EVERYMAN'S ASTRONOMY

MARY PROCTOR F.R.A.S.

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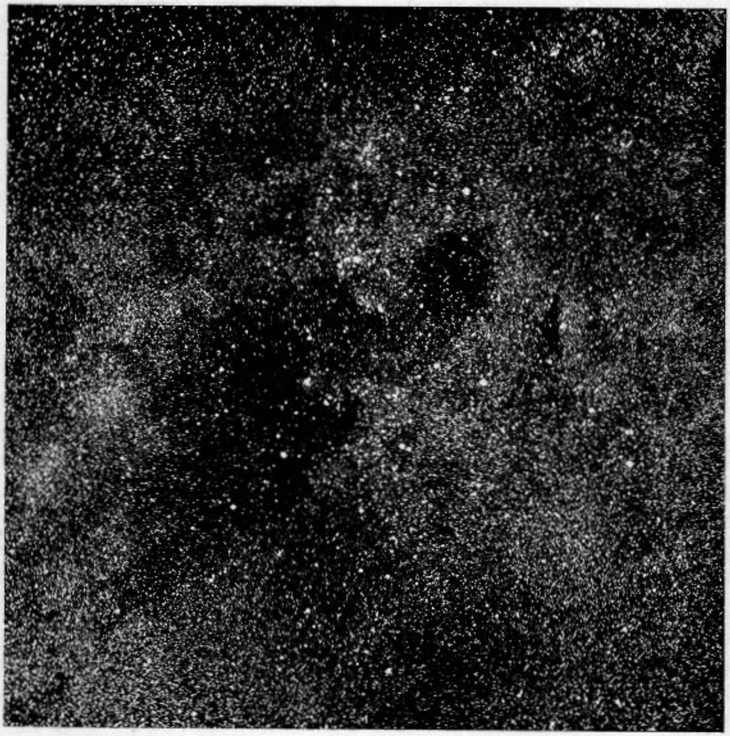

REGION OF THE MILKY WAY, NEAR X CYGNI. PHOTOGRAPHED SEPTEMBER 3RD, WITH THE 10-INCH BRUCE TELESCOPE BY PROFESSOR E. E. BARNARD. PERMISSION FROM DIRECTOR, YERKES OBSERVATORY.

EVERYMAN'S ASTRONOMY

By

MARY PROCTOR, F.R.A.S.

(Daughter of R. A. Proctor)

Author of

"*The Book of the Heavens*", "*Evenings with the Stars*",
"*Wonders of the Sky*", "*Romance of the Sun*",
"*Origin of Comets*", *etc., etc.*

WITH NUMEROUS ILLUSTRATIONS

THE SCIENTIFIC BOOK CLUB

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PREFACE

THIS book contains an account of certain astronomical facts which are likely to make a wide appeal to those who have no technical knowledge of the subject, such as new stars, those sudden apparitions, which always arouse such worldwide interest; clusters of stars, and the romance of double stars with their marvellous contrasting hues as seen with a telescope. Family parties of stars drifting across the depths of space, "Celestial photography," and the "Ever Widening World of Stars", indicate the advances which have been made in our knowledge of the wonders of the sky.

"The Future of the Moon", "Meteoric Astronomy", "Streams of Meteors", and "Meteors Trapped by a Camera", show what an amateur can accomplish in this branch of science. Just set up a camera, strap it to a telescope, wind up the clock, and trust to luck that a meteor *may* flash across that part of the sky during the course of the exposure of the photographic plate. Every meteor will draw its own portrait as long as the telescope is made to turn westward as fast as the earth rotates eastward. That is why a driving-clock is absolutely necessary for the amateur photographer who is desirous of obtaining accurate results.

The story of "The Great Meteor Crater of Arizona", "The Great Siberian Meteorite", "Streams of Meteors", "Return of the Leonids in 1833, 1866, and 1899", and an account of "Meteors Trapped by a Camera", bring this section of the book to a close.

Each chapter in the book is independent of the other, yet they are all linked in a way, helping to sustain interest as treated from a popular standpoint. Many thanks are due to Dr. W. S. Adams of the Mount Wilson Observatory, California, and Dr. A. C. D. Crommelin, Mrs. Evershed and other astronomers who have so kindly read the MS.; and for the use of valuable photographs and illustrations, with permission from the Mount Wilson, Lick, and other Observatories.

MARY PROCTOR.

London, September, 1938.

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CHAPTER I

SUNS IN FLAMES

SOME two thousand years ago, Hipparchus who has been termed the Father of Astronomy, observed a new star which suddenly blazed out in the constellation of the Scorpion. It must have been a remarkable object for it was visible in full daylight, shining with a light many times brighter than that of Sirius, the blazing Dog-star. Chinese chronicles relating to the times of Hipparchus, state that in 134 B.C. a new star was recorded as having appeared in Scorpio. This was nine years before the date of a catalogue which Hipparchus made of the stars, so impressed was he with the startling appearance of a new star in the heavens.

Nowadays we know that when a new star is observed where none had before been seen, what has really happened has been, that a star too remote to attract our attention has become visible through some rapid increase in its splendour. When the new splendour fades, this does not mean that the star no longer exists, but simply that a faint star which has blazed out with abnormal brilliancy has relapsed into its original condition. Nevertheless, the why and the wherefore of the outburst of a sun in flames revealing the presence of a new star in the heavens is one of the most amazing riddles of the universe. Despite the various theories which have been advanced as an interpretation of the problem, the solution still remains a hidden secret of the stars. All we know for a certainty regarding the sudden access of brilliancy in a star hitherto so dim as to be beyond the range of the unaided eye, is that it may be due to some explosive force, but what is the cause of such a catastrophe?

The outburst of light in a new star may be due to its crashing into another, resulting in a conflagration of stupendous magnitude judging from the brilliancy of the display. Or, the new star may have plunged into a vast cloud of gaseous matter raising its temperature to such a degree that for awhile it exceeds in splendour the brightest star in the heavens. It resembles, though on a large scale, the momentary flash of light one sees when a meteor plunges headlong into the atmosphere surrounding our planet. Colliding with numberless particles on the way, friction ensues, and a dazzling glow marks the termination of its brief career. Now in the case of a new star, the display has been known to last for weeks, even months at a time, with regard to "Tycho's star" which appeared in November, 1572. This is the first outburst of a sun in flames of which we have any detailed information. One evening when Tycho was returning from his laboratory to his dwelling-house, he found a group of country people gazing at a star, which he was sure did not exist an hour before. This was the star in question.

The star remained visible about sixteen months, during which time it kept its place in the heavens without the least variation, close to the straggling W formed by the five chief stars of the constellation Cassiopeia, and above the middle angle of the W. In old-time star maps, this group of stars represents the star-gemmed chair in which Cassiopeia is supposed to sit, and the new star is a little to the left of the seat of the chair, supposing the chair to be looked at in its normal position. But as the chair is always inverted when the constellation is most conveniently placed for observation, the position of the new star as indicated with regard to the straggling W, is undoubtedly the best guide. It is not certain whether it still exists as a star which can be seen with a telescope, but for all we know it may be any one of several which are near to the place determined by Tycho. As the appearance of a new star led Hipparchus to undertake the formation of his famous catalogue, so did the appearance of the star in Cassiopeia, lead the Danish astronomer, Tycho Brahe, to construct a new and enlarged catalogue, but as this was before the invention of the telescope it only includes stars visible with the naked eye as seen in the northern hemisphere.

The description of the new star in Cassiopeia and its various changes is most interesting at the present time, more so even than at the time it was blazing in the firmament. The star is said to have had all the radiance of the fixed stars, and twinkled as they do. Moreover, it was said that it was like Sirius in all respects, but surpassed it in brightness and magnitude. It appeared larger than Jupiter, which was at that time at its brightest, and was scarcely inferior to Venus. The chroniclers of that day tell us that it did not acquire this lustre gradually, but shone forth at once of its full size and brightness, as if it had been of instantaneous creation. For three weeks it shone with full splendour, during which time it could be seen at noonday "by those who had good eyes, and knew where to look for it". Before it had been visible a month, it seemed to shrink in size and appear smaller, and from the middle of December, 1572, till March 1574, when it entirely disappeared, it continually diminished in magnitude. "As it decreased in size," said the chroniclers, "it varied in colour: at first its light was white and extremely bright; it then became yellowish; afterwards of a ruddy colour like Mars; and finished with a pale livid white resembling the colour of Saturn."

Towards the end of September 1604, a new star made its appearance in the constellation Ophiuchus, or the Serpent Bearer. Its place was near the heel of "Ophiuchus huge". Kepler tells us that it had no hair or tail, and was certainly not a comet. It was at one time as bright as Jupiter, and remained visible to the naked eye for about a year. Like the other fixed stars, it kept its place unchanged, showing that it belonged to the star-depths. "It was exactly like one of the stars," we are told, "except that in the vividness of its lustre, and the quickness of its sparkling, it exceeded anything that had ever been seen before. It was every moment changing into some of the colours of the rainbow, as yellow, orange, purple, and red; though it was generally white when it was at some distance from the vapours of the horizon."

In fact, these changes of colour not only indicate the superior brightness of a star, but are specially characteristic when it is close to the horizon. When Tennyson wrote:

> "the fiery Sirius alters hue,
> And bickers into red and emerald,"

he referred to it in such a case, but Kepler's new star in 1604, was brighter than Sirius, and was about five degrees lower down, when at its highest above the horizon, than Sirius when it culminates or passes through the celestial meridian of a place. Five degrees being equal to nearly ten times the apparent diameter of the moon, it will be seen how much more favourable the conditions were in the case of Kepler's star for producing the various coloured and twinkling effects of that particular orb. It must have been a most impressive sight.

Sirius never rises high above the horizon in the northern hemisphere, but is at its highest near midnight in winter, while Kepler's star at its greatest height above the horizon was little more than three-fourths that of Sirius, or equal to about the sun's elevation at midday on January 13, or 14, in any year.

The first new star which was kept in view from the time of its apparent creation when its presence was first made known, was a star of the fifth magnitude which was discovered in the constellation Ophiuchus, on April 20, 1848, by Mr. Hind who at that time was superintendent of the *Nautical Almanac.* It was in quite another part of the constellation from that which had been occupied by Kepler's star, in 1604. A few weeks later it rose to the fourth magnitude, but afterwards its light diminished until it became invisible to the naked eye, though it could still be seen with a telescope shining as a star of the eleventh magnitude. That is, it was five magnitudes below the faintest star discernible with the naked eye.

A typical first magnitude star is defined to be one hundred times brighter than a sixth magnitude star—that is to say, the amount of light which reaches us from the former is equivalent to the light emitted from one hundred stars each of the sixth magnitude. The fainter the star is the larger the number expressing its magnitude. The faintest stars visible in the largest telescopes are of the nineteenth magnitude approximately; thus, Sirius appears roughly about a hundred million times brighter than the feeblest star ever seen.

These examples suffice to indicate the relative brightness of the stars and their scales of magnitude. It is possible not only to trace their changing appearance, in the case of new stars, by means of the telescope; but by glancing at photographs taken years before of the same region of the sky in which they temporarily flashed out, the astronomer can turn back the pages of Time, as it were, and read their story when they were in their normal stage of obscurity, far too dim in most cases, to be seen except with the most powerful telescopes.

The first new star to be subjected to the searching scrutiny of the spectroscope, or light-sifter, made its appearance on May 12, 1866, shortly before midnight, in the constellation of Corona Borealis, the Northern Crown. It attracted the attention of Mr. Birmingham of Tuam, who was surprised at the sight of a star of the second magnitude where hitherto no star visible to the naked eye had been known to exist. The star was remarkable for the fact that it was located forty degrees from the Milky Way, whereas all new stars which had hitherto been discovered had shown a tendency to lie close to that region. The star was brighter before the outburst than any other temporary star which had yet been recorded. Its period of brilliancy was unusually short, enduring but a few months.

On the evening of May 13, it was discovered independently by Dr. Schmidt of Athens, and a few hours later it was observed by a French engineer named

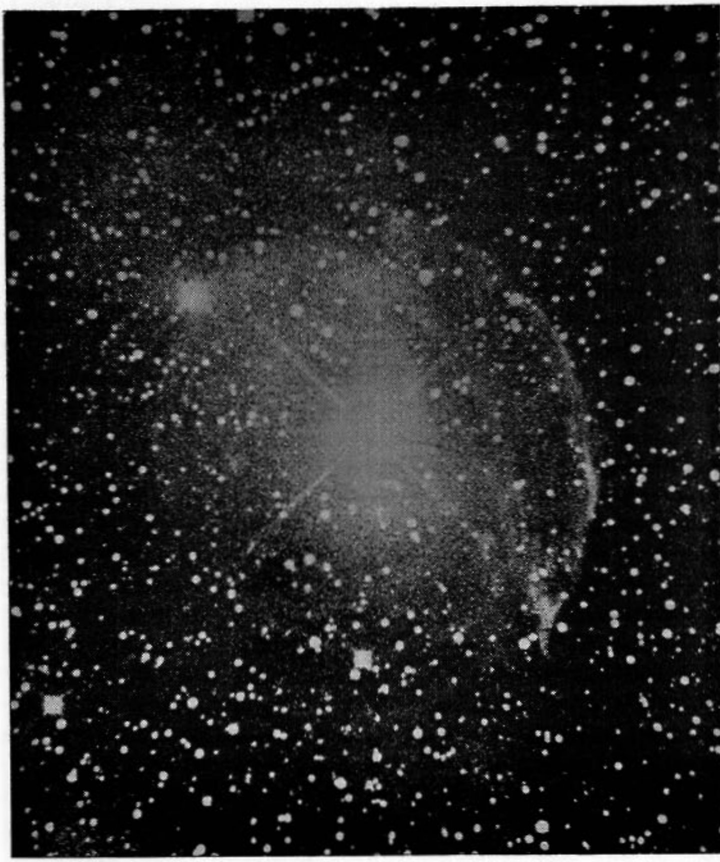
Courbebaisse. Afterwards Mr. Baxendell of Manchester, and others independently saw the star. Dr. Schmidt, examining Argelander's charts of 324,198 stars, found that the new star had been set down as between the ninth and tenth magnitudes. It was therefore not actually a new star which had suddenly come into existence, but one which had risen from obscure origin, into which state it relapsed within a brief period of a few months.

T. Coronae, as it is now known, was the first new star to be examined by the spectroscope, which Dr. Huggins had been using in his study of the stars and other celestial objects. When Mr. Birmingham wrote to him with regard to the new star, he turned his spectroscope in its direction, and found that the new star showed the rainbow-tinted streak crossed by dark lines, which indicated its sunlike nature. But, standing out on that rainbow-tinted streak as on a dark background, were four exceedingly bright lines—lines so bright, though fine, indicating that clearly most of the star's light came from the glowing vapours to which these lines belonged. Three of the lines belonged to hydrogen, the fourth was not identified with any known element. The inference was, that enormous masses of hydrogen around the star were glowing with a heat far more intense than that of the star itself within the hydrogen envelope. It is certain that the increase in the star's light, rendering the star visible which before had been far beyond the range of ordinary eyesight, was due to the abnormal heat of the hydrogen surrounding that remote sun.

According to Sir William Huggins, "the sudden blazing forth of this star, and then rapid fading away of its light, suggested the rather bold speculations, that in consequence of some great internal convulsion, a large volume of hydrogen and other gases was evolved from it, the hydrogen by its combination with some other element," (in other words, by burning), "giving out the light represented by the bright lines, and at the same time heating to the point of vivid incandescence the solid matter of the sun's surface." As the liberated hydrogen gas became exhausted, the flames gradually abated, and with the consequent cooling, the star's surface became less vivid, and the star returned to its original condition.

Modern photographic methods are now responsible for many discoveries of new stars, most of them in the remote depths of space; but it remains the privilege of the amateur to see them first, always providing he is so well acquainted with the constellations as to recognize an intruder in their midst. We have a notable instance, in the case of the first new star discovered in the twentieth century, which blazed out on February 22, 1901, in the constellation Perseus. It was discovered by the Rev. T. D. Anderson of Edinburgh (the second to his credit, the previous one being that of Nova Aurigae in 1892), just as he was concluding his night's observations at the approach of dawn. Looking up at the sky in the direction of Perseus, he noted a star near Algol, in a region where no star had been previously known to exist. Dr. Anderson informed the Director of the Royal Observatory at Edinburgh, and thanks to his speedy transmission of the news, the whole astronomical world was soon actively interested in the new star. Every telescope was turned in its direction, and even with the naked eye it was possible to observe the star which at the time of its discovery already surpassed in brightness all the new stars that had been observed since 1866. The fact that, on the evening of the 22nd, it had reached the first magnitude encouraged the hope that it might even rival the famous new stars of 1572, and 1604, which are inseparably associated with the names of Tycho Brahe and Kepler. However, this hope was not realized, for in the course of a few days it was seen that the star was distinctly on the low grade. Still Nova Persei ranks as the brightest star of its class which had appeared for nearly three centuries, and was the only one during this period which had been observed before attaining its maximum brilliancy.

On referring to the stellar photographs taken each night at the Harvard and Arequipa Observatories, by which all the principal stars visible every fine night are registered, no indication of any star as bright as the eleventh magnitude was found prior to February 19, in the place now occupied by the new star. Therefore, at that time there was certainly no star of a ten-



NEBULA SURROUNDING NOVA PERSEI. SEPTEMBER 20TH, 1901.
G. W. RITCHEY. MOUNT WILSON 60″.

thousandth part of the luminosity of that which was seen three days later. It is, of course, impossible to say what the actual brightness was before this amazingly sudden and tremendous outburst of energy took place, and equally impossible to believe that there was no stellar object at all in that part of space prior to the conflagration. It was later shown that in three days it had risen from the thirteenth to zero magnitude.

The outburst of Nova Persei gave evidence of a surrounding nebula which was photographed some months after the outburst revealed the presence of a faint nebulosity surrounding the star. Later on, photographs showed that the nebulous mass was apparently expanding outward with the inconceivable velocity of more than 100,000 miles a second. The renowned scientist Kapteyn solved the problem, with the suggestion that as the *light* from the new star travelled outward it illuminated the nebula until it reached its outer boundary. We were able, in this notable instance, to watch the light as it sped on its way. It is estimated that the distance of Nova Persei is about 330 light-years. Therefore, the tremendous stellar conflagration we witnessed in 1901, actually took place about the time of the Spanish Armada, yet the news transported on the wings of light with a speed of over 186,000 miles a second did not reach us until 330 light-years later.

Thirty-eight hours after the discovery of the new star in Perseus, it was as bright as Capella, but later on it began to fade irregularly, brightening up again for awhile and then disappearing and reappearing in a most unexpected way. Sir Robert S. Ball gave an amusing account at the Royal Astronomical Society, of his experiences, at the time when the fluctuations of the star were such as to cause it to appear and disappear when least expected. He had taken a party of visitors into the open to show them the new star, only to find that it had vanished; on the next night he took out another party to show them where the star had disappeared, and *there it was again.* However the star has now faded out of sight, though it still remains a very faint object visible in large telescopes.

In 1903, a new star was discovered in the constellation of Gemini, the Twins, as a result of being used as a guide star for one of the Oxford astrographic plates. Investigation as to why the plate was wrongly centred led to the discovery of Nova Geminorum. A new star in the constellation of Aquila, the eagle, was discovered by Dr. W. J. Luyten at Utrecht on June 6, 1918, while engaged in making a drawing of the Milky Way. It was then of magnitude 5.8. Two days later it was as bright as a first magnitude star, and on June 9, it had become the brightest star in the northern sky and almost as bright as Sirius, resulting in many belated discoveries of Nova Aquilae. (Those were the days during the Great War when many eyes were turned skyward—not in search of new stars, but in watching the beams from searchlights in quest of possible airplanes on mischief bent. On the evening of June 8, it was seen by the writer who, little suspecting its origin, watched it carefully for an hour or more, as it hung suspended seemingly over central London, apparently guarding the inhabitants below from an unexpected attack. That the bright green light was a new star was totally unexpected, as in those troublous times, the mind was not concentrated on astronomical objects of interest.) The new star in Aquila, which, as shown by an examination of photographs taken of the region of the sky in which it appeared, before it flared up to magnitude minus one, actually 300,000 times brighter than the sun, was formerly of the tenth magnitude, and long ago returned to its original obscurity.

Finally, we come to the most recent discovery of brilliant new stars, and of special interest as showing what an amateur can do in this way, providing he is so well acquainted with the leading bright stars forming the well-known constellations as to recognize at first sight an intruder in their midst. The star is known as Nova Pictoris, and was discovered on May 24, 1925, by Mr. R. Watson, of Beaufort West, South Africa, at 5.50 a.m. Examinations of photographs taken prior to its discovery show that it had risen from the twelfth to the first magnitude. Previously, it had been slightly fainter and smaller than the sun, but on May 24, it had increased its diameter to 40,000,000 miles or 50 times larger than the sun, and two weeks later was of the first magnitude, and nearly 80,000,000 miles in diameter, exceeding that of the sun 100 times. At present (1938), the star is no longer visible to the unaided eye.

The main interest of the discovery, as told by Mr. Watson, is that it is a useful guide in showing not only *what* an amateur can do, but *how* he can best make his discovery of value, by reporting it at once to the director of the nearest Observatory.

"It happened like this: I had to be at my work at 6 a.m. on Monday, May 25, and, having to walk about half a mile southwards, I left my house at 5.45 a.m. Upon opening my door I saw a glorious vision of the planet Mercury. The zodiacal light was there, too, heralding the dawn. Turning down the street, Canopus first caught my eye, low down in the south-east, with the larger Magellanic Cloud above it. In the south-west appeared the Southern Cross, and due south I noted Beta Carinae practically on a level with Alpha Crucis. Then the unfamiliar spectacle presented itself, for further to the eastward, in line with Alpha Crucis and Beta Carinae, and at the same interval from the latter, I noted a pair of stars. I regarded them carefully, and noted their position with respect to Canopus and the Magellanic Cloud.

"My thought was, 'I was sure there was no pair of stars there before.' I almost returned to consult my atlas, but I did not care to keep an officer who had been on duty all night waiting, and I also realized that the news would be of no use to anyone before evening, so I proceeded on my way, making as careful a note of the position as I could. At breakfast time I was able to ascertain from Norton's Atlas that the fainter star must be Alpha Pictoris and that the unmarked star must be a nova. I then took its approximate Right Ascension and Declination from the Atlas, and telegraphed the information to the Royal Observatory. I was conscious that I was acting rather hastily, but it was a public holiday, and I was afraid the Observatory staff might be absent if I deferred wiring till evening. It is also very important, too, that a nova should have its spectrum photographed at an early stage."

By September 9, 1925, four months after it had reached its greatest splendour, the new star had already faded to less than one-tenth of its maximum brilliancy so that it was no longer visible except with a telescope. Nova Pictoris is typical of a nova or temporary star, which rises with almost startling rapidity from insignificance in the sky to comparative and in some instances unrivalled splendour; slowly fading away thereafter to its original obscurity. The last word on the subject may be said to be the following account of the star, given by Dr. H. Spencer Jones, at that time, His Majesty's Astronomer Royal, at the Observatory at the Cape of Good Hope, on the occasion of the Centenary Meeting of the British

Association for the Advancement of Science, held in London, the latter part of September, 1931.

He referred to the new star in Pictor as being in a state of rapid expansion up to the time of the first maximum, at which period in its career shells of gas-light emitted by the star were flung off, the radius of the star at that time being about 380 times the radius of the sun. "A summary is given of the observations at Johannesburg of the nova as a multiple star, and of the surrounding nebulosity. The increase in the diameter of the latter is in good agreement with the hypothetical parallex of 0".0015. Possible causes of the outbreak are considered; the hypothesis that it is due to a sudden release of energy within the star, rather than to a collision with another star or to the star entering a nebulous region, seems to accord best with the various facts which have been taken into account."

A star is a storehouse of heat, more than half of which consists of imprisoned radiant energy—ether-waves travelling in all directions trying to break through the material which surrounds them. When the pressure from within becomes too great, the temperature rises to such a degree, that the outflowing stream of ethereal energy is powerful enough to exert a direct mechanical effect on the equilibrium of the star, and a terrific explosion occurs, after which, the pressure being relieved, the star once more subsides to normal. That, at any rate, seems to have been the case with the new star in Pictor which blazed out in 1925.

CHAPTER II

BEACON LIGHTS IN THE OCEAN OF SPACE

UNLIKE the new stars of 1572 and 1604, memorable in the history of astronomy for the remarkable way in which they suddenly blazed out in the heavens, there are certain stars known as "variables", because their light waxes and wanes with such regularity that they may be compared to beacon lights in the ocean of space. Travellers by sea are familiar with the appearance of a revolving beam of light flashing at regular intervals, indicating the presence of a lighthouse stationed on the sea-coast, as a warning to passing ships of the presence of rocks, shoals, or other dangers. For instance, there is the famous Eddystone lighthouse which flashes a beam of light, the intensity of which equals that of 79,000 candles, warning mariners of the proximity of the Eddystone Rocks which lie about fourteen miles off Plymouth. The revolving light comes slowly and gradually into power, at equal and comparatively long periods and then as gradually disappears.

Suggestive of such varying flashes of light, are the so-called "variable" stars, the first of which was discovered in August, 1596, in the constellation of Cetus, by Fabricius. In October of the same year he observed that omicron Ceti, better known as "Mira, the Wonderful", had grown fainter, and finally disappeared. At the time, it was supposed to be a new star, like the one observed by Tycho Brahe in 1572, and for awhile aroused a certain amount of interest, but after it faded from view it was completely forgotten. Nevertheless, it must have increased and decreased in splendour at least forty times before it again attracted attention by its ruddy glow in 1638. Thus, it became apparent for the first time that it was possible for stars to brighten up, fade out and vanish, to reappear again like the flash of a beam of light from a lighthouse.

However, in the case of the star Mira, it was found to be oddly capricious in its ways, so that it has been termed an irregular variable star. For instance, it has been known to reach its maximum brilliancy a month or so ahead of time, or prove equally dilatory in arriving at the minimum stage at which time its light falls to the ninth magnitude, and is therefore invisible to the naked eye. Again, its magnitude at maximum has been known to vary in a remarkable way, for usually it is then of the third or fourth magnitude, but occasionally it reaches the second. In 1779, when observed by Sir William Herschel it resembled a star of the first magnitude and was nearly as bright as the star Aldebaran in the constellation Taurus. Four years later, he tells us, it was invisible even in his telescope, yet such irregularities in the brightness of this star remain still unexplained, and are among the unsolved problems of the sky.

It has been suggested that the variability of Mira may be due to the same cause as that which makes the sun an irregular variable star. From observations which have recently been made at Mount Wilson Observatory, there is probable, if not final evidence that the sun is a variable star. This may be due to sun-spots on its surface, apparently caused by depression after a sudden expansion of the solar gases from within the sun, while floating vapours of calcium in the atmospheric envelope surrounding the sun must also contribute their share to the intermittent increase of its brilliancy. In 1843, Schwabe of Dessau, an apothecary interested in astronomy, announced as the result of patient observations of the sun during the course of eighteen years, that the number of sun-spot groups varied from month to month and year to year, in a definitely regular period of ten years—recent investigations showing that the average period is eleven years. There is a regular sun-spot cycle from maximum to minimum back to maximum again, the sun-spots coming and going in a fairly regular manner. Thus, the variability in the light of the sun, may be due to the sun-spot cycle, which for all we know may be duplicated on Mira. The heat-radiation of Mira is about one-thousand times that of the sun but the most wonderful fact concerning this star is, that it is hottest not while it is attaining its greatest brilliancy but when it is waning, another baffling problem as yet unsolved. It has also been estimated that Mira is at a distance of 220 light-years from our planet, so that we do not see it as it *is*, but as it was more than two centuries ago, though its light message has been travelling at the stupendous rate of *eleven million miles a minute.*

Mira remains at maximum about ten days, then during a period of eight months its light grows dim after which it rises to maximum sometimes very rapidly. At minimum Mira is shining at only one thousandth its maximum brilliancy, so that if we can imagine a planetary world circling around this star, we have only to carry the phantasy a step further to picture the state of affairs which would prevail on the Earth, should the light of our Day Star, the sun, decrease in like manner. Then visualize the gloom which would prevail in consequence at irregular intervals of eight or nine months.

Regarding the size of Mira, measurements recently made at the Mount Wilson Observatory reveal the astounding fact that its diameter at maximum is 260,000,000 miles, so that if it were hollowed out there would be ample room for the sun at the centre, and planets Mercury, Venus, the Earth and Mars to circle around it, with a goodly margin to spare between the orbit of Mars and the inner surface of the star. Could a tunnel be made, through the centre of this giant star, there would be room within for three hundred globes the diameter of the sun placed side by side. In October, 1923, Professor Aitkin of the Lick Observatory discovered that Mira has a faint companion star, blue in colour and certainly a member of the group of stars known as white dwarfs, which are remarkable for their small size, weight and luminosity, and apparently old age, since they seem to have reached the final stage in stellar evolution. One can gain an idea of the contrast in size between Mira and its companion star, by seeing the model of the two, at the Science Museum, South Kensington. A label on the model of Mira, informs us that it is 1,000,000 miles to the inch, while the comparative size of the companion star is about the size of a very small pin's head, a minute speck.

While looking at this model it may be as well to recall the warning conveyed by the author of *The Universe Around Us*, in which Sir James Jeans gives a hint as to what happens to stars which are liable to shrink, and in so doing to reduce their radiation to a tiny fraction such as that at present emitted by the companion star of Mira: "The shrinkage of the sun to this state would transform our oceans into ice and our atmosphere into liquid air; it seems impossible that terrestrial life could survive. The vast museum of the sky must almost certainly contain examples of shrunken suns of this type with planets like our earth revolving round them. Whether these planets carry on them the frozen remains of a life which was once as active as our present life on earth we can hardly even surmise."

Another class of variable stars are those known as eclipsing binaries, of which Algol (B Persei) a star in the constellation of Perseus is a type. It is the brightest star in the constellation, and forms a right angle with Algenib and Almaack in Andromeda. These "Algol" stars usually remain at a nearly constant magnitude for some time, following which their brightness rapidly wanes to a minimum remaining dim for a brief interval then brightening again, the waxing being as rapid as the waning. Among them, different degrees of light variations are found, depending upon the position of their orbits in space as seen from the earth, and the brightness and size of their companion stars.

The Arabs noting the varying sinister light of Algol called it Al-ghoul the Demon Star. According to the Greek legend of Perseus and Andromeda, it was the evil eye of the Gorgon Medusa turning everything to stone which came within its range, and thus destroying the sea-monster Cetus sent by Neptune to kill Andromeda. The phenomenon of its varying light can easily be detected by the naked eye, from the time it shines at its brightest as a star of the second magnitude until it grows dim and sinks to the fourth magnitude. It is then as faint as the stars near-by, but it remains thus obscured for only a few minutes, when it brightens up and regains its former brilliancy. As long ago as 1670, an observer named Montanari noticed that B Persei or Algol was sometimes fainter than at others, and afterwards Maraldi found that it was subject to variations in brightness.

However, no attempt was made to ascertain either the period or law of variation, until John Goodricke (1764-1786), concentrated his attention on the star in the year 1782, when he was but a lad of eighteen, and was fascinated by its changing appearance. He continued his observations for some time, comparing the light of Algol with that of other stars in its vicinity until he became convinced that there were times when Algol exceeded, and then again was inferior to them in brilliancy. One has only to follow his example and compare Algol with the small third-magnitude star Rho, which is a few degrees south of Algol, and almost in a direct line with it and Alpha in Perseus, to verify his observation. As Rho is fainter than Algol, it is interesting to compare the changing appearance of Algol with regard to both these stars. The dates and times of minima are to be found in the *Nautical Almanac*, astronomical journals, and almanacs.

Goodricke found that the variations in Algol were periodic, occurring at regular intervals. As we now know, the period from maximum to minimum is 2 days, 20 hours, 48 minutes, 51 seconds. For about 2 days, 11 hours, the star remains at about the same brightness. During the next five hours it loses twothirds of its light, and returns to its original brightness in the five hours following. Goodricke was of the opinion that the variation in brightness might be caused by the partial eclipse of Algol by a large body revolving round it, but as the existence of double stars with varying light was unknown at that time (1782), his explanation was forgotten until revived by Professor E. C. Pickering of the Harvard Observatory, a century later. Since then, about two hundred stars have been under close observation, in connection with their varying light apparently due to a companion star causing a partial eclipse at regular intervals.

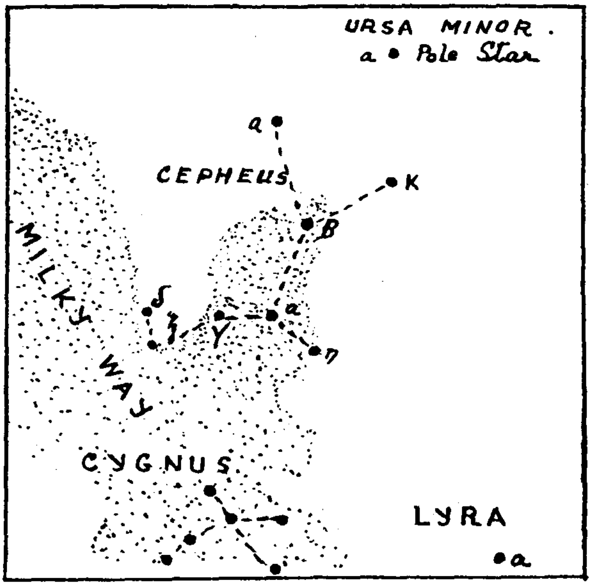
The eclipse theory suggested by Goodricke has been abundantly confirmed by means of the spectroscope, which has shown that Algol is composed of two stars. One is a hundred times brighter than the sun, and periodically passes behind the slightly larger star which is only ten times as bright as the sun. When the stars are side by side, Algol shines with their combined light as a star of the second magnitude. As the brighter star passes behind the larger star its magnitude falls between the third and fourth, or to about one-third of the normal amount of light. Another eclipse occurs when the bright star is in front diminishing the combined light by only four per cent. However, there was still a percentage of light which could not be accounted for until recent investigations revealed the presence of a third star.

Let us consider Algol, by the names Algol A and Algol B, the bright component being Algol A, and the faint component Algol B, while the third star is Algol C. It is now known that Algol A and Algol B together, travel in an orbit around the hitherto unsuspected Algol C. We had believed that when Algol A was partially eclipsed all the remaining light came from Algol B, but according to "The Story of Algol", told by Professor Eddington, in his book *Stars and Atoms*, "it is clear that it belongs to Algol C, which is shining without interference."

In the year 1784, Goodricke made another interesting discovery with regard to the variability of a star, and this time it was in connection with the star B Lyrae. At first he was inclined to fix its period of variation at 6 days, 9 hours; but after continuing his observations for some time, he found that the star had actually two maxima and two minima, the light curve being aptly described as saddle-backed. When it attains its maximum brightness, B Lyrae shines as a star of the third magnitude. At one of its minima it appears between the fourth and fifth magnitude, and at the other between the third and fourth. These interesting particulars were fully confirmed in 1844, by M. Argelander, and the generally accepted period at present, for this star is about 12 days, 19 hours. The following is a brief extract from a letter written by Goodricke, June 27, 1785, and printed in the *Philosophical Transactions* for that year:

"On the 10th of September, 1784, whilst my attention was directed towards the part of the heavens where B Lyrae was situated, I was surprised to find this star much less bright than usual, whereupon I suspected that it might be a variable star: my suspicions were afterwards confirmed by a series of observations, which have been regularly continued since that time. . . . At first I thought the light of this star was subject to a periodical variation of nearly six days and nine hours, though the degree of its diminution did not then appear to be constant; but now upon a more close examination of the observations themselves, I am inclined to think that the extent of the variation is twelve days and nineteen hours, during which time it undergoes certain changes."

The light-curve of this star shows two crests of equal height, and two unequal depressions, and it has been shown that its variability like that of Algol is due to the revolution of two stars round a common centre of gravity. The tidal influence of one sun upon the other plays an important part in the observed variations, the waxing of the light of the larger star when it is in front of the smaller, and its waning in apparent brilliancy when the reverse is the case. The two stars are so close together as to seem inseparable, appearing as one even when observed with our largest telescopes. However by means of the spectroscope their duplicity has been revealed, hence such stars are known as *spectroscopic binaries* seemingly linked by invisible chains,



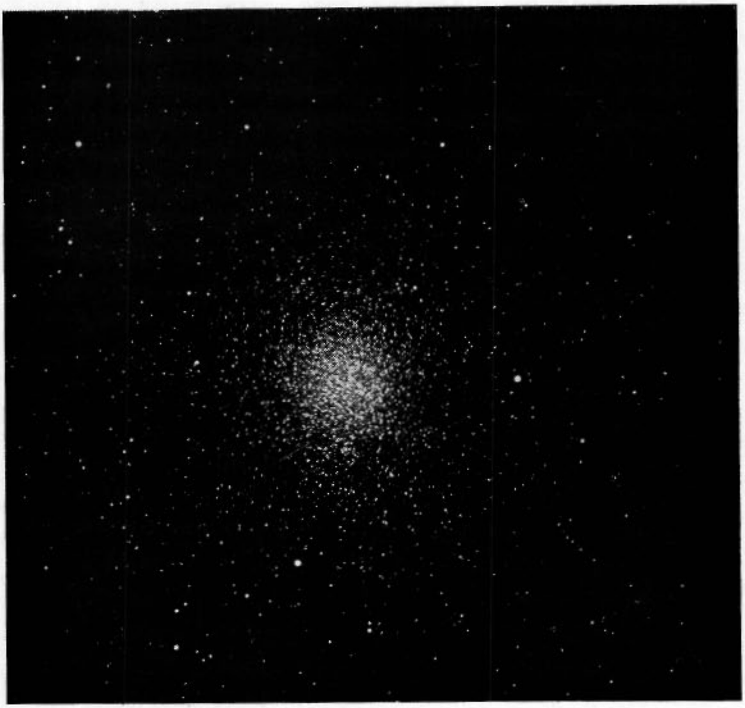
HOW TO LOCATE DELTA IN CEPHEUS.

due to the mystic law of gravitation which prevails throughout the Universe.

Now we come to an account of the remarkable discovery made by Goodricke, October 19, 1784, in connection with the variability of the star δ Cephei, which unlike Algol or B Lyrae is not a binary, but a single star. The best time for locating δ Cephei, is during the month of October, about 8.30 p.m. when it occupies a position a few degrees north of the point overhead. A line drawn from the Pole Star, passing through B in the constellation of Cepheus, and extended a few degrees north of Υ and ζ reaches the star δ as shown on the accompanying chart. Note the position of the Milky Way, and the broad gap, δ hovering on the brink, easily discerned, on a clear starlit night.

Stars of this type are known as Cepheid variables. The light of δ Cephei undergoes regular changes in the course of 5 days, 9 hours. At its brightest it is of magnitude 3.7, and at its faintest it reaches magnitude 4.6, so that at minimum it is not quite one half as bright as at maximum. It rises rapidly from minimum to maximum in 30 hours, but requires 4 days, and 3 hours to sink to minimum again. Observations with the spectroscope reveal that the star swells outward at or near the time of maximum light, and contracts at the time of minimum, so that it is, as it were, a pulsating star swelling and contracting with perfect rhythm. Yet there is undoubtedly an element of mystery surrounding variables of this type. The spectroscope fails to reveal the presence of a companion star, for δ Cephei, but it has been suggested that its evolution is only a matter of time, and may follow as a result of the star breaking in two. Yet according to Sir James Jeans: "There is not a single star in the sky of which we can say, here is a star which has certainly started to break up by fission, and will certainly end as a binary system."

Cepheid variables have periods ranging from a few hours up to about fifty days or more. On account of their continuous variation, they are easy to find, and are the delight of the amateur in search of work easily within range of a small telescope. Careful study of photographs will show a large number of variables of the Cepheid type. They are excellent time-keepers, veritable beacon lights in the ocean of space, registering regular time-intervals in all parts of the heavens. Moreover, many of them are giant stars of great luminosity, and can therefore be detected when at a very great distance. Incidentally, they show a great preference for the Milky Way, or to a place in clusters of stars such as the great Hercules cluster which contains many Cepheid variables. The majority of their periods is little more than half a day; and the richest of all the clusters in variable stars is ω Centauri and Messier 3, their light waxing and waning against a background of silvery haze. One memorable evening a few years ago, the writer saw the latter cluster with



THE GLOBULAR CLUSTER, ω CENTAURI.
R.O. CAPE OBSERVATORY, 24″ VICTORIA TELESCOPE.

the great 40-inch refractor at the Yerkes Observatory. Words fail to convey the impression of that amazing scene, of stars seemingly blending their light, the brighter orbs patterned in delicate tracery against the combined mass of fainter stars in the cluster, yet so remote as to be scarcely distinguishable one from the other.

There can be no doubt that the waxing and waning light of Cepheids seen in these clusters, indicate that they are actually members thereof, and at the same distance from our planet. Knowing the period of their waxing and their waning, and their luminosity as compared with the brightness of the sun, we are able to determine their distance. Their absolute magnitude, is the luminosity a star would have if brought to a distance of ten parsecs; then if the sun were removed to that distance it would appear a little brighter than a star of the fifth magnitude, or about as bright as δ Cephei appears to us, that being the *standard star* for the measurement of the distances of the stars.

A parsec corresponds to 3.26 light-years, a light-year being equivalent to the distance light travels in a year, viz: 6,000,000,000,000 miles, at a speed of 11,000,000 miles a minute. Ten parsecs would correspond to 32.6 light-years, but this would only account for the distance of the nearer Cepheid variables. In the great cluster of Hercules, there are many whose periods and apparent brightness has been observed, from which it has been possible to determine their absolute brightness and hence their distance has been found. This reaches the immense figure of 36,000 light-years.

According to Dr. G. E. Hale, in his fascinating book *The Depths of the Universe*: "If this measure is correct, and there is much independent evidence to support it, we take a tremendous leap into space and time when we reach out to this cluster." In 1912, during the course of an examination of photographs taken of the small Magellan Cloud at the Harvard Observatory, Miss Leavitt was the first to notice the varying brightness and regular periods of certain stars of the Cepheid type, the periods ranging from half a day to 127 days. By comparing the apparent brightness of each star with its period of variation, she was able to detect a connection between the two. Thus, if the period of a star belonging to this type were known, she could predict its average brightness. As all the stars of the small Magellan Cloud are at about the same distance from us, the differences in their apparent brightness corresponds to differences in absolute brightness. The light of the brighter Cepheids in this Cloud was found to fluctuate more slowly than the light of the fainter ones. The period of light fluctuation depending upon its luminosity or candle-power, it became possible to infer the distance of Cepheid variables at a greater or less distance than *standard*; just as it is possible to determine the distance of a beam of light from a lighthouse, or that of a street-lamp shining with a thousand candle-power.

There is an undoubted fascination in pursuing the study of variable stars, the beacon lights in the ocean of space, and as Professor H. N. Russell remarks: "If we really understood the cause of stellar variation, we should probably have advanced a long way towards the solution of the whole problem of stellar evolution, if not have solved it completely."

CHAPTER III

ROMANCE OF DOUBLE STARS AND COLOURED STARS

GAZING upon the heavens on a clear starlit night we are impressed with the splendour of the scene, although we may know little of the meaning of the display, until we turn a telescope in its direction, when literally "new heavens" come into view. Thousands of stars which appeared single before that remarkable invention was made some three hundred years ago, prove to be double, triple and in many cases multiple, the companion stars being linked together by the all-pervading power of gravitation. The same law which keeps the planets circling round the sun, prevails among the double and multiple stars, compelling them to circle round their common centre of gravity. A lonely star like the sun is the exception rather than the rule, and for all we know it may have a companion star which though suspected, has so far escaped detection.

It was not until the middle of the seventeenth century that the first double star was discovered. In 1650, an observer named Riccioli turned his telescope in the direction of Mizar, in Ursa Major, and found there were two stars instead of one. This does not refer to the faint star to the north of Mizar and well known to the early watchers of the sky as Alcor, the Rider, guiding the three horses attached to the Plough, as they make their ceaseless round of the Pole Star, in the northern heavens. Alcor also means "the near one", since its apparent distance from Mizar is nearly equal to one-third of the apparent diameter of the moon. To see Alcor is a test of good eyesight, for although it is a star of the fourth magnitude and therefore visible to the naked eye, yet it is so near to Mizar as to be almost lost in its glare. However, with a good field-glass or even with an opera-glass, the apparent distance between the two stars is greatly increased, and it is evident they are in no way physically connected. Moreover, an opera-glass brings out their difference in colour. With a small telescope the increase of brightness and distance between the two stars admits of direct comparison, but the inversion as seen with a telescope must be borne in mind, or their identity will be perplexing.

In *Astronomy with an Opera Glass*, Mr. Serviss tells us that with a very powerful glass we may be able to see near Mizar and Alcor a minute star which a German astronomer discovered nearly two hundred years ago, and taking it for a planet he named it Sidus Ludovicianum. In 1889, when Professor Pickering, at that time Director of the Harvard Observatory, U.S.A., obtained a photograph of the spectrum of Mizar (Zeta Ursa Majoris, as it is technically termed), he found that the dark lines doubled at regular intervals of fifty-two days. Evidently this star is composed of two which revolve around their common centre of gravity in an orbit which is turned nearly edgewise to us. As we view them, when one of the stars is moving towards us, the lines indicating its spectrum are shifted towards the violet end of the spectrum and when the lines are shifted towards the red end of the spectrum the star is receding. From the distance of the lines apart the relative velocity of the stars can be found, and from this is determined the size of the orbit and the mass of the stars. Such couples are termed *spectroscopic binaries*, Mizar having the distinction of being the first of this type discovered. From observations made by Vogel (1900-1901) the period of this couple as they circle around their common centre of gravity is found to be 20.6 days, their distance apart is 28,330,000 miles, and their mass about nine times that of the sun.

The next discovery in connection with the Mizar family, was that both Alcor and the minute star with the long name have their companion stars, each pair being far too close for separation even by the most powerful telescopes. However, their duplicity was revealed by the spectroscope, so that like Mizar they are known to be spectroscopic binaries. Thus, as Sir Richard Gregory remarks, in his book, *The Vault of Heaven*, "we are presented with the interesting spectacle of six stars rotating in pairs round their common centre of gravity, each pair possessing in addition an independent rotation of its own." Moreover, there is evidence to show that the three pairs are physically connected. Over a thousand spectroscopic binaries have so far (1938) been detected, and duly catalogued.

The telescope shows numerous cases in which two stars lie so near each other that they can be separated only by a high magnifying power. At present more than twenty thousand such couples are known. In a few cases the two components of a double star are at very different distances from us, and appear close together in the heavens only because they lie nearly in the same line of sight. These are called *optical* pairs to distinguish them from the great majority of double stars which are *physical* pairs such as Mizar, where the opponents are really near each other and revolving in slow orbital motion. When the orbital motion is clearly perceptible, the pair is called a *visual binary*, such as Mizar and Alcor. While a few physical pairs are so widely separated that they appear double when seen with a field-glass or even with the naked eye, other binaries are so close they can be seen separate only when observed with the most powerful telescopes. We have already seen how the spectroscope is required to separate certain types of double stars which are seemingly blended as one, and finally there are couples too close for separation by means of a telescope however powerful, and too faint for spectroscopic study. These are termed *eclipsing binaries*, the first of which was Algol detected in 1670, a model of this class with its waxing and waning light, and one which is well within the range of an amateur, provided with good eyesight, and aided by a field-glass.

After the first discovery of a double star by Riccioli in 1650, no attention was paid to them until 1700, September 7, when according to Rev. T. W. Webb, as he tells us in his well-known book *Celestial Objects*, Mizar and its companion star were again noticed in 1775 by Gottfried Kirch, and his scientific wife, Maria Margareta, "as probably travelling together through space, and in very slow orbital motion, forming a noble group with Alcor, of the 5th magnitude, and another star which is said to have been seen without a telescope." Shortly after 1775, attention was again revived in double stars by Sir William Herschel who began the first systematic search for such objects.

He had supposed in the case of two stars where one was large and the other small, that the smaller one was usually some distance beyond the other, as is sometimes the case. If this were so, there would be a perceptible change in the position and distance of the two stars from each other during the course of the year, but instead of finding what he had expected, he observed that one of the stars was slowly describing a regular orbit around the other. To use his own expression, he tells us, "he went out like Saul to find his father's asses, and found a kingdom",—the dominion of gravitation extended to the stars, unlimited by the boundary of the solar system. He made the discovery that double stars, unlike most astronomical discoveries are found in many instances by simply looking for them with a telescope. A trained eye, good atmospheric conditions, and a telescope of excellent optical quality are the main requirements, as well as a catalogue for reference to make sure the double star is not one which has already been discovered.

That double stars were visual binaries, was first recognized by the keen eyes of Sir William Herschel in 1803, and his catalogues (1782 to 1784) contain about 700 double stars, including many important binary systems—the number now known exceeding 1500. In making his catalogues, it was necessary to find what double stars had already been recorded, but instead of visiting libraries in search of the necessary information, Herschel decided to view the heavens himself since Nature, that great volume, seemed to him to provide the best catalogue. As a result of his search, he presented to the Royal Society on January 10, 1782, a catalogue of 269 double stars, of which 227 were of his own finding; followed by a second list of 434 in December, 1784. But although his double star work did not help him, in ascertaining, as he had hoped, the extent of the Universe so far as it is possible for us to penetrate into space, yet he was able to prove beyond doubt that while some of the double stars observed were optical, though apparently double as they passed by each other along independent paths in space, the greater number were actually double stars, the two circling round their common centre of gravity. Herschel's catalogue not only included about 700 double stars, but many important binary systems, such as: Castor in the constellation Gemini, Gamma Leonis, Epsilon Boötes, Delta Serpentis, Gamma Virginis, and Zeta Herculis—all noted binaries; and came to the conclusion, that they proved to be "real binary combinations, intimately held together by the bond of mutual attraction".

In 1803, Herschel drew attention to the typical "double-double" star, Epsilon Lyrae, in itself an amazing revelation marking the beginning of a series of investigations of the utmost variety and importance. To quote Arago, the discovery of binary stars was "one with a future". According to Flammarion, "the Annus Magnus of this quadruple system of Epsilon Lyrae, cannot be less than a million years". As the two components are a twentieth of a degree apart, good eyesight aided by an opera-glass or field-glass enables one to see them separately on a dark clear night, but with quite a small telescope each star is seen to be a double star, the brightest of the four stars being a spectroscopic binary. Therefore, this wonderful star Epsilon Lyrae, which appears single to the unaided eye (though just resolvable into two by a keen eye without aid), is in reality quadruple, and there is reason to believe that the stars composing it are connected in pairs, the members of each pair revolving round their common centre of gravity, while the two pairs in turn, circle around a centre common to all. It has been estimated that the periods of the closer pairs must be many centuries in length, and that of the wide pair is probably several hundred thousand years. Sir William Herschel saw Epsilon Lyrae several times as a double, and Bessel also relates that when he was a lad of thirteen he could see it double. A small telescope will show the colours of this double-double, the components of one being yellow and ruddy, and the other couple being both white. Between the couples, there are three faint stars, possibly forming with the quadruple a single system. With a five-inch telescope a fine view should be obtained of this little colony of stars.

The feeling that the Herschels and their successors the Struves had practically exhausted the work of discovering double stars, at least in the northern hemisphere continued for thirty years after the appearance of the Pulkowa Catalogue issued by Struve in 1843. Nor were any new lines of investigation in double star astronomy developed during that period. Then in 1873, a short paper appeared in the *Monthly Notices of the R.A.S.*, entitled, "Catalogue of Eighty-one Double Stars, discovered with a six-inch Alvan Clark Refractor," by S. W. Burnham, Chicago, U.S.A. At the time, Burnham was not a professional astronomer, but an expert stenographer employed as official reporter in the United States Courts at Chicago. His interest in double stars had been aroused by a small book on astronomy, entitled *The Geography of the Heavens*, by E. H. Burritt which he came across on a second-hand bookstall; and the chapter on variable and double stars, was the foundation of his successful work in that special branch of astronomical research.

In 1861, he secured for himself a three-inch telescope with alt-azimuth mounting, and some years later he purchased a three and three-quarter-inch refractor, "good enough," he tells us, "to be of some use, and poor enough to make something better more desirable than ever." Accordingly, in 1870, he purchased the six-inch refractor from Alvan Clark, and erected it in a small observatory in the garden at his home in Chicago. When the nights were fine, he disappeared within—what the irreverent neighbours called the Cheese-box; and when nights were cloudy he went to the Library, and industriously copied page by page, the records of double stars from Struve's Catalogue of thousands of stars. These were embodied by Struve in three great volumes, and his complete survey embraced the examinations of 120,000 stars, in 129 nights of actual work, during the period from November 1824, to February, 1827. Professor Burnham's nightly programme consisted of selecting a star in the finder attached to his telescope, bringing it into the field of view of the large telescope, examining it, and if double, entering it into the observing record, with a general description, and an approximate position determined by circle readings, and upon this method he pursued his work. The date of the appearance of his first paper presented to the R.A.S. "may be taken", as Dr. R. G. Aitken remarks, in his book, *The Binary Stars*, "as the beginning of the modern period of double star astronomy, for to Burnham belongs the great credit of being the first to demonstrate and utilize the full power of modern refracting telescopes in visual observations; and the forty years of his active career as an observer cover essentially all of the modern developments in binary star astronomy, including the discovery and observations of spectroscopic binaries, the demonstration that the 'eclipsing' variable stars are binary systems, and the application of photographic methods to the measurement of double stars."

Professor Burnham's career has been unique. He held positions in four observatories, the Dearborn, the Washburn, the Lick, and the Yerkes, and also discovered double stars with the twenty-six inch refractor at the United States Naval Observatory; the sixteen-inch at the Warner Observatory; and with the two refractors at the Dartmouth College Observatory. In all, he discovered more than 1,340 new double stars and made thousands of measures of inestimable value owing to the great accuracy and the care with which he prepared his observing programmes. And yet, except for the two short periods spent at Madison and Mount Hamilton, he continued meanwhile his work as Clerk of the United States District Court of Chicago, until about 1909. He retired from the Yerkes Observatory in 1912, and the results of his observations between the years 1871 and 1899, are recorded in the first volumes of the *Yerkes Observatory Publications*, which has been justly termed "a monumental work". Burnham's work introduced the modern era of double star astronomy, the end of which is not yet in sight, as evidenced in the work of Dr. R. G. Aitken, a former Director of the Lick Observatory, who, when he went there in June, 1895, acknowledged in his book on *Double Stars*, already referred to, that "he had had the benefit of advice so generously given to him and other double-star observers of his generation, by Professor Burnham then at the Yerkes Observatory".

THE BIRTH OF BINARY SYSTEMS

According to the theory recently advanced by Sir James Jeans concerning the probable origin of double star systems, the stars must be endowed with rotation at their birth. As a star shrinks, its speed of rotation increases, and as it grows older it spins faster and faster until it eventually breaks in two. Sometimes, these sections in turn break up, thus accounting for family parties such as Mizar, or double-doubles such as Epsilon Lyrae, already referred to; or Zeta Cancri, composed of three yellow stars forming one system. They are all connected by the law of gravitation which holds every particle in the Universe under its control, and sways them by its hidden power. So intricate are the movements of this celestial trio as they advance and recede in their dance, that an analysis of their steps proved a difficult task at first, but may be explained as follows. If we call the stars A, B, and C; then it has become apparent that the star C reverses around A and B at an average rate of about half a degree a year, requiring a period of 600 or 700 years to make one complete turn. Its path consists of a series of loops in traversing which C alternately advances and recedes, sometimes quickly, sometimes slowly, even hesitating at times as if uncertain as to the next step, while at the same time it is ever increasing or diminishing its distance from the centre of motion. The constellation Cancer, to which this triple star belongs—(which cannot be seen without a telescope), is characterized by a cluster of stars known as Praesepe, or the Beehive. To the unaided eye it appears merely as a hazy-looking object between Gemini and Leo, but with an opera-glass Praesepe is resolved into a silvery hazy spot lying between two rather faint stars. This is the Praesepe or Manger, as it is sometimes referred to, which is to be found in the centre of the constellation Cancer. The two stars on either side of it are called the Aselli, or the Ass's Colts, and the ancients pictured them as feeding from the silver manger. With an opera-glass the Manger appears to consist of a group of small stars, seen to still better advantage with a powerful field-glass. The Manger was a weather sign in the days of old, and

Aratus, the poet-astronomer, in his "Diosemia" bids his readers:

> ". . . watch the Manger: like a little mist
> Far north in Cancer's territory it floats.
> Its confines are two faintly glimmering stars;
> These are two asses that a manger parts,
> Which suddenly, when all the sky is clear,
> Sometimes quite vanishes, and the two stars
> Seem to have closer moved their sundered orbs.
> No feeble tempest then will soak the leas;
> A murky manger with both stars
> Shining unaltered is a sign of rain."

In fact, it is only when the air is perfectly transparent that the Manger can be clearly seen; while when the air is thick with mist, the harbinger of coming storm, it fades from sight, a wise old weather-saw well worth bearing in mind when one is contemplating a yachting trip.

COLOURS OF THE STARS

Sir William Herschel was not only the first to observe double stars, but their lovely contrasts in colour, where in very truth "one star differeth from another in glory". The phrase, "Nature finds gladness in a thousand tints," applied to the colours of flowers of the earth, may be well applied to the colours of the stars with their exquisite beauty and variety. Even a field-glass or an opera-glass will reveal the golden-yellow of the star Albireo, in the constellation of the Swan, as contrasted with its smaller companion of a deep, rich blue. A small telescope shows not only the ruddy glow of Arcturus in the constellation Boötes, but brings into view its distant pale blue companion. Herschel was of an artistic temperament, so that he did not hesitate—it would seem, to enjoy the beauty of the celestial scenes unfolded before his eyes as he gazed upon them through his great reflector, moments of pure enjoyment—a rest from the arduous undertaking of charting the star-depths.

Even with an opera-glass an amateur can gain some idea of the glories revealed—though but a faint echo of those observed by Herschel. In the springtime, when Arcturus and Spica are in the sky at the same time, it is interesting to compare the ruddy hue of the one with the dazzling white of the other. Then glance at the pearly lustre of Capella in the constellation Auriga, and compare it with the sparkling bluish tinge of Vega, in the constellation Lyra. Even with the unaided eye the varied hues of these leading brilliants of the summer sky are seen clear and distinct against the dark blue background of the sky. However, in our climes with the lengthy twilight almost extending to the dawn, little can be seen at this season of the year before half-past ten or later, and by 4 a.m. the approach of dawn is already causing the light of the stars to fade from view.

During the summer months the stars of the Scorpion may be seen creeping along the southern horizon, but according to ancient legend when the constellation of

Orion appears announcing the approach of winter, the Scorpion vanishes, for the two are in perpetual pursuit of each other, the Scorpion reappearing as Orion dips below the western horizon early in the springtime evenings. The ruddy hue of Antares marks the heart of the Scorpion which is closely followed by the constellation of Sagittarius, the Archer, who, legend records, aimed the fatal dart which is of no astronomical importance, save for the fact that it helps one to recall the position of these two groups of stars with regard to each other. Antares has a minute green companion nestling in its glare, but for a long time this double star had been a source of perplexity to astronomers. It was well known as a brilliantly red star, yet when it was watched closely, a peculiar green tinge seemed to flash out, which could only be accounted for as due to a companion star of that colour. For a long time search was made for the suspected object but without avail, until it was finally detected by Professor Mitchell with a new telescope which had been erected at the Cincinnati Observatory, U.S.A., in 1845. The discovery of the green companion star, was the first noteworthy achievement of this instrument, and was a source of great gratification to the Director, until he heard the disturbing news that at another Observatory *two* green companions could be seen attending Antares. Again and again he searched for the alleged second green star, but without success until finally the welcome news arrived that the telescope of the other Observatory was at fault. It had a way of dividing small stars on its own account—that is to say, it divided stars which really were single. Doubt still remained with regard to the green of the companion star, for it was too minute an object, and too close to its primary—Antares, to be separated by artificial means, such as a small cross-bar of iron or copper introduced into the telescopic eyepiece for the purpose. However, doubt vanished when the moon came to the assistance of the astronomer, at the time of an occultation of Antares, for while it hid that ruddy star from view, the small green companion was seen for a brief second shining clearly and alone in the field of view of the telescope. There was no longer any doubt as to its green colour. Antares is attended not only by its small green companion, but by another still closer which has never been seen, but of whose existence we have been made aware by means of the spectroscope which shows the shifting lines in the spectrum of the primary.

The star Beta in the constellation of the Scorpion is also a double star, pale yellow and green in colour, the two being visible with an opera-glass, which will also show two small stars hanging like a pendant from the larger star; with which however they are not connected. The star Epsilon in the same constellation is a double star, the components being yellow and blue, and a white fifth magnitude star lying close to the primary makes it actually a triple star. Below Epsilon is the star Mu, which an opera-glass will resolve into two stars, each one seemingly making an attempt to rival the other in brightness. Zeta consists of two stars, one a glowing red in contrast to the soft blue tint of its companion. In fact, for the student of stars, the Scorpion supplies a wealth of attractions, not only in the way of double stars but also of clusters, such as M. 4* near Antares. In 1783 when Sir William Herschel turned his great ten-foot reflector in its direction, he saw this cluster which even with an opera-glass is conspicuous, resolve itself into a cluster of stars. Above Lambda are the two clusters M. 7 and M. 6 which resemble a silvery haze begemmed with stars, when looked at with a powerful field-glass. Finally before we leave this region with its wealth of stars, there is the cluster M. 80 to the north of Antares, which Herschel described as "the richest and most condensed mass of stars which the firmament offers to the contemplation of astronomers." On May 21, 1860, an astronomer named Auwers, a noted observer, saw a star of magnitude 6.5 in the cluster, which had not attracted attention before, but by the middle of June of that same year it had disappeared and has not been seen again. It is suspected that it is a variable star, or maybe it was the expiring gleam of a star approaching extinction.

We have a notable instance of the disappearance of

*M. stands for Messier, and 4, 6, 8, etc. for the number of cluster in Messier's Catalogue.

stars, in the beautiful cluster of stars known as Kappa Crucis, which hovers on the edge of the Coal Sack, a dark cavernous-looking space beside the Southern Cross, and therefore not visible in the northern hemisphere. This marvellous cluster is among the treasure-trove in southern skies, though with an opera-glass it seems but a reddish star of the seventh magnitude. It is actually a wondrous example of celestial colouring; and vividly described by Sir John Herschel, who continued his father's work by cataloguing the stars in the southern hemisphere. He says, Kappa Crucis is "a most vivid and beautiful cluster of 50 to 100 stars. Among the larger there are two greenish; south of the red star is one 13th magnitude also red and one of the 12th magnitude, bluish . . . though neither a large nor a rich one, is yet an extremely brilliant and beautiful object when viewed through an instrument of sufficient aperture to show distinctly the very different colours of its constituent stars, which gives it the effect of a superb piece of fancy jewellery."

In his catalogue, he gives the position of 110 stars in the cluster, ranging from the 7th to the 16th magnitude. Mr. Russell's observations of this cluster at the Sydney Observatory (N.S.W.) of which he was at the time Director (1872), show several changes in the position of the stars, as laid down by Sir John Herschel, which may probably be the result of proper motion. Herschel had mapped the positions of these stars in 1830, but when in 1872, Mr. Russell made a chart of the cluster with a refractor seven and one quarter inches clear aperture, he found that some remarkable changes had taken place, with regard both to the relative position of the stars and their colour. Five of Herschel's stars were missing, but *twenty-five new ones* had put in an appearance. Many of the stars had drifted considerably since the Cape drawing was made by Herschel, and if changes such as these had taken place in such a brief interval (1830-1872), "it is evident," according to a statement made by Mr. Russell, in the R.A.S. *Monthly Notices*, Vol. XXXIII, part 2, (1872), "that more attention should be paid to this cluster."

WHY STARS DIFFER IN COLOUR

When we examine the stars with the unaided eye we find they differ in colour. Possibly these colours are seen at their best on clear nights in the depth of winter, when the rose-red light of Aldebaran, the blue-white radiance of Rigel, the orange hue of Betelgeuse, and the pearly glow of Capella form such a marvellous contrast as seen against the dark-blue vault of heaven. But why are some stars red, others blue, and other varying tints to be found, ranging through all the colours of the rainbow? It all depends on the temperature of the star under consideration, and indicates the stage of development at which it has arrived. If the outside of the star known as the photosphere, the region from which comes its light, has risen to a temperature of forty thousand degrees, it has apparently become as hot as the make-up of a star permits, and may be described as passing through the giant stage indicating the youth of a star.

The colour of a star is a clue given us by Nature showing that they differ in kind. By means of the spectroscope we can decode the message even though we lose the beauty of the colours in the process, for they affect the film only as a background of light on which the dark lines of the spectrum of the star are engraved. Each colour has its own wave-length, the wave-lengths corresponding to the separate colours arranged in order of magnitude, the wave-length of violet, for instance, being least, and that of red the greatest. Using the analogy of sound, the violet would be soprano, running down the chromatic scale, to red denoting the bass.

The Harvard Observatory was the first to undertake the photography of stellar spectra on a large scale. With a prism placed over the lens of a telescope, the spectrum of every star of sufficient brightness in the field of view can be photographed. By means of these photographs it is possible to classify the stars from the position and strength of the lines in their spectra. The stars are arranged in the following order, Classes B.A.F.G.K.M. six divisions including the great majority of the stars. B goes before A in the astronomer's alphabet, because when it was too late to reverse the letters, the B stars were found to precede the A stars in life-history. The so-called B.A.F. classification, is easy to remember, if we recall that Sir R. S. Ball, once suggested that B.A.F. stands for "baffling".

When an astronomer speaks of a Class A star, he refers to white stars like Sirius and Vega, their spectra informing us that hydrogen predominates in their atmosphere, while blue-white stars like Rigel in the constellation Orion have an abundant supply of helium in their atmospheres. Twenty-five years ago it was assumed that stars differ in composition, the A stars having a monopoly of hydrogen, and the B stars, of helium, but the combined labour of chemists, physicists and astronomers have proved beyond doubt that the differences are mainly due to temperature, and the colour of a star expresses the temperature which is required to produce the observed atmospheric conditions. Moreover, the classification of stars has shown that there is no new kind of matter in the universe, for the same substances known on Earth are to be found in the stars as shown by their spectra.

A quarter of a million stars have already been arranged in forty classes founded upon a study of the Harvard photographs, providing a wealth of material for studying the architecture of the Universe. We can trace the story of the stars according to their decreasing temperature and increasing redness. The lines in the spectrum tell us the life story of a star, in youth rarified and red, in middle life very blue, hot and radiant; and in old age, shrunken, dense and again red. The youthful stars are the giants like Betelgeuse, and Antares while the dwarfs are stars in the late condensed stage, resembling the glowing embers of an expiring fire. Our Sun belongs to Class G, and may be termed a middle-aged star which in the course of time will dwindle to the "dwarf" stage and finally sink into obscurity. Stars like our Sun are scattered over the sky, in the highways and byways of the universe, but whether they are rulers of a planetary system, such as the one of which our Earth forms part, is a conjecture we are unable to confirm, but is quite within the bounds of probability. It is interesting to consider the possibilities of the conditions upon a world travelling around such a system, if the coloured stars convey red, green, or purple light to its surface, though now we know the colour is merely the index of their temperature, as for instance in the case of our Sun which is actually blue, as we should find if the atmosphere surrounding our planet were removed.

The reason why stars are of different colours is because they differ in temperature. They exhibit a complete scale of colours from a dull red, through yellow and white, to vivid violet and their range of temperature is correspondingly great. As Sir James Jeans tells us in his book, *The Stars in Their Courses.* The dull red stars are the least hot, with temperature of about 1400° Centigrade, or about 2550 degrees on the ordinary Fahrenheit scale. Yellowish stars are at least twice as hot. After these come stars like the sun, with temperatures of about 5500° Centigrade or 10,000° Fahrenheit, and so on until we come to the hottest stars of all, with temperatures of perhaps 70,000° Fahrenheit. The whole observed range of temperature—from about 2550° to 70,000° Fahrenheit—is immense, and most of it lies entirely beyond anything we know on earth.

The range of colours of the spectrum is easily remembered by means of the well-known lines of Thomson:

> First the flaming red
> Sprang vivid forth, the tawny orange next,
> And next delicious yellow; by whose side
> Fell the beams of all-refreshing green.
> Then the pure blue that swells autumnal skies,
> Ethereal played; and then of sadder hue
> Emerged the deeper indigo (as when
> The heavy-skirted evening droops with frost),
> While the last gleamings of refracted light
> Died in the fainting violet away.

CHAPTER IV

STAR DRIFT

LET us watch the constellations, some starlit night as they come into view, passing with stately motion along their nocturnal paths until by dawn those seen rising above the eastern horizon earlier in the twilight are observed to vanish in the west at the approach of sunrise. This apparent motion is due to the rotation of the Earth, owing to which we daily witness the rising and setting of the Sun, Moon and stars, during the course of the day and night. But there is another motion of the stars, known as their "proper motions", that is, the real motions which go on independently of terrestrial changes of position. Every star is in motion, all are drifting at various rates of speed, and it is a slow star which has a record of but nine miles a second. Between this, and many known velocities of stars there is a wide divergence, culminating in that of Arcturus, which rushes through space at the rate of more than 200 miles a second.

The proper motion of a star may arise from its own motion, or from a motion of the solar system in space. In the former case there is no similarity in the proper motions of stars which have their own individual rate of speed, and direction; but in the latter case there would be a general drift of the stars in an opposite direction to the movement of the solar system. The stars might be compared to steamers which, when watched from the shore, appear to move very slowly as seen on the distant horizon, even though their speed might be very great. In fact, hours may pass before one is able to detect any perceptible change in their position. In the same way, the stars are so far away that their real motions are scarcely discernible, and are only revealed by observations over a long period of time. Hipparchus made a catalogue of the positions of some of the stars about 125 B.C. Eighteen hundred years later, Halley compared their positions with those found in his day, and the comparison showed unmistakable changes of position which had occurred during the interval. Until that time the stars were referred to as "fixed", but now a "fixed star" is unknown.

To the unaided eye no signs of stellar motion are apparent, which explains why for centuries stars were known as "fixed stars". This is not surprising since there are not even ten stars in the heavens whose motions in a thousand years would cover a space that the unaided eye could estimate. Nowadays, by means of the skilfully constructed instruments in use in modern observatories, the astronomer is enabled to measure the scarcely perceptible movements of the so-called "fixed stars". In ten years, or in twenty, no change of position may be detected; but when we compare the observations of our day with those which were made a hundred years ago, the traces of stellar motion become in many cases, unmistakable. Sir William Herschel, in estimating the drift of the Sun and planets, endeavoured in his usual direct way, to treat the subject in the simplest possible manner. Striking a balance between the proper motions of only seven stars, he was led to infer, in 1783, from simple geometrical considerations, that the point to which the Sun was drifting, was marked by the star Lambda Hercules. As a result, he was led by the unerring instinct of genius to a result which was nearly correct. In 1805, he made a new determination, finding a position 30″ distant from Lambda Hercules.

Sir William Herschel gave evidence of his great skill in dealing with observed facts, when he discovered that the Sun with his family of planets—including the Earth—is sweeping onwards with enormous velocity through the depths of space. The only evidence he had respecting the movements of the Sun were derived from the apparent motion of objects surrounding him, just as when we are in a moving train, and our attention is drawn by the apparent motion of trains which may be going in the same or opposite directions as compared with that of our own train which seems practically motionless. In the same way, the stars on all sides around the path of the Sun, must be affected with apparent motions unless they are travelling in the same direction and at the same rate of speed as the Sun. There is no irregularity in the stately progress of the Sun through space to give us the impression, who move with him, that he is not at rest. Herschel pointed to a region among the stars towards which our Sun is travelling, and around that region all the best determinations of modern times have ranged themselves. According to the determination of the Solar Apex by Wilson, Campbell and Moore, (see *Handbook of the Stars, B.A.A.* for 1939), the Right Ascension is 271° and the Declination + 31″. The point in the sky towards which the solar system is moving, is not far from the bright star Vega.

During the month of September, when the sky becomes dark enough early in the evening so as to make it possible to see some of the brighter stars, Vega with its steely-blue radiance gleams brightly overhead. When crossing the ocean in the summer months, there is nothing more restful than watching the stars from the upper deck of a steamer as it forges its way at full speed across the ocean; and forgetting all our surroundings while we look overhead at the constellations when Lyra with its leading star Vega is in the zenith. Listening to the clank of the engines, we calculate the hundreds of millions of years which would be required for our ship to reach that star, if she could make her course in that direction across the ocean of space without ever stopping. Yet a moment's reflection assures us we are actually making that journey at a speed compared with which that of the steamer is indeed slow. Each moment we are thousands of miles nearer than we were a moment ago. The Sun's speed would carry it with its accompanying family of planets in 75,000 years, over a space equal to the distance of the nearest star. Alpha Centauri with its near-by attendant Proxima, are the two nearest stars in the direction towards which the Sun is moving, Vega being more than six times farther away. In fact, Vega is at a distance of twenty-six light-years, so that there is no possibility of a collision, since that star is winging its way onward and athwart the pathway of the solar system.

There is ample room in the star-depths for the individual stars to make their journeys in space free from disturbance, and—as we have already seen—collisions are rare. Our little fleet with its pilot the Sun, will assuredly steer its way unharmed to the point in the heavens where Vega now gleams, continuing onward beyond that point in safety. To attain to the stars was the seemingly vain wish of an ancient philosopher, yet the whole human race is to a certain extent attaining that goal, as fast as a speed—that of the Sun of twelve and a half miles a second, can bring it about.

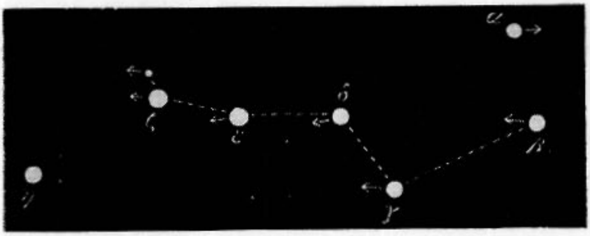
That Sir William Herschel regarded his attempt at tracing the movement of the Sun among the stars, as nothing more than an experiment, is shown by a letter written to Dr. Wilson of Glasgow in 1783, in which he expressed his apprehension lest his paper on the Sun's motion, "might be too much out of the way to deserve the notice of astronomers," little knowing that like a master-bowman, though he seemed to aim so carelessly at the mark, yet he struck it not far from the position determined by later results. These have been deduced from the proper motions of fainter stars indicating a point farther north and east, near Vega in the constellation Lyra. Herschel's conclusion regarding the solar translation obtained little notice, and less acceptance from his contemporaries, and immediate successors. Even his son, Sir John Herschel, rejected them as untrustworthy, while Bessel, the greatest authority in his time in the science of "how the heavens move", declared in 1818, that the sun's apex might be situated in any other part of the sky with as much probability as in the constellation Hercules. Herschel's theory was not accepted until 1830, when Argelander with improved data, arrived at practically the same result, after completing many exact observations of a number of bright stars. He compared the positions of 390 of these, with those found by Bradley in 1755. The interval of seventy-five years between the observations, provided him with a very considerable change of base—the distance through which the solar system had moved in seventy-five years. His research, which was carried out with considerable mathematical refinement and skill, abundantly confirmed Herschel's earlier result.

Finally, Herschel's work obtained the recognition it deserved. "To discern the proper motion of the Sun between so many other motions of the stars," Herschel considered, as well he might, "an arduous task." He argued that if the Sun alone was in motion, the stars would appear to drift backward from the "apex" or point on the sphere to which it was journeying. The stellar ranks would open out before it, and close up after it had passed onward. It was like the widening prospect and narrowing vista of trees for the traveller approaching or receding from a woodland glade in the direction of the open country. Unlike the motionless trees, the stars are flitting about, some in one direction, some in another, in what would appear to be, a rather haphazard manner. This must have increased the difficulty experienced by Herschel, in disentangling the drift of the Sun from that of stars in its neighbourhood, in order to determine its path in their midst.

Since Herschel's time it has been found that there are laws of motion associating stellar movements in a special manner, without any actual association of the individual orbs. About 1868, after making a close study of Herschel's work in connection with solar drift, the writer's father, R. A. Proctor formed the opinion, that if the proper motions of the stars were *mapped*, there would be rendered apparent, signs of association between stars which are much farther apart in the heavens, than between members of the widest double or multiple stars systems then known. Groups of stars traversing the star-depths together, showing a sociable tendency would afford significant evidence of being related to each other, having associated proper motions in one and the same direction. He therefore proceeded to map down the proper motions of the stars, which the Astronomer Royal (Sir George Airy) had made; subsequently adding upwards of 400 stars, whose proper motions had been calculated by Mr. Stone of the Greenwich Observatory, from observations as trustworthy as those which he had used in preparing a catalogue of 1,167 stars dealt with by the Astronomer Royal. The maps showed the estimated position of the Solar Way, according to the researches of Sir William Herschel, Otto Struve, Argelander, Madler, Sir George Airy, and others.

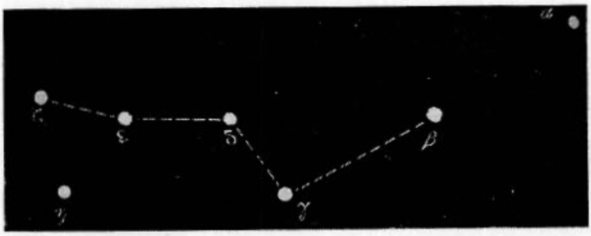
In the two maps published by R. A. Proctor in his book, *The Universe of Stars*, arrows have been added over all parts of both maps, corresponding in length and direction with the estimated apparent motion of a star of the first magnitude supposed to be at rest, but changing in apparent position on account of the motion of our sun. Thus, it becomes possible to determine at once whether a star or a group of stars in any region be moving or not, in a way corresponding with the effects due to the Sun's motion. Taking into consideration the fact, that the stars which are visible to us lie at different distances, we see that if a real group of stars exists as a unit in space, having dimensions which cause it to appear to cover a widely-extended region of the heavens, we must expect to find that other stars in the same region are in no way connected with the group. Not only so, but it must be looked upon as highly probable that the stars seen in any direction may belong to three, four or more star-groups, if the existence of such groups is a reality. Therefore, we might expect the existence of such star-groups to be more or less concealed by the effects which would follow from their apparent mingling with stellar aliens to which they were in no way related. If, for instance, a general drift of a group of stars in one direction is to be held as indicating that the stars so moving form a single system, the direction of their drift is easily determined; but when it comes to disentangling their motions from those of another drift belonging to an entirely different group travelling in another direction, difficulties are apt to arise. Still more so, if three or more star-drifts are mixed up together in this way, which results in the problem becoming even more perplexing and almost hopeless. Thus, all that was to be hoped for, or so it seemed, was that here and there some sufficiently well-marked cases of star-drift might not be disguised by the effect of other motions. Some set of stars would be seen as a family party, detached from stars in their immediate neighbourhood, and pursuing an independent path in the heavens.

According to R. A. Proctor's experience, the result of his investigations was more satisfactory than he had anticipated. He found, that by comparing maps of the same region taken a hundred years or so apart, there were unmistakable evidences of drift in some regions, of large groups of stars drifting bodily in a definite direction. The most remarkable instance of this sort, occurs in the stars which form the constellations of Gemini and Castor. All these amounting to seventy or eighty stars, were found to be drifting towards the Milky Way, with the exception of three stars which apparently belong to another system. A still more remarkable instance was found in connection with the stars in the constellation Taurus, the drift in this part of the heavens being in an opposite direction to that of Cancer and Gemini. Of the seven bright stars in Ursa Major, five were found to be travelling in a common direction with uniform velocity. "We cannot doubt," as R. A. Proctor states in his book, *The Universe of Suns*, "that they form a system drifting along bodily." This was proved in 1868, by means of the spectroscopic investigations of Sir William Huggins, and the theory of star-drift advanced by R. A. Proctor, became established on a firm basis of fact. This was the first time the spectroscope had been applied for such a purpose. It is well known that the position of a line in the spectrum of a star, or whatever may be under observation, is determined by the number of vibrations which are received each second. If the source of light is approaching the observer, more



THE GREAT BEAR

AS IT NOW IS.



THE GREAT BEAR AS IT WILL

BE 100,000 YEARS HENCE.

Original Chart by R. A. Proctor; illustrating the "Star-Drift" theory, November, 1869.

vibrations are received per second than happens when the source of light is at rest. Suppose the spectrum of a star, for instance, contains known lines due to iron. These will all be displaced in the normal spectrum of iron; and the amount of displacement affords a means of comparing the velocity of the source of light towards the observer with the velocity of light which is about eleven million miles a minute. If the source of light is receding, the light will be shifted towards the red end of the spectrum; or should it be approaching the lines are displaced towards the violet end. When Sir William Huggins applied this test to the well-known group of seven stars in Ursa Major, he found ample verification of the fact that five of the stars were slowly shifting their position, the arrow attached to each star as shown in the chart, indicating the amount of the shift during a period of 36,000 years. Were we to return to this planet at that remote period, the familiar Ursa Major group would be unrecognizable. As R. A. Proctor stated, at the conclusion of the chapter on Star-Drift, which originally appeared in the *Student* for October, 1870: "To deal, *now*, with generalities alone, as the Herschels did, would be to destroy these scarcely recognizable indications which can alone guide us to new knowledge. We must in future examine the sidereal scheme detail by detail, feature by feature. The work will not be light, and many workers will be wanted. But the result will be worth the toil. Not in our day, perhaps not for many generations, may the fruits of such labours be reaped. But gradually astronomy will gather in her harvest, and when it is garnered, the rich reward of many years of toil will be found in a clear knowledge of the relations presented by the wondrous galaxy to which our Sun belongs."

His prediction has long since been verified, photography, increased telescopic powers, improved methods of research opening out wider fields within which new discoveries are being made, concerning the drifting populace of the heavens. Furthermore, he realized that the star-drift in Ursa Major is only one instance out of many. Looking more closely at the sidereal system of which our Sun is a member, he found on studying the star-charts that it was breaking up into subordinate star-systems of greater or less extent. He was of the opinion that the Sun himself may not be a solitary star as has been commonly supposed. "From among the orbs which deck our skies, there may be some which are our Sun's companions on his path through space, though countless ages perhaps must pass before the signs of such companionship will be rendered discernible. If the Sun is moving now in a definite direction, it can by no means be inferred that this motion will always continue to be directed towards the same region of space. All the analogies which surround us teach us to believe rather, that his path is of the nature of a gigantic curve re-entering into itself mayhap like the planetary orbits, or possibly of a complex figure, resembling the paths of those comets which belong indeed to the solar scheme, but are swayed continually into new orbits by the attractions of the larger planets. Whichever of these views is correct, it is certain that the part of his path which the Sun is at present describing, must be looked upon as a portion of a gigantic circle. For, no matter what the figure of an orbit may be, any small portion of the curve may always be regarded as belonging to some definite circle. And astronomers have set themselves to inquire into the nature of the vast circle on which, for present purposes, we are to regard the Sun as travelling."*

In an article on "Star-Drift", by R. A. Proctor, in his book, *The Universe of Stars*, second edition, published 1878, the author also calls attention to the fact that the star-drift in Ursa Major was only one instance out of many. "On every side we see drifting star-schemes, and comparatively few stars are to be recognized as voyaging in solitary state through space. From the complexity of such systems as we see in Gemini and Cancer, to schemes such as the one in Ursa Major, and thence to solitary stars such as Arcturus and Sirius appear to be, we recognize a number of gradations, and it yet remains to be determined to what class of these schemes our Sun belongs."

Concerning this interesting discovery about star-drift made in 1868, a lengthy correspondence on the

*From *The Student*, an article by R. A. Proctor, October, 1870.

subject ensued between R. A. Proctor and Sir John Herschel, whose replies are to be found incorporated in the latter part of R. A. Proctor's book, *Other Suns Than Ours*. The work in connection with associated motions of stars as shown in the chart, especially in connection with the Taurus-stream which composes part of the Pleiades, was not resumed until 1905, when Kapteyn rediscovered that the peculiar motions of stars was not at random. Lewis Boss published his *Preliminary General Catalogue* of 6,188 stars, confirming this theory in 1910, *forty years* after my father's pioneer work had been achieved by the laborious examination of star-charts. The star-drift theory is now a well-known established fact, the researches of Boss, Hertz-sprung and others showing the nature of star-drift in a new light, while Kapteyn in 1922, carried it still further with his account of the star-streaming Universe, which "still remains a puzzling phenomenon; tentative explanations have indeed been offered, but it would appear that its complete elucidation is a task for future astronomers."*

According to Professor Eddington, in his book entitled, *Stellar Movements and the Structure of the Universe*, published 1914, great strides have been made in our knowledge of star-drift. The Ursa Major group of five stars—companions in their journey across the star-depths, has been found to include a number of other stars, scattered over a great part of the sky, the

* *The Sun, the Stars and the Universe:* p. 177, by W. M. Smart.

most interesting of these scattered members being Sirius, the evidence of the association being very strong. The bright stars of the constellation of Orion (with the exception of Betelgeuse), appear to form a system of stars, intertwined with a nebulous haze surrounding the whole constellation as revealed by means of photography. The same remark applies to the Pleiades, in which we have evidence of a cluster in the ordinary sense of the term, and, as might be expected, the motions of the principal stars and at least fifty fainter stars in this cluster are equal and parallel. Miss A. M. Clerke, in her book, *The System of Stars*, aptly describes them as: "battalions of stars, marching in widely extended ranks, by a concerted plan, along a prescribed track, under orders sealed perhaps for ever to human intelligence."

However, a great advance has been made in our knowledge of stellar movements since these words were written by Miss Clerke, for according to the recent researches of astronomers, it would seem as though "the sealed orders" were being gradually deciphered. For the Pleiades and their stellar adherents are now known to form part of one of the two great star-streams which are passing athwart each other in the heavens, while a third stream, to which our own stellar system belongs, forms the grand-stand as it were from which we are watching the passing throng. The Taurus-cluster appears to be a globular cluster with a slight central condensation; and in the neighbourhood of the Sun we have nothing to compare with this collection of magnificent orbs. "These stars, it is true," as Professor Eddington tells us, "are separated by distances of the usual order of magnitude; but their exceptional brilliancy marks out this portion of space from an ordinary region. Whether there are or are not other fainter members accompanying them, the term cluster is appropriate enough. There can be no doubt that viewed from a sufficient distance, this assemblage would have the general appearance of a globular cluster. The known motion of the Taurus-cluster permits us to trace its past and future history. It was in perihelion (or at its nearest to the Sun) 800,000 years ago; the distance was then about half what it is now. Boss has computed that in 65,000,000 years it will (if the motion is undisturbed) appear as an ordinary globular cluster about 20 in diameter, consisting largely of stars from the ninth to the twelfth magnitude."

The star Capella—the most brilliant star in our northern sky has a faint companion star, accompanying it in its journey through space. It is a case of a giant and a dwarf star in close association, the dwarf—a faint star of the 10th magnitude leading. Should Capella overtake its dwarf companion, which depends on their relative speed, will their experience be similar in years to come with that of *a* Centauri which is accompanied by a faint star of the 11th magnitude about 2° away. The measured proper motions of *a* Centauri (itself a double star easily seen as such in a small telescope), and its faint companion appropriately named Proxima Centauri, are nearly identical, and as they are conspicuously large the close relationship between the stars is beyond doubt. In the case of *a* Centauri, the changing appearance of the sky in its neighbourhood during the course of thousands of years, has been skilfully shown in a series of three charts, by W. J. Luyten, Assistant Professor of Astronomy, Harvard University, in his book, entitled *The Pageant of the Stars.* In the first chart, the stars *a* and B Centauri are shown as Pointers to the Southern Cross, as they appear now. Four thousand years hence, the second chart shows *a* and B Centauri close together forming a beautiful double star, the appearance of the Southern Cross as yet unchanged; but 14,000 years hence *a* Centauri will have reached a position straight above the upper star of the Cross which will be considerably lower down, almost destroying the outline as we know it now. At that same period (as can be shown in a few minutes by that ingenious device the Zeiss Planetarium), the constellations Orion, Gemini, Taurus, which now adorn our winter heavens, will be visible in the summer night sky. As Dr. R. G. Aitken, Director of the Lick Observatory, states in a "Foreword", to a booklet regarding the Zeiss Planetarium, written in 1926, by Dr. W. Villiger: "The Zeiss Planetarium is the most remarkable instrument that has ever been devised to exhibit impressively, and with the illusion of reality, the motions of the heavenly bodies, and the phenomena which result from these motions."

Naturally, the Planetarium has its limitations, and shows in the artificial firmament only a few of the stars which can be seen on any clear night with the unaided eye; but since the invention of the telescope in 1610, the ever-increasing power of telescopes culminating in the great 100-inch reflector at Mount Wilson Observatory combined with the photographic plate, has gradually widened our knowledge by revealing a new heavens to our eyes. Could an instrument be devised to bring the millions of universes, composed of millions of stars, distributed throughout space within our ken, their motions condensed into a brief interval of Time, an observer endowed with infinite powers of vision would see in an immeasurably short period double stars whirling around their common centre of gravity; moving clusters of stars urging their way onward through space, and—as recent investigations have shown, the Galaxy or Milky Way composed of possibly 30,000,000,000 stars making one complete revolution in about 250,000,000 years. "The mind reels with its own weight of thought", at the contemplation of the scene thus conjectured, by a vision of the past combined with that of the present, swiftly merging each instant, into the future. What we actually see in the starlit heavens is but an echo of the past, since the light messages from the stars take years to reach the shores of our isle in space as we accompany the Sun in its onward journey. We do not see the stars as they *are*, but as they *were*—some of them centuries ago. According to Dr. Hubble, of Mount Wilson Observatory, using light as a measuring-rod, he has found that the most remote objects visible in the biggest telescope on earth are so distant, that light travelling eleven million miles a minute, takes about 140 million years to come from them to us. Truly, if we could for a moment yield to the power of fancy, we should see the countless host of fixed stars moving in groups hither and thither, nebulae wandering through space becoming condensed and dissolved from cosmic clouds into clusters of stars, thus evolving during vast periods of time, from star-dust to star, even as on our Earth's surface the flowers are unfolded from the seed, the leaf and the blossom, a counterpart in miniature of the evolution of the flowers of the sky.

CHAPTER V

CELESTIAL PHOTOGRAPHY

THE discovery of celestial photography as a means of charting the stars, instead of the laborious method referred to in the previous chapter, came about in a rather sensational and unexpected manner. In 1882, a brilliant comet appeared in the southern heavens, which could be seen in full daylight; but in the northern hemisphere only a fairly good view was obtained of the visitor from space. While it was still a magnificent spectacle in southern skies in the hours before dawn, many amateur photographers tried to obtain photographs of the comet, but without success owing to the rotation of the earth carrying them and their cameras with it, resulting in pictures that were blurred and valueless. Thereupon, Sir David Gill, at that time Director of the Government Observatory at the Cape of Good Hope, invited one of the enthusiasts to come to the Observatory and strap his camera to the equatorial telescope (which was fitted with clock-work to counteract the earth's motion). Immediately beautiful pictures of the comet were obtained, as well as of stars begemming the background. The number of stars shown on these photographs was amazing, and attracted general attention.

Sir David Gill was so greatly impressed, that he felt convinced that here was a unique method for constructing star maps on any required scale, down to any specially selected order of magnitude. He was led to expect the best results from photographs taken with a doublet portrait lens, having a large field and giving sharp definition, than from an ordinary telescope. Immediately he wrote to Dr. Dallmeyer, an authority on the subject, for a large lens to test the scheme, and by means of a grant from the Royal Society, he was enabled to obtain the services of a photographer from England who set up an efficient apparatus for photographing stars down to nine and a half magnitude in the southern hemisphere. This had already been done by Argelander in the northern hemisphere by the laborious method of charting, and observing each star with a telescope having the small aperture of two and a half inches. This instrument is preserved as a valued memento of his work, at the Bonn Observatory. (The writer saw it while on a visit to the Observatory, in 1922, and noticed that the tube of the telescope was polished till it glistened like gold).

With this small telescope Argelander observed and catalogued 324,198 stars, which he included in forty separate charts. During the early seventies, these charts were incorporated in one chart by R. A.

Proctor, who completed the work in six or seven weeks. As he states in his book, *The Universe of Stars*, "it is only necessary to compute the time for marking in the stars to see that the work could not readily be compressed into a shorter interval of time. At the moderate rate of one minute for ten stars, 32,400 minutes or 540 hours would be required, but the time actually occupied amounted to only 400 hours. I was pleased to find that along the line in which the last day's work was brought up to the first day's, no sign of any change in the style of mapping could be noticed. Had the star-magnitudes been enlarged or diminished in the interval, a sharp line of demarcation would unquestionably have been recognizable. As it is, I think I may defy the acutest observer to determine along what radial line the work began and ended." (Two sections of the map are shown between pages 158 and 159, in *The Universe of Stars*, and the complete map on a greatly reduced scale, in *Other Suns than Ours*, by the same author. The chart itself is on view in the Astronomical Exhibit, at the South Kensington Science Museum.)

Now, by means of telescopes specially constructed for photographic work, there is not only an immense saving of time in charting the stars, but accuracy as well may be assured. Such telescopes are usually made with two tubes like an opera-glass on a large scale. One tube is the photographic telescope, while the other is a visual telescope provided with crosswires in the field of view. By means of this arrangement, the astronomer can watch the stars under observation, while they are being photographed. If the clock-work is not in good order, the error will be detected at once, for a star will drift away from the intersection of the cross-threads in the field of view, as seen by the observer looking through the visual telescope. The slightest tendency in that direction can be instantly rectified by the adjustment of certain screws and other devices. With these the observer can correct any error of the clock while it is actually running, and of the photographic plate while it is exposed. These improvements were delayed for a few years, during what might be termed the experimental stage, which followed Sir David Gill's first attempt at photographing the comet of 1882.

In that same year, the Henry Brothers of the Paris Observatory, on seeing the comet picture with its wealth of stars in the background, came to the conclusion that their catalogue of stars could best be completed by means of photography. They then constructed the first of the astrographic telescopes which have been used since that time, all over the world for the construction of the great Star-Map, better known, as the International *Carte du Ciel.* This was started by Admiral Mouchez, with the help of Sir David Gill, and the Henry Brothers, at the Paris Astronomical Congress, which met in Paris in 1887. The plan decided upon was to photograph the whole sky upon glass plates about eight inches square, each covering an area of 2° square (four square degrees), showing all the stars down to the fourteenth magnitude. The typical instrument adopted for the work, has an aperture of about fourteen inches, and a focal length of about eleven feet, the object-glass being specially corrected for the photographic rays. A nine-inch visual telescope is enclosed in the same tube so that the observer can watch the position of the instrument during the whole observation.

The *Astrographic Catalogue* planned in 1887, by co-operation among nineteen observatories and now partly completed, will contain the positions of three or four million stars derived from 44,000 plates. When the great Star Chart is complete, should another be started after the same plan—say in 1987, comparisons between the two may lead to further developments with regard to stellar motions of which we are at present unaware. If only we could glance into the Future, and decipher the code which the Star Chart at present conceals!

Goethe charged Newton with taking all the poetry out of the rainbow in analysing light with the prism, yet there is far more poetry in the revelations made by the scientific study of light to the mind's eye than in those made by the rainbow or the sun-set sky to the natural eye. However, rightly to appreciate the marvellous scene presented to the trained imagination by the interpretation which modern science has given to the rainbow, and the colours of dawn and twilight, and even to the ethereal blue of the sky itself, that half knowledge through which Goethe saw but hazily, must be replaced by a clear and sufficient apprehension of what the science of optics really teaches. With such knowledge the scientific wonders of light surpass in beauty the phenomena recognized by ordinary vision, as greatly as the colours of the prismatic spectrum surpass in splendour the tints of the rainbow.

It is likewise with many of the results of scientific research which seem at first view the least attractive and the dreariest: For example, consider a star chart showing many dots—what can seem less impressive, unless we realize that each dot indicates the impression left by the light from a sun, so remote that possibly hundreds of years have passed since its message started earthward? Again, who can be moved by recognizing that in some parts of the chart of many stars, the dots are closer than elsewhere? And who would devote even an hour to producing a result which might as easily be obtained by spattering a large brush full of paint, deftly in dots over a sheet of paper? Yet that is the appearance presented by these charts which have been steadily collecting since the work of the Great Chart began in 1887. From the Report of the *International Union* which met at Paris in 1835, we read, that the sections of the sky observed and charted have been completed at the following Observatories: Greenwich, Oxford, Paris, Algiers, Hyderabad, the

Cape of Good Hope, the Vatican, Toulouse, Bordeaux and San Fernando, as well as Helsingfors and Catania. Potsdam has been compelled to relinquish its share of the work which has been taken over by the Uccle Observatory, and Hyderabad may lend a helping hand. Sydney's share has been taken over by James Nangle, Superintendent of Technical Education, N.S.W.

Reproduction of the charts from the various Observatories engaged in the work since its inception in 1887, are to be found at the R.A.S. Library, Burlington House, London. These are carefully enclosed in a cabinet specially prepared for the purpose. One finds a world of meaning concealed in these charts, with their scattered dots irregularly distributed over a white background. The charts have been printed in the usual way, and regarded as a product of the press, they have been well printed, the little dots showing neatly and distinctly. Even when one is told that each dot indicates the place of a star, the picture only represents itself as a star chart, obviously not differing in character from many other star charts which have appeared in treatises on astronomy. (The following is quoted from an article written by R. A. Proctor, in 1888.)

"Nevertheless, when the real nature of the chart is taken into account, there is seen to be evidence of a fact which should impress the least thoughtful mind. No one who looks at these charts, knowing what they represent, and how those tiny dots have come to show themselves there, can fail to be stirred with a feeling of awe and wonder, as when we hear strains of solemn music floating through an ancient abbey making its old arches vibrate with grand harmonies awakening echoes which for centuries have resounded through the abbey since it was built. The thought of the men of old who had wrought and prayed when the old abbey was building, the even rhythm of the lives of generations which had passed away since then, and even deeper sources of emotion than these, would share in unison with the harmony of the music heard by the natural ear, and stir the profoundest springs of emotion. In like manner, thoughts of infinite space and eternal time, of unlimited power, of immeasurable benevolence, of omnipresent life come over the mind as one studies the chart of many stars."

"The negative from which the charts were printed is no actual work of human hands. The forces which engraved on it their message from the stars have worked from beyond distances which for us are seemingly infinite. They began their work—not at the same moment—but at periods depending upon various distances, long, long ago. They represent giant energies, such as exist in the sun, and in stars far surpassing it in size and splendour. They bear witness of the existence of worlds which for all we know may be circling around those distant stars, other suns like ours. The imprint of these stars on the negatives, from which the charts are made, *is the work of the stars themselves.*

"Tracing back the earlier stages separating the charts as we see it, from the star-fields represented, the impression conveyed is, that it has been taken in the usual way from a zinc plate, in which the stars are severally shown as minute circular depressions differing in size according to the lustre of the several stars. There is nothing so far to suggest the celestial character of the workmanship. Nor when we inquire into the process by which these depressions were made we do not recognize aught which is unusual in the zincographic engraving. The depressions indicate the action of a powerful acid which has eaten into the zinc where those depressions are seen. The acid was poured upon a film which had been rendered capable of resisting the action of the acid everywhere except at points, or rather at small circular spots, corresponding to the impressions cut by the acid into the zinc. Where the acid could get through the film, it did its work in cutting down the surface of the disc, but elsewhere the surface remained untouched. There is nothing extraordinary in this, for it is the usual result when a photograph is in process of making.

"We are so familiar with the chemical processes involved, that their significance scarcely impresses us. Yet when we consider what chemical affinity really signifies, we cannot but wonder that we had been so slow of comprehension. The forsaking by certain atoms of others with which they had been in alliance, in order to associate themselves with atoms to which they are, as it were, nearer in kinship; and the consequent entire change of appearance and nature in the materials so acting and acted upon, are among the every-day marvels of chemistry, but they are none the less marvels in occurring under so many varying conditions, that we regard them as common. Common they may be, but they are among the most impenetrable of nature's mysteries. Then consider the wonderful meaning of that action of light, as one of the agents involved in the process by which the metallic plate has been engraved. The light employed is sunlight.

"The sun's rays pass through a sheet of fine glass on their way to the gelatinous film, and had that sheet been unmarked the whole film would have been affected by the action of the sun's light. But on the glass were hundreds of tiny dark dots of different sizes, through which the sun's light could not penetrate. The glass plate was in fact, a negative, presenting a view of the field of stars photographed as a multitude of black discs, differing in size according to the brightness of the stars severally pictured. It is when we ask ourselves how those discs came there, that we find ourselves faced by one of those appalling mysteries of time and space beyond our comprehension.

"Let us select a chart, and concentrate our attention on one particular dot, one of the largest, yet not exceeding one twentieth of an inch in diameter. The dot represents a certain portion of the photographic film which has undergone a change akin (in a sense), to that produced by the solar light on the gelatinous film. The light-waves which have effected the atoms have come across the fathomless depths which separate us from a glowing sun, whose presence they reveal as existing at that region in the sky. They have been many years on their journey ere they reached the telescopic glass which was to carry their converging rays to a focus, and thence through smaller lenses to the final shore on which atoms those waves were to leave their record. We know this is the image of a star—a sun like our own. Any one among the more conspicuous stars recorded on the chart by means of its light, may be regarded as probably as large as our sun, some may be even larger. The real diameter of our sun is 864,100 miles, the area of its surface is about 12,000 times that of the surface of the earth. Therefore, the light record of a star having the same area as the sun would picture for us half of its surface (that is the half turned in our direction), an area equivalent to 1,000,000,000,000 square miles.

"From every part of that inconceivably enormous surface, myriads of light-waves blended into a single point-like source of light, radiating earthward, combine to help in forming a photographic record of that star. Consider what that means? Millions of square miles glowing with the intense lustre of sunlight, radiating millions of pencils of starlight which finally concentrate on a small dark disc on the surface of the photographic film. This inconceivably minute object denotes the presence of a remote sun, equally if not surpassing our own sun in glory. The great Star Chart reveals the presence of millions of such suns in the depths of immeasurable space." (R.A. Proctor).

CHAPTER VI

THE EVER WIDENING WORLD OF STARS

IF "we consider the heavens" when the stars "shine innumerable" we are overwhelmed at the wonder of the display. Each twinkling light is in reality a glowing sun, many far surpassing the splendour of our own bright Day Star which provides us daily with the light and heat, as well as other electric and chemic influences which are as necessary as light and heat for the welfare of the inhabitants of our planet. For all we know there may be other inhabited worlds like ours circling around those distant stars, the inhabitants as ignorant of our existence probably, as we are of theirs. Yet we cannot imagine for one instant that ours is the only inhabited world throughout the length and breadth of this mighty universe, of which we form such an infinitesimal part.

Until fairly recently our knowledge of the extent of the Universe was limited to the boundary of the Milky Way, and a few outlying nebulae vaguely defined in the mists beyond. Nearly a century earlier Sir William Herschel with his star-gauging method had endeavoured to determine the structure of the stellar system. Sweeping the whole of the northern heavens

GREAT DOUBLE CLUSTER IN PERSEUS, PHOTOGRAPHED BY ROBERTS.

with his eighteen-inch telescope whose light-gathering power extended the range of vision to about eight hundred times its natural limit, he could count some five or six million stars, and succeeded in reaching a fair conception of the flattened or watch-shaped form of the sidereal system. In the constellation Perseus—one of the groups of stars well placed for observation during the month of January, when it occupies a position overhead, and is visible at a convenient hour (between eight and nine o'clock), there is a great cluster of stars which can be seen with the aid of a good opera-glass, or better still with a field-glass which has object glasses 1.6 inches in diameter, and a magnifying power of about 3.6 times. (It is essential that the two barrels of the opera-glass coincide, so that the fields of view blend perfectly together. If they appear to overlap, the fault arises from the barrels of the opera-glass being too far apart, so that their optical centres do not coincide with the centres of the observer's eyes.) Some glasses have an arrangement for adjusting the distances between the barrels to suit the eyes of different persons, and provided an opera-glass is so adjusted, a glance at the Great Cluster in Perseus which can be easily detected by the naked eye as a wisp of luminous cloud, reveals a double cluster. With a telescope of medium power it appears as one of the most marvellous objects in the sky.

The stars Υ and δ Cassiopeia point towards this cluster, which is rather farther from δ than δ from Υ, and a little south of the line produced from these stars. The cluster located, then if seen in a telescope of moderate power is a magnificent object, the stars bright enough to be clearly distinguished from one another, and yet so numerous as to dazzle the eye of the observer. It is the finest cluster for observation with a small telescope, and is one to which the observer is apt to turn again and again, fascinated by the sight of the gleaming points of light seemingly massed together.

The illustrious Herschel penetrated on one occasion into this region with one of his great telescopes until as he tells us, he found himself gazing into unfathomable depths whose light could not have reached him in less than four thousand years. No wonder that he withdrew from the pursuit conceiving that "such abysses must be endless". It is also of interest in connection with our acceptance of the theory of "island universes" to-day, to recall Herschel's remark to Miss Burney in 1786, regarding his discovery of "fifteen hundred whole sidereal systems, some of which might well outvie our Milky Way in grandeur". Since his day, and that of his son Sir John Herschel who so ably supplemented his father's researches in northern skies, by continuing this work in the southern hemisphere, our conception of the universe around us has widened amazingly.

The construction of more and more powerful telescopes has opened out vista after vista in stellar realms, until like the voyage in space, described in Richter's dream, we may well exclaim, "Is there no end, is there indeed no end?" After contemplating photographs taken with the giant reflectors at the Mount Wilson Observatory showing the impress of innumerable stars, we might well think there was indeed no end! According to the latest investigations at the leading observatories, the stars now estimated at some 30,000,000,000 in number are not equally scattered in space, but seem to be less densely massed as their distance from our planet increases. This would seem to indicate a thinning out of their number on the borderland of space. Nevertheless, with the increased optical power of the great 200-inch reflector now in course of construction, there may be revealed other stellar systems as yet unknown and unsuspected.

Until the invention of the telescope 300 years ago, man could only depend upon the unaided eye for his observations of the stars. Since the pupil of the human eye is about a fifth of an inch in diameter, it receives only a minute fraction of the light which comes to us from a star. Thus, his view was limited to stars ranging from the first magnitude, such as Sirius, Arcturus, etc., to stars of the sixth magnitude, the faintest visible to the unaided eye. In the entire heavens, including the northern and southern hemisphere, the number of stars thus seen does not exceed six thousand. It was not until 1610, when Galileo turned his small telescope admitting a hundred times as much light as the human eye, in the direction of the stars, that the number which now became visible was enormously increased. With his telescope Galileo was provided with a means of testing astronomical theories of the day, and proving that those advanced in the preceding 2,000 years by Aristotle, Ptolemy, and others were hopelessly wrong. As soon as he turned his magic glass on the Milky Way, "a whole crowd of legends and fables", Sir James Jeans remarks in his book, *The Universe Around Us*, "as to its nature and structure had vanished into thin air; it proved to be nothing more than a swarm of faint stars scattered like golden dust on the background of the sky. Another glance through the telescope had disclosed the true nature of the moon, the planets, and their accompanying moons, until in reply to the query, "where does man stand in the universe?" came the answer that "man's home in space is only one of a number of small bodies revolving round a huge central sun". Nineteenth century astronomy swung the pendulum still further in the same direction, saying: "There are millions of stars in the sky, each similar to our sun."

Galileo's best telescopes did not magnify more than thirty-two or thirty-three times, yet they widened the view through the portals of the heavens revealing "eternities of twilight beyond". Three hundred years have elapsed since then, and telescopes have meanwhile increased in power and size, culminating in the giant reflectors of to-day. The largest is to be found on the summit of Mount Wilson, one of the highest peaks in the Sierra Madre range. Here in the Astrophysical Observatory with its indispensable Laboratory, in Pasadena, fundamental discoveries are being made, both celestial and terrestrial. A co-operative investigation of the chemical, physical and astronomical aspects of the nature and properties of matter under the widest range of conditions has been in progress during the past few years in conjunction with the California Institute in the valley below. Stars now have their temperatures taken by methods similar to those used with factory furnaces; their diameters have been measured with an interferometer revealing the enormous size, for instance, of the diameter of Mira in the constellation Cetus as being 260,000,000 miles. It is larger than any known star except Antares which has a diameter of 400,000,000 miles almost dwarfing our old friend Betelgeuse in Orion, which is only 215,000,000 miles in diameter. Yet it may well be entitled to the name of giant since, for if it were hollowed out, there would be sufficient room within for the Sun in the centre and the Earth to circle around it at a distance of nearly 93,000,000 miles, and there would still be thousands of miles to spare. The largest stars we know have a diameter several hundred times that of the Sun which is about 864,000 miles so that it is a mere dwarf star in comparison.

Not only can the diameter of the stars be measured, but the amount of the gravitational pull as well, which they exert on each other. It has been found that no star exists whose weight is known or suspected to be less than about a tenth that of the Sun; while few exist which have as much as ten times the Sun's weight, probably about one in a hundred thousand, the remainder having weights intermediate between a tenth and ten times the weight of the Sun.

Another undertaking at Mount Wilson is the measurement of the heat of the stars which can be accomplished by means of a thermocouple attached to the upper end of the tube of the Hooker 100-inch telescope. Thousands of observations have been made with this apparatus by Pettit and Nicholson, which have led to many important conclusions of interest both to the scientist and layman. Heat-measuring devices have been developed by physicists to such an extraordinary standard of sensitiveness that changes of temperature amounting to a millionth of a degree can easily be recorded and measured. With the aid of a large telescope such as the 100-inch, it is possible to detect the heat from a candle flame at a distance of 100 miles, if there were no loss due to absorption by the intervening atmosphere. Instruments for measuring heat are now so sensitive that we can actually detect the heat coming to us from Sirius or Arcturus, or indeed from much less conspicuous stars. All the stars combined (excluding, of course, the sun) furnish us with about as much heat as a candle, 400 yards away.

Now let us consider the enormous light-gathering power of the two giant reflectors at the Mount Wilson Observatory, the one having a mirror sixty inches in diameter and the other (known as the Hooker telescope after the name of its donor), with a diameter of 100 inches. Imagine the pupil of the human eye enlarged to that of the 60-inch. It would cover an area 57,600 times that of the human eye. (This is the value of the actual 60-inch with about one-third of the light cut off by the convex mirror. It is not the area of the 60-inch.) With the 60-inch reflector, stars of the eighteenth magnitude have left their impress on the photographic plate, and with an exposure of four or five hours it has been possible to reach stars of the twentieth magnitude.

Let us imagine the pupil of the eye enlarged still further to a diameter of 100 inches so that it would cover an area 160,000 times that of the human eye, the value of the actual 100-inch, with about one third of the light cut off by the convex mirror. Suppose it endowed with a correspondingly increased magnifying and cumulative photographic power like that of the 100-inch reflector at Mount Wilson. Then it would possess the power of penetrating millions of light-years into space revealing more than a thousand million stars in our own galactic system, and thousands of "island universes" beyond the Milky Way. Not satisfied with this stupendous advance into stellar realms, arrangements are now nearly completed in the construction of a 200-inch telescope capable of penetrating three times as far into space as the 100-inch, thus opening out for investigation an unexplored sphere of about thirty times the volume of that which has been hitherto sounded. Equipped with a powerful auxiliary apparatus Dr. Hale, Honorary Director of the Mount Wilson Observatory, whose tireless and enthusiastic efforts in its behalf had been the mainspring of its success, hoped that the new telescope would be fully ten times as powerful as the 100-inch. It is expected that when it is completed it will penetrate to a distance corresponding to hundreds of millions of light-years into space, or possibly even a thousand million light-years. (Since a light-year is about 63,000 times the earth's distance from the sun, that distance being nearly 93,000,000 miles, one can gain some idea of the meaning of a thousand million light-years). Such a powerful mirror would bring under observation countless millions of stars and nebulae as yet unseen, besides increasing our present knowledge of the nearer objects visible with the aid of existing instruments. Perhaps, however, the most important use of the new instrument and its accessories will be in the more intensive investigation of objects already known, but inadequately studied because of our present limitations. It is estimated that the 200-inch telescope will collect 100,000 times as much light as the human eye, and should show stars down to the twenty-fifth magnitude. This is equivalent to the light of a candle 41,000 miles away, or a sixth of the distance from the earth to the Moon. It is also estimated that this telescope will show nebulae to a distance of 400,000,000 light-years, and that within this range their number will amount to perhaps 50,000,000. In an article written for *Harper's Magazine*, November 1929, Dr. G. E. Hale, with reference to the new 200-inch telescope and its many auxiliaries, described it as: "the key to cosmic laboratories, which afford temperatures, pressures and masses greatly exceeding those attainable on earth."

The 200-inch will doubtless reveal by means of photography new wonders in the star-depths, in connection with dark furrows and rifts shown on some of Barnard's photographs as apparently free of stars. These regions seem as though they had been swept by a celestial spring-cleaning, a process which so far from being finished, may require at least 10,000 million years for completion, as Professor Eddington remarked in a broadcast talk, on "Matter in Interstellar Space", which was printed in *The Listener*, for April 17, 1929, for the benefit of those who missed hearing this fascinating discourse.

This talk gave an insight not only into the far-reaching and definite advances which have been made regarding our knowledge of the marvels of the heavens, but shows how such knowledge makes a wide appeal to the imagination, which should not be overlooked. There is material galore for the narration of thrilling events taking place in celestial realms, from the swift rush of the meteor doomed to oblivion after a brief flash of transitory splendour ere it plunges through the atmospheric net surrounding the Earth; to the career of a star rushing at headlong pace across the star-depths with the possibility of experiencing a collision with an equally impetuous stellar colleague coming from the opposite direction. It is true such collisions are exceedingly rare owing to the vastness of interstellar space, and the extreme isolation of stars from one another. Yet when they crash, a stellar conflagration occurs resulting in the appearance of what is termed a new star (examples of which are given in the first chapter, on "Suns in Flames"). After awhile its splendour ebbs, it grows dim, and gradually sinks to its former obscurity. This rare accident may have happened to our Sun—"an accident to the Sun", to quote from Professor Eddington's Swarthmore Lecture entitled *Science and the Unseen World*, "but to us the cause of our being here. A star journeying through space casually overtook the Sun, not indeed colliding with it, but approaching so close as to raise a great tidal wave. By this disturbance jets of matter spurted out of the Sun; being carried round by their angular momentum they did not fall back again but condensed into small globes—the planets."

Then again, we have the story of a small spiral nebula which has been known for many years, as occupying a position near one of the poles of the Milky Way. Early in 1929, its spectrum was photographed with the 100-inch reflector at Mount Wilson. It is very faint and probably one of the most distant objects within the range of present telescopes. It was found to be moving away from the earth at the apparent velocity of nearly 2,800 miles a second, nearly double the velocity of any cosmical object so far observed. Place it beside one of our swiftest outgoing steamers leaving Liverpool for New York, and let them start a race across the Atlantic. One second, and presto! the race is at an end with the spiral an easy winner. This is no fairy tale but fact deduced by means of light imprinting its message on the photographic plate and decoded by means of the spectroscope later on. (These large shifts in the spectral lines are probably due to some other cause than actual velocity in the line of sight, hence astronomers usually speak of *apparent* velocity). No matter how remote a celestial object may be, as long as the astronomer can secure a specimen of its light, he can tell by means of the light-sifting spectroscope what it is made of, its age, its distance, and whether it is advancing or receding from our planet. He can also determine in the same way, its composition as clearly as if he had had a private interview with it in a chemical laboratory where he could examine it at leisure.

In R. A. Proctor's book, *Mysteries of Time and Space*, written in 1883, he anticipated one of the present methods discovered forty years later by Dr. Adams, Director of the Mount Wilson Observatory, and others, regarding differences in spectral type and intensities whereby absolute magnitudes, and consequently "spectroscopic parallaxes can be determined as in the case of the Cepheid variables". The following is an extract from an essay on this subject in the book above referred to: "These spectra . . . are not all exactly alike. They are distinguished from each other by the greater or less breadth and diffuseness of the lines of hydrogen, and also by various degrees of strength and visibility of the finer lines. It may possibly be that hereafter in such distinctions as these, we may be able to recognize evidence as to the size of a star . . . if so, we shall have a new means of dealing with the architecture of the heavens for, knowing something of the real size of a star in this way, we may infer its distance from its apparent size, and thus place it correctly in position in space, instead of knowing only the direction in which it lies, at some distance unknown."

Such are some of the queries which have been answered by the 100-inch telescope; and other fundamental discoveries of equal importance which have been made, both celestial and terrestrial, has resulted in the provision for the 200-inch telescope; and its accessories will be new and powerful means of extending them and widening still further our knowledge of the heavens.

Meanwhile, we have learned so much that it would seem as though all knowledge were within our grasp, but have we any better reason now than the astronomers had of old to consider the mysteries of the universe as fully revealed and interpreted? It is true that we have learned much regarding the amazing variety and the infinite vitality that pervades every portion of the universe. Yet with powers of vision increased a millionfold by means of the 200-inch telescope, the extent of the world of stars will be considerably widened and marvellous revelations may now be awaiting us, giving a clearer understanding of that mystic passage in Holy Writ: "Lo! these are but a portion of His Ways, they utter but a whisper of His Glory."

CHAPTER VII

ORION AND OTHER MARVELS OF NORTHERN SKIES

"Begirt with many a blazing star,
Stands the great giant Algebar,
Orion, hunter of the beast:
His sword hangs gleaming by his side,
And on his arm the lion's hide
Scatters across the midnight air
The golden radiance of his hair."

Longfellow.

UNDOUBTEDLY, the constellation of Orion, with its magnificent array of bright stars is the greatest marvel of northern skies from the spectacular standpoint. Early in the evening in October the "great giant Algebar", as the Arabians termed him, is ushered in by the Pleiades, hovering "like a swarm of fire-flies" in the north-east, followed by the ruddy Aldebaran, the glowing eye of Taurus. Our first view of Orion is a curved line of faint twinkling stars outlining his left arm and the "lion's hide" until by midnight he is erect and striding towards the western horizon:

"see great Orion rise,
His arms extended stretch o'er half the skies
His stride as large, and with a steady pace
He marches on, and measures a vast space;

NEBULOSITY, SURROUNDING STARS, OF ORION.
EXPOSURE 10 HOURS, DECEMBER 21-22, 1919. TESSA LENS.
WITH PERMISSION FROM DIRECTOR, MOUNT WILSON OBSERVATORY.

On each broad shoulder a bright star display'd,
And three obliquely grace his hanging blade,
Three stars, less bright, but yet as great, he bears,
But farther off removed, their splendours lost;
Thus grac'd, and arm'd, he leads the starry host."

By the middle of May he has disappeared from view, for this is the time of year:

"When the shining daffodil dies, and the Charioteer
And starry Gemini hang like glorious crowns
Over Orion's grave, low down in the west."

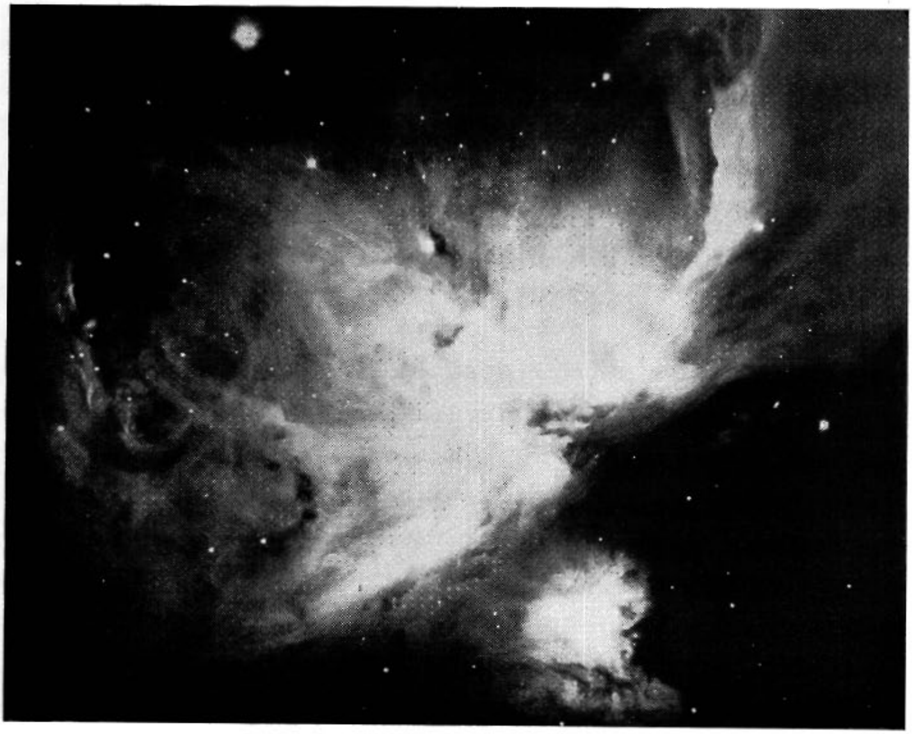
However, in the latter half of July, the very early riser can catch a glimpse of him in the east just before daylight. As M. E. Martin suggests in her fascinating book on *The Friendly Stars*, "it was, no doubt, in this month that the 'rosy-fingered dawn' took him for her lover, as she is reported to have done."

Passing from the poetical view of the constellation to the facts, we find they are interwoven with a romance all their own. A photograph taken of the constellation Orion by Dr. E. P. Hubble of the Mount Wilson Observatory with a lens a little over one inch in diameter and an exposure of ten hours shows the entire region begemmed with stars to the seventeenth magnitude against a background of nebulous mist—translucent clouds, reflecting the light of the stars and so becoming visible. The very appearance of this nebulous haze suggests that they are clouds lit up by the light of the stars, a fact definitely established by

Dr. Slipher of the Lowell Observatory, Arizona, in 1912. He photographed the spectrum of the brighter regions of the cloud and found a resemblance to that of the stars in what might be termed the foreground of the nebula, the spectrum being quite unlike that of any other nebula then known.

The three stars in the Belt of Orion which is about three degrees in length, is sometimes referred to as the "Ell or the Yard". It is divided by the central star into two equal parts like a yard stick serving as a graduated standard for measuring the distances of the stars from each other. Sometimes they are referred to as the "Three Stars", "the Magi" or the "Three Kings", and in Upper Germany they are called the "Three Mowers". The Eskimos believe that the three stars are seal-hunters who missed their way, and for this reason they call them the "Lost Ones". According to the traditions of the Iroquois Indians they are three brothers who left their home, where they had been ill-treated. They are pursued by their parents who have been ceaselessly chasing them but never overtake the truants.

The three stars are named Delta or Mintaka; Epsilon or Alnilam; and Zeta or Alnitak. Delta is a wide double star when seen through a small telescope, the companion being greenish white. Epsilon, the second or middle star in the belt, has a distant blue companion and is partially veiled in nebulous mist. Zeta, the third and lowest star in the belt, is a close



R.A.S. NO. 221 GT. NEB., ORION (CENTRAL PORTION) 16/9/09. RITCHEY.

double, the two stars being of about the same magnitude and colour. An opera glass turned in the direction of Delta, Epsilon and Zeta will enable one to see a number of twinkling stars interspersed between the three brighter stars.

Below the belt there is a row of three stars hanging downward which is popularly referred to as the sword of Orion. A silvery wisp of light clinging around Theta, the central star, is the celebrated Nebula in Orion, one of the most marvellous objects in the heavens. It is visible to the unaided eye, and thus seen covers an area larger than the full moon, but with an opera-glass extensions can be seen reaching out from the centre to a considerable distance beyond. When observed under favourable conditions with a telescope such as the great 40-inch refractor at the Yerkes Observatory, this irregular mass of gas presents the appearance of a ghostly bat flitting through space. The nebula covers a region so vast that light travelling at the rate of eleven million miles a minute would require at least ten years in spanning this vast abyss.

The nebula in Orion is no longer considered to be a crucible within which stars are being fashioned and formed, but a vast cloud of "dust" visible only by means of reflected starlight. The particles may be of all sizes from separate molecules to masses as large as planets but it is easy to show that, ton for ton, the fine dust has far the greater light-stopping power. We have a familiar illustration of such effects in smoke, condensed steam or fogs such as the black fogs occasionally experienced in London. These are opaque although, even in the densest fog, the suspended particles of dust form but a small portion of the mass of the layer of air in which they lie.

Undoubtedly nebulae of this kind are clouds of non-luminous material, a view strongly supported years ago by the late Professor E. E. Barnard and also by Dr. Max Wolf of Heidelberg, and now generally accepted. Dark rifts and openings as he thought them in starry regions, were described by Sir William Herschel as among the most impressive of celestial phenomena. His sister, Caroline, informs us in her diary that she possessed an indelible recollection of hearing her brother, in the centre of his observations one night, exclaim after a long and awful silence: "Hier ist wahrhaftig ein Loch in Himmel!" (Here, truly, is a hole in the sky); and he returned again and again to an examination of this dark region without ever clearing up to his satisfaction the mystery of its origin.

The most marvellous instance of a so-called dark nebula is the famous Horse's Head Nebula near the star Zeta Orionis, the lower stars of the three in the Belt of Orion. This black mass has the outline of a horse's head, hence its name, the horse appearing to emerge above an ocean of star-illumined waves. Its presence was not suspected until this region was photographed by Prof. J. C. Duncan, with the 100-inch reflector, while he was engaged on research work at the Mount Wilson Observatory. The photograph was taken on November 11, 1920, the exposure lasting three hours. One can well imagine the thrill on developing the plate when a dark mass about 5° wide gradually came into view. It had a silver lining, as if from the glow of a star or bright stars behind it, illuminating the border of a mass of cosmic dust—the blackest and densest so far observed. And now we come to the amazing evidence which has been supplied by means of the spectroscope, viz. that a cloud of filmy matter fills interstellar space which, until recently, was considered to be a vast empty void.

In 1904, strong suspicions were aroused concerning the existence of a rarefied cosmic cloud filling in the spaces between the stars. There are vestiges of matter everywhere as a glance at the photograph of the Pleiades reveals, since it is apparent the brighter stars are veiled in mist and wisps of filmy matter reaching from star to star, so that they present the appearance of a rope of pearls. The Network Nebula in Cygnus, the Swan, is another remarkable instance of a delicate tracery of stars spangled over a gauzelike veil of cosmic cloud; yet except for occasional glimpses such as these the presence of all-pervading matter remained undetected in interstellar space. It was not until 1923, that all doubts as to the existence of cosmic matter thinly diffused throughout space were removed by a very far-reaching investigation made by Dr. J. S. Plaskett with the 72-inch reflector at Victoria, B.C.

(the largest telescope in the British Empire and the second largest in the world). This would suggest that the celestial highway through which throng the drifting stars, is paved with cosmic "dust", each particle endowed with vitality, suggesting the fanciful illustration pictured by Emerson, in the following lines:

> "Has Matter motion? Then each atom
> Asserting its perpetual right to dance
> Would make a Universe of dust
>
> . . . .
>
> For the World was built in order
> And the atoms march in time."

Now let us turn our attention to the three leading stars in Orion; namely Betelgeuse (Alpha), and Bellatrix (Gamma), which adorn his right and left shoulder respectively (according to the picture in old-time maps), and the brilliant star Rigel which glitters on his left foot. It is interesting to compare the dazzling bluish-white of Rigel with the deep orange hue of Betelgeuse described by Lassell as "singularly beautiful in colour, a rich topaz" and the yellowish hue of Bellatrix. Then following the direction of the three stars in Orion's Sword upward, glance at the ruddy colour of the star Aldebaran in the constellation Taurus. Following the direction of the three stars downward, we find Sirius in the constellation of

Canis Major flashing low down on the south-eastern horizon with all the colours of the rainbow. Thus:

"the fiery Sirius alters hue
And bickers into red and emerald."

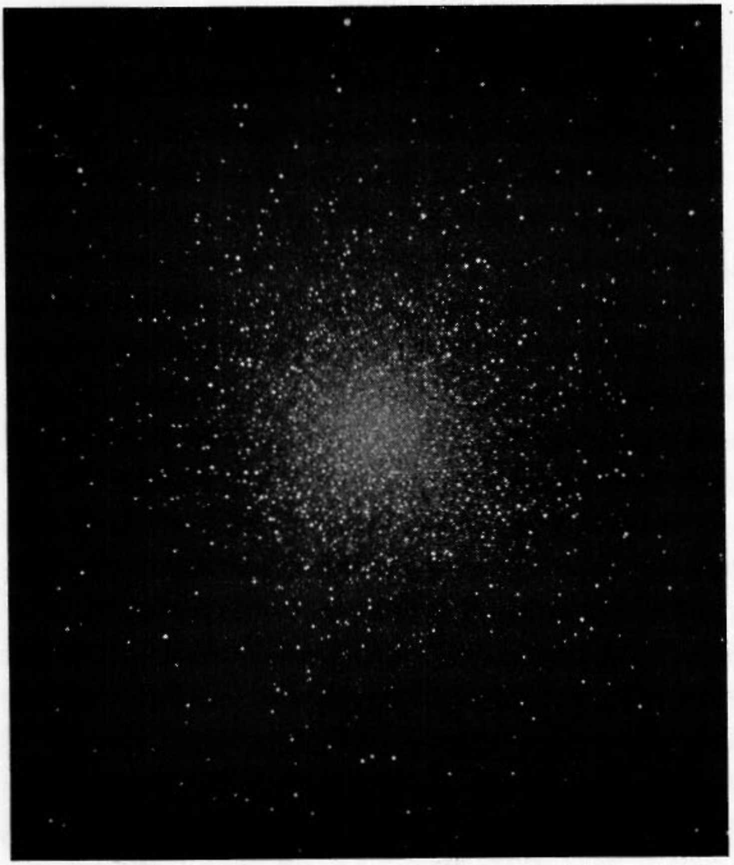
How splendid it must appear in the skies of the Orient where the Arabians have given it the name of Barãkish meaning "Of a Thousand Colours" for, according to them, as many as thirty changes of hue have been observed in the light of this star. Yet it is noticeable that, when Sirius is well above the horizon, the prismatic hues vanish and it assumes a brilliantly white colour, sometimes inclining towards a steely blue. Such observations of the colour of the stars show how they differ from one another in glory, but they also differ in many other ways as shown by recent investigations and new methods which have been devised. "It is possible to take their temperatures", as Sir James Jeans tells us in his fascinating book, *Eos*, "by methods similar to those used with factory furnaces. Astronomy can measure their sizes with a specially designed stellar interferometer and can calculate their weights from the gravitational pull they exert on companion stars, just as we calculate the weight of the earth from the pull it exerts on the moon to keep it in its orbit. And the measurements disclose an immense variety of big and little stars, of bright and faint stars, and of hot and still hotter stars."

Let us consider for a moment the result of the measurement of the angular diameter of the star Betelgeuse first made on December 13, 1920, with an apparatus designed by Professor A. A. Michelson. Hitherto, every star had appeared as a mere point of light and no test had been able to show it otherwise. But on that eventful evening, a 20-foot interferometer constructed at the Mount Wilson Observatory was turned on the star Betelgeuse, and the measurement revealed that it had a disc one twentieth of a second of arc in diameter, or equivalent to the size of a half-penny as seen from a distance of fifty miles! Converting its apparent size into approximate actual size, Betelgeuse is found to be some 215 million miles in diameter. If it were hollowed out there would be room in the centre for the Sun and about ninety-three million miles away the Earth would have room to circle around it in its usual orbit and there would still be millions of miles to spare to the outer boundary of the star. According to the astronomer's multiplication table, a million globes the volume of the earth would make a globe the size of the Sun and ten million globes would make one star as large as Betelgeuse. Thus, it may well be termed a giant star, and the interferometer measurements indicate some kind of pulsation so that it expands to a still greater extent and then slowly contracts. This may be due to the combined influence of gravitation and the elasticity of the gases of which it is composed. The greater the heat the greater the expansive force. Compared with the giant star Betelgeuse, the Sun is but an average dwarf star.

This expansion and contraction indicates that Betelgeuse is a variable star of the irregular type, as it is called. Investigations of the last few years have revealed the fact that most of the bright stars in Orion form a large moving cluster, and that a number of faint variable stars are actually members of this cluster. They were mainly discovered on photographs made at Harvard, though some were found elsewhere, especially on photographs made at Heidelberg by Professor Max Wolf. A glance at the photograph of the constellation Orion embedded in nebulosity suggests that the stars and the diffuse nebula are connected with each other, the stars being in some way responsible for the illumination of the nebula. The variation in brightness doubtless arises from the relative movement of stars and nebulous matter, the moving nebulous material coming at times between the stars and the observer on earth.

As already noted in Chapter II, there is another class of variable stars known as the *Cepheids*, their model being the fourth magnitude star in Cepheus, Delta Cephei. They are as regular as clockwork in their light variations, repeating themselves with such extreme accuracy that they might be compared to the beam of light from a distant lighthouse guiding the mariner at sea. The Cepheids can be seen at far greater distances than ordinary stars so that they provide a very efficient yardstick for measuring the distance of the stars. Jeans' graphic illustration for the method of using Cepheids is as follows: "The method is simply that of a mariner who estimates his distance from land by identifying a lighthouse, looking up its candle power in a book of reference, and noticing its apparent brightness at the spot where he happens to be."

It is possible to predict when Cepheids will brighten up or grow dim and the periods are usually short, from three to seven days. The brightest representative is the Pole Star, heading the list of stars which can be observed with very modest equipment. Valuable observations can be made at odd times by amateurs engaged in other occupations and, as the author of *Aspects of Science* remarks in the chapter entitled, The Amateur Astronomer, "there is probably no pursuit which affords more pleasure, and provides in itself a more liberal education." The Variable Star Section of the British Astronomical Association has long since established its position in the astronomical world, and it is, perhaps, the department in which the activities of the Association are most striking. In its tenth report published in 1929, there is a record of "43,590 observations of 51 stars made by 48 observers": and again, "14,000 observations of Long-period Variables made in 1928" are in themselves remarkable. "This particular department is well suited to amateur energies



THE GLOBULAR CLUSTER MESSIER 13 IN HERCULES
PHOTOGRAPHED WITH THE 72-INCH REFLECTOR, AT DOMINION ASTROPHYSICAL OBSERVATORY, VICTORIA, B.C.

and may justly feel proud of their achievements", to quote from the Address of the President of the British Astronomical Association at the Annual General Meeting held October 30, 1929. There is also a flourishing American Association of Variable Star Observers in the United States, co-operating in valuable work in this direction.

The writer's introduction many years ago to the study might be compared to working from a climax back to an amateur's observation of the variations of the star Algol. One memorable night, owing to the courtesy of the late Professor E. E. Barnard, in the year 1911, when he was a member of the Yerkes Observatory staff, the writer was granted the extremely rare privilege of looking through the lens of the 40-inch refractor, the largest in the world. In the centre of the field of view was the magnificent cluster of stars in Hercules, a display almost impossible to describe adequately in words. A glance at the photograph taken with the 72-inch reflector at the Dominion Observatory, Victoria, B.C., may give some idea of the inspiration of a feeling of awe and wonder while gazing upon this marvellous sight. From a blaze of light near the centre of the cluster densely covered with stars, sprays of stars reach out in all directions like the tendrils of a vine. This cluster, which is barely visible to the naked eye, is globular and represents a great mass of glowing suns, each acting under the control of all the others, without any dominating central sun. It is estimated that the cluster contains the equivalent of a million of our suns, and a great many of them are much more brilliant than our own sun. However, the distance of each sun from its nearest neighbour is thousands of millions of miles, and so great is the distance of the cluster from our tiny isle in space that these brilliant suns seem like faint stars. Even with the largest telescope, the stars at the centre of the cluster cannot be seen separately and distinct from each other. A recent estimate of the distance of the globular cluster in Hercules (Messier 13), which is subject to considerable uncertainty, places it so far away from us that light travelling at the rate of eleven million miles a minute would require nearly forty thousand years to reach us. So that on that eventful night at the Yerkes Observatory, the Hercules cluster was not seen as it was then, but as it appeared *forty thousand years ago!* when its message started earthward.

On learning that this was the writer's first view of a cluster of stars through the lens of 40-inches of the Yerkes refractor, and that many of the stars were variable, attention was called to the star Algol in Perseus, which was due to pass through its phases of bright to dark and back again to its former brilliancy at a convenient hour the next evening for observation. Its period is 2 days, 20 hours, 48 minutes, 45.4 seconds, which is subject to a variation in light due to the interposition of a less luminous star companion rushing forward between our point of view and Algol, that star moving backwards and *vice versa* when the dark star is receding after the eclipse. During most of the time the star remains of the second magnitude. As it grows dim it loses about five-sixths of its light, falling to the fourth magnitude in about four and one-half hours, remaining at the minimum for about twenty minutes, then recovering its former brilliancy in three and a half hours. The *Nautical Almanac* gives the times of maximum and minimum, so that one can make their arrangements accordingly. No telescope is required, but an opera-glass or, better still, a good field-glass is an advantage.

On the night of Wednesday, September 14, 1911, although the moon was shining brightly, a drawback in a way, yet seeing that Algol would pass through its changes and regain its usual brilliancy about one o'clock in the morning; adopting the suggestion made by Professor Barnard, the writer decided to observe the variation of the star's light from the flat roof of the Yerkes Observatory building, overlooking a fine view of Lake Geneva (Williams Bay, Wisconsin) in the distance. Knowing that Algol would be at its faintest at about a quarter to ten, observations began at a quarter to eight. After a careful study of this star for several nights previously it was possible to know how bright it usually is as compared with stars in the neighbourhood. It forms a triangle with Alpha, a second magnitude star in Perseus, and Gamma, which is also a second magnitude star, marking the foot of Andromeda. A few degrees south of Algol, and almost in a direct line with it and Alpha in Perseus, is a small third magnitude star usually referred to as Rho Persei. As it was fainter than Algol, comparison was made between the two stars, while Algol gradually grew dim, with Alpha in Perseus, which still retained its usual standard of brightness.

At a quarter to eight there was a perceptible difference in the appearance of Algol as compared with the brighter star and during the course of the next hour the light of Algol became so dim that gradually it equalled the paler light of Rho, and by a quarter to ten was fainter than that star. For about eight or ten minutes, possibly a little longer as a cloud drifted in front of Algol, about nine-fifty-five, that star remained dim. Then it slowly regained its former brilliancy, and by one o'clock was itself again. All these observations were made with the unaided eye, as Algol is plainly visible throughout its variations, but it added to the interest to look at it once in a while with an opera-glass. Every now and then a meteor flashed into view and was duly recorded, to be entered in the writer's diary next day, although it was actually next day at the time, or 1 a.m. before the observations were over.

It was surprising to note the change which had meanwhile taken place in the appearance of the sky. The constellations which had been visible earlier in the evening sky had gradually drifted westward. Merry, twinkling Capella which was just rising above the tree tops, smiling a welcome, was by now high overhead and from low down in the eastern horizon the winter constellations were climbing upward during the "wee sma' hours". Slowly rose the Pleiades above the low-lying mist hovering over Lake Geneva, and an hour later the fiery gleam of Aldebaran announced the approach of Orion still below the horizon, awaiting the moment when his appearance in the celestial pageant was due. His rising was preceded by the starry stream Eridanus. As the hours passed on the moon approached the western horizon, its light reflected in Lake Geneva conveying the impression that the latter was bestrewn with silvery isles. On the opposite shore lights twinkled here and there, as the stars overhead faded at the approach of dawn:

> "Checkering the eastern clouds with streaks of light."

In his *Star Names and their Meanings*, R. H. Allen gives some interesting facts regarding the origin of the name Algol. The Arabians, noting its remarkable changes in brightness, called it the Demon Star and the Blinking Demon, the name Al Ghul signifying literally a Mischief-maker, the well-known Ghoul of the Arabian Nights. Hipparchus and Pliny made a separate constellation of the Head of Medusa, the star Algol marking the evil eye. The Hebrews knew it as the head of Satan and as Lillith, the nocturnal vampire from the lower world that re-appeared in the demonology of the Middle Ages, as the witch Lilis, one of the characters in Goethe's *Walpurgis Nacht*. It is also supposed to be allied to "Lamia", the Greek and Roman title for the fabled woman, beautiful above but a serpent below, reproduced by Keats in his "Lamia".

Passing from fiction to fact, it is interesting to note how the attention of John Goodricke was drawn to the star Algol, in 1783. After several observations, he came to the conclusion that the varying light of this star was caused by a large body revolving around Algol at regular stated periods, thus causing its eclipse. It was not until a century later that this theory was definitely accepted as the true explanation, from proof obtained by means of the spectroscopic work of Vogel in 1889. Like the Cepheids, the Algol variables form a class of their own. At present two hundred stars of this eclipsing type are known and their light variations are so conspicuous that they can be easily seen with the unaided eye. The light of Algol is about two hundred times that of the sun, whilst the darker eclipsing body has a surface temperature intensity ten times that of the sun, so that it can no longer be referred to as a dark and therefore invisible star.

New stars that occasionally blaze up with startling rapidity and then gradually decline again in brilliancy would seem to occupy an intermediate position in character between stars of the Algol type, the Cepheids and the irregular variables found mainly in clusters and the cosmic cloud in which the stars of Orion are enwrapped. They may be due to the results of a star plunging through a nebulous region, causing it to gain a sudden access of splendour, a case being on record of a star attaining to the first magnitude in a rapid rise from the fifteenth magnitude within the brief period of twenty-four hours. This would correspond to an increase of a million times light emission. Occasionally a new star, after declining in brilliancy, suddenly blazes up again, but generally "a single flashing up", according to Dr. Shapley, "and irregular fading away to the original magnitude, followed eventually by slight irregular variability throughout several years, constitute their photometric history". Moreover, the new stars are confined to the Milky Way and regions amid vast clouds of the all-pervading lucid matter in space. While it is true these star clouds are no longer as mysterious as they were to the astronomers of old, yet we have no better reason than they had for considering the mysteries of the universe as fully revealed to us and interpreted. After penetrating by means of the telescope combined with the photographic film to depths inconceivable, we find ourselves still surrounded by mysteries unsolved. The infinite star depths must ever remain unfathomable owing to the feebleness of man's conceptions in the presence of the infinite wonders of creation. Truly, the German poet Richter has expressed this thought in the wonderful dream poem so ably translated by our own prose poet, De Quincey:

"God called up from dreams a man into the vestibule of heaven, saying, 'Come thou thither, and see the glory of My house'. And to the angels which stood around His throne He said, 'Take him, strip from him his robes of flesh; cleanse his vision, and put a new breath into his nostrils, only touch not with any change his human heart, the heart that weeps and trembles'. It was done; and with a mighty angel for his guide the man stood ready for his infinite voyage; and from the terraces of heaven, without sound or farewell, at once they wheeled away into endless space. Sometimes with the solemn flight of angel wings they passed through Zaharas of darkness, through wildernesses of death, that divided the worlds of life; sometimes they swept over frontiers that were quickening under prophetic motions from God. Then from a distance which is counted only in heaven, light dawned for a time through a shapeless film; by unutterable pace the light swept to them, they by unutterable pace to the light. In a moment the rushing of planets was upon them; in a moment the blazing of suns was around them.

"Then came eternities of twilight, that revealed but were not revealed. On the right hand and on the left towered mighty constellations, that by self-repetitions and answers from afar, that by counter-positions, built up triumphal gates, whose architraves, whose archways, horizontal, upright, rested, rose at altitude, by spans that seemed ghostly from infinitude. Without measure were the architraves, past number were the archways, beyond memory the gates. Within were stairs that scaled the eternities around; above was below and below was above, to the man stripped of gravitating body; depth was swallowed up in height insurmountable, height was swallowed up in depth unfathomable. Suddenly, as thus they rode from infinite to infinite, suddenly, as thus they tilted over abysmal worlds, a mighty cry arose that systems more mysterious, that worlds more billowy, other heights and other depths, were coming, were nearing, were at hand.

"Then the man sighed and stopped, shuddered and wept. His overladen heart uttered itself in tears, and he said, 'Angel, I will go no farther; for the spirit of man acheth with this infinity. Insufferable is the glory of God. Let me lie down in the grave, and hide me from the persecution of the Infinite, for end I see there is none'. And from all the listening stars that shone around issued a choral voice, 'The man speaketh truly; end there is none that ever yet we heard of!' 'End is there none?' the angel solemnly demanded; 'is there indeed no end? And is this the sorrow that fills you?' But no voice answered, that he might answer himself.

Then the angel threw up his glorious hands to the heaven of heavens, saying, 'End is there none to the universe of God. Lo! also, there is no beginning'."

THE PLEIADES. PHOTOGRAPHED BY PROFESSOR E. E. BARNARD, WITH THE 10-IN. BRUCE TELESCOPE, BY PERMISSION FROM THE DIRECTOR, YERKES OBSERVATORY.

CHAPTER VIII

"THE SWEET INFLUENCE OF THE PLEIADES"

"Seven the names they bear:
Alcyone, Merope, Celaeno, Electra,
Sterope, Taygeta, and stately Maia.
Though small their size and pale their light,
wide is their fame,
Both when they rise at dawn and when
at eve; such Zeus' will
Who bade them mark the entrances of
summer and winter,
And the seasons."

The Skies. *Aratus.*

AT Athens, in the time of Meton, about 430 B.C., the apparent time when the Pleiades at rising were so far above the sun as to be visible on the horizon, occurred about the middle of May, marking the beginning of summer, while their apparent rise in the evening skies about the end of September marked the season of ploughing and the beginning of winter. As, in consequence of the earth's annual movement, the stars every night gain four minutes on the sun, the star that on a given day rises about the same time as the sun will only do so on one day in the year. To say, then, that a given star rises or sets at sunrise or sunset is a mode of defining a particular period of the year, and was employed in the infancy of astronomy.

However, it must be taken into account that this coincidence of the rising and setting of the star with the sun varies, in the first place with the latitude of the spectator. For this reason it often happened that a calendar invented by astronomers for the latitude of Alexandria was used at Athens or Rome, and the results were naturally misleading. Moreover, even in the same latitude, the risings and settings of the stars gradually change in the course of ages by means of the slipping back or procession of the equinoxes, so that the times no longer agree. Thus, the period which they defined in the latitude of Athens in the time of Hesiod, was very different from the period which they defined in the time of Aratus. Therefore, it becomes necessary to discontinue this mode of defining epochs, grand and poetical as it is, to escape from dire confusion which ceased on the invention of almanacs, based on more exact knowledge of the length of the year.

Temples were erected in honour of the Pleiades in Greece, and this cluster of stars was watched as a herald of the equinoctial sun. Therefore, the earliest temples in Greece were oriented in connection with the vernal equinox. For instance, the Archaic temple of Minerva at Athens was oriented 1530 B.C., to the rising sun, as heralded by the Pleiades. Closely following their disappearance at the approach of dawn, the first ray of sunlight illumined the entrance to the temple. Maybe a statue within was rendered glorious by the coloured sunlight falling upon it, so that it appeared aflame with the roseate hues of dawn, as seen against the gloom of the unillumined background beyond. At Sunium in Greece, there was another temple of Minerva, dated 845 B.C., oriented axially to the setting sun on February 21, the feast of the Lesser Mysteries.

Thus, we see that the ancient temples of the world were all built for a special purpose, and a star was chosen in or near the ecliptic so that its light would enter the temple sooner than that of the rising sun, giving due warning of the approach of dawn. These stars were chosen for the determination either of the equinoxes or the solstices, and the early observers would find them of use as related either to their agricultural labours, festivals, or some definite period of the year. Now in the earliest times, the constant apparent movement of the stars would have been obvious as contrasted with the inconstant movements of the sun, and there can be little doubt that the first fixing of any point in the year was by the rising or setting of some star at sunrise, or possibly sunset.

In the case of many star temples, the orientation of a temple may have been laid down in accordance with ritual long before the building was actually erected; or a new temple may have been built on an old foundation at a later date, with the result that the orientation now agrees no longer with that of the architectural remains of former times. This may be seen in several cases where the old foundations of sun or star temples have been excavated. We have an instance of the latter in the archaic temple of Minerva on the Acropolis of Athens, and the temple of Jupiter of Olympus on a lower site.

When the constellations were first designed, the Pleiades rose with the sun at the beginning of April. They heralded the return of spring, and the patriarch Job referred to them in the Biblical passage: "Canst thou bind the sweet influences of the Pleiades or loose the bands of Orion?" Aratus wrote of them:

> "Men mark their rising with the solar rays,
> The harbinger of Summer's brighter days."

To the Greeks in Hesiod's age their "heliacal rising", that is when they first became visible before sunrise, announced each May the opening of the season for navigation; and thus their name, derived from the word *plein*, to sail, became interpreted as meaning the "sailing stars", though the Greek *pleiones* meaning "many", or *pleios* full, would seem to be a better interpretation. It was represented in Latin by "Vergilae" (from *ver*, spring), a designation possibly commemorative of the ancient coincidence of the stars with the vernal equinox. They were chosen doubtless, about the same epoch—probably 1730 B.C.—(when precession carried the equinoctial point into Aries) by the Hindus to mark the first lunar mansion, called "Krittika", general of the celestial armies, and long occupied the same post in Chaldea, under the title of "Thurayya", the crowd. Thus, Tennyson's lines:

> "Many a night I saw the Pleiads rising in the
> mellow shade,
> Glitter like a swarm of fireflies tangled in
> a silver braid."

aptly symbolize the ancient traditions regarding the swarm of celestial "fireflies". Bayard Taylor, however, in his *Hymn to Taurus* refers to the Pleiades represented in olden maps, as clustering on the shoulder of the Bull:

> "Cluster like golden bees upon my mane."

The Greek farmers in days of old reaped their corn when the Pleiades rose at sunrise in May and ploughed their fields when this cluster of stars set at sunrise in November. The interval between the two dates is six months. Both the Greeks and the Romans dated the beginning of summer from the heliacal rising of the Pleiades, and the beginning of winter from their heliacal setting. Pliny, who dated the rising of the Pleiades on the 10th of May, and their setting on the 11th of November, regarded the autumnal setting of the Pleiades as the proper season for sowing the corn particularly wheat and barley. He tells us that in

Greece and Asia all the crops were sown at the setting of that cluster. Moreover, the civilized Greeks supposed that the Autumnal setting of the Pleiades was the cause of the rains which followed.

The reason for the association between the rising and setting of the Pleiades with the rainy season is obvious, since men must very soon have learned that the best time of the year for planting and sowing is when the earth is moistened by rain, and it follows that the newly-planted seeds or roots will be quickened by abundant rains. Moreover, it is noticeable that fruits grow more plentifully after a heavy fall of rain than when the weather is dry.

Crossing over to the southern hemisphere, we find that the Pleiades were well known to the Indians in Brazil and that this cluster was worshipped by some tribes at Matto Grosso. In the valley of the Amazon, they say that while these stars are still low in the sky, the birds and fowls sleep in the lower branches of trees, moving higher up when the Pleiades are seen to mount the sky. The cluster is supposed to bring with it cold and rain, and there is a quaint legend to the effect that when it is no longer visible in the sky, serpents lose their venom. The reeds used in making arrows must be cut before the Pleiades reappear or else they will be worm-eaten. Therefore, as the stars disappear in May and reappear in June, the reeds were a matter of great importance, as connected with Indian warfare.

The magnificent sun-temple at Cuzco, in Peru, now in ruins, had a cloister with halls adjoining it, one of which was dedicated to the Pleiades. The Incas venerated these stars, because of their curious position and the symmetry of their shape.

> "Each page of clustered stars illumined by a sun."

They were supposed to picture with unerring pen:

> "The destinies of gods, as well as those of men."

In this cluster of stars the Peruvians saw a resemblance to their cherished stores of corn. It made their maize grow, and was worshipped accordingly, in order that the maize might thrive and not dry up. The beginning of the year dated from the time when these stars were visible in the east after sunset, according to the belief of the Indians of Orinoco.

One of the most impressive ceremonies of the Aztecs of Peru coincided with the exact moment the Pleiades reached their highest point overhead at midnight. The ceremony occurred at the end of a great period of fifty-two years when it was expected that the stars would cease to revolve, and the earth itself would come to an end. Hence, when the critical moment drew near, it was the duty of the priests to watch from the top of a high mountain for the precise instant when the Pleiades were seen to cross the meridian. If nothing happened the people were overwhelmed with joy for it meant that the world would endure for another cycle of fifty-two years. Just as in the Druidical rite on the eve of November 1st, every fire in the country is extinguished in anticipation of the great event, but after the Pleiades had reached their culmination a new fire was started and runners carried glowing embers at full speed to all parts of the kingdom.

For the Druids, the 1st of November was a night full of mystery, on which the reconstruction of the world was celebrated annually, and not after a period of fifty-two years as in Peru. On the night of November 1, the Druids extinguished the sacred fires which were kept continually burning in the temples, and at a certain signal all the fires in the island were put out one by one, so that a primitive night reigned throughout the land. Then the phantoms of all those who had died during the year passed along to the west, and were carried away by boats to the judgment seat of the gods of the dead. One wonders if this custom has been borrowed from Peru, or *vice versa.*

It is obvious that the Pleiades occupied an important part in the calendar of bygone days, both in the northern and southern hemisphere, and for some reason unknown apparently attracted the attention of the untutored savage more than any other group of stars in the heavens. It was for him a celestial clock in the sky which enabled him to time the various operations of the agricultural year, by noting the exact period of its rising or setting with the sun. Even among the Australian aborigines, we are told that they too, according to their custom, worship the hosts of heaven, and believe particular constellations rule natural causes. For such they have names, and sing and dance to gain the favour of the Pleiades (Mormodellick), the constellation worshipped as the giver of rain; but if it should be deferred, instead of blessings, curses are apt to be bestowed upon its stars.

Some of the aborigines of New South Wales denied that the sun is the source of heat, because he also shines in the winter when the weather is cold. They attributed the real cause of warm weather to the Pleiades, because as the heat of summer increases, that constellation rises higher and higher in the sky, reaching its greatest elevation at midsummer, and gradually sinking again in autumn as the days grow cooler, till in winter it is barely visible or lost to view altogether. (It should be taken into account that their winter corresponds to our summer, which explains why it is that the Pleiades which form so fascinating a part of the winter skies in the northern hemisphere are absent during this season in the southern hemisphere.)

Mr. James Dawson, who was well acquainted with the natives of Victoria in the early days of the colony, tells us in his book on *Australian Aborigines*, that an old chief of the Spring Creek tribe taught the young people the names of the favourite planets and constellations, as indications of the seasons. For example, when Canopus is a very little above the horizon in the east at daybreak, the season for emu eggs has come; when the Pleiades are visible in the east an hour before sunrise, the time for visiting friends and neighbouring tribes is at hand.

In New Zealand the Maori relied on the heliacal rising of the Pleiades as marking the New Year, and like many other nations the rising stars were used for marking seasons, the time for sowing and reaping, and other agricultural occupations. The Pleiades held the highest rank among the Maori people, since this cluster of stars not only ushered in the New Year, but marked its progress as well, and its appearance was a sign of plenitude of food supplies. It was also used as a favourite guiding star at sea, thus supplementing the lack of a compass. Not only did the Pleiades prove of importance with regard to agricultural occupations and navigation, but they were also objects of veneration among the Maori, who greeted them at the New Year with singing and dancing, and their heliacal rising was marked by a joyous festival. Offerings of young shoots of the sweet potato were made while a certain ritual was intoned, consisting mainly of a request for a bountiful supply of such food in the future.

The Society Islanders in the South Pacific divided the year into two seasons, which they determined by observation of the Pleiades. The first they called

Matarii i mia, Pleiades above. It commenced when, in the evening, these stars appeared on or near the horizon; and the half-year, during which, immediately after sunset, they were seen above the horizon, when they were called *Matarii i nia*. The other season commenced, when, at sunset, the stars were invisible, and continued until at that hour they appeared again above the horizon. This season was called *Matarii i raro*, Pleiades below.

Among the South Sea Islanders idolatrous worship was paid to the Pleiades, and this continued in Danger Island and at the Penrhyns until the introduction of Christianity in 1857. Heretofore, the people in many of these islands indulged in extravagant manifestations of joy at the rising of this cluster of stars out of the ocean. This festival lasted on Humphrey's Island for over a month, and expression was given by the natives to their joy, by singing, dancing, and blowing shell trumpets. Throughout Polynesia the rising of the Pleiades (variously known as Matariki, Mataliki, etc.) seems to have marked the beginning of the year. The inhabitants of the Solomon Islands were guided by the Pleiades in selecting the times for planting and taking up the yams. The natives of the Torres Straights Islands observed the appearance of the Pleiades on the horizon at sunset, and when they see this cluster of stars they say that the new yam time has come, from which we may conjecture that this was the time for planting yams.

Two agricultural tribes of New Guinea determined the season of their labour in the fields by observation of the Pleiades, and the time for such labours is when the Pleiades are visible above the horizon at night. In some districts of Northern Celebes, the rice-fields are prepared for cultivation when the Pleiades are seen at a certain height above the horizon, among the Dyaks of Sarawak, we read that the Pleiades themselves tell them when to farm; and according to the position of this cluster in the heavens, morning and evening do they cut down the forest, burn, plant and reap. The Malays are obliged to follow their example, or their lunar year would soon render their farming operations unprofitable. When the season for clearing land in the forest approaches, a wise man is appointed to go out before dawn and watch the Pleiades. As soon as the constellation is seen to rise above the horizon while it is yet dark, they know that the time has come to begin work. But the Dyaks do not consider that it is desirable to burn the fallen timber or sow the rice until the Pleiades are at the zenith.

In some districts of Sumatra much confusion in regard to the period of sowing is said to have arisen from a very extraordinary cause. Anciently, the natives say, it was regulated by the stars, and particularly by the appearance (heliacal rising) of the Pleiades; but after the introduction of the Mahomedan religion they were induced to follow the returns of the great annual fast, and forgot their old rules. The consequence of this was obvious; for the lunar year of the hejirah being eleven days short of the sidereal or solar year, the order of the seasons was soon inverted; and it is only astonishing that its misleading guidance with regard to agricultural pursuits should not have been immediately discovered. The bataks of central Sumatra date the various operations of the agricultural year by means of the positions of Orion and the Pleiades. When the Pleiades rise before the sun at the beginning of July, the Achinese of Northern Sumatra know that the time has come to sow the rice. The natives of Nias, an island to the south of Sumatra pay little attention to the stars, but they had names for the Morning Star and the Pleiades. When this cluster appears in the sky, the people assemble to till the fields, thinking it useless to do so earlier.

The Kaffirs of South Africa date their new year from the rising of the Pleiades just before sunrise, and this determines the time for sowing grain. They calculate only twelve lunar months for the year, for which they have descriptive names, and this results in frequent confusion and difference of opinion as to which month it really is. The confusion is always rectified by the appearance of the Pleiades just before sunrise, and a fresh start is made and things go on smoothly, until once more the months get out of place and reference has to be made again to the stars. According to an authority on the Bantu tribes in South Africa, the rising of the Pleiades shortly after sunset was regarded as indicating the planting season. The Bechuanas are directed by the position of certain stars in the heavens, that the time has arrived in the revolving year, when particular roots can be dug up for use, or when they may commence their labours in the fields. This is their turning, or what we should call the spring of the year. The Pleiades they call selemela which may be translated "cultivator", or the precursor of agriculture, from lemela, the relative verb to cultivate *for*, and *se*, a prenominal prefix, distinguishing them as the actors. Thus, when this constellation assumes a certain position in the heavens, it is the signal to commence cultivating their fields and gardens.

An early Moravian missionary who settled among the Hottentots, reports that these people date the seasons of the year by the rising and setting of the Pleiades. At the return of this cluster the natives celebrate the anniversary as follows: As soon as these stars appear above the eastern horizon, mothers will lift their little ones on their arms, and running up to elevated spots, will show them to those friendly stars, and teach them to stretch their little hands towards them. The people of a kraal will assemble to dance and sing according to the custom of their ancestors. The chorus always sings: "O Tiqua, our Father above our heads, give rain to us, that the fruits (bulbs, etc.) may ripen, and that we may have plenty of food, send us a good year."

With some tribes of British Central Africa the rising of the Pleiades early in the evening is the signal for the hoeing to begin. In Masailand in East Africa, the Pleiades are above the horizon from September till about the 17th of May, and as the natives express it they know whether it will rain or not according to the appearance or non-appearance of the six stars called the Pleiades which, "follow after one another like cattle". When the month which the Masai call "Of the Pleiades" arrives, and the Pleiades are no longer visible, they know that the rains are over, for the Pleiades set in that month and are not seen again until the season of showers has come to an end, when they re-appear. The Nandi of British East Africa have a special name (*Koremerik*), for the Pleiades, and it is by the appearance or non-appearance of these stars that the Nandi know whether they may expect a good or a bad harvest. The Kikuyu of the same region say that the Pleiades is the mark in the heavens to show the people when to plant their crops. They plant when this constellation is seen in a certain part of the sky early in the night.

The Abipones of Paraguay, who neither sowed nor reaped, nevertheless regarded the Pleiades as their ancestor. As this cluster of stars is invisible in the sky of South America for several months every year, the Abipones believed that their ancestor was then dying. On reappearance of the Pleiades in the month of May they greeted the stars with shouts of joy, and the glad music of flutes and horns. The following day they collected wild honey, from which they brewed a favourite beverage, and at sunset they feasted and made merry all night by the light of torches. A sorceress, who presided over the revels, shook a rattle and danced.

The Lengua Indians of Paraguay connect the rising of the Pleiades with the beginning of spring, and the Guaranis of this same country knew the time when it was best to sow seed by observing when the Pleiades were visible. They revered this cluster, and dated the beginning of their year from the time of its rising in the month of May. The Indians of north-western Brazil, an agricultural people who subsist mainly by the cultivation of manioc determine the time for their various field labours by the position of certain constellations, especially the Pleiades, knowing that when that constellation has sunk beneath the horizon the regular heavy rains set in.

In European Calendars, the last day of October and the first and second days of November, when the Pleiades culminate at midnight, are designated as the festivals of All Hallowe'en. Originally, they commemorated the festival of All Saints and All Souls, as formerly observed at or near the beginning of November by the Peruvians, the Hindoos, the Pacific Islanders, the people of the Tonga Islands, the Australians, the ancient Persians, the ancient Egyptians, and the northern nations of Europe. The commemoration had three days duration among the Japanese, the

Hindoos, the Australians, the ancient Romans, and the ancient Egyptians.

Among the Highlanders, Hallowe'en is known by a name meaning the consolation of the spirits of the dead, and is with them and almost every race among whom the festival is observed, connected with harvest; or south of the Equator, with a first fruits celebration, somewhat like our Harvest Festival. So convinced are the Irish peasantry that the spirits of the dead are roaming about at Hallowe'en more than at any other season of the year, that they remain at home secure from ill-omened meetings on that night. The Hallowe'en torches of the Irish, the bonfires of the Scotch, the Coel Coeth fires of the Welsh, and the Tindle fires of Cornwall lighted at Hallowe'en, are all memorials of an ancient custom connected with the festival of the Dead.

Formerly, the month of November was called Mordad, the angel of Death, by the Persians, and in Ceylon a combined festival of agriculture and of the dead takes place at the beginning of November. Among the Egyptians the commemoration of the dead was connected with a deluge, which was typified by the priest placing the image of Osiris in a sacred coffer or ark, and launching it into the sea till it was borne out of sight. Numerous Egyptian calendars have been found which are all regulated by the culmination of the Pleiades at midnight. On this day, the solemn festival of Isis was inaugurated, which lasted for three days, and was celebrated in honour of the dead and of Osiris, the Lord of Tombs.

Everything in the year connected with Egyptian festivals, was linked with the lunar and sidereal mansions in the sky by the priests who concealed the facts from the people with most watchful care, veiling the true meaning beneath the form of myths and symbols. Even when the mystic secrets of the stars were revealed to those who were to be initiated into the priesthood it was safeguarded by the sanctity of oaths, and the terrors of superstition. Stories clothed in strange language were invented to explain the simple truths of astronomy, their true meaning being understood only by a favoured few. The memory of those secrets so jealously guarded must have faded gradually, but the myths in which their meaning was so skilfully concealed remained, lingering long after the key that could unlock their mystic treasures had been lost and forgotten.

That a primitive calendar must have formerly existed among all ancient nations, will be apparent by comparing the data which has been obtained, and the unquestionable fact of the actual existence of the year of the Pleiades among many existing nations. In Haliburton's *New Materials for the History of Man* as derived from a comparison of the calendars and festivals of nations, he sums up the result of his extensive researches in a most convincing manner leaving one to infer that the myth of Osiris and Proserpine originated in a mythical account of the death and revival of the stars of Taurus. "Those who were initiated at the ancient mysteries really learned something as to the astronomical basis of their religion, we have every reason to infer; but it is plain that Herodotus and many other ancient authors were either ignorant or prudently silent as to the secret sources of classical mythology." Chaermon and others, however, according to Eusebius, not only believed, but also declared that the Egyptians held that the stars were the only deities, and that all festivals had been instituted in their honour. Likewise, that:

"The heroes whose names appear in the almanacs, are nothing else than charms for the cures of evils, and *observations of the risings and settings of stars*." They were also of the opinion that legends about Osiris and Isis, and all other mythological fables had reference either to the stars, their appearances and occultations, and the periods of their risings, or to the increase and decrease of the moon, or to the cycles of the Sun, or to the diurnal and noctidiurnal hemispheres.

The Egyptian view of the astronomical connection between the observance of festivals with the year of the Pleiades supplies a missing clue to the problem which had hitherto evaded all enquiry. According to Haliburton: "If the deities of the Egyptians were merely representative of the stars, and of the year, then their symbols must also have had a hidden meaning connected with the year or its seasons." At least, so one infers from *The Mystical Hymns of Orpheus*, as translated by T. Taylor.

"Terrestrial Jove, thy sacred ear incline,
And pleas'd, accept the sacred rites divine,
Earth's keys to thee, illustrious king, belong,
Its secret gates unlocking, deep and strong;
'Tis thine abundant annual fruit to bear,
For needy mortals are thy constant care."

CHAPTER IX

ORIGIN OF THE CONSTELLATIONS

"Some nameless stars,
Whose similitudes some mortal noting in days long agone
Assigned judiciously a common name
To aggregated multitudes. It had passed his skill,
Nor aided recognition to have given particular
names to every luminary,
Thronged as they are, and each to other like
In size and hue, and in their circling orbs.
So he devised to group them in such wise
That standing in succession side by side
They simulate living forms. Easily thus he named
Heaven's host; and now no star rises unrecognised,
Of those that are arranged in definite forms
Conspicuous."

The Skies and Weather Forecasts. *Aratus.*

LEARNED antiquarians have searched every page of heathen mythology, and ransacked legends, poetry and fable, in a vain endeavour to discover who were the inventors of the constellations, but without avail. Even Aratus,* the poet-astronomer who lived in Greece about 270 B.C. and was therefore a contemporary of Euclid and Theocritus, failed to solve the

*According to Mr. Maunder (See *Astronomy Without a Telescope*, p. 4) the poem of Aratus contains clear internal proof that it was not based upon actual observations made in Greece by either Aratus or Eudoxus, but upon a description of the heavens made quite 1,500 years earlier.

problem, as shown in the above quotation from his poem concerning the starry heavens. In the opinion of the Greeks, his poem came next in honour to the poems of Homer, and it is assumed that the constellations referred to therein were known to the Hebrews of old, which may be inferred from the paraphrase of the opening verses as quoted by St. Paul in his sermon on Mars Hill. Aratus, like St. Paul himself, was a native of Cilicia, and had been educated at Athens. His arrangement of the constellations corresponds to those of Ptolemy's catalogue, with a few minor differences, the latter being the earliest complete catalogue of the stars thus arranged.

Ptolemy, the astronomer of Alexandria, made his catalogue in A.D. 137. It contains a list of forty-eight constellations, many of which are of pre-historic antiquity, such as those of the zodiac and about the northern pole. In ancient times the stars were grouped by "constellations" or "asterisms", partly as a matter of convenient reference and partly as superstition. To these groups were given fanciful names, mostly of heroes or animals—such as Orion the Hunter or Taurus the Bull—conspicuous in the mythological records of antiquity. In some cases one can trace in the arrangement of the stars a vague resemblance to the object after which the constellation is named, but generally no reason can be assigned why the constellation should be so named or bounded. Other catalogues have been formed, including stars never seen by Ptolemy on account of their nearness to the southern pole, a great number of which are connected in some way or other with the Argonautic expedition and the Southern Cross.

From the writings of Homer and Hesiod we infer that the constellations were known more than a hundred years before, since Hesiod in the second book of his *Works and Days*, refers to several:

> "Orion and the dog, each other nigh,
> Together mounted to the midnight sky,
> When in the rosy morn Arcturus shines
> Then pluck the clusters from the parent vines.
>
> . . . .
>
> Next in the round do not to plough forget
> When the Seven Virgins and Orion set."

The same constellations are also referred to by Homer in the fifth book of the Odyssey, as follows:

> "And now, rejoicing in the prosperous gales,
> With beating heart Ulysses spreads his sails:
> Placed at the helm he sate, and marked the skies
> Nor closed in sleep his ever-watchful eyes
> Then view'd the Pleiades and the Northern Team,
> And great Orion's more refulgent beam,
> To which around the axle of the sky
> The Bear, revolving, points his golden eye."

Several of the ancient constellations were familiar to the Greeks, as evidenced by representations of the signs of the zodiac, such as the outline of a ram or a lion found on Greek coins. Yet earlier, square pillars known as "boundary stones" from Babylonia, covered with inscriptions, seem to prove, judging by the date of the earliest boundary stone discovered, that the Babylonians knew of our constellations as far back as the twelfth century B.C., that is to say, whilst Israel was under the jurisdiction of the *Judges*. The origin of some of the constellations cannot be traced, but their position can be recognized by eliminating from a modern celestial globe all those of recent origin, leaving only the groups of stars known by Aratus and Ptolemy. This will reveal the fact, that a large space in the south remains unoccupied, for the simple reason that as those stars never rose above the horizon they were not seen by the ancient astronomers. We have a practical illustration of this, when journeying from the northern to the southern hemisphere. As we go further south the old familiar groups of stars, such as the Great Bear and Cassiopeia, gradually drop out of sight as it were, while new groups, such as Argo, the Southern Cross, etc., come into view.

In R. A. Proctor's book, *Myths and Marvels of Astronomy*, he remarks: "I have before me as I write, a picture of the southern heavens, drawn by myself, in which this vacant space—eccentric in position but circular in shape—is shown. The centre lies close by the Lesser Magellanic Cloud—between the stars Kappa Toucani and Eta Hydri of our modern maps, but much nearer to the last named. Near this spot, then, we may be sure, lay the Southern pole of the star-sphere when the old constellations, or at least the southern ones, were invented." According to E. W. Maunder, in his account of the origin of the constellations, given in *Astronomy without a Telescope*, he considers that the radius of the void space, the centre being the south celestial pole of that date gives approximately the latitude of the place. This was roughly speaking, N. Lat. 38°, and the date not very far short of 3,000 B.C.; say about 2,800 B.C. According to Mr. Maunder "this date brings out a number of interesting relations. The constellation figures were all arranged so as to be either upright when on the meridian, or else recumbent; they were not inclined to it. Then the twelve signs of the zodiac were symmetrically divided by the colures. The spring equinox was in the middle of the Bull; the autumnal in the middle of the Scorpion; the summer solstice in the middle of the Lion; and the winter in the middle of the Water Carrier."*

About this period then, before the Christian era the southern constellations according to the more recent theory advanced by Mr. Maunder, occupied the position described, the invisible southern Pole lying at the centre of the space free from constellations. This period, or a definite period within it, must be that to which must be referred the beginning of exact astronomy. Moreover, in the year 2,170 B.C. or there-

*Comparison between R. A. Proctor's theories advanced in 1888 and those of Mr. Maunder in 1902 is of special interest in bringing this matter up to date. With a *Planetarium* the facts could be proved definitely within a few minutes.

abouts, the Pleiades rose to their highest above the horizon at noon, or culminated at noon, at the time of the spring equinox. To minds filled with a belief in the influence of the stars on the lives of mortals on the earth this fact would have great significance.

Owing to the gradual increase in the effect of the sun's rays higher and higher above the celestial equator, changes would be brought about at that season of the year. These would be attributed, in part at least, to the remarkable star-cluster being seemingly in the neighbourhood of the sun in the heavens, though unseen. This may explain the reference in the book of Job to the "sweet influences of the Pleiades". Moreover at the same period, 2,170 B.C. when the sun and the Pleiades opened the year, at the beginning of the season of spring, the star Alpha of the Dragon, which was the pole star of the period had that precise position with respect to the true pole of the heavens which is indicated by the slope of the long passage extending downwards aslant from the northern face of the Great Pyramid. When due north below the pole, the pole star of the period shone directly down that long passage, and very likely it could be seen not only when it came to that position during the night, but also when it came there during the daytime.

Groups of stars, which appeared to maintain the same position relatively to each other, became known in time as the familiar constellations in use to-day.

They serve as convenient sign posts leading the observer by easy stages from one constellation to another. The twelve constellations forming the zodiac are on the whole a product of the Babylonian system, which made its way to the west, and through Greek influence back again to India and the distant East. The number of constellations distinguished by the Babylonian astronomers has not yet been definitely ascertained. They certainly recognized more than twelve, and further investigation shows that they knew most of the forty-eight constellations enumerated by Ptolemy.

The general regularity of the "courses" taken by the sun, moon and planets, as seen against the background of the zodiacal constellations, made it a comparatively simple matter to map out the limits within which these bodies moved. These limits impressed the Babylonians with the thought of the eternal and unchangeable laws ruling the planets. The path taken by the sun served as a guide, and its path—the ecliptic—became known as the "way of Anu", since Anu was the name of the chief god of heaven according to the Babylonian religion, and the personification of heaven. Next came the division of the ecliptic into certain sections; the course of the moon and planets was determined with reference to this division, and gradually the zodiacal system was evolved. Its perfection is shown by the fact that so much of the astronomical language of the present day is the same as that used by the ancient astronomers of the Euphrates Valley. (This statement has since been confirmed by the arduous researches of Mr. Robert Brown, who traces the constellations back to the head of Euphrates Valley.)*

At the northern pole of the heavens, between 2,400 and 2,000 (2,800, according to more recent estimate made by Mr. Maunder) years before the present era, we find the great Dragon, which in any astrological temple of the time must have formed the highest or crowning constellation surrounding the very key-note of the dome. He has fallen away from his proud position since that remote date. In fact, 4,000 years ago he only held to the pole, so to speak, by his tail, and we have to travel back 2,000 years or so to find the pole situate in a portion of the length of the Dragon which can be regarded as central, recalling Homer's description of the Shield of Hercules:

> "The scaly horror of a dragon, coil'd
> Full in the central field, unspeakable,
> With eyes oblique retorted, that aslant
> Shot gleaming fire."

With regard to the antiquity of the constellations, which have had the place of their origin traced back to the head of the Euphrates Valley, certain authorities are in favour of the opinion, that the importance of the

*Mr. Maunder, in his book *Astronomy Without a Telescope* (see page 3) tells us that Mr. Brown traced back many of the constellations beyond the Greeks, who in turn had received them from the Semitic Babylonians, to those Turanian peoples who inhabited Mesopotamia before the Semitic invasion of the Akkadians and Sumerians.

constellation Aries in some nations, and its symbolical importance in the mythology of others, may best be explained by the supposition that the choice of this constellation as "Prince and Leader" of the signs "was made, *not* when its stars marked the *spring equinox*, but when they marked the *winter solstice*."* According to this hypothesis in connection with ancient symbolism, the *four* constellations—Aries, Cancer, Libra and Capricornus—marked the *four seasons* and the *cardinal points*, 6,000 B.C.

Next in this order to Aries came Cancer, the Crab, though in Babylonia it was replaced by a tortoise, and in Egypt by a beetle.

The beetle of scarabaeus marked in ancient calendars the spring equinox when in *conjunction* with the sun, and the autumn equinox when in *opposition*. And as it was so presiding *visibly in opposition* we may reasonably suppose that it gained such honour in Egypt. For the autumn, not the spring, is in that land the time when vegetation begins to burst into life, and when all Egypt rejoices. Moreover, certain convincing facts connected with the worship of the Apis Bull seem to indicate that the Egyptians considered the constellations in *opposition* to the sun to be those which presided over particular months and seasons.

From the last days of June to the end of September

*As to Aries being the equinoctial sign, Mr. Maunder states: "Even apart from tradition—and tradition is on this point clear and conclusive—it is certain from the position of the constellations themselves, that they were mapped long before the spring Equinox entered Aries." *Astronomy Without a Telescope*, p. 6. E. W. Maunder.

the Nile swells and overflows its banks. During the latter part of the month of July when the lowest land is inundated, people are busy planting flax, grapes and cotton of a certain species.

In the month of August the Nile has reached one half its height. The sluices are opened on the banks of the river and the canals fill rapidly. Lower Egypt looks like an arm of the sea thickly dotted with hills on which are houses and gardens. Communication with land has altogether ceased, and on the highest points people are seen harvesting the cotton peculiar to the country, cutting clover, and gathering olives and tamarinds. From the middle of September to the middle of October, the Nile has reached its greatest height, and now begins to fall slightly, and by November as it recedes more and more, it uncovers clammy-looking patches of earth. Wherever this happens a narrow plough drawn by two oxen makes furrows, and behind the ploughman toils a sower who, wading to his ankles in the earth oozing with water, scatters wheat which he carries in an apron, in handfuls.

By the month of December, the waters have decreased more and more, wider regions of land are laid bare, the grass becomes higher and thicker, and mingling with the blades are flowers of the most varied hues and delicious odour. Like islands in a green sea, flowers make their appearance blending in hues of white, azure, yellow or rosy like a magic carpet such as a description in the Arabian Nights alone might rival in beauty. The following account of the scene in February, written by Osborn in the first chapter of his book *Monumental Egypt*, conveys some idea of the transformation which has taken place in this region:

"The vivid green of the springing corn, the groves of pomegranate-trees ablaze with the rich scarlet of their blossoms, the fresh breezes laden with the perfumes of gardens of roses and orange thickets, every tree and every shrub covered with sweet-scented flowers. These are a few of the natural beauties that welcome the stranger in the land of Ham. There is a considerable sameness in them, it is true, for he would observe little variety in the trees and plants, whether he first entered Egypt by the gardens of Alexandria, or the plains of Assouan. Yet it is the same everywhere, only because it would be impossible to make any addition to the sweetness of the odours, the brilliancy of the colours, or the exquisite beauty of the many forms of vegetable life, in the midst of which he wanders. It is monotonous, but it is the monotony of Paradise."

But what has made this dream a possibility, and how do the stars enter into the general scheme? That is a query easily answered, since were it not for a timely warning given by the bright star Sirius one morning early before dawn, at the summer solstice when it mingles its light with that of Rā, the Sun, the annual overflow of the Nile would prove an overwhelming disaster. So dependent were the Egyptians upon the yearly inundation, that everything connected therewith was invested with supreme importance. The rising of Sirius at dawn, indicating the approaching elevation of the river, caused that star to become an object of veneration. It was worshipped as a deity, temples were erected in its honour, and it became known as the Dog-star giving warnings each year of the coming inundation.

There is ample evidence that one of the temples at Denderah was dedicated to Hathor, also worshipped under the name of Isis, for according to Plutarch both names were representative of the same divinities in Egyptian times. Moreover, Sothis is simply the Greek form of the Egyptian name (Sept) of the star Sirius. Among the inscriptions in the temple of Isis with its portal turned to the east, the sun shining thereon when it rises to illuminate the world, is one which indicates its purpose very plainly.

"Her Majesty's Isis shines into her temple on New Year's Day, and she mingles her light with that of her father Rā on the horizon."

The temple of Isis at Denderah really pointed to Sirius about 700 B.C., and at that date Sirius rose with the sun on the Egyptian New Year's Day, so that in mythical language, she mingled her light with that of her father Rā on the great day of the year. The summer solstice—that is the 21st of June, the longest day—was the most important time of the Egyptian year, as we have already seen, since it was a warning of the rise of the all-fertilizing Nile. It was really New Year's Day.

Sirius was not only indirectly associated with the yearly inundations of the Nile, but also with the intense heat of summer, as referred to by Virgil, in the lines:

> "Parched was the grass, and blighted was the corn,
> Nor 'scape the beasts, for Sirius from on high
> With pestilential heat infests the sky,"

which is explained by the fact that during this season Sirius is overhead in the daytime, but invisible in the glare of sunlight. The eastern nations generally believed the rising of Sirius would be productive of great heat on the earth. Accordingly, to that season of the year when Sirius rose with the sun, and seemed to blend its own influence with the heat of that luminary, the ancients gave the name of Dog-days (Dies Caniculares). At that remote period the Dog-days commenced four days after the summer solstice, and lasted until the 14th of September. At present the Dog-days begin on the 3rd of July, and continue to the 11th of August, being one day less than reckoned by the ancients.*

Hence it is plain that the Dog-days of modern times have no reference to the rising of Sirius, or any

*In ancient times, both in Chaldea and in Egypt, there was a cycle comprised of 1461 years of 365 days, known as the Sothiacal or Canicular Period. The name is derived from Sirius, and the cycle began when the heliacal rising of that star coincided with the summer solstice. (See pages 41-42. *The Calendar*, by Alexander Philip.)

other star, because the time of their rising is perpetually accelerated by the precession or backward movement of the equinoxes. They have reference only to the summer solstice which never changes its position in respect to the seasons.

The time of the rising of Sirius varies, moreover, with the latitude of the place and even the time is changed after a course of years, owing to the precession of the equinoxes. (For this reason star catalogues become out-of-date after a certain interval, with reference to the Right Ascension and Declination of the stars.) This fact, taken into due consideration, enables us to trace backward with the greatest accuracy the dates of many events of antiquity, such as eclipses of the sun, which cannot be well determined by other records. We do not know, for instance, in what precise era Hesiod lived. Yet he tells us in his *Opera et Dies*, lib. ii. v. 185; that Arcturus in his time rose with the sun, 60 days after the winter solstice, which was then in the 9th degree of Aquarius, or 39° beyond its present position. Now 39° : 50¼″=2,794 years since the time of Hesiod, which corresponds very nearly with history.

When a star rose at the time the sun was setting, or set when the sun was rising, it was called the Achronical rising or setting. When a planet or star appeared above the horizon just before the sun in the morning, it was called the *Heliacal* rising of the star; and when it sank below the horizon immediately after the sun, in the evening, it was called the *Heliacal* setting. The rising and setting of the stars thus described, often occurs in the writings of Hesiod, Virgil, Ovid and Pliny, and they served to mark the times of religious ceremonies, and the seasons as related to husbandry, and events of like importance to shepherds, huntsmen or those who ventured out to sea.

"In those days, the first observations of the heavens were made of necessity by men who depended for their subsistence on a familiarity with the progress and vicissitudes of the seasons, and doubtless preceded by many ages the study of astronomy as a science. And yet the observations made by those early shepherds and hunters, unscientific though they must have been in themselves, are full of interest to the student of modern exact astronomy. The assertion may seem strange at first sight, but it is nevertheless strictly true, that if we could but learn with certainty the names assigned to certain star-groups, before astronomy had any real existence, we could deduce lessons of extreme importance from the rough observations which suggested those names.

"In these days when observations of such marvellous exactness are daily and nightly made, when instruments capable of revealing the actual constitution of the stars are employed, and observers are so numerous, it may seem strange to attach any interest to the questions whether half-savage races recognized in such and such a star-group the likeness of a bear, or in another group the semblance of a ship. But although we could increase our knowledge from more exact observations, yet even such rough and imperfect records would have their value. If we could be certain that in long-past ages a star-group really resembled some known object, we should have in the present resemblance of that group to the same object, evidence of the general constancy of stellar lustre, or if no resemblance could be recognized we should have reason to doubt whether other suns (and therefore our own sun) may not be liable to great changes."*

The subject of the origin of the constellations is full of interest to the chronologist who inquires in what era of the world exact astronomy began, when the moon was assigned her twenty-eight lunar mansions, and the sun his twelve zodiacal signs. It is full of interest to the antiquarian in his study of the buildings raised in long past ages, which tell us mutely by their orientation certain facts regarding times of sunrise or sunset, rendering the thought impressive that the stars which we see to-day were gazed upon by those who watched them in the very infancy of the human race.

If Hipparchus or Ptolemy should rise from their sleep of two thousand years—nay, if the earliest priests of Babylon should come to life again and view the heavens, they would not perceive any change to have taken place in the relative positions of the stars. The general configurations of the constellations would be exactly that to which we are accustomed. Had they

*_Myths and Marvels of Astronomy_, by R. A. Proctor, pp. 333-334.

been exact observers they might notice a slight change in the position of Arcturus but not in that of any other star: Arcturus has been moving ever since the time of Job, at the rate of probably more than two hundred miles per second—possibly three hundred miles.

The best known example (already referred to, in Chapter IV) of this movement among the stars, termed star-drift, as a result of R. A. Proctor's comparison of star-charts made a hundred years apart, is in connection with the well-known group of seven stars in Ursa Major, familiarly termed Charles's Wain in England, and the Great Dipper in America. Five out of the seven stars are drifting in the same direction, having a proper motion in Right Ascension of nearly 8″ per century, the other two stars in the group of seven not sharing in the motion in that direction. When we project their motions on a map, we find that the actual direction in which the stars are drifting is nearly the same for all five stars, and it is worthy of remark that these observations when submitted by R. A. Proctor in 1867 to Sir William Huggins, for purpose of confirmation by means of spectroscopic investigations, were abundantly confirmed.*

*In the preface to the *third* edition of *Other Worlds than Ours*, published in 1872, the author wrote: "While it has been passing through the press, a great discovery has been announced by Dr. Huggins which definitely establishes my theory of star-drift, and with that theory my chief views regarding stellar distribution."

CHAPTER X

THE FUTURE OF THE MOON

WE are hearing strange stories about the moon nowadays, regarding its origin. According to the latest theories advanced; some two thousand million years ago the moon actually formed a minute part of the sun, until that stupendous event took place which brought the moon, the earth and all the planets into being. Until that happened, doubtless for millions of millions of years the sun had been pursuing its solitary way through space unattended. No companion star had shared its rambles until at some remote period in time a star approaching too near, overtook the sun. While there was no actual collision, yet the two very narrowly escaped running into one another. Nevertheless they were so near, that huge tides were raised on the two stars involved, and long streamers of gas were flung forth from the internal furnaces of the sun, to a distance so great that they did not fall back on its surface. Instead, "condensing into drops" as they cooled in the depths of space, they were later rounded into planets, which circled around the sun and thus we are told, the planetary system was evolved.

Immediately after their birth, the planets began to

PHOTOGRAPH OF THE MOON. AGE, 14 DAYS, 1 HOUR.
PERMISSION FROM DIRECTOR, LICK OBSERVATORY.

cool down, the largest such as Jupiter and Saturn most slowly, for maybe they are still intensely hot within, while the smaller ones cooled more rapidly. Then came the next step, viz.: the formation of the satellites accompanying the planets, and once more the performance was repeated though on a minor scale, the sun taking the part originally played by the intruding star. In some such way, we are told, the planetary moons may probably have made their début in the solar system.

Jupiter and Saturn were provided with nine moons apiece (until recently, when Jupiter acquired moons X and XI), Uranus with four, Mars with two, Neptune and the Earth with one each, and Venus and Mercury with none. However, it is with our one and only moon that we are specially interested, and its subsequent career which was apparently much disturbed. The earth was rotating much faster at that early period than it is now, and the moon was actually in contact therewith until the great catastrophe took place. So fast was the earth spinning that the moon was flung off its surface, not as the rounded globe we are familiar with now, but as a huge fragment of molten matter, and thereafter it had to fend for itself. This was long ages ago, when the earth was still molten and plastic, so that life was not as yet possible on its surface. Otherwise, the inhabitants would have had the curious experience of having a day and month of equal length.

Gradually the moon receded farther and farther away, taking longer to complete its journey round the earth, and meanwhile the month gradually increased in length. The day also lengthened, because the earth was slowing down, taking longer to rotate on its axis, but the month increased in length at a greater rate than the day. Presently the month became equal to two days, then to three and so on, the process going on until there were twenty-nine days in the month. This is known as the *synodic* month which we ordinarily mean when we speak of a month, and is the time between successive new or full moons.

There is also the *sidereal* month, the time it takes the moon to make its revolution *from a given star to the same star again*, as seen from the centre of the earth. The moon rotates on its axis once during a sidereal month; that is, exactly the same time as that occupied by its revolution around the earth. Meanwhile, it keeps the same face turned almost exactly towards the earth, so that we see the same aspect of the moon as Galileo did in the days when he first turned his telescope in its direction.

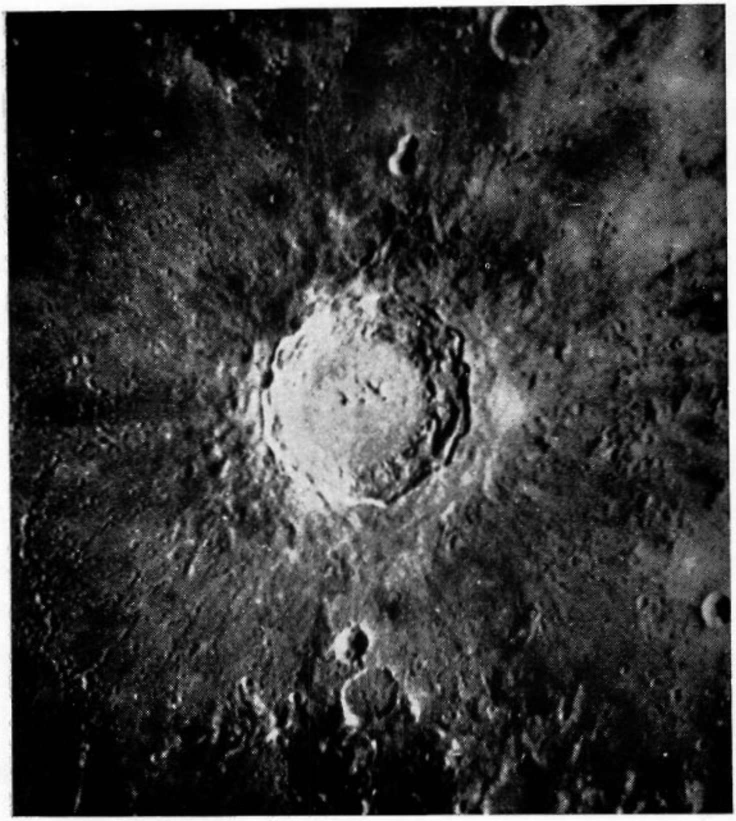
Many find difficulty in seeing why a motion of this sort should be called a *rotation* of the moon, until convinced by the following simple illustration. Walk round a circular table placed in the centre of the room, and always keep facing the table. While doing so, look at the pictures hanging on the opposite wall, and it will be found on completing the tour that all the pictures have been seen in turn. To make this possible it is necessary that one should turn completely round, just as the moon does when it circles around the earth during the course of a month.

The slowly lengthening day causing the earth to slow down so that it will take longer to rotate on its axis, is due to the energy of the tides which act as a kind of brake. Huge masses of water are held back by the moon, thus exerting a dragging effect on the rotating earth. The force of the tides must be slowing down the earth in consequence, and little by little the day is lengthening and the moon is slowly retreating. To-day is longer than yesterday, and in a thousand years the alteration in the length of the day will only be a small fraction of a second, but the process is continuous. Yet it is this small but continuous increase in length, which is bound to produce very considerable effects in the course of the millions of years with which astronomy deals.

We have as an instance of the culminating effect produced in thousands of years, the illustration of what is accomplished by a tiny drop of water falling from the roof of a stalactite cavern to the floor beneath, building up during the progress of thousands of years a colossal shaft of crystal extending from floor to roof. A century may not suffice for the falling drop to add much to the stalactite down which it trickles, or to the growing stalagmite on which it falls, but the stately column we now so much admire tells us mutely its own story. Just as the tiny drops of water have contributed to its growth, so has the incessant ceaseless drag of the tides through immeasurable ages gradually altered the length of the day by possibly a mere fraction of a second in a thousand years.

In the far distant future we can visualize the earth at the period when it will continually turn the same face to the moon, so that for the inhabitants in one hemisphere of our planet there will be moonlight every night, while on the other side of the earth the moon will never be visible. We can imagine parties planned specially for excursions to the regions enjoying the glamour of moonlight, or to the other side of the earth where in the absence of the moon it may be possible to see the stars undimmed by its light. By this time the length of the day and the month will be identical, each being equal to about forty-seven of our days at present. This state of affairs, according to the calculations of scientists, will not prevail until about 50,000 million years hence. After this vast period of time has elapsed, tidal friction will no longer have the effect of driving the moon further away from the earth.

Its path while receding, which may be described as a sort of spiral gradually uncoiling outward, will then, as it were, begin to wind up again, owing to the slowing down of the earth's rotation due to the joint effect of solar and lunar tides. The distance between the moon and the earth will gradually lessen until finally, after vast æons of time, the moon will be dragged down



LUNAR CRATER COPERNICUS
PHOTOGRAPHED WITH 100-INCH REFLECTOR AT MOUNT WILSON, CAL.
PERMISSION FROM DIRECTOR, MOUNT WILSON OBSERVATORY.

to within about 12,000 miles of the earth. It has been suggested that the tides thus raised by the latter in the solid body of the moon would shatter it into fragments, but this is unlikely, as the oceans on our planet are likely meanwhile to be frozen or dried up, with the cessation of tides, long before that stage is reached.*

*Thus, *if* we possessed the "Times Machine" so ingeniously devised by Wells, a slight reversal of the lever in the direction of the Future, might produce a most startling effect, in providing us with a glimpse of the moon at a time when it will be only 200,000 miles away; then at a later epoch when it will be at a distance of 100,000 miles. Tracing its spiral path as it winds closer and closer through thousands of millions of years, then, according to the suggestion made by Wells, the coils creeping slowly inwards towards the earth.

This is a mere phantasy of the imagination, and by no means to be taken as a scientific explanation of what may happen to the Moon in the future.—M.P.

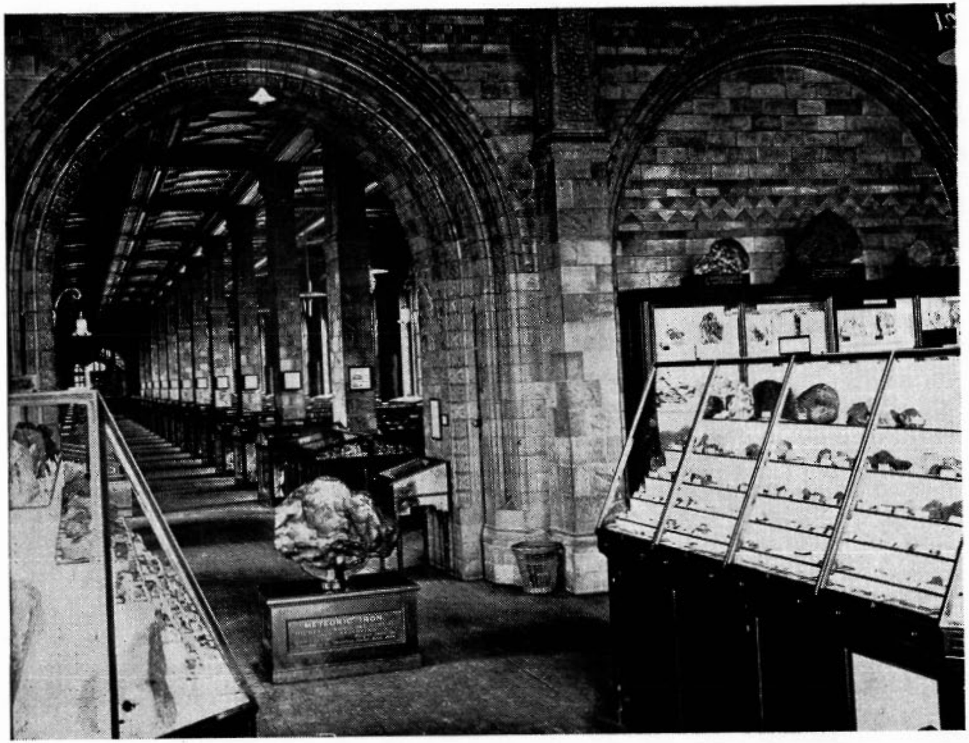
CHAPTER XI

VISITORS FROM INTERPLANETARY SPACE

"Casually I roam
As through a wide museum—from whose stores
A casual rarity is singled out
And has its brief perusal, then gives way
To others all supplanted in their turn."

DURING the course of the year, visitors to the British Museum Mineralogical Department, which includes a famous collection of meteorites in the Pavilion at the end of the Mineral Gallery, will find a lecturer awaiting them. On entering the Gallery attention is at once directed to the picturesque arrangement of two important meteoric irons, viz.: the Otumpa or Campo del Ceilo, found at Argentina in 1783; and in the background, a mass weighing about three and a half tons, the largest meteorite in the collection. To the right of the "Cranbourne" as this meteorite is called, is the Cañon Diablo meteoric iron, and on the other side is one that was found at Coahuila, Mexico.

A glance around the Pavilion, likewise shows other meteoric "irons" and "stones" of all kinds and shapes, from huge masses weighing tons, to small particles of stones and iron. Some quaintly shaped like buttons,



MINERAL GALLERY (PAVILION SHOWING METEORITES, INCLUDING OTUMPA) BRITISH MUSEUM (NAT. HIST.)
WITH PERMISSION OF DIRECTOR, DEPARTMENT OF MINERALOGY, DR. L. J. SPENCER, M.A., SC.D., F.R.S.

as a visitor once suggested were left by celestial messengers, but no matter how small all these particles may be, they are carefully preserved under glass covers. Occupying a lofty position on the top of a wall case containing fine specimens of minerals, is a cast of iron weighing 2,520 lb., a duplicate of a meteorite found in 1909, at Murnpeowie, Mount Hopeless, South Australia. The original is in the South Australian School of Mines, and was presented by the Governor of South Australia to the South Australian Museum, in 1917. It is a relief after craning one's neck looking upward at this, and other "skied" specimens surmounting wall-cases, to turn our attention to meteoric irons such as the "Thunda", known since 1886, when it was found at Windorah Grey Co, Queensland, and was presented to the Museum bequest in 1927, of Professor R. Sinetidge, F.R.S., which specimen with many others is conveniently within reach.

The most interesting of all, is the "Cranbourne", the largest meteorite in the collection, which was found by Mr. James Bruce, in 1862, at Cranbourne, near Melbourne, Australia. Picture to yourself, Mr. Bruce entertained by a squatter at Cranbourne, when his attention was drawn to an odd-looking piece of iron over the fire-place. The squatter explained that there was another piece like it in the adjoining neighbourhood of Sherwood. On Mr. Bruce expressing a desire to see it, he was at once taken to the spot, and here he was shown an irregular mass of iron projecting above the ground. After a superficial examination he came to the conclusion that it was a mass of meteoric iron. Mr. Bruce looked upon it as a veritable treasure-trove, and when he asked its price, he was informed that he could have it for a sovereign. The purchase was concluded at once, and on his return to England the meteor was presented by Mr. Bruce to the Museum Collection. Large sums of money were offered for this splendid mass of meteoric iron, but to all such offers, Mr. Bruce gave the invariable reply: "No, I have bought it for a sovereign; and I am going to give it to the British Museum," where it is to be seen to this day.

It is labelled as follows:

> Cranbourne, Melbourne, Victoria, Australia, known in 1854. Weight 3½ tons.
> Presented by James Bruce Esq., 1862.

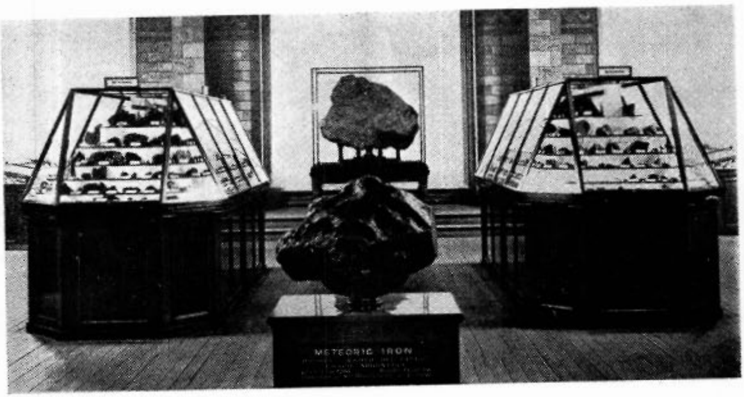
A photograph was taken of the "Cranbourne" when it was first found, by Mr. R. Daintree, the Agent-General for Queensland, after the tertiary sandstone enclosing it had been removed. A glance at the "Cranbourne" will show the cracks where the molten mass flowed as it passed through its fiery ordeal when plunging through the atmosphere of our planet. One can see where portions of the iron have been chipped off, leaving sharp jagged edges at the places where they have been severed.

The "Cranbourne" tells its own story very plainly, regarding the final chapter in its career, but we know nothing of the strange episodes in its earlier history ere it took the final plunge which landed it in Australia. It is a silent witness of possibly centuries of glorious freedom as an independent particle in space, yet dependent withal to the sway of the sun from which—according to a recent theory, it was ejected in bygone days, thereafter to wander aimlessly in space until suddenly its career was brought to an abrupt end in a final flash of splendour. For more than half an hour, one summer afternoon, the writer stood in front of the pedestal on which the "Cranbourne" is enthroned, trying to visualize its story, and wishing this solid mass of iron had been gifted with the power of speech. It could then relate its experiences millions of years ago when it was inside the Sun; later on when it was a happy-go-lucky wanderer in space; its plunge downward through our atmosphere; its unexpected arrival in Australia; and final destination, the South Kensington Museum.

The smaller mass of iron was sent to the International Exhibition in London, in 1862, and was eventually bought by the Trustees of the British Museum for £300. The "Cranbourne" or larger mass was at first taken to Melbourne, and placed in the University Grounds, near the shore, but here it was unfortunately exposed to the action of sea-water. When it finally arrived in England, and reached the

South Kensington Museum, some holes were drilled in its under surface, and it was fixed on a turn-table in the Pavilion of the Mineral Gallery. It was found to decay to a considerable extent, fragments becoming oxidized and crumbling off, while drops of iron chloride exuded here and there. By injecting clear shellac varnish, the crumbling was stopped to a very great extent, and reduced to a minimum. Incidentally, it was noticed that the part of the meteorite which was so rapidly decaying presented a very marked crystalline appearance, as well as many of the fragments when reduced to their formal original condition by special treatment. Minute analysis showed that the meteorite consisted entirely of metallic minerals, such as nickel, cobalt, phosphorus, sulphur, etc., but the absence of all combined carbon was fully established.

To the right of the "Cranbourne" is a specimen of meteoric iron found in 1891, at Cañon Diablo, Arizona. This is a polished slice showing a large carbonaceous inclusion containing a diamond, and also numerous crystals of the carbide of iron cohenite. In the inscription under this specimen, which like the "Cranbourne" is distinguished by the position it occupies on a separate pedestal, are the words, "Diamonds have been found in some of the masses of iron from this locality", inspiring the adventurous with the desire to visit the Cañon Diablo, or Coon Butte region, in search of such treasure-trove for themselves. As a matter of fact, there is a standing invita-



PAVILION CONTAINING A COLLECTION OF METEORITES, SHOWING THE METEORIC IRONS OF CRANBOURNE AND OTUMPA. BRITISH MUSEUM. (NAT. HIST.)

tion from the Standard Iron Company, who own the Meteor Crater region, where the Cañon Diablo meteorites are located, to visit the crater and make a study of the specimens on exhibit in the Museum at the Crater. To the left of the "Cranbourne", is a Meteoric Iron, named Bolson de Mapimi, supposed to have fallen in 1837, at Coahuila, Mexico. It weighs over 250 lb., and like the "Cranbourne", and "Cañon Diablo" meteorites, occupies a separate stand.

The "Ring Meteorite" or "Signet Iron", so-called on account of its peculiar shape was found in the Santa Catarina Mountains, about thirty miles north-west of the city of Tucson, Arizona, and its existence was known to the Spaniards for at least two hundred years, before the region became part of the United States. Tradition, indeed, relates that this and many other fragments fell in a single meteoric shower about the middle of the seventeenth century. According to Professor John L. Leconte, the iron was utilized in 1851, for making anvils, by the blacksmiths of the town. In 1863, it was taken to San Francisco, and thence transported by way of the Isthmus of Panama to the Smithsonian Institute at Washington, D.C.

The earliest meteorite known to have fallen in the British Isles is the one seen to fall at Wold Cottage, near Scarborough, on December 13, 1795. It is now on view in the South Kensington Museum Collection. Among other falls of meteorites which have occurred in England, there was one at Launton, Oxfordshire on February 15, 1830; at Aldsworth, Gloucestershire, on August 4, 1833; at Middlesbrough, Yorkshire, on March 14, 1881; at Appley Bridge, Wigan, Lancashire, on October 13, 1914; and at Rowton, Shropshire, on April 20, 1876. Of these, the most interesting from the historic standpoint, were the falls recorded at Rowton, Middlesbrough, and Wigan.

Regarding the first, we are told that some years ago, a farmer living near Rowton, in Shropshire, was surprised at the discovery of a hole on a path in the field, where he was certain one had not been seen before. How did it come there, and what was the mysterious agent which had hollowed it out of the ground? On inquiry, he learned that some of the labourers in the field had heard a peculiar sound like the thud of something falling sharply on the ground. When the farmer put his hand in the hole, he felt something hot, so he took a spade and dug out a piece of iron, weighing about seven pounds. Naturally he was amazed at the discovery, wondering where the iron had come from, and was loth to believe that it had fallen from the sky. An hour after the explosion announcing its arrival had been heard, it was found where it had plunged downward through four inches of soil, and fourteen inches of clay. The main mass of this meteorite is now in the South Kensington Museum Collection.

The meteoric stone which fell at Appley Bridge, Wigan, Lancashire, was preceded by a fireball, which was seen moving from S.S.E. to N.N.W. at 8-45 p.m., on October 13, 1914, *illuminating* the whole countryside with its light which was observed from many places in Lancashire and Cheshire. After a short interval there was a tremendous report followed by a series of rumblings, and at several places windows were shaken as if an earthquake had taken place. On the following day, the meteoric stone which had caused all this disturbance, was found in a hole eighteen inches deep, which it had dug for itself in a field belonging to Haliwell Farm, four miles N.N.W. of Wigan. When weighed, the meteorite was found to be merely a mass of 33 lb., which seemed very small after making such an elaborate display.

Regarding the fall of a meteoric stone weighing 22 lb., which fell at Middlesbrough, Yorkshire, on March 14, 1881, a very interesting account was given by A. S. Herschel, in a letter addressed to the Newcastle *Daily Chronicle.* He described the fall as occurring on a bright, sunshiny day, when the air was perfectly calm. Suddenly a rushing or roaring noise was heard overhead, by some platelayers, and scarcely had it ceased, than it was followed by a loud thud as though a heavy body had fallen to the ground some distance away. The platelayer in the signal house, the windows of which were open, also heard the noise, and supposed that his companions had thrown something at the signal-box to attract his attention.

Meanwhile, the other platelayers went in the direction where they supposed the object had fallen, and seeing a round, newly-made hole, one of them put in his hand, and withdrew it again quickly on finding he had touched something warm. However, diving again a few minutes later, he pulled out a meteorite of a shell-like shape, measuring about five or six inches in length, and about three inches in width. As we have already seen, it weighed about 22 lb., and was covered with a thin, black molten crust, the frayed edges of the stony structure inside showing here and there at the crumbling edges. The loose mould adhering to it was easily brushed off, exposing the smooth surface to view. As it was supposed to be a piece of slag flung out from a place nearby where some blasting operation was in process, it was left on a ballast-heap until the next day when it was submitted to Mr. Herschel for examination. After a brief study of the unusual-looking stone he was convinced that it was a meteorite.

He found it very remarkable in appearance, both in its shape and the depth and regularity of the indentations on its surface caused by friction as it penetrated the atmosphere. According to Mr. Herschel, the exposure to intense heat and fusion in the flames must have been fiercer than that of any forge, during the first moments this wandering missile of the sky came into collision with the particles forming the earth's atmosphere. Grains of iron-pyrites, but none of metallic iron, were found on the surface of the stone.

There is one more specimen in the British Museum collection, which though small—weighing only 14 lb., is yet of considerable interest, since it is said to be part of the famous Mazapil Meteorite, which fell in Mexico, on November 27, 1885, during the great shower of meteors of that date. It is suspected as forming a part of the debris of a shattered comet viz: Biela's Comet first seen in 1826 by an Austrian officer named Biela, after whom it was named. During its brief career it broke in two, and afterwards went to pieces. One of these—the Mazapil Meteorite, fell about 9 p.m., on a ranch about thirteen kilometres east of Mazapil, and was found by Sr Mijares, the owner of the ranch, and attracted the attention of several other Mexicans. Unfortunately, Sr Mijares did not actually see it fall, but only after it had fallen and was still glowing from the intense heat caused by friction as it plunged through the atmosphere. If it is actually a piece of Biela's Comet, it is the first piece of a comet known to have fallen to earth.

Explorers in the Arctic regions have found implements made from meteoric iron in the possession of the Eskimos, such as weapons with iron points; an axe-head set in bone, with a socket of wood; a tool for cutting leather, a knife with a blade of meteoric iron, formed like the earlier specimens discovered.

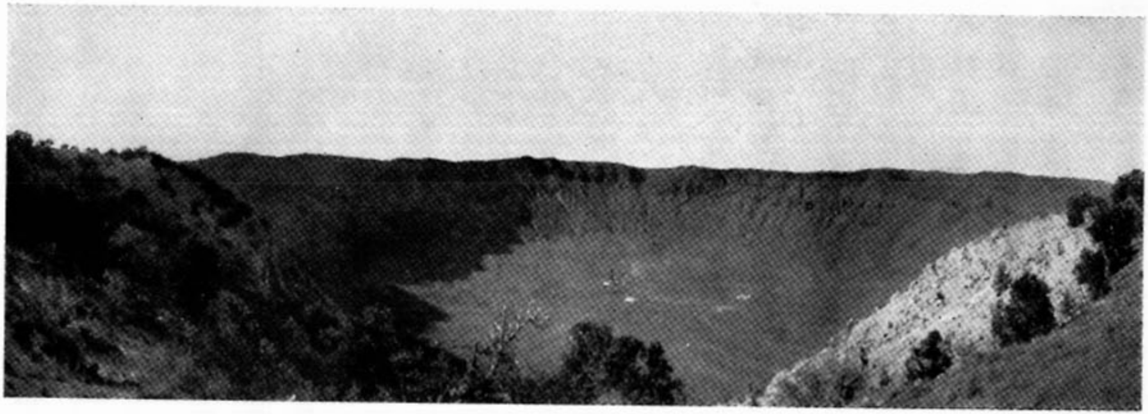
CHAPTER XII

THE GREAT METEOR CRATER OF ARIZONA

(Formerly called Coon Mountain or Coon Butte).

FAR exceeding in size the alleged Siberian meteor (1908), which incidentally has not yet been discovered, so that one must accept with reserve, the stories of its fall,* is the great meteor which delved for itself a crater in Arizona, three quarters of a mile in diameter, and 550 feet in depth. (To give some idea of what 550 feet means, if the Nelson Monument at Trafalgar Square were duplicated four times, each surmounting the other, yet the top of the fourth would reach but 30 feet above the rim of the crater, the monument being 145 feet high.) To fully appreciate the dimensions of the crater, one should take a walk round the rim, meaning a three mile tramp! It has been estimated that the crater was caused by a gigantic meteorite which displaced more than 400,000,000 tons of rock in its fall, burying itself so deeply beneath the debris that the main part of the mass was not located by a drill hole, until 1920.

*According to Dr. L. J. Spencer, Keeper of the Department of Mineralogy, British Museum (Natural History) in the *Natural History Magazine*, published by the Trustees of the British Museum (July, 1930), "after much search in the region of the Stony Tunguska River, several craters have been found in the ground, but no meteorite has been discovered."



INTERIOR VIEW OF CRATER, LOOKING N.N.W.

Difficulty in locating the possible position of the main mass of meteoric iron, presumably buried underground, was due to the fact that it was taken for granted that the impact was vertical, with the result that search for the missing object was made in the centre of the crater. However, by means of an accidental discovery made by Mr. Daniel Morean Barringer in 1908, he was enabled to locate where the main mass of the meteoric iron had fallen. This was due to an experiment he made with a replica of the Arizona crater in miniature, represented by stiffish mud, into which he fired bullets, from a high powered rifle at short range. Even when holding the rifle at an angle as low as forty-five degrees from the vertical, the resultant crater was almost round, and the splashing distribution of the ejected material was exactly similar to the Arizona crater, and similar in appearance to the lunar craters.

"In fact," to quote from Mr. Barringer's remarks, in the *Scientific American*, 1927, on the *Origin of the Crater and Other Features of the Lunar Surface*, "if one will make a careful study *on the ground* of the Arizona crater, and then study the appearance of the lunar craters as carefully as I have done, he cannot escape the conclusion, there being so many similar features, that they have a similar origin."

As a result of his experiment, Mr. Barringer came to the conclusion, that instead of coming down vertically, the vast meteor had approached the earth at an angle of forty-five degrees from a direction slightly west of north, making a slight curve to the west in its slanting flight owing to the rotation of the earth, and burrowing a hole for itself under the southern wall after penetrating through more than half a mile of solid rock composed of limestone and sandstone. In 1920, a drill-hole 1,600 feet deep was made, but the drill struck at this depth, doubtless owing to its becoming embedded in the outer shell of the meteorite, largely composed of the shale-ball variety of iron meteorites. From 1,200 feet down, the drill brought up an increasing quantity of meteoric iron. The shale-ball iron has meanwhile undergone oxidation, as shown by the specimens brought up. More recently a shaft has been sunk to a depth of 700 feet, south of the southern rim, in an attempt to reach what might be termed the nucleus of the mass, but work on it has been discontinued owing to the heavy flow of water. According to Mr. Barringer: "We are no longer so sure of the exact water conditions, and could expect no results till we sank the shaft 800 feet further and then tunnelled 1,000 feet north."

In addition to locating the mass, the most important development, is the generally accepted belief that the mass is not a single body, but a cluster of iron meteorites ranging in size from the smallest pebbles to masses ten feet or more in diameter. All of these seem to have been rounded off during the course of æons of time while they travelled together in space—a veritable swarm of meteorites, ere they took the final plunge. The readjustments of the particles within the swarm have knocked off the corners infinitely slowly, just as in the case of the action of water gradually rounding off pebbles on the beach. The shale-balls which have been found in the millions of tons of very fine white silica which were formed by the shattering of the sandstone at the impact, are representative of this swarm. These when exposed to the atmosphere, oxidize and disintegrate very fast. The Cañon Diablo meteorites proper are the unoxidizable residue of these shale-balls, and have frequently been found within them. The composition of the Cañon Diablo meteorites is 94-5 per cent. iron, and 5 and 6 per cent. nickel, and about an ounce of platinoid metals per ton. The shale-balls carry metals in the same proportion allowing for the addition of oxygen caused by their oxidation.

Various theories have been advanced with regard to the origin of this mass of meteoric iron, which has a diameter estimated to be 300 to 400 feet, and a minimum weight of about five million tons. Olivier and other authorities on meteorites, are of the opinion that it may have been once a small and relatively dense comet composed of a swarm of rounded meteorites travelling closely together, which on striking the earth, produced the Meteor Crater. The theory now generally accepted is, that the enormous cavity in the earth's surface has been produced by the impact of a swarm of iron bodies such as form the nuclei of comets. Plunging downward from space they have left their impact on the surface of the Arizona Meteor Crater, showing a remarkable similarity to the craters on the Moon. A glance at one of the remarkable photographs of the lunar surface, taken at the Mount Wilson Observatory, California, is more than convincing—it is actually confirmatory. They cannot but convince even the most prejudiced that the origin of the Meteor Crater at Arizona, like the Craters on the Moon, has been due to impact.

Richard A. Proctor was among the first to advance the theory that the craters on the Moon are due to impact. In the first edition of his book, *The Moon*, published in 1873, he refers to this theory, as follows: "Now as far as the smaller craters are concerned, there is nothing incredible in the supposition that they were due to a meteoric rain falling when the Moon was in a plastic condition. Indeed, it is somewhat remarkable how strikingly certain parts of the Moon resemble a surface which has been rained upon while sufficiently plastic to receive the impression, but not too soft to retain them. Nor is it any valid objection to this supposition that the rings left by meteoric downfall would only be circular when the falling matter chanced to strike the Moon's surface squarely, for it is far more probable that even when the surface was struck very obliquely, and the opening first formed by the meteoric mass or cloud of bodies was therefore markedly elliptic, the plastic surface would close in round the place of contact until the impression formed had assumed a nearly circular shape."

How this meteoric theory was accepted as the solution of the problem, was told by Mr. Daniel Morean Barringer, in an account of the Proceedings of the Academy of Natural Sciences of Philadelphia, December, 1905. In October, 1902, he heard for the first time, in casual conversation with Mr. S. J. Holsinger, about a remarkable crater located at Coon Mountain or Coon Butte in the northern part of Arizona. It is situated about six miles south of Sunshine Station, Coconino County, along the Atchison, Topeka, and Santa Fe Route. Here on a broad, open plain, is to be found a most striking confirmation of the meteoric theory. Scattered for miles around are something like two thousand masses of metallic iron, the fragments varying in weight from half a ton to the fraction of an ounce. There is little doubt these masses once formed part of a meteorite or comet, as the case may be, although no record exists as to the date of its fall. "Coon Butte" is simply the raised rim of the so-called Meteor Crater, formed by the downfall of meteorites, a few falling around the rim. It may also be said to bear a striking resemblance to an indentation caused by the downfall of a mighty mass striking the ground with such force, that it penetrated deeply beneath the surface.

In 1903, Mr. D. M. Barringer, and Mr. B. C. Tilghman, both well able to undertake the task of solving the problem satisfactorily because of their general scientific knowledge, collected an astounding array of evidence in support of the theory that the great cavity in the earth was undoubtedly caused by the impact of a gigantic meteorite. They came to this conclusion, which is now generally accepted, after a prolonged and careful study of the rocks in the interior of the cavity, and its surrounding neighbourhood covering an area of five miles; and comparing these with rocks found beyond this region.

To gain some idea of the difference between regions where the rocks are igneous, as compared with those which are non-igneous, as at Meteor Crater, one should pay a visit to the San Francisco Mountain, some forty miles away to the west and north-west, with its great flow of lava which once poured out of its numerous craters over the surrounding area of sedimentary rocks. Then make a visit to the well-known "Sunset" crater, about thirty miles west of the Meteor Crater, which will enable one to see eruptive rocks, formed by an old volcano from which lava flowed in bygone days. By this time, one is prepared for a visit to the Meteor Crater, where it will be possible to compare all three. The conclusion is inevitable, viz.: that there is not a single point of similarity, excepting the circular outline of the interior basin. There are no eruptive rocks of any kind in the neighbourhood of this crater, which is found to be enclosed in an area composed of level beds of stratified rocks (carboniferous sandstones, limestones, and shales), which extend uninterruptedly with the exception of the above-mentioned volcanic areas, for about seventy miles in every direction.

In the Meteor Crater, some twenty-seven drill holes have been put down in the centre of the crater mostly to the undisturbed rock below, which is all sedimentary. All around are to be found nothing but stratified sedimentary rocks. Viewed from the railroad across the perfectly level plain, Coon Mountain as the Crater was formerly called, presents a very peculiar appearance to anyone accustomed to study the sky line. Such an observer would see a small mountain or butte, about one and a half miles long, rising out of the level plain, the sky line of which (the rim of the crater), is very irregular, the mountain differing widely in this respect, as well as in its light colouring as compared with that of other mountains in the region, which show the usual soft undulating outlines, and the dark reddish colour due to the eruptive rocks of which they are composed. Meteor Crater is most deceptive in appearance, not suggesting even at close range, the existence within of a large crater, approximately 3,800 feet in diameter, and 550 feet deep. There are cedars growing on the rim which are upwards of 700 years old. In fact, it is estimated that the crater may not be more than 2,000 or 3,000 years old, and perhaps much younger. The interior of the crater can best be likened to a great bowl, except that there is an almost vertical escarpment running around the upper portion of the bowl, formed of cliffs composed of limestone and the overlying sandstone. Coon Mountain caused by the catastrophe has an extreme elevation of about 160 feet above the level of the plain, and an average elevation of about 130 feet. It is surrounded by a more or less rocky plain, with a very thin covering of soil, and in some places the soil is entirely absent owing to violent winds which prevail at certain times of the year.

From the evidence obtained by the various scientists, geologists and chemists, etc.; Mr. Barringer sums up the result of his investigations, as follows: "It is certain that the crater was made *in an instant of time, after which all was quiet as before.* Anyone visiting the locality is impressed by the many evidences of this fact. It is also certain that the crater is very recent, comparatively little or no erosion having taken place since it was made. The evidences of this are to be found on every side. If there had been much erosion such as must have taken place in order to account for the great amount of slope which is to be observed on the inside of the crater, supposing it to have accumulated in the usual way, the crater would certainly not be as round as it is. If originally round, it would certainly have been greatly deformed by the process. It could not *weather* round. It is perfectly clear that this is con-

IN MINERAL DEPARTMENT, BRITISH MUSEUM, (NAT. HIST.) CROMWELL ROAD, LONDON, S.W.7. METEORIC IRON FOUND IN 1891 AT CANYON DIABLO, ARIZONA, U.S.A. DIAMOND HAS BEEN FOUND IN THIS, AND OTHER MASSES OF IRON FROM THIS LOCALITY.

trary to any known mode of action of erosion. Therefore, it is certain that the slope did not accumulate in the usual way, and that its presence and distribution must be explained on some other theory than that of weathering. This view receives further support from the fact that the very low angle (about twenty degrees from horizontal) which the upper portion of the slope on the interior of the crater makes in its descent to the base of the almost perpendicular cliffs is a very unusual one."*

Between ten and fifteen tons of meteoric iron have been shipped away from this locality, most of it going to the various museums of the world, and these are known to the scientific world as the Cañon Diablo siderites. A fine specimen is to be found in the British Museum (Natural History), weighing 83,497 grams (1,000 grams=2,205 lb.); and there are two fragments in the Foyer collection, Natural History Museum, New York, U.S.A., one of which weighs 1,087 lb. These were described by Professor Huntington, in the account of the *Proceedings of the American Academy of Arts and Sciences, Boston,* for 1894. A slice of the meteorite in which a diamond was found, is in the British Museum (Natural History) collection. By far the greater portion of this meteoric iron has been found lying on the plain immediately surrounding the crater, and much of it has been found on the rim itself. At

*From *Proceedings* of *The Academy of Natural Sciences of Philadelphia.* December, 1905.

Cañon Diablo, a merchant, Mr. F. Volz shipped nearly ten tons of this iron, and before he came to this country a merchant from Winslow shipped perhaps half as much. Both of these merchants hired Mexicans to look for iron specimens in the neighbourhood of the crater, and they found several pieces weighing from 600 to over 1,000 pounds.

The presence of platinum and iridium in the iron specimens was ascertained for the Standard Iron Company by Mr. H. H. Alexander of the Globe Smelter Co. Denver, by subjecting the iron and the magnetite to the fire assay test samples of each specimen which had been sent to him for the purpose. Their presence was also confirmed by the well-known chemical authority, Dr. J. W. Mallett, F.R.S. of the University of Virginia. In a letter written to Mr. Barringer of Philadelphia, dated August 17, 1905, he gives the main results of the assay experiments made by himself and Mr. Alexander, asserting that the specimens of the original meteoric iron sent to him for examination not only contained gold and platinum but microscopic diamonds; adding the following postscript, regarding a specimen of the Cañon Diablo iron:

"From the specimen of Cañon Diablo iron you left for me, with drill holes in it, and a memorandum as to drills being blunted and spoiled, I have obtained five excellent microscopic diamonds—quite like those of South Africa in appearance and markings."

For centuries diamonds have been laboriously dug

CANYON DIABLO. WEIGHT, 1087 LBS. DIAMONDS HAVE BEEN FOUND IN SPECIMENS OF THIS FALL.

from the earth often at great depths, but now that it has been proved conclusively from the separate points of view of a physicist, chemist, mathematician, and a geologist as in the case of Mr. Barringer, that diamonds have actually been known to fall from the sky enclosed in meteorites, it is an idea that appeals strongly to the imagination. Here, in very truth, the diamond may be said to be literally, a gift from heaven. The discovery of meteoric diamonds was made by the late Dr. Foote, an ardent mineralogist, while an assistant was cutting a section of a meteorite, when it was found the tools were injured by something vastly harder than metallic iron. "He examined the specimen chemically, and soon after he announced to the scientific world that the Cañon Diablo meteorite contained black and transparent diamonds. This startling discovery was afterwards verified by Professor Moissan and Professor Friedel. The former, working on 183 kilograms of the Cañon Diablo meteorite, found smooth black diamonds, and transparent diamonds in the form of octahedra with rounded edges, together with green hexagonal crystals of carbon silicide. The presence of carbon silicide in the meteorite shows that it must at some time have experienced the temperature of the electric furnace. Since this revelation has been made, the search for diamonds in meteorites has occupied the attention of chemists all over the world."*

*The account, as above quoted, of the discovery of a diamond in a meteorite, was given by Sir William Crookes, F.R.S., in a lecture delivered before the *British Association for the Advancement of Science*, at Kimberley, South Africa, on September 5, 1905.

Finally, to sum up the present day conclusions regarding the Meteor Crater, Professor H. N. Russell, Director of the Observatory at Princeton University, expressed the opinion, in a paper read before *the Academy of Sciences*, at its Autumn Meeting at Princeton, November 16, 1909: "that the mass which made the crater was composed of many thousands of iron shale-balls, the Cañon Diablo meteorites being the unoxidizable residue. The meteoric mass in passing through the atmosphere would necessarily push before it a great mass of compressed and highly heated air. There would be no time for the air to escape sidewise to any great extent. A mass of the great size (perhaps several hundred feet in diameter) necessary to account for all the phenomena observed, moving at fifteen to thirty miles per second—which is the sort of velocity to be expected—would cut out a "wad" of air, going through the atmosphere like a charge of shot going through a board in front of the muzzle of a shot-gun. The total mass of this entrained air might be as great as that of the original meteorites. In this way the blow at the earth's surface would be to a certain degree cushioned which would help to account for the absence of notable evidences of the volatilization of the iron. The mass of hot air would be fairly driven into the sandstone and limestone strata by the first impact, and would then escape upward around the advancing projective, and be very efficient in removing the pulverized and shattered rock, and so in digging the crater." Professor Russell also considers it probable that many, if not most of the meteorites found in the uppermost layers of the débris, and all of those found on the open plain, fell directly from the sky, as stragglers following the main mass.

Summing up the principal theories advanced, Professor Russell has arrived at the following conclusion:

"*First*, that the crater was made by a great cluster of iron meteorites weighing in all not less than a million tons, for the cluster must have had very considerable superficial area or opposing surface.

"*Second*, that if the shale ball and other iron meteorites stripped off the cluster while it was penetrating the strata and carried backward out of the crater, especially those which were thrown out last, were saved from being volatilized by the cushion of compressed air, practically all the rest of the iron meteorites which remained in the cluster were likewise saved from such a fate.

"*Third*, that we have a very fair sample of the composition and general characteristics of the individuals composing the cluster in those torn off from its outer portions.

"*Fourth*, that probably upwards of ninety per cent. of the mass lies in the bottom of the crater or beneath the cliffs which form its walls. The mass of compressed air having escaped from in front of the projectile, it is conceivable that there would have been an opportunity for the individual meteorites composing that portion of the cluster which remained in the crater, to separate to a limited extent in the space dug by the compressed air in front of the cluster, while the flying fragments were still in the air, and before some of them settled back into the crater and filled its lower portion."

PILE OF METEORITES FROM THE DESERT NEAR GIDEON, S.W. AFRICA. THE PILE WAS SELECTED AND DEPOSITED IN THE PUBLIC PARK, WINDBOCK, PHOTO TAKEN, SEPTEMBER, 1929. THE SPECIMEN TO WHICH DR. SPENCER IS POINTING WITH HIS STICK, IS NOW IN THE NAT. HIST. MUSEUM, S. KENSINGTON.

CHAPTER XIII

METEORIC IRONS FROM SOUTH-WEST AFRICA

AT the *International Geological Congress* in 1929, a long excursion was made through South-West Africa, and the members of the Congress were accompanied part of the way by Dr. Paul Range formerly Government Geologist of German South-West Africa. On arrival at Windhoek he showed them a pile of meteorite irons, weighing over twelve tons, collected by him in 1911-12. At that time, he informed the members of the Congress, he accounted for fifty-one large masses with a total weight of over fifteen tons. Some of these had been exported to Germany, and there are large masses in the Museums at Hamburg, Frankfurt-on-Main, Bonn, Stuttgart, Berlin, Copenhagen, and Harvard University (Cambridge, Mass., U.S.A.). In the British Museum no large mass had so far been represented, but only fragments and slices, the largest weighing fourteen and a half pounds.

Naturally, when Dr. L. J. Spencer, Keeper of the Department of Mineralogy of the British Museum, who was one of the members of the Congress present, gazed upon the wealth of this display, and having seen two fine specimens of the meteoric irons in Cape Town and

Pretoria, he felt encouraged on arrival at Windhoek, to put in a plea for a specimen for the British Museum collection of meteorites at South Kensington. Needless to say his request was granted, and as he tells us, whilst refraining from selecting one of the largest pieces, he chose one which showed prominently the characteristic pitted and cavernous surface usual with meteoric irons. The piece selected weighs 299 lb., and measures 26×13×10 inches. This valuable donation from the Administration of South-West Africa was made by Mr. L. G. Ray, the Chief Inspector of Mines, September, 1929. The specimen is now on view at the British Museum (Natural History), and the writer happened to be present on the afternoon in August, 1930, when it was installed on its pedestal in proximity to the Otumpa meteoric iron, from Chaco, Argentina. If the two could talk they might have interesting conversations with each other, regarding their varied experiences in space, ere they finally landed on our planet.

On the railway journey made by Dr. Spencer from Luderitz Bay to Windhoek, and also on the return journey from Tsumeb to Cape Town, the train made a short stop at Gibeon. There, he had hasty interviews with the Stationmaster, Mr. P. James, and the Sergeant of Police on the subject of meteorites. They both independently informed him, that several large masses are still lying on the Kameelhaar farm, about twelve miles east of the Gibeon railway station, and

Mr. P. James gave him a specimen of the meteoric iron for the Museum collection.

In the account Dr. Spencer has given of the Meteoric Irons from South-West Africa, in the *Natural History Magazine*, Vol. II, No. 15, he tells us: that this mass is a complete specimen of good shape, and weighing only 195 grams; and is specially interesting on account of its small size. Although complete individuals of meteoric stones of small size—no larger than a pea—are not uncommon, complete *irons* of small size appear to be unusual, and possibly the latter may often be merely weathered remnants of larger masses. This little meteorit he carefully kept in his personal baggage, and on the return journey from Cape Town it gained for him the first prize at the fancy dress ball on board. Mounted on a disc of card (from a chocolate box) with the inscription "The Most Noble and Celestial Order of the Fallen Star", and suspended by a red ribbon (also from a chocolate box), it made a handsome decoration. Through the recommendation of Dr. Spencer, the meteoric irons which had been lying in the open on the Kameelhaar farm exposed to the weather, are now under cover in a museum building.

The masses of native iron in Great Namaqualand were first heard of in 1836, by Captain (afterwards General) Sir James Edward Alexander. They were known to the natives, who hammered fragments of the malleable metal for fashioning their weapons. In 1837, Captain Alexander reported finds of large masses up to two feet square on the east side of the Great Fish River, at a spot three days' journey north-east of the Mission Station of Bethany. Apparently he collected only chips of the iron, and one of these was used by Sir John F. W. Herschel for a chemical analysis. From the amount of nickel found, the latter was able to come to the conclusion that the iron was of meteoric origin. Another small chip weighing two grams was presented by Captain Alexander to the Geological Society of London, in 1838. This piece which afterwards came into the possession of the British Museum in 1911, appears to be all that has been preserved of Alexander's "Great Fish River" iron. Later, other masses were found between Bethany and Bersheba, on the Lion River, on the Springbok River; and near Gibeon on the farms Amalia, Goamus, and Mukerop. Although these names are mentioned, indicative of the separate irons, yet in all probability they all fell together.

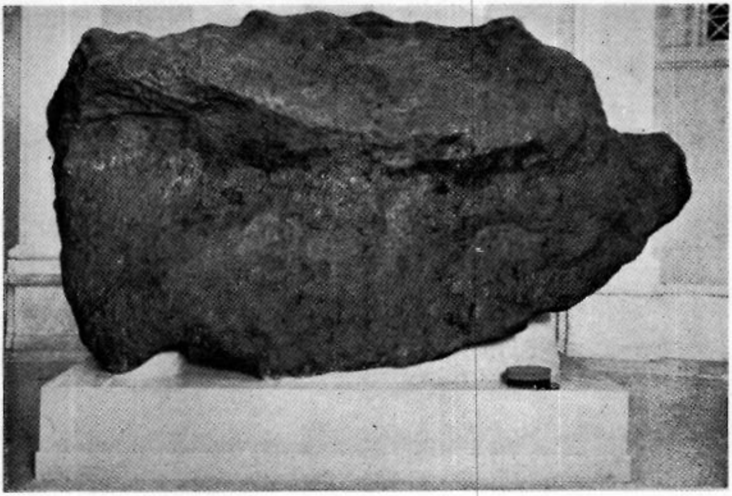
They have been found over a tract of country extending for almost a hundred miles from Bethany in the south south-west, across the Great Fish River, to Gibeon, in the north north-east. Chemical analysis shows the presence of about eight per cent of nickel alloyed with the iron, and polished and etched sections of the different masses all show much the same type of crystalline structure with prominent Widmanstatten (seemingly etched) figures. Undoubtedly, there must have been a terrific shower of these masses of iron, although there is no record of the actual fall. The inhabitants, if any there were at the time, must have been considerably alarmed, for although showers of meteoric stones have taken place during historic times, yet showers of iron are fortunately very rare. For example, near Poltusk in Poland, a hundred thousand stones weighing from 1 gram to 9 kilos, fell at 7 p.m. on January 30, 1868; and on the desert near Holbrook in Arizona, on July 19, 1912, at 7.15 p.m. there was a shower of about fourteen thousand stones, ranging in weight from a few grains to fourteen and a half pounds. Many complete stones from each of these meteoric showers are shown in the British Museum collection.

Since about 1920, a far larger mass of meteoric iron, dwarfing even the Cape York Meteorite the "Ahnighito" which weighs thirty-six and a half tons; and the Bacubirto meteorite iron, which lies where it was found in 1863 in Mexico, recent estimates placing its weight at twenty-seven tons; is the gigantic "Hoba" meteorite, which still reposes on Hoba West Farm, twelve miles west of Grootfontein at the end of the railway in South-West Africa. This mass was visited by Dr. Spencer in 1929, and as he remarked in connection therewith, he much regretted he was quite unable to collect it for the British Museum. He gives the following description, which with the illustration used with kind permission of Professor W. T. Gordon, gives some idea of its great size:

"It has the form of a roughly rectangular block with its large upper surface level with the surrounding ground. When first found only a small portion was exposed, but a pit has now been dug partly round the mass. It is embedded in surface limestone (Kalahari Kalk), and is surrounded by a layer one foot in thickness of laminated 'iron shale', which has obviously been formed by the weathering of the iron. A dozen people can walk round on the level surface of the meteorite. Measurements taken by me are 295× 284 cm. (about 10×9 feet) on the large flat surface, with a thickness at one end of 111-122 cm. and at the other end of 55-75 cm. From these measurements, I calculated the weight of the mass to be about 60 metric tons (or 2,204 lb.) Other estimates of the weight of the mass range from 50 to 70 tons."

Regarding the composition and structure of the Hoba meteoric iron, only a preliminary examination has yet been made. A chemical analysis gave 17.42 per cent. of nickel, and a polished and etched section showed traces of crystalline structure without Widmanstatten figures. This iron, therefore, according to Dr. Spencer, probably belongs to the group of "nickel-rich ataxites", whereas the Bethany (Gibeon) irons are classed as "octahedrites". The two are thus markedly different in character, and, apart from their widely separated localities, they evidently belong to different falls.

In the final paragraphs of his interesting account of



AHNIGHITO, THE GREAT CAPE YORK METEORITE. WEIGHT, MORE THAN 36.5 TONS. THE LARGEST AND HEAVIEST METEORITE KNOWN.

THE HOBA METEORITE. HOBA, NEAR GROOTFONTEIN, S.W. AFRICA. SEPTEMBER 1929.

meteoric irons in South Africa, Dr. Spencer calls attention to an enormous mass of meteoric iron, said to measure 100 metres in length, and forty metres in height, which it is stated have been found, together with smaller masses, in 1921, near Chinguetti in the Adrar desert, Mauretania, French West Africa. A piece of four and a half kilos sent to Paris was described by Professor A. Lacroix in 1924, but there has been no confirmation of the existence of the larger mass. A mass of iron weighing 130 lb., stated to have been found in 1922, near the village of Piedade do Bagre in Minas Geraes, Brazil, and believed to be meteoric, was submitted by Mr. N. Medawar in January, 1929, to the Mineral Department of the British Museum for examination. The following description of the mass fully confirms the supposition of its meteoric origin: "Meteorite found in 1922 given by a local native, to Mr. Medawar, in March of 1927, at a place about ten miles S.W. of the village of Piedade do Bagre in Minas Geraes, which is about 155 km. W.S.W. of Diamantina. As near as can be determined, the position of the find is given by 18° 56½′ S., long. 44° 59′ W."

Now let us see what happened to that meteorite, typical of the treatment of all meteors under observation, before its identity was fully established, and its claim to admittance to that class of celestial trove settled satisfactorily. The celestial emigrant had no passport to show, and had to depend entirely on its main characteristics such as chemical analysis would indicate, and its weight, measurement and general appearance. First it was weighed and measured, the weight being 130 lb., and the maximum dimensions in three directions at right angles were found to be $15\frac{5}{8} \times 12\frac{5}{8} \times 6\frac{3}{4}$ inches. It then had its photograph taken by the Museum photographer, Mr. H. G. Herring, and coloured plaster casts were made of it by Mr. P. Stammwitz, in the Department of Zoology. With Mr. Medawar's approval an end-piece was then sawn off, and from this a corner weighing nineteen grams was cut off for chemical analysis. After smoothing and polishing the two cut surfaces, the end-piece weighed $2,127\frac{1}{2}$ grams. This piece was generously presented to the Museum by Mr. Medawar. Sawdust and filings weighed about 100 grams, leaving the main mass at 125 lb. The general shape of the mass called for no special remark, and to the uninitiated might look not unlike any ordinary stone, but to those who make a study of such objects, there were certain peculiarities such as the broad, concave surface shown by most iron meteorites apparently the result of atmospheric weathering. A small amount of scale was detached in the process of weathering, and portions of the scale proved to be magnetic, attracting the filings from the mass. A full account of the stringent tests to which this meteoric iron was exposed, in the way of chemical analysis, is to be found in the *Mineralogical Magazine*, June, 1930, Vol. XXII, No. 129, pp. 271-282, for those who are specially interested in the subject, but is somewhat too technical for inclusion in a popular treatise such as this. At any rate, after all the usual tests had been applied, and the meteoric particle had "passed muster", we may feel certain that its claims to a celestial origin were firmly established. It can no longer be looked upon as an ordinary piece of iron, or a stone, but as a celestial wanderer in space, during the early period of its career.

One of the finds of special value, was that of the Mbosi meteoric iron discovered in October, 1930, by Mr. W. H. Nott, a land surveyor of Johannesburg who was making a geological survey of Tanganyika Territory, at a place ten miles south-east of the Mbosi Mission station in Rungwe (formerly Tangenburg) district. He was erecting a triangulation beacon near the spot where the meteorite lies exposed for some two feet above the surface of the ground. He ordered a native to go near the spot, but the native refused, explaining that to do so, he must pass a sacred stone. On making a search himself, Mr. Nott found the mass of iron. He promptly pegged the area as a base metal claim, and it was taken in charge, and put to the usual tests by the officers of the Geological Survey. The meteorite is roughly wedge-shaped, about 10 feet long, 3 feet wide, and 4 feet deep, and its mass is from 12 to 15 tons.

CHAPTER XIV

STORY OF THE GREAT SIBERIAN METEORITE

OUT of the solitude and wilds of north-eastern Siberia, comes the slowly unfolding record of one of Nature's great tragedies, which apparently occurred some thirty years ago. At the meeting of the *British Association for the Advancement of Science*, at Dublin, in 1908, there was a discussion on wave motion, during the course of which Sir Napier Shaw gave an account of several instances of wave motion revealed by autographic meteorological instruments. Among his illustrations was a diagram, technically called a microbarogram, showing a series of waves which occurred on June 30, 1908, between 5 and 6 a.m. Sir Napier commented on "the succession of four undulations commencing with a range of about five-thousandths of an inch, lasting about a quarter of an hour, and then violently interrupted by a sudden, though slight explosive disturbance, which set up different, and much faster oscillations for a similar interval. It would seem," he remarked, "that the disturbance if not simultaneous at the different places, travelled faster than 100 miles per hour."

It was not until Mr. C. J. P. Cave, to whom we owe the barogram from Petersfield, of the great aerial disturbance which was experienced in Siberia on June 30, had verified the date, that the source of the air waves shown on the English records was recognized. How it happened that the attention of the scientific world had not been drawn earlier to the fall of the great meteor is incomprehensible, but there seems to have been only one contemporary notice, and that in Russian. It is to be found in the Bulletin of the Central Seismic Commissions (of Russia) and is condensed into three short paragraphs. Translation of the last two is as follows:

"*June* 30, *Town of Kansk*—The first shock caused the doors, window and votive lamp to shake. Subterranean rumblings were heard. About five to seven minutes later there was a second shock accompanying the rumbling. A minute later there was a further shock less severe than the preceding two. It is stated that the earthquake was accompanied by the fall of a meteorite near the village of Dalaia. Peasants relate that seventy kilometres north of Kansk in the Ustianovski district, there was also an earthquake accompanied by subterranean rumblings.

June 30. *Kuriski-Popovich Village. District of Kansk*—At $0^{h}37^{m}$ a severe earthquake was observed in the vicinity of the village. After this there were two loud bursts like the firing of a large calibre gun near Lovat Village. It was afterwards found that a large meteor had fallen." As Greenwich Mean Time was used in the *Bulletin*, then the earthquake at Kuriski-Popovich must have taken place at about 7 a.m. by local time. The Director of the Irkutsk Observatory made inquiries, and ascertained that the meteor which produced all the disturbances must have fallen near the great river called Stony Tunguska which is some 600 km. from Kansk.

The next chapter in the story of the meteor occurred in 1921, when Leonard Kulik, a Russian geologist with two other scientists found means to go to Kansk to gather information, and to make plans for the expedition. A collection of reports were obtained, which showed how exceptional the phenomena of 1908 had been. From the lips of densely ignorant peasants came the story of what they saw on the eventful morning of June 30. They told of a great fiery body rushing through the air with a rumbling sound like thunder, spreading havoc and destruction in its wake.

According to a Tungus living on the Teter River, his brother (now an old man, speaking scarcely any Russian) was living some years ago on the Chambe River when a terrible explosion occurred. The force of the explosion was such that for many versts along the Chambe River trees were uprooted on both sides of the river. His brother's tent was hurled down, the wind carried away the top, deafened his brother, and dispersed his reindeer, which, when he had recovered his senses, he could not collect, except a very few of them.

In the part of the forest where the meteor fell, a big hole appeared from which a stream flowed into the Chambe River. The Tungus road formerly passed through this place; but is now abandoned because it is blocked and impassable. Furthermore, the natives are too terrified to go near the place, fearing they know not what. There are other reports regarding the uprooting of trees over an area which extended some 600 km. from the place where the meteorite fell. The way the trees had fallen indicated how the air compressed in front of the meteoric mass had blown outwards, the position of the trees in the forest when seen from a height presenting a fan-like appearance. They were lying prone, stripped of branches and bark, but here and there the bare trees are still standing, and there are places in which groves of trees have survived.

The actual spot where the meteorite fell is in a cup-like valley, and on the surrounding hills all vegetation had been burned. The central part of this burned area shows traces of lateral pressure which has produced folds and funnels, the sides of which are precipitous leading down to a mossy and marshy ground, sometimes with traces of rising ground in the interior. It is in many ways somewhat like the appearance of photographs of craters on the moon. Clearly each of the funnels contains a meteorite which has forced its way in, but to what depth is not known. Professor Kulik made an estimate of 130 tons for the total weight of the meteorites, but on what ground it is not stated.

According to his theory the cloud of incandescent gas in front of the meteor was carried right down to the ground instead of being dissipated in the atmosphere, as happens when a meteor loses its velocity at a great height. In the case of the Siberian meteorite, when the incandescent cloud reached the ground, the air was driven outwards on all sides. The place where the meteor fell is said to be about 100 km. north-west of Vanovara. The latitude and longitude are given as 61°N. and 71°E. of Pulkova. The stream from the crater-like valley falls into the Chushmo, which flows eastwards into the Chambe. We are told that Professor Kulik made the greater part of his laborious journey on these waterways.

When about 500 miles north of Taishet, a village on the Trans-Siberian Railway, which the members of the expedition reached only after weeks of perilous progress through dense undergrowth and swamp land, infested with snakes and insects, they began to find evidence of what they were in search of. Trees lay flat and charred upon the ground, and scattered here and there were scorched or whitened skeletons of deer which had been trapped in the conflagration. Thirty miles further on through increasing signs of desolation they came at last to the object of their search—the spot where it is believed the great meteoric mass or group of meteorites plunged downwards. Professor Kulik described the appearance of the ground as not unlike that of giant ridges or waves of water which doubtless arose from the central impact.

For a distance of ten to fifteen miles around them the country-side was scorched and scarred as though by a tremendous conflagration. The air pressure was evidently so great, that for an additional distance of ten or twenty miles, making a total of fifty or sixty miles in diameter on every side, hundreds of trees lay in concentric circles, each tree with its dead top pointing outward from the explosion. Had this gigantic meteorite fallen on any of our great modern cities, all life at the central point of contact would have been destroyed. Samples of the meteoric material which have been examined by specialists, are reported to be of a rare iron type.

The local effect of the air waves from the meteor have been variously described, although due allowance must be made for the fact that the evidence was obtained many years after the event. One witness at Vanovara told Professor Kulik "after the flame disappeared there was an explosion which threw me off my feet to a distance of seven feet or more. . . . The glass and frames of the window broke, and clods of earth were thrown up from the square in front of my hut." Another witness said that the door of the Russian stove flew out into a hammock on the far side of his room. The glass from the windows burst inwards, and afterwards there was a sound like the roar of thunder dying away to the north."

It must be taken into account, that Vanovara was not far from the region where the trees were uprooted and felled. The evidence indicates clearly, that as a result of the air waves from the meteor, there was a pressure wave which broke windows inward, which was followed by a suction wave, which forced clods out of the ground and hurled the stove door across a room. At Kejm, on the Angara, merely "a peal of thunder was heard, then another, the sound of which gradually died away northwards." At Murskoff Rapids, also on the Angara, there was such a cannonade, that all the workers on one of the boats rushed to the cabin for shelter, forgetting the danger threatening them at the rapids. The sounds, which gradually increased in intensity, lasted from three to five minutes. As for the boatmen, they were completely demoralized, which is not surprising, under the circumstances.

At a place called Boikit, somewhere to the north of the Stony Tungaska River near which the meteor fell, there was the sound of the firing of guns and loud peals of thunder which made the earth shake, the disturbance lasting about a quarter of an hour. The most distant point at which the sounds were heard was near Twurokhansk, almost on the Arctic Circle . . . "Away to the east I heard three or four dull thuds in succession like distant artillery fire. . . . It was impossible not to notice them," was the remark of one of those who heard the crash.

An account was also given of a number of striking incidents which occurred near Kansk. An inhabitant, I. I. Ilinski, now a stationmaster, was at Lialka Siding, when suddenly he felt what seemed to be a violent vibration of the air, and heard a loud noise. He told Professor Kulik that he was terrified, and that the engine driver of train No. 92, was so scared that he stopped the train, fearing it might be derailed. When he reached the siding he asked the stationmaster and others to examine the train to see whether some of the goods might have exploded.

A master tanner, named E. E. Saricheff, said: "I was washing wool with my workmen on the banks of the Kan River when all of a sudden I heard a noise like the whir of the wings of frightened birds . . . and downstream the waters of the river took on an undulatory movement. This was followed by one sharp thud, then dull noises like an underground roaring. The thud was so severe that one of the workmen fell into the water." Another witness in the same area, said that her husband was using horses for carting earth. The shock caused some of the horses to fall, but others kept their feet. An eye-witness stated that men and cattle twenty miles away were lifted in the air, and the earth shock was distinctly felt at the railway-station which was at a distance of 500 miles. At the University of Irkutsk, 1,000 miles distant the disturbance was registered on the seismograph, and supposed to indicate a minor earthquake at about that distance away. The disturbance the vibrations of which were propagated to the seismological stations, originated at $\overset{h}{0}\ \overset{m}{15}$ G.M.T. and the supposed earthquake was felt by the inhabitants at Kansk some thirty minutes later.

There are many marvellous features in the story of the Siberian meteor, a story without parallel in historic times. It is most remarkable that such an event should occur in our generation, and yet be so nearly ignored. No civilized man sought out the falling place of the meteoric mass for twenty years, and even now no one has followed up the track of the pioneer!

Fortunately, seismographs were in readiness to demonstrate that earth-waves can be produced by the impact of a meteor with the ground. Microbarographs had been invented just in time to preserve records of the air waves generated in the atmosphere. If the meteor had fallen even five years earlier there would have been no evidence for the spreading of the air waves beyond the immediate locality of the fall; if it had fallen twenty years earlier we should have known nothing here in England of the disastrous effect caused by the air waves. Fortunately, both seismograph and microbarograph were in readiness to receive the message, and convey it from the wilds of Siberia, to the Meteorological Offices at South Kensington, Leighton Park, Cambridge, Shepherd's Bush, and Petersfield. Air waves coming from Siberia would reach the stations in the order in which they have been written. The distance from Cambridge to Petersfield is about 160 km. (99 miles) so that the time of the passage of a wave travelling with the velocity of sound (about 1,100 feet per second) between these places would be eight minutes. "It would seem," to quote Sir Napier Shaw's remark at the Dublin Meeting in 1908, already referred to, "that the disturbance if not simultaneous at the different places, travelled faster than 100 miles per hour."

Incidentally, the microbarograph—the instrument by means of which the air-wave record was obtained, was invented by Sir Napier Shaw, and Mr. Dines in 1903. It consists of an aluminium bell which floats on mercury. The inside of the bell is in communication with a vessel containing air so that the movements of the bell are controlled by the difference between the pressure of the external atmosphere, and that inside the vessel. These movements are magnified by a lever. There is communication between the vessel, and the outer air through a capillary tube, so that the pressure inside and out are gradually equalized. The result is, that rapid changes of pressure are shown on a large scale, but slow changes are ignored. For rapid changes the scale is about twenty times that of a mercury barometer. The time scale is 0.6 inch to the hour.

CHAPTER XV

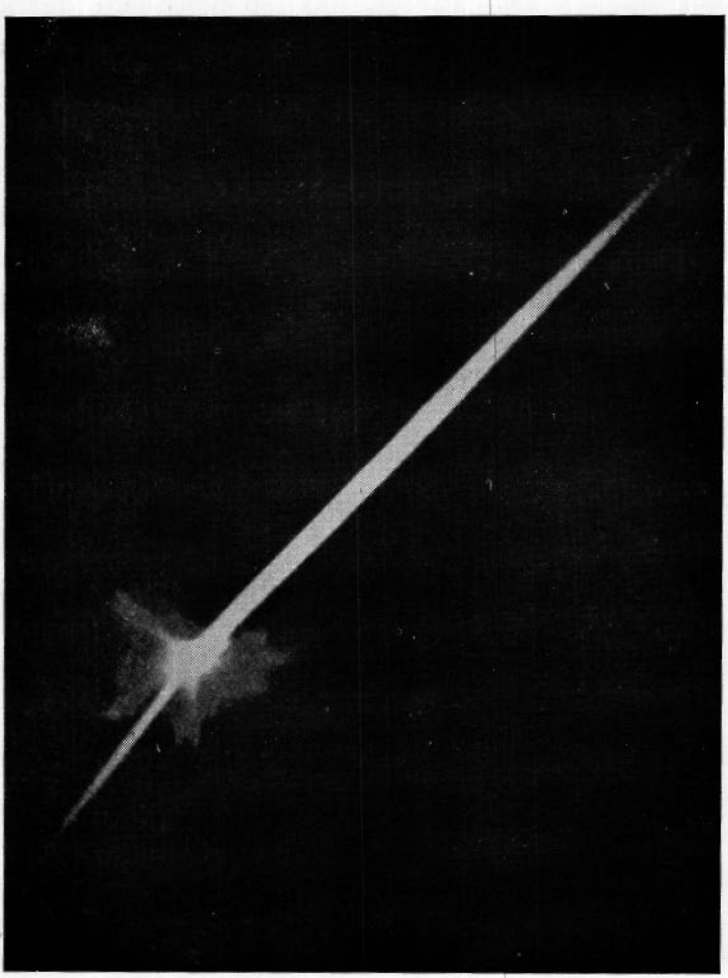
SHOOTING-STARS AND STREAMS OF METEORS

A CAREFUL observer looking for any long interval of time towards any quarter of the evening sky, is almost certain to catch a fleeting glimpse of a shooting-star; sweeping silently and swiftly across the depths of space and vanishing from view in a brief interval of time. Now on one side, now on the other, he will see these pale gleaming lights on any clear night, with an average of six shooting-stars an hour. More appear after midnight, the most favourable time for observation being from 1 a.m. to 3 a.m. especially in tropical regions where shooting-stars and meteors shine far more brilliantly than in our northern latitudes. This peculiarity is due doubtless to the purity and serenity of the air within the tropics. In writing of the transparency of the dry atmosphere of Bokhara, a place not farther south than Madrid, but raised 1,200 feet above sea-level, Sir Alexander Burns remarks: "The stars have uncommon lustre, and the Milky Way shines gloriously in the firmament. There is also a never-ceasing display of the most brilliant meteors which dart like rockets in the sky; ten or twelve of them are sometimes seen in an hour, assuming every colour; fiery red, blue, pale, and faint."

Many of these sudden apparitions come and go in the twinkling of an eye, while others leave a luminous trail in the sky for a brief second or so and then swiftly vanish from sight. Apparently a star has fallen from its place in the sky, but to call these transient shining objects which sparkle and fade out so rapidly by the name of star, is a libel upon the glorious suns which shine so brilliantly in infinite space. As we have already seen, some of these transient visitors which plunge through the atmosphere at our planet, coming to rest on its surface, are masses of stone or iron, weighing tons, but fortunately for us these are extremely rare, and moreover have a way of selecting regions such as the Siberian wastes, the desert regions of Arizona, or Western Africa for their final resting place. But the shooting-stars of daily occurrence are usually specks of cosmic dust travelling with an average velocity of about thirty miles a second, the friction caused by their collision with particles in the atmosphere making them at first red-hot, after which they melt and are reduced to vapour. Such particles rarely fall to earth, since they are consumed usually in the upper layers of the atmosphere.

In our northern climate most of the shooting-stars are white, a few are yellow or orange-coloured, while others are tinged with a green or bluish tint, so that in many cases we are actually able to recognize them by their colour, as belonging to well-known systems or swarms of meteors. "Whence come these uncounted millions of bodies, rushing through space with inconceivable velocity? What purpose do they fulfil in the economy of the solar system? Are they the chips in the great workshop of Nature," queried R. A. Proctor, in an article on the subject, "the sparks which have flown from the mighty grindstone, the shreds of clay which the giant potters, Attraction and Repulsion, have cast aside as useless?"

Fireballs are less common, but far more effective in appearance than shooting-stars, and many of them are splendid objects blazing out suddenly with a brilliancy often exceeding that of the full moon. The photograph here reproduced of an exploding meteor in Andromeda, obtained by C. P. Butler, F.R.A.S., November 23, 1898, and taken with a 2-inch lens, shows a magnificent specimen, resembling a sword brandished aloft in the sky. Sometimes fireballs look like miniature comets, with trains extending outward from the nucleus. Their motion is often a series of wavelike undulations, resembling the coils of a serpent apparently winding in and out among the stars. They can be seen rapidly changing in form, and usually disappear with a loud, explosive noise. Occasionally a meteor breaks up into a number of distinct fragments each adorned with a minute train; while luminous fireballs have a way of breaking up into miniature globes which swell out and burst, pouring



EXPLODING METEOR
THIS LARGE METEOR EXPLODED IN THE AIR WHILE ITS TRAIL WAS BEING PHOTOGRAPHED (PHOTOGRAPHED BY C. P. BUTLER).

forth smoke and vapour along their tracks, after which they shine with renewed lustre and finally disappear. In some instances, we are told, the crash of explosive fireballs has been so great that "houses tremble, doors and windows open, and men imagine there is an earthquake."

In the Middle Ages, the phenomena presented by shooting-stars, were supposed to be due to exhalations in the upper regions of the air; but whatever these objects are, the writers of those days and even in more recent times were positive that they were in no way to be regarded as astronomical. They were not even supposed to belong to the solar system, until 1872, when their claim for membership in that family, consisting of the sun, planets and comets, was firmly established by Signor Schiaparelli of Milan, who had exceptional opportunities for observing them in all their beauty as they flashed into view in the clear Italian skies. As a result of his research work in Meteoric Astronomy, he was able to prove beyond a doubt that there is a definite connection existing between comets and streams of meteors, and in recognition of his work in this direction, he was awarded the Gold Medal of the *Royal Astronomical Society*, in 1872.

Schiaparelli had observed that when the earth arrived at a particular part of her orbit corresponding to August 10, she came across a swarm of meteors at this stage of her circuit round the sun. Whenever she crossed that particular point, one might be assured of such a display. It is precisely as though a person who travelled continually on a certain road noticed that at some section some peculiarity such as a gust of wind was usual. The phenomenon might be described as purely local in its nature, peculiar, in fact, to that particular part of the road: so we, in our journey with the earth along a circular path around the sun, may be absolutely certain, that when we come to the section of the earth's orbit where it is due on August 10, we may expect a display of meteors bombarding our planet from the direction of the constellation Perseus, hence their name of Perseids. It had been noticed in very early times that a display of meteors nearly always occurred on this date, which is called St. Lawrence's Day in calendars. For this reason, the meteors which fall on August 10, have been called "the tears of St. Lawrence".

Schiaparelli set himself the problem, of finding out why this cloud of meteors so persistently presented itself in this region of the sky, on this particular date. Each meteor is as surely acted upon by the sun's mighty influence, as this earth on which we live; and like the earth its safety lies in motion, otherwise it would be attracted towards the sun's surface, and annihilated. Meteors must also keep above the atmospheric net spread so invitingly around our planet, if they would avoid disaster, otherwise too near an approach means destruction; a sudden blaze of evanescent glory revealing their presence as they rub against every particle they meet on the way; then instant annihilation as they fade into obscurity. The real velocity of the August meteors as they take their final plunge cannot possibly exceed thirty miles per second. Their orbit is in the form of a closed ring within which they travel in a definite direction in a period of one year, other meteors following in their track. Many millions of miles separate the first set from those seen later; and the inference is, that along the whole range of those millions of miles there are meteors travelling at the same speed in the same direction and always along a definite track, the meteors seeming to fall from one and the same part of the celestial sphere, though the earth is travelling rapidly onwards. Thus, the shower *radiates* from a determined point of the star-sphere enclosing the earth on all sides.

After ascertaining these facts concerning the August meteors, Schiaparelli went a step further by speculating somewhat daringly, that the orbit of the August meteors closely resembled that of the path of the great comet of 1862. Observing that the comet passed close to the earth's orbit on a course somewhat resembling that of the August meteors, he came to the conclusion after careful consideration of the motions of the comet of 1862, that if the earth had been close by the point where her orbit is crossed by the comet, when it actually traversed that point, the comet's course would have seemed to be directed from the radiant of the

August meteors. Schiaparelli was assured that the actual course of the comet as regards velocity and direction was identical with that of the August meteors, from which he was assured that the comet of 1862 and the August swarm of meteors were closely allied.

Meanwhile, J. C. Adams, the discoverer of the planet Neptune, had been making valuable researches regarding a swarm of meteors moving in a long ellipse with a period of thirty-three years. In 1864, H. A. Newton (U.S.A.), showed by an examination of old records, that there had been a number of great meteoric showers in November, at intervals of thirty-three and thirty-four years, and he confidently predicted a repetition of the shower on November 13-14, 1866, and the prediction was fulfilled. Shortly after, Schiaparelli had published his paper regarding the August meteors and their relationship with the comet of 1862; Leverrier published his orbit of the Leonid meteors so termed because they radiate from a point in the constellation Leo. Almost at the same time, but without any idea of a connection between the orbits, Oppolzer published his orbit of Temple's comet of 1866, which was at once seen to be identical with that of the Leonids. A single such coincidence might be accidental, but scarcely two. Five years later an agreement was found to exist between a shower of meteors which fell on November 24, called the Andromedes, because they radiate from a point in the constellation

Andromeda; and still another swarm of meteors connected with the comet known as Biela's Comet after the name of its discoverer. Here, again, a relationship was shown to exist between certain well-defined swarms of meteors, and—what might be termed—their parent comet. As time passed on, a careful comparison of meteor showers emanating from a certain point in the constellation Aquarius in early May, showed that they were connected with Halley's Comet. After that, and following the discovery of many other comets and their accompanying swarms of meteors either preceding or following in their wake, proving the relationship between the two, all doubts on the subject vanished. The wonder is the problem remained so long unsolved, now that the facts are known, but when one considers the utter insignificance of these momentary flashes in the evening sky, it is not surprising that scientists were loth to connect them with comets, the most stupendous objects we are able to see in the sky at comparatively close range.

When a comet is first seen, it is usually so faint that it can be detected only by means of photography, or with the aid of powerful telescopes. For instance, in the case of Halley's Comet at its return in 1909, after an absence of seventy-five years, it was first detected on a photograph taken by Herr Wolf at the Heidelberg Observatory. The news was cabled to the leading Observatories announcing the fact on September 12, and was followed on September 15, by a message from the Lick Observatory, Mount Hamilton, California, to the effect that a photograph of the Comet had been obtained by Dr. Heber. D. Curtis with the aid of the Crossley reflector. On Wednesday morning, September 15, Professor S. W. Burnham, a member of the staff of the Yerkes Observatory, at Williams Bay, Wisconsin, sighted Halley's Comet by means of the great refractor with its forty-inch lens, while at the same time it was photographed with the two-foot reflector in an adjacent dome, by Dr. Oliver J. Lee. The Comet was again detected by Professor Burnham the following morning, September 16, and it was again registered on the photographic plate by Dr. Lee.

The next day, the writer arrived at Williams Bay as a guest of the Barnards, and that night the great 40-inch refractor, the largest in the world, was in the care of Professor Barnard who courteously invited her to come to the Observatory next morning at 3 a.m. escorted by his niece Miss Calvert, for the purpose of looking through the telescope, and obtaining a view of Halley's Comet. Making a first visit to the Observatory in the darkness preceding dawn was a novel experience in itself, but the glimpse of the Comet after its absence of seventy-five years is one never to be forgotten, nor is it easy to describe. For the first second or so, all seemed darkness down the length of that great tube (63½ feet in length), but presently a faint, very misty outline as of a minute cloud could be seen. That was the Comet.

By May 4, 1910, this faint misty cloud had developed into a full-grown Comet, with a nucleus shining as a star of about the second magnitude, and surrounded by envelopes of gaseous material expelled from the nucleus. Extending outward like the beam of a searchlight gleamed the train nearly fifteen degrees in length, or three times the distance between the Pointers in Ursa Major. A glance at the photograph of the Comet showing an extension of the train to 200 degrees, obtained that same morning by Professor Barnard with the great refractor at the Yerkes Observatory will give some idea of its splendour. On May 19, we are said to have passed through the train of the Comet as it swung round the Sun from the eastward to the western sky. A photograph taken on June 9, gave evidence of a fainter and smaller comet accompanying the larger, from which we are led to infer that at its next return in 1985, it may present the appearance of two comets sailing along side by side, though separated by a distance of millions of miles. Meanwhile the Comet has been receding in space, gradually losing the fragments which formed its train, and by now it has passed beyond the orbit of planet Neptune in the same undecorated condition—as when it was first seen in 1909. In 1943, it will be rounding the curve of its long ellipse for the return journey sunward, coming within view of the inhabitants of our planet about 1985, when it will be crossing the orbit of Jupiter. The wonder is, that it is possible to follow the movements of a comet long after it has passed beyond the reach of the most powerful telescope, and is far too faint to record its image on a photographic film.

What has all this to do with meteors, one may ask, and the reply is, that swarms of meteors which have been identified as closely related to comets, are undoubtedly the débris or fragments which help to form the train of a comet as it approaches the sun. The nearer it approaches the Ruler of the Planetary System, the longer its train. No débutante about to be presented at Court, could adorn herself with a train of such splendour, millions of miles in length, and composed of myraids of particles reflecting the golden light of the sun. As the comet recedes from the neighbourhood of the sun, it gradually discards the particles which had been driven forth from its nucleus by the intense heat and repelling force of the sun, thus forming this magnificent train which later on is dispersed in fragments along its track. Coming in contact with others thus dispersed at previous journeys of the comet outward in space, they combine, forming streams or swarms of meteors, such as that of the Aquariids I of early May, which is related closely to Halley's Comet. This meteor swarm moves in a parallel path with that Comet, though actually separated by several million miles from its orbit. It is of interest to keep this fact in mind, on the dates when it may be possible to see fragments of Halley's Comet, Tuttle's Comet of

1862, Tempel's Comet of 1866, and Biela's Comet, represented respectively by the meteoric displays of Aquariids I, the Perseids or the Leonids scattered along the pathway of the Comets of which they once formed part.

It is likewise of interest to look back down the corridors of Time, and visualize the previous displays of meteors, having in mind their origin as part of what must have been a magnificent comet in bygone days. The earliest known account of the Leonids dates back to the year A.D. 902, and was given by one of the Saracen historians, who records the month as October of that year, when the following event occurred:

"On the night of the 12th, when King Ibrahin-Ben-Ahmed died, it is mentioned by Conde in his Arabian history that an immense number of falling stars were seen to spread themselves over the face of the sky like rain." The vivid impression produced by this spectacle was long remembered, and the year in which it happened was thereafter known as "the year of stars". In A.D. 934, Chinese, Arabian and European chronicles, all speak of a display which seems to have taken place on October 14. In a Chinese record, the date of the display is given as October 15, A.D. 1002; while in A.D. 1101, the chronicle of St. Maxentius states, "17 Octobre. Visa sunt stellae de coelo cadere". In A.D. 1202, the Saracen writers record a very remarkable shower which occurred that year on October 18, when it is said: "Stars shot hither and thither, and flew one against another like a swarm of locusts. This phenomenon lasted until dawn. People were thrown into consternation, and cried to God the Most High with confused clamour. There was never seen the like, except on the coming out of the Messenger of God, on whom be benediction and peace!" There is also a Portuguese record of a remarkable shower which took place in A.D. 1366, probably on October 22, three months before the death of the King of Portugal, Pedro I, when "there was in the heavens a movement of stars such as man never before saw or heard of. At midnight and for some time after, all the stars moved from the east to the west, and after being collected together, they began to move in one direction and others in another. And afterwards they fell from the sky in such numbers and so thickly together, that as they descended low in the air they seemed large and fiery, and the sky and air seemed to be in flames, and the Earth as if ready to take fire." Fortunately, nowadays Science has partially dispelled the feeling of alarm at such a display, and notice is given in the daily press well ahead of the expected event, with advice as to the date, and when and where to look for the shooting-stars, providing the clouds do not conspire together to hide them from view. Thus, Science not only enables us to trace back the records of these showers in the past, as in the case of Chinese records dating back to the ninth century and earlier, but it can inform us authoritatively what may be expected in the future, even centuries ahead of the present time.

To give an idea of what we may expect, as the date of the November meteors draws near, the following account is given of a display of Leonids which occurred on November 12, 1799, by the famous traveller Humboldt and his companion Mons. Aimé Bonpland, while travelling in South America. Mons. Bonpland had risen early to enjoy the freshness of the air when his attention was attracted by a large number of falling stars of an extraordinary kind which he saw in the eastern sky. For over two hours, thousands of fireballs and shooting stars became visible, and so numerous were they, that throughout the night the heavens seemed filled with them at every moment. Their long luminous streaks remained visible for seven or eight seconds, while many blazed out suddenly, and then swiftly vanished from sight.

Many of the falling stars on this memorable occasion had a very distinct nucleus which flashed sparks of vivid splendour. Several fireballs appeared to explode, but the largest disappeared without emitting sparks. As the inhabitants of Cumana had risen before four o'clock to attend the first Mass, they were witnesses of these phenomena, which excited great alarm in the minds of the older inhabitants who called to mind that the dreadful earthquake in 1766, had been preceded by similar appearances in the sky. As the morning advanced, the meteors became more rare, yet for a quarter of an hour after sunrise, a few were seen flashing with a splendid white light, and were easily distinguished by the rapidity of their motion.

While engaged in their great expedition to the Rio Negro, Humboldt learned that the display of meteors had been observed as far as the borders of Brazil beneath the equinoctial line, and those who had seen them compared them to artificial fireworks. On their return to Europe, the scientists were informed that meteors had been visible on November 12, over a large portion of the earth, comprising sixty-four degrees of latitude, and ninety-one degrees of longitude, for they had been seen as well from various parts of the American continent, between the equator and Labrador, likewise in Greenland. From these facts it was possible to estimate that the height of the meteors above the earth's surface, exceeded 1,400 miles. It was also inferred that many must have fallen into the sea between Africa and South America to the west of the Cape Verde Islands. Humboldt was of the opinion that meteoric displays are apt to be more frequent in the tropics than in the temperate zone. His description of the shower attracted the attention of the scientific world, and his theory that nearly all such phenomena are periodic gave reason for hoping that the cause thereof might be discovered. Observations of meteors began to be systematically made in England, and records of meteoric displays in France were searched bringing to light the fact, that no less than ten returns of the November meteors had already been made, a period of thirty-three years elapsing between each return visit.

By this time popular interest had been aroused with regard to the possible return of these meteors in 1830, and early in November of that year, Dr. Lardner who had been on the lookout, recorded that meteors were sufficiently numerous as to attract special attention. In 1831, the shower of meteors had increased in intensity, and according to the noted French astronomer Arago, at 4 a.m. on November 14, the sky being perfectly cloudless and a copious dew falling, "we saw a number of shooting-stars and luminous masses. During upwards of three hours more than two per minute were seen. One of these meteors which appeared in the zenith, left an immense train like a luminous band reaching from east to west, and the colours of the rainbow were distinctly visible. The breadth of the luminous band was equal to one half of the Moon's diameter, and the light it gave did not disappear for many minutes. We were then on the coast near Carthagena."

The display of November meteors was repeated in 1832, according to the following record of Captain Hammond at Mocha, on the Red Sea: "From one o'clock a.m., till after daylight, there was a very unusual phenomena in the heavens. Meteors were bursting in every direction. The sky was clear at the time, the moon and stars were shining bright, while the sky was interspersed with streaks of light and thin white cloud. On landing in the morning, I inquired of the Arabs if they had noticed anything unusual. They said they had been watching the meteors most of the night. I then asked them if ever the like had appeared before. The oldest of them replied that it had not."

At Limoges, a retired officer stated that on the night of November 11, 1832, the workmen engaged in laying the foundation of a new bridge near the River Vienne observed the heavens ablaze with meteors, which at first aroused their interest, but after some hours the number and splendour of these luminous bodies were so greatly increased, that the ignorant and superstitious feared that the end of the world was at hand. On being questioned next day as to what they had seen, their accounts varied to such a degree that one can gain some idea of the impression produced on the imaginative. Some declared they saw streams of fire in the sky, moving downwards in all directions, so that they were in constant fear of the flying rockets falling upon them. Others beheld bars of red iron crossing each other, and all agreed that the phenomena was diffused over every part of the sky, from 11 o'clock at night, until 4 o'clock the next morning.

CHAPTER XVI

RETURN OF THE LEONIDS IN 1833, 1866, AND 1899

AT the return of the Leonids in 1833, Professor Denison Olmstead, of Yale College, U.S.A., in narrating his experience, stated that it was impossible to do justice to an account of the display. To form some idea of the phenomena, let the reader imagine a constant succession of fireballs, gigantic rockets, radiating in all directions from a point in the heavens. As they radiated from that direction outward, the lines along which they moved if produced upwards would have all met in the same part of the heavens. Just before the celestial fireballs disappeared, they were seen to explode though no report of any kind was heard.

The shower in 1833, attained its maximum on November 12, presenting a spectacular appearance which baffles description. Words fail to convey the vivid aspect of the heavens, which literally seemed ablaze with shooting-stars. At Boston, U.S.A. the display continued for a period of several hours, and it was estimated that during that interval, at least 234,000 meteors were seen. In England, as might be expected, the night was cloudy as is usually the case in November, and nothing unusual was observed; but along the whole of the eastern coast of North America, from the Gulf of Mexico to Halifax, the shower was well observed, and even the glow at dawn as the sun rose above the horizon failed to end the wondrous sight, brilliant meteors continuing to flash forth in the full light of day.

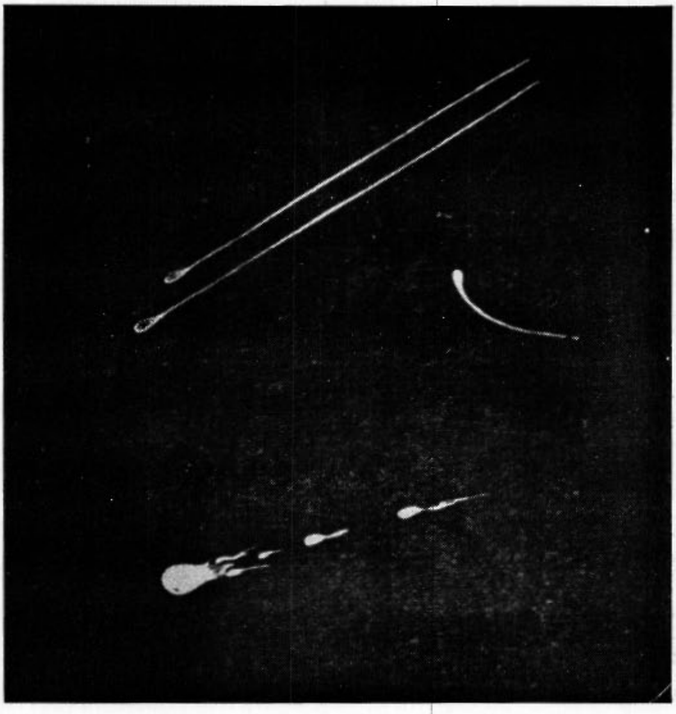
About 5 a.m. on November 13, the meteors fell so thickly, that observers said they were equal in number to one-half the flakes which fill the air during an ordinary snowstorm. One observer is said to have estimated that during the interval from 4 to 6 a.m., about 1,000 meteors might have been counted per minute. Not a cloud obscured the broad expanse of sky, giving full view to thousands of meteors as they sped on their way. We are told, that they fell as thickly as flakes in the early snows of December. One fireball was witnessed which left a path of light that was clearly discernible for more than ten minutes after it had exploded. Compared with the splendour of the display witnessed on this occasion, the most brilliant artificial fireworks bore less relation than the twinkling of a star in the broad glare of the sun at noon.

The shower was witnessed from the West Indies to Canada, and from 60° to 100° West longitude, according to Professor Kirkwood who was one of fortunate observers. Not only astronomers but the villagers who had a clear view of the heavens, were attracted by the shooting-stars which could not fail to attract the attention of all those who happened to be out-of-doors. From 2 to 6 a.m., the meteors were so brilliant that people sleeping in rooms with uncurtained windows were awakened by the flashes of light, and some declared these rivalled the Moon in size.

An illiterate farmer on the afternoon of the day succeeding the shower, on describing his impressions of the display, told Professor Kirkwood, that "the stars continued to fall till none were left," adding, "I am anxious to see how the heavens will appear this evening, for I believe we shall see no more stars." He was evidently unaware of the wide distinction between falling stars and fixed stars, which is not unusual. (The writer well remembers when twelve years of age, being soundly scolded by her teacher, for saying she had a bit of a star at home, which proved to be a meteorite—but was referred to as a particle of a shooting-star, a confusion in terms.)

In 1833, the fall of meteors created a feeling of terror among the negroes of South Carolina, which was described as follows by a planter, conveying some idea of the effect this startling display had upon these people: "I was suddenly awakened by the most distressing cries that ever fell on my ears. Shrieks of horror and cries for mercy I could hear from most of the negroes of the three plantations, amounting in all to about 600 or 800. While earnestly listening for the cause I heard a faint voice near the door calling my name. I arose, and taking my sword, stood at the door. At this moment I heard the same voice still beseeching me to rise, and saying: 'The world is on fire!' I then opened the door, and it is difficult to say which excited me most—the awfulness of the spectacle, or the distressed cries of the negroes. Upwards of a hundred lay prostrate on the ground—some speechless and some with the bitterest cries, but with their hands upraised, imploring God to save the world and them. The scene was truly awful, for never did rain fall much thicker than the meteors fell towards the earth; east, west, north and south it was the same."

Dr. Lardner says the phenomena was witnessed from the Atlantic Ocean to Central Mexico, and from the North-American Lakes to the southern side of the Island of Jamaica. "Everywhere within these limits the first appearance was that of fireworks of the most imposing grandeur, covering the entire vault of heaven with myriads of fire balls resembling sky-rockets. The meteors exhibited, on closer inspection, three distinct varieties—the first, consisting of phosphoric lines, apparently described by a point; the second, of large fire balls, that at intervals darted along the sky leaving numerous trains which occasionally remained in view for a number of minutes, and in some cases for half an hour or more; the third, of undefined luminous bodies which remained nearly stationary for a long time." During this brilliant display the fact that the meteors radiated from a point central in the sickle-shaped group of stars in Leo was



CURVED DOUBLE METEOR, AND A FIRE BALL
(FROM A DRAWING BY W. F. DENNING OF BRISTOL).

plainly discernible, and the position of this centre was accurately determined by Professors Olmstead and Aiken.

In 1834, November 12, Professor A. C. Twining of West Point, New York, saw many meteors radiating from Leo. They were also noticed at other places in America, too numerous to be mentioned. In 1835, November 13, meteors were again observed at the hourly rate of about forty or fifty, and in diminished numbers as compared with the display of 1833. An unusual number was recorded at several other stations, and Sir John Herschel observed a fine display at the Cape of Good Hope, on the night of that same date. In 1836, November 12, Mr. Dunster, Springvale, Maine, U.S.A., saw 253 meteors, in a watch extending over two and three-quarter hours. At Randolph College, Va, 500 were seen on this date, and 400 at Newark, New Jersey. In 1837, November 12, Professor Olmstead reported 226 meteors seen by eight observers at New Haven, Connecticut, between 1.05 a.m. and sunrise. At another station, fifty-two were counted by one observer during the period of an hour and a quarter.

In a letter to the *Times*, dated November 12, 1838, Mr. R. C. Woods of London, relates that from 3.25 to 3.55 a.m. "nothing could exceed the grandeur of the heavens. From E.N.E. to N., meteors fell like a shower of bomb-shells in a bombardment, and in such rapid succession as to defy every attempt to watch their particular directions, or to ascertain their numbers. At 3.55, the shower ceased." Mr. Woods estimated that he saw 400 or 500 meteors during the half hour. On November 13, eight observers at Cambridge, Mass: counted 233 meteors, during the course of four and a quarter hours. In 1839, November 12, the fact that 120 meteors were observed by Heis at Aachen, from 7 h. 28 m. to 12 h. 7 m. indicated that our planet was still passing through the swarm of meteors, these several showers representing well-defined returns of the Leonids, though not to be compared with the splendid display of 1833. These displays were repeated in November for a few years, until the earth had traversed the stream and pursued its way beyond the region near the meteor swarm. Whenever the earth reaches the part of its course where the display of Leonids may be encountered, then it happens that though the whole of the great shoal has completely passed the review point as observed from our planet, yet there are always a few stragglers scattered along the route. Thus, in 1833, the meteors were scattered so widely that minor displays of shooting-stars occurred in consecutive years, but as the intermediate period was reached after a lapse of sixteen or seventeen years where they came to the bend of their curve, before they started on their return journey, their number had dwindled considerably until only a few were to be seen. In another sixteen years they again increased in number until they had completed one more journey in their long drawn-out ecliptic orbit around the sun, and once more as we shall see, a brilliant display occurred.

The magnificent procession of Leonids in 1833, may be said to have heralded the dawn of meteoric astronomy, for the event was so striking that this hitherto neglected branch of astronomical work aroused the earnest attention of astronomers, especially when in 1864, Professor H. A. Newton, of Yale College, Princeton, U.S.A., predicted a repetition of the shower of Leonids in 1866. His prediction was amply fulfilled to judge from the account given by Sir Robert S. Ball, of what happened on the night between November 13, and 14, when the earth once more plunged into the densest part of the shoal of meteors:

"The night was fine; the moon was absent. The meteors were distinguished not only by their enormous multitude, but by their intrinsic magnificence. I shall never forget that night. On the memorable evening I was engaged in my usual duty at that time, of observing nebulae with Lord Rosse's great reflecting telescope. I was of course aware that a shower of meteors had been predicted, but nothing that I had heard prepared me for the splendid spectacle so soon to be unfolded. It was about ten o'clock at night when an exclamation from an attendant by my side made me look up from the telescope, just in time to see a fine meteor dash across the sky. It was presently followed by another, and then again by others in twos and in threes, which showed that the prediction of a great shower was likely to be verified. At this time the Earl of Rosse (then Lord Oxmantown) joined me at the telescope, and after a brief interval, we decided to cease our observations of the nebulae and ascend to the top of the wall of the great telescope, from whence a clear view of the whole hemisphere of the heavens could be obtained. There, for the next two or three hours, we witnessed a spectacle which can never fade from my memory.

"The shooting-stars gradually increased in number until sometimes several were seen at once. Sometimes they swept over our heads, sometimes to the right, sometimes to the left, but they all diverged from the east. As the night wore on the constellation Leo ascended above the horizon, and then the remarkable shower was disclosed. All the tracks of the meteors radiated from Leo. Sometimes a meteor appeared to come directly towards us, and then its path was so foreshortened that it had hardly any appreciable length, and looked like an ordinary fixed star swelling into brilliancy, and then as rapidly vanishing. Occasionally luminous trains would linger on for many minutes after the meteor had flashed across, but the great majority of the trains in the shower were evanescent. It would be impossible to say how many thousands of meteors were seen, each one of which was bright enough to have elicited a note of admiration on any ordinary night."

A fine display was seen in England, when 100 meteors were visible per minute to one observer at about the time of maximum, which occurred at 2 h. 10 m., but showers of considerable brilliancy were also observed in 1867 and 1868 in America. In 1867 the weather was cloudy in England, but in 1868 a display of fine meteors was seen at Greenwich on November 13, after 3 a.m., though clouds greatly impeded observation. The Leonids were observed by Mr. Bradford at a place fifty miles N.N.W. from Pekin in China, on the morning of November 15, 1867, or some twelve hours after the maximum display had been observed at various places in the United States.

Conspicuous displays of Leonids seemed to have come to an end, after 1867, but those enthusiasts who continued their watch for meteors during the wee sma' hours in November never failed to see a few swiftly emerging from the Sickle-shaped group on Leo. As the time for the expected return of the Leonids in 1899 approached, more meteors were seen—as for instance, in 1897, and 1898, at any rate enough to raise the hopes of those who were looking forward to a return of the displays of 1833 and 1866. Unfortunately, the display in 1899, was a great disappointment, in U.S.A., despite the energetic efforts of Professor Olivier, at that time Director of the McCormick Observatory, Virginia. He had carefully organized six parties of two observers each, which were scattered at intervals along a line some forty miles in length running north and south through the Observatory itself. These parties were equipped with cameras, and the usual maps, with a carefully arranged programme, and all taking part in the scheme were keenly enthusiastic.

Alas! the night was cloudy, and observations could be made only for short periods of time of glimpses of the sky through openings between the clouds. Only seven meteors in all were recorded on that occasion, the next night was cold and brilliantly clear, and observations were carried out from midnight to dawn, netting only twenty meteors fourteen of which were Leonids, the remainder being intruders. "It is true," as Professor Olivier remarked, "that at other stations throughout the world a few more were seen, but nothing that by the wildest stretch of imagination could be called a shower."

The writer's experience in 1899, while watching for Leonids with two friends from the roof of an apartment house in New York City, was equally disappointing. The bright moonlight was undoubtedly to blame in the earlier part of the watch, but our record, all told, was only sixty-eight. Where were the thousands we had been led to expect? Never was dawn so welcome to the weary observers, whose enthusiasm was not nearly so chilled by the cold November night, as by the disappointment in connexion with the expected display. We were advised to make another attempt the following year, but only forty-four Leonids were seen between midnight and dawn of November 13-14, and seven of these were intruders. In 1902, the display of Leonids was a great improvement on that of the two preceding years. The cause of the failure was attributed by some to the disturbing influence of the planet Jupiter, which was said to have switched the meteors temporarily off the direct route. Instead of running smoothly along the prescribed track, the Leonids undoubtedly swerved aside sufficiently to turn them away from the main track in 1898 and 1900. Great expectations were entertained concerning the possibility of a display of Leonids in November 16-17 (the radiant having slightly shifted), in 1931, but nothing of special importance happened, though hundreds were on the watch for possible meteors on that occasion. Dr. A. C. D. Crommelin, in his report given at the Meeting of the British Astronomical Association on November 25, 1931, remarked that on the night of November 16-17 he kept a fairly continuous watch up till 1 a.m., after which he contented himself with short glimpses at hourly intervals. The sky was tolerably clear at one o'clock, but deteriorated later. He did not see any meteors. His observations were made at Greenwich. The writer had the same experience while observing at Norwood from 11 p.m. to 1.30 a.m. However, Mr. Prentice, the Director of the Meteor Section had better luck at Stowmarket, where he observed thirty-nine meteors in a watch lasting 2 h. 45 m. on November 16-17, and many were of the first magnitude. A similar report came from Mr. A. King of Lincolnshire, and Rev. Jameson at Willesden Green. The maximum display seems to have come late in the night, so that America had a better record. It appears this may have been the case, as 289 meteors were observed at Dubugue, Iowa.

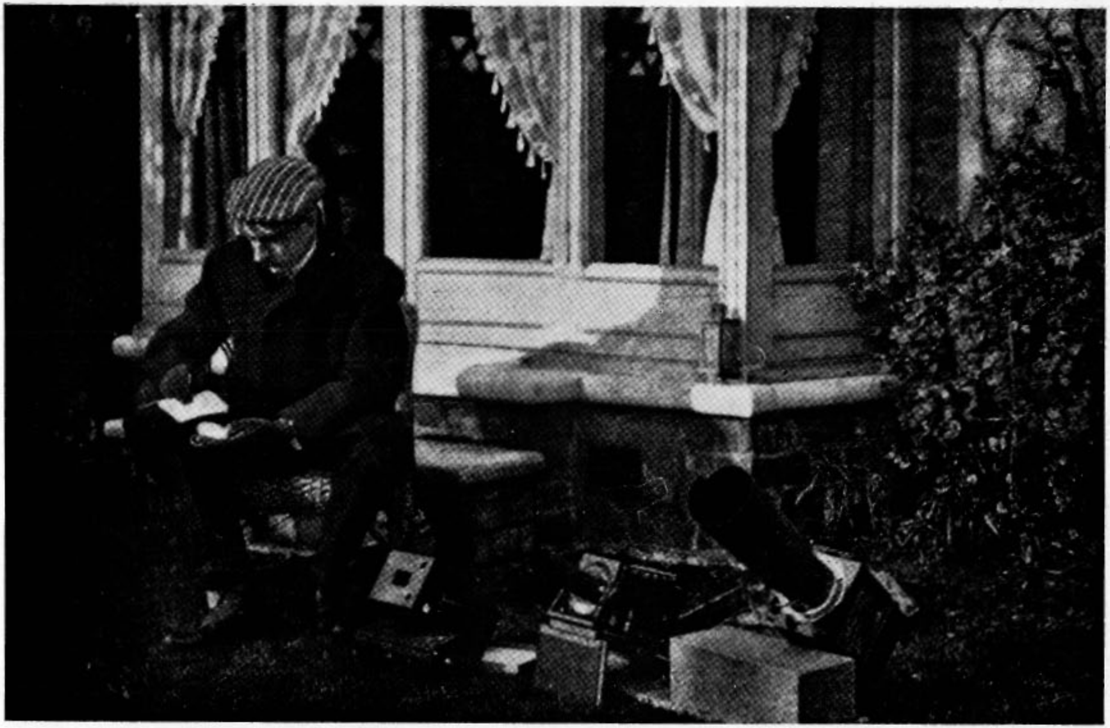
CHAPTER XVII

HOW METEORS ARE TRAPPED BY A CAMERA

DURING the course of observations of November Meteors made in 1899, recourse was had to photography which had the great advantage of giving more reliable and accurate records than those obtained by visual observations. The latter cannot always be implicitly trusted, as they have been found to differ when compared with each other. Personal equation has to be taken into account, the tendency to exaggerate, the excitement of the moment, all of which have no effect upon the portrayal of an object which impresses itself on the photographic plate. There can be nothing more thrilling to an amateur after developing a plate, than to find thereon a totally unexpected meteor pictured in its swift flight through space.

The photographic lens has proved invaluable for work of this class so surely, that no one who has such an instrument will attempt to use anything else for the purpose. Most important and interesting work can be done by means of the short focus lens, and there are many advantages in using a comparatively small lens which is far more rapid than the larger portrait lens, giving a wider field of view though the scale is necessarily small. The diameter may be one inch and a half, and 5.3 inches focus. This is the kind of lens used in the ordinary projecting lantern, and can be purchased for a few shillings. Such a lens is within the reach of every amateur, and could be used to good effect on evenings when there is every prospect of trapping a meteor in its flight. It may be as well to do a little "trailing", but in such a case it is best not to use the visual focus of such a lens, but to determine the focus by means of the star "trails" themselves. Moreover, in using such a lens for the purpose of trapping meteors, it is best to have it attached to an equatorial with clockwork motion, though this is not altogether necessary for those who do not wish to go to the additional expense. It is reassuring for them, that very valuable results can be obtained by simply pointing the instrument in the direction of some known stars, and fastening it to a board tilted in the proper position—the beginning and ending of the exposure can thus be noted. The star-trails impressed on the plate by the meteor, enable one to locate the position of any meteor-trail which may appear on the plate, if the time of its flight is noted.

It is important that the plates should be frequently changed and marked, to avoid confusion as to the time of the appearance of the meteor. Thus, one can use a small battery of portrait lenses all turned in the direction of the sky during the course of the night, changing the plates from hour to hour, and looking



CAMERA TRAPS SET TO CATCH THE WILY METEOR (PHOTOGRAPH TAKEN BY W. F. LONGBOTTOM) forward with pleasure to their development next morning. It is a novel form of entertainment which may be startling in results, although of no special value from the standpoint of a scientist. Nevertheless, very important work can be done, especially by those who are provided with equatorial telescopes, if two or more of these are equipped with cameras, and are stationed several miles apart with the instruments directed towards the zenith, for the determination of the parallax of the meteors.

With regard to photographing meteors with a lens attached to an equatorial supplied with clock motions, one of the finest results has been obtained by Dr. W. Y. S. Lockyer, with a camera specially designed for recording meteors. It was oriented to the polar stars simply to enable one to identify the stars and thus to deduce the path of the meteor. Otherwise, no interest is attached to the polar trails as such. Incidentally, the star trails shown in the photograph, give an excellent idea of what happens to a photograph of the stars, when the clockwork is allowed to run down.

When this photograph was taken, the telescope with the accompanying camera, was stationary during all exposure of a little over two hours. As a result, the stars are not photographed as points of light, but appear as bright and faint lines in sections of circles, since the telescope was pointed to the pole of the heavens. The main interest in this photograph is due to the fact that a meteor should have chosen this exact instant to dash across that part of the sky during the course of the exposure, thus resulting in one of the most interesting photographs of a combination of star-trails and a bright meteor ever obtained. It was one of those pieces of luck which are extremely rare, and therefore of all the more value.

To quote Dr. Lockyer's account of the photograph which appears in *Monthly Notices*, of the R.A.S. for December, 1922: "It is my usual practice now, at the Norman Lockyer Observatory, when working with the 9-inch prismatic camera at night, to expose a plate to the north polar region of the sky in a fixed camera outside the dome. This camera is home-made, consisting of a square-section wooden tube with a slot at one end to carry a plate $8\frac{1}{2} \times 6\frac{1}{2}$ inches. The objective is an old portrait doublet of $5\frac{1}{4}$ inch aperture, and 28 inches focal length, and includes a rack-and-opening for focusing. The whole instrument is mounted in the meridian on a stout wooden frame, the top surface of which is inclined at an angle to suit the latitude. During the night of November 16, the plate (Marion's 'Record' Hand D 500), was exposed from 8 h. 58 m. to 11 h. 12 m. G.M.T., thus covering the period of 134 minutes. The weather was cloudless during the whole of the exposure."

Dr. Lockyer's photograph is one of the best photographs of a meteor ever obtained, for it seems to include nearly the whole path, and shows the variations

PHOTOGRAPH OF A BRIGHT METEOR AND STAR TRAILS. (DR. W. J. S. LOCKYER). THE CAMERA WITH WHICH THE METEOR WAS PHOTOGRAPHED WAS PLACED SPECIALLY FOR RECORDING METEORS. ONE DASHED ACROSS THAT PART OF THE SKY DURING THE COURSE OF THE EXPOSURE.

in the light and apparent magnitude of the object very distinctly. The object appears to have been a fireball coming from the direction of the constellation Taurus, these being quite abundant during the early part of November, and until about November 25. Such a photograph should prove an incentive to an amateur owning an ordinary camera, designed for the portrayal of human beings, but capable of being adapted as well for the capture of celestial wayfarers at that instant of their meteoric career, when they blaze with a glory often outrivalling in appearance that of the stars. As Shakespeare expresses it, they are: "Like a bright exhalation in the evening," vanishing into obscurity, so that "no man sees them more."

There are hundreds of amateur observers who make a practice of watching the skies each night for the flash of a meteor, but for those observations to be of any value they should be carried out in a systematic way. Certain suggestions may be of value for those who are planning to watch either the August, or the November showers and others, such as the meteors radiating from the constellation Draco, January 2; the Lyrids, from the constellation Lyra, April 20; the Aquariids, radiating from the constellation Aquarius, May 6; of interest because they are closely allied to Halley's Comet. On July 28, another shower but of minor importance is due, from a radiant in Aquarius. The Perseids may be looked for August 12; the Orionids, on October 20; the Leonids, November 14; the Andromedes, November 24; and the Geminids, December 10.

The following are a few hints regarding a systematic method to be employed in observing meteors to the best advantage. First of all, one should note carefully the exact time when the greatest number of Leonids are visible. Incidentally, it is well to have a radium wristlet watch at which one can glance with ease, and thus determine the exact instant the observation is made. This must be recorded at once in a note-book kept handy for use, but as all this takes time, it is as well to be one of a party of three: one to make the observation, a second to note the time, and a third to make the record in a note-book. The next feature of importance in the display, is to count the number of meteors visible per minute at maximum, which is not as easy as it sounds. Try to count the number of snowflakes falling in a minute, during a heavy snow-storm and one can judge of the difficulty the observers had in 1833, and 1866, when we are told the meteors "fell as thickly as snowflakes". Due allowance must be made for personal equation, some observers claiming their view of hundreds, while others—giving up counting—have declared the meteors as numberless, which must have been nearly the truth in the case of the great displays of Leonids in 1833 and 1866.

The direction of the flight of the meteor so as to determine its radiant point is also of paramount importance, necessitating a fourth in our little party of observers. A straight wand two or more feet in length held in the hand ready for the purpose, should be projected upon the path of every meteor directly it is seen, and then its position and slope relative to the stars nearby should be noted, and reproduced on the chart which is kept in readiness for the purpose. Incidentally, one requires to be familiar with the names and positions of the stars, as there is no time to consult a star-map on these occasions. A large outline of the main stars in Leo, and the Sickle-shaped group is a necessity in preparation for the display of the Leonids. The record should be made on the chart while it is fresh in the memory. After awhile, from these records it will be possible to determine the diameter of the radiant if diffuse, as well as the beginning of the meteor-flash, as traced by its passage near some well-known star, and the end of flash in the same way, this giving the length of the path. (Five degrees is the distance between the Pointer in Ursa Major, which may be useful to remember in determining the length of the trail.) So rapid is the flight of the meteor, that not a fraction of a second should be wasted in lifting the wand in position, and holding it in position indicating the path of the meteor ere it fades from view. That is where speed of action and quickness of perception are requisite, if the results obtained are to ensure accuracy.

Some shooting-stars travel more swiftly than others, the November Andromedes, for example, being slow since they overtake the Earth; the Leonids, on the contrary moving swiftly. They also differ in colour, the Andromedes being reddish, and the Leonids bluish-green. The colour test often proves uncertain and unsatisfactory, for though an observer may be accurate as to timing the observation, yet when the colour test is in question, it is remarkable how many varieties of tint have been attributed to the same meteor by different observers. When the Leonids were seen in such great numbers in 1866, they were variously described as of a ruddy, gold, copper, white, blue or yellow hue. The colour of the streaks were described as a bright emerald green. Thus, it would seem, that according to the impressions recorded by different observers, the meteors on this occasion showed all the colours of the rainbow. The streaks or after-glows visible along the path of meteors is another characteristic feature, for as a rule the brighter the meteor so will be the streak, and the longer its duration. Some have remained visible for ten or fifteen minutes and even longer, and they are often serpentine in appearance, wriggling their way among the stars, as they slowly drift under the influence of a current of air in the upper region of the atmosphere. They change rapidly in appearance as they move onward, finally vanishing mysteriously in the darkness of the night. Sometimes the streaks move in sections and are intensely bright at those points where a great outburst of light has been seen, and again their paths are straight ending in a point like the tip of a sword.

The fortunate owner of a camera may succeed when photographing the sky with wide-angled lenses, in trapping a meteor in its flight across the region being photographed. The moving point of light thus affecting the sensitive plate, marks out a track among the star images which is permanent, and whose position can therefore be measured with the greatest accuracy. If a second camera, situated at some distance from the other is also engaged in photographing the same part of the sky, the meteor trail will be recorded by both cameras, and its displacement on the two plates as photographed from these two points on the earth can be determined accurately. By this means the distance of the meteor can be ascertained. Such an instance occurred some years ago at the Yerkes Observatory at Williams Bay, Wisconsin, where the same meteor was photographed with two cameras, by Professor E. E. Barnard and an assistant, who were separated by a distance of 400 feet. The displacement of the trail among the stars was clearly shown, and measures of the two plates served to indicate that the meteor was about ninety miles above the surface of the earth.

Watching for meteors is a delightful hobby for leisure hours, training one to make accurate observations of celestial phenomena, visible during a minimum amount of time. Fugitive and erratic in their appearance they are quite beyond the range of telescopic work, with the result that they were practically ignored until their origin was recognized, and it was found possible to trap them with a camera. From their inferior position as mere nondescripts, their close relationship with comets has definitely established their claim to membership in the solar system over which our Day Star the Sun, holds sway.

London, 1938.

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