; the five messengers are our five senses. Only if our five senses serve us in a trustworthy and accurate manner, and keep us properly informed of all that occurs in Nature, and if, further, our brain is in a condition correctly to grasp what the senses report to it, and digest it thoroughly, only then will our image of the universe, our ideas of it, be true and not distorted. We all know, though, that our senses are subjected to very many delusions, to a far greater extent than is generally believed, as they do not often force themselves on the attention of persons who are not scientifically trained and who do not constantly control the traps laid for us by our own senses. Moreover, it is probable that there is much that is absolutely inaccessible to our faculties, that things or powers are existent in Nature which we pass by blindly, as we have no organ able to recognise them. Let us remember that for a very long time we had no cognisance whatever of that most extraordinarily potent force, so prominent alike in human life and actions and in Nature—electricity, as it does not immediately impress itself on our senses, but only appears when it has been converted into light, sound, or other energy perceptible to our faculties. Besides, the principles of thought, the manner and laws according to which our thinking apparatus works, are unknown to us. The innermost procedure of thinking, the arriving at final deductions built up on things that have become noticeable to us, is an entire mystery still; ay, we are not even in a position to state how perception and sensibility ensue from the various impressions the senses carry to the brain. The physiologist Dubois-Reymond once declared, in an address on the "Limitations of the Conception of Nature" (which became both celebrated and hotly disputed), that it would never be given to us to cross the barrier set to our knowledge. And even if man became so far advanced as to see and calculate the position and motion of all the many particles composing the brain, even if, as predicted by Dubois-Reymond, there will have to be an "astronomy of the brain," containing as precise information on the motion of the brain particles as the astronomer possesses of the motion of the stars, even then we shall not know why this thought is created when the particles are in a certain position, and why, at a different combination, that other thought results!

Nor do we really know whether the universe truly does exist in the shape in which it appears to us, whether this image is not purely a product of our imagination. Immanuel Kant expresses this idea in one of his works, when he talks of a "thing in itself" that rests at the foundation of all we perceive, but is in truth something totally different from what it appears to our senses and our brain to be. The things of the outside world really do exist, but what to us appears in the guise of a plant, a stone, or a sun, is, as a "thing in itself," a reality, perhaps something totally different.

Are we Downhearted ?—It would be very foolish to allow oneself to be discouraged by these shortcomings of human powers of comprehension. We shall, in all likelihood, never be able to recognise the primary cause of all things, but the sum total of knowledge grows in a most astounding fashion, as the story of past centuries amply proves. These reveries are meant but as a warning against an overweening conceit of our knowledge and achievements, for, despite all the successes of science, it were well for us to be modest. The universe is still full of problems and mysteries, and will ever be so. The innate being, the reason of the universe, its origin, remain an eternally unsolved, insoluble question for human knowledge. Physiology and philosophy are unable to reveal anything here, nor are other branches of science, which believed themselves to be in a position to set positive facts before us, in a happier condition. The mysteries of the universe lie hidden behind an impenetrable veil, and nobody has been able to step behind and draw back the curtain that divides the perceptible from all that is eternally concealed and inaccessible.

The old forester and I had wandered on farther and farther across the snowy heights. Clouds had veiled the heavenly canopy from our sight, the stars had been extinguished like the sparks of a firework, and now millions of other stars gazed down on us, daintily patterned in crystallised water. They danced in front of us in the light of the lantern; they settled in the old man's grey beard, and dissolved in the breath of his mouth. He had listened to my words in silence, and now he nodded his head meditatively, whilst he slowly said, as we descended into the valley whence the cottages sent forth a kindly beacon of light: "Whilst you were speaking it was almost as if I myself had seen the universe created and grow; all riddles appeared solved, and yet again I see that those last great questions, the solutions of which we all desire, both on scientific and purely human grounds, are not to be answered. The reason for the universe and for our own small existence is wholly hidden from us. It seems to me as if man could not do better than strive after perfection in his own little circle—the perfection which you tell me the Unknown also strives for. To do good in his own narrow set, to aim at all that is lofty and right, as a tiny part of the Infinite, appears to me to be the purpose of our being."

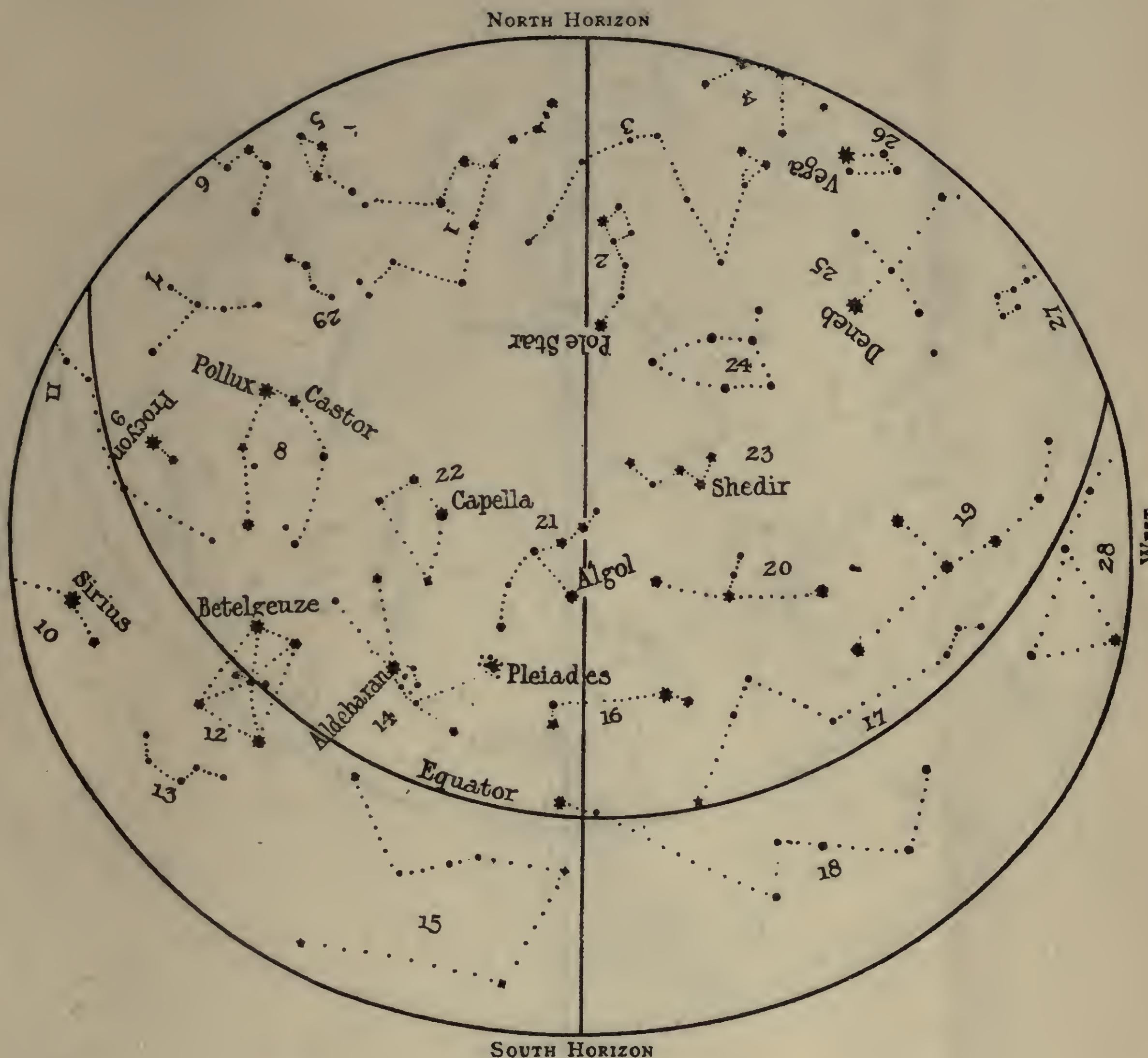


Chart I.—The Stars on January 1st, 8 p.m.

(Also on December 1st, at 10 p.m., and February 1st, at 6 p.m.

1, Ursa Major; 2, Ursa Minor; 3, Draco; 4, Hercules (part); 5, Leo Minor; 6, Leo Major (part); 7, Cancer; 8, Gemini; 9, Canis Minor; 10, Canis Major (part); 11, Monoceros; 12, Orion; 13, Lepus; 14, Taurus; 15, Eridanus; 16, Aries; 17, Pisces; 18, Cetus; 19, Pegasus; 20, Andromeda; 21, Perseus; 22, Auriga; 23, Cassiopeia; 24, Cepheus; 25, Cygnus; 26, Lyra; 27, Delphinus; 28, Aquarius (part); 29, Lynx.

Chart II.—The Stars on April 1st, 9 p.m.

(Also on March 1st, 11 p.m., and May 1st, 7 p.m.)

1, Ursa Major; 2, Ursa Minor; 3, Draco; 4, Hercules; 5, Leo Minor; 6, Leo Major; 7, Cancer; 8, Gemini; 9, Canis Minor; 10, Canis Major; 11, Monoceros; 12, Orion; 14, Taurus; 20, Andromeda (part); 21, Perseus; 22, Auriga; 23, Cassiopeia; 24, Cepheus; 25, Cygnus (part); 26, Lyra; 29, Lynx; 30, Corona Borealis; 31, Serpens; 32, Bootes; 33, Canes Venatici; 34, Coma Berenice; 35, Hydra; 36, Crater; 37, Corvus; 38, Ophiuchus.

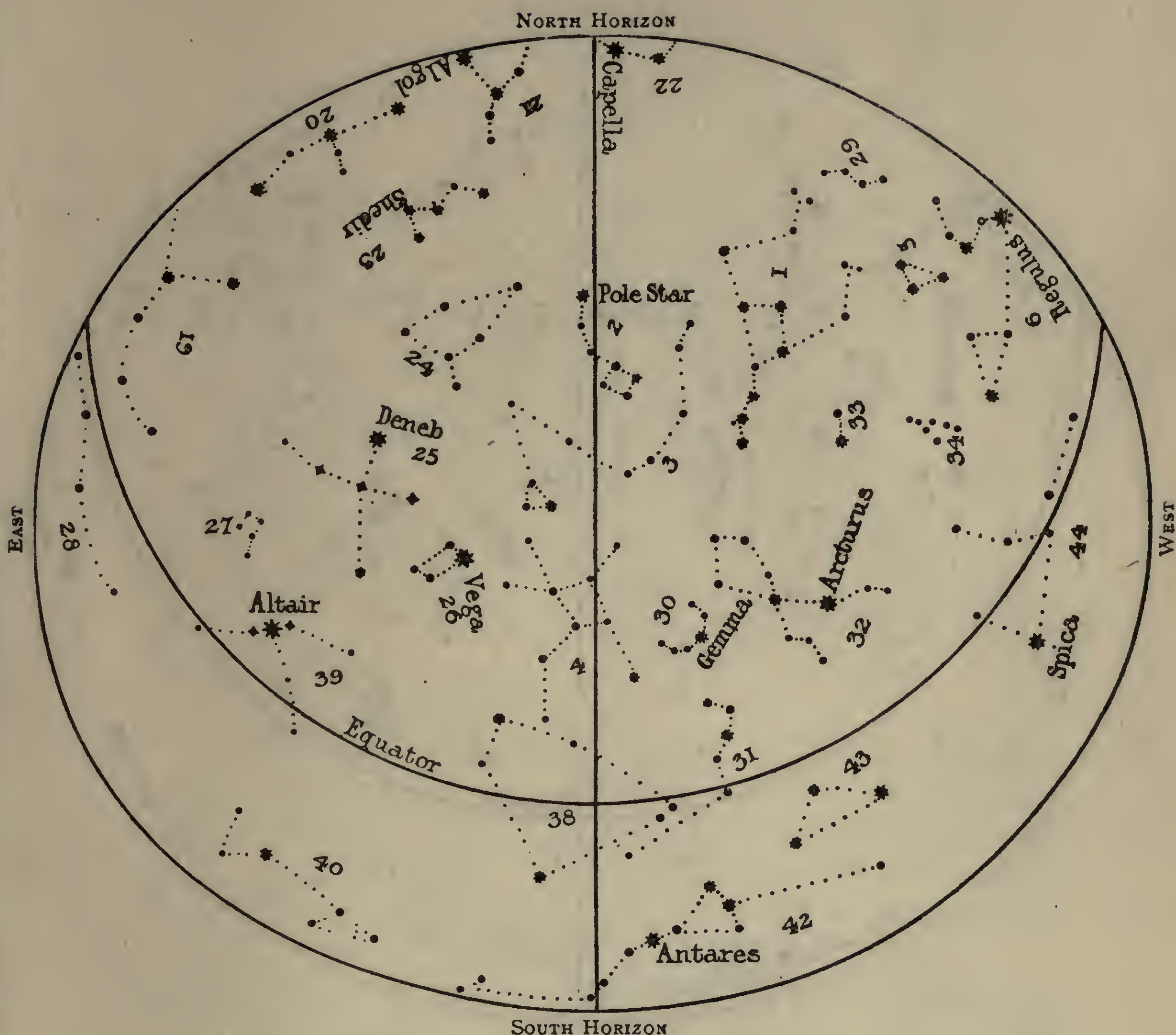


Chart III.—The Stars on July 1st, 10 p.m.

(Also on August 1st, 8 p.m., and June 1st, 12 p.m.)

1, Ursa Major; 2, Ursa Minor; 3, Draco; 4, Hercules; 5, Leo Minor; 6, Leo Major; 19, Pegasus; 20, Andromeda; 21, Perseus (part); 22, Auriga (part); 23, Cassiopeia; 24, Cepheus; 25, Cygnus; 26, Lyra; 27, Delphinus; 28, Aquarius (part); 29, Lynx; 30, Corona Borealis; 31, Serpens 32, Bootes; 33, Canes Venatici; 34, Coma Berenice; 38, Ophiuchus; 39, Aquila; 40, Sagittarius; 42, Scorpio; 43, Libra; 44, Virgo.

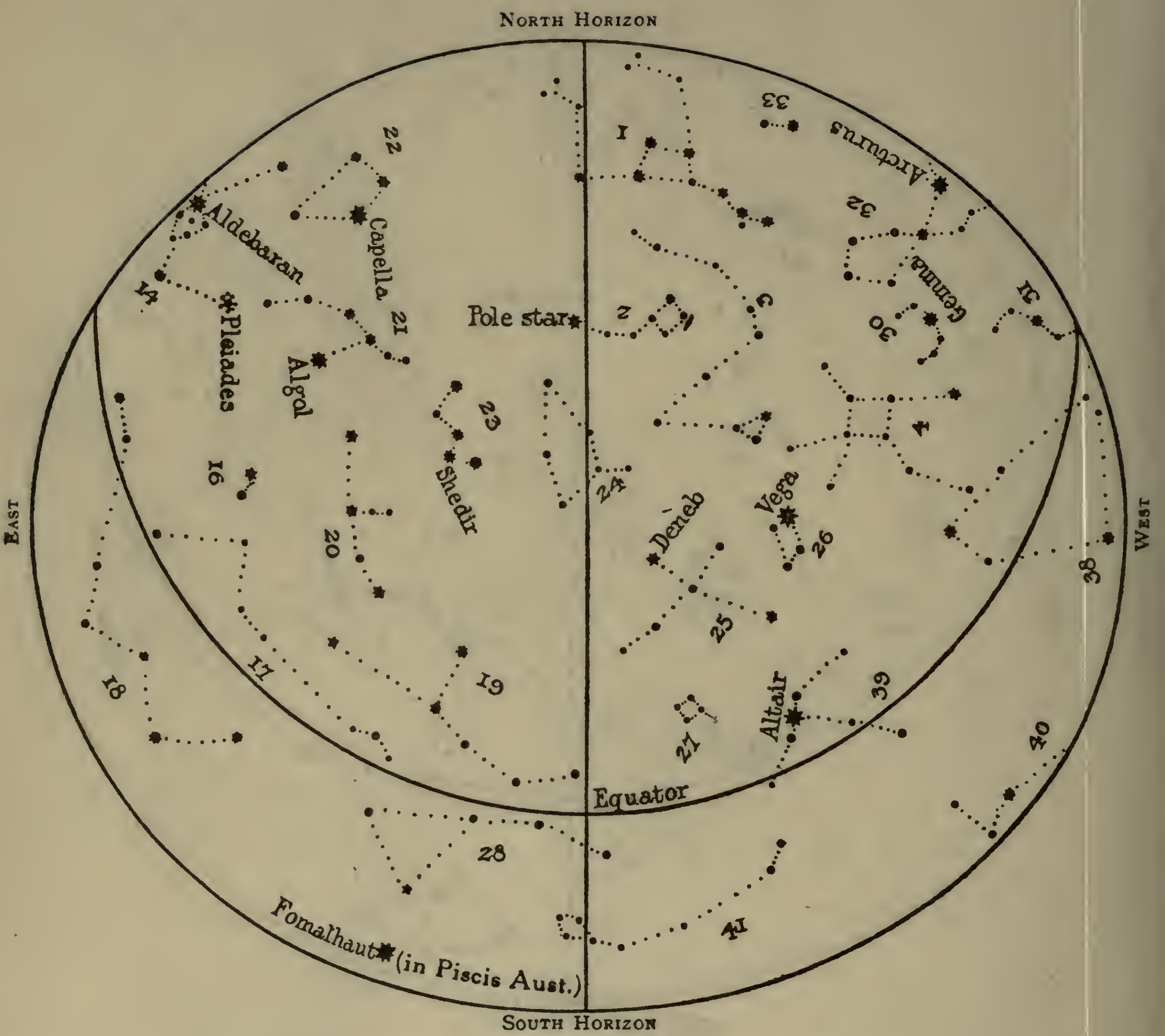


Chart IV.—The Stars on October 1st, 9 p.m.

(Also on November 1st, 7 p.m., and September 1st, 11 p.m.

1, Ursa Major; 2, Ursa Minor; 3, Draco; 4, Hercules; 14, Taurus (part); 16, Aries; 17, Pisces; 18 Cetus; 19, Pegasus; 20, Andromeda; 21, Perseus; 22 Auriga 23, Cassiopei ; 24, Cepheus; 25, Cygnus; 26, Lyra; 27, Delphinus; 28, Aquarius; 30, Corona Borealis; 31, Serpens; 32, Bootes; 33, Canes Venatici; 38, Ophiuchus; 39, Aquila; 40, Sagittarius (part); 41, Capricornus.

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