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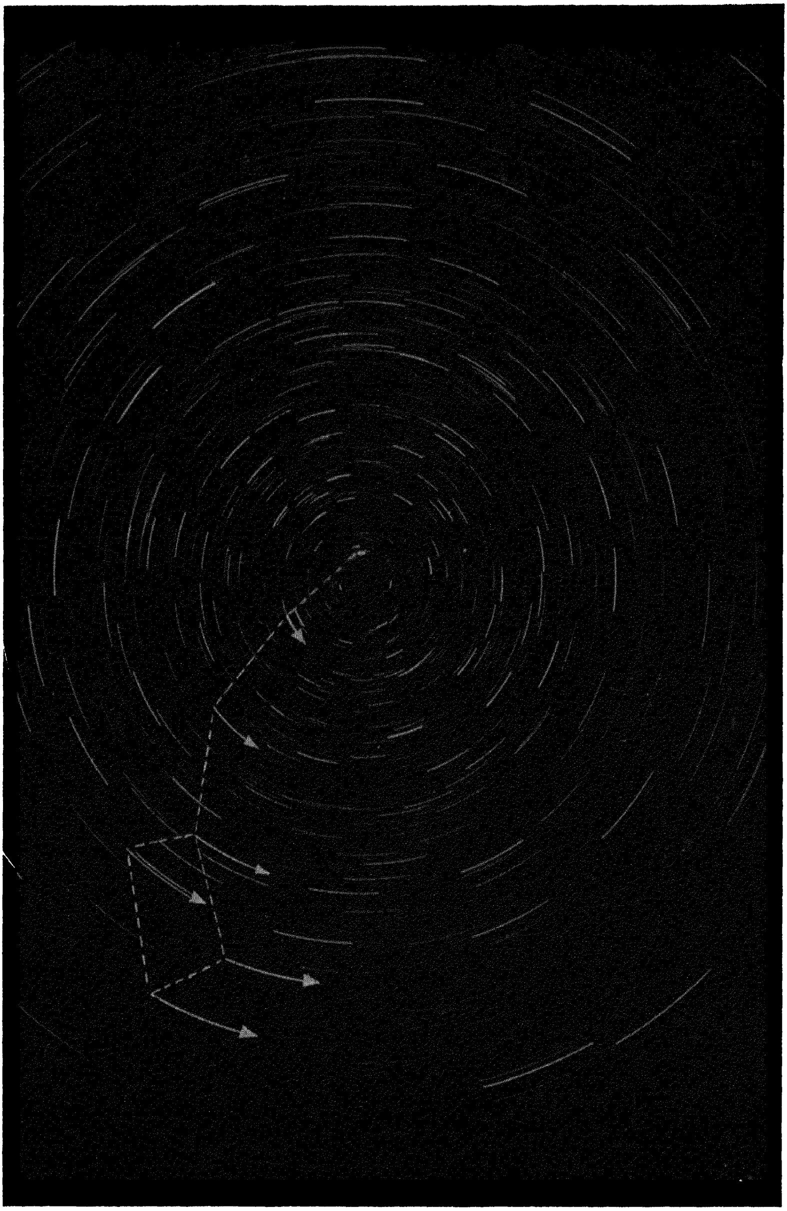
HANDBOOK OF THE HEAVENS



Dana K. Bailey, J.A.C.

CIRCUMPOLAR TRAILS. A small camera, focused with a magnifier, was placed upon the ground and pointed at the North Star and its neighbors. In an hour's exposure, the stars revealed the rotation of the earth by recording on the photographic plate a fraction of the apparent daily circle of each. The group arrangement of the Little Dipper with the Pole Star at the end of the handle has been indicated at the initial position and the trails show its subsequent motion. This picture was made with a fine lens in the clear desert air of southern Arizona, and the original negative shows the trails of forty stars within the diurnal circle of Polaris. Anyone with even a box camera can make similar pictures.

HANDBOOK OF THE HEAVENS

SPONSORED BY

The American Museum of Natural History

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To

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in charge of

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Grateful acknowledgment is here made to the many people who have taken part in the preparation of this book. First thanks are due to the contributors, members of the Junior Astronomy Club at the American Museum of Natural History, whose genuine enthusiasm for their hobby of astronomy has made the book possible.

We are indebted to Dr. Harlow Shapley for his unfailing interest and encouragement, and especially thank our many friends at the American Museum of Natural History.

To Dr. Charles S. Adams, Director of Mount Wilson Observatory, and to Dr. Otto Struve, Director of Yerkes Observatory, we are indebted for the photographic illustrations.

The unique assistance rendered by Dean Guy Stanton Ford, Mrs. Chauncy Cooke, and Miss Anne E. Rumpf is gratefully acknowledged, as well as that of many others who have aided greatly in this undertaking.

The Editors.

American Museum of Natural History,
September, 1935.

FOREWORD

My first impulse in writing to the Junior Astronomers about their *Handbook of the Heavens* is to greet them in behalf of the profession and congratulate them on their unearthly interests. But the second is to warn them not to take the science too seriously. As an avocation, there is nothing more mind-cleansing than astronomy; as a profession, it is a hard master.

The young student should first discover in himself a high talent for mathematics or for making experiments, or the possession of a constructive imagination, before he ventures to change his interest in stars and planets, lenses and mirrors, from a healthy hobby into a business. The amateur astronomer and the unprofessional student are blessed with freedom from deadening responsibility; they answer only to the personal urge to do or to know. They can observe and read and think of velocities, masses, distances, and durations that are uncommon to the inhabitants of the earth's crust. They can play, at least in thought, with meteors and galaxies—which are so different in size, so similar in origin, meaning, and obedience to cosmic laws. In a life of petty turmoils, the Junior Astronomer, by detaching himself from the earth, is preparing for one of the highest enterprises in the realm of contemplation—the wholly impersonal Dream.

Harlow Shapley.

Harvard College Observatory,
Cambridge, Mass.,
September, 1935.

CONTENTS

In addition, there are 32 charts and diagrams which appear in the text but which are not listed here.

HANDBOOK OF THE HEAVENS

Exploring among the Stars

It is fun to watch the stars and to make friends with them—to see the Big Dipper and to know that by this star picture Greek shepherds told the hour of the night, American Indians timed the planting of their crops, and Columbus guided his boat to a new world.

Memories of the rough-hewn men who first looked to these stars for guidance and companionship return to us. And they conflict with thoughts of civilizations which will rise and fall under these same stars. That is the romance of the skies.

Just as the bird lover rejoices to hear the notes of the first robin in the spring and the gardener smiles to see the early crocus pushing through the wintry soil, so those who have discovered companionship in the stars welcome the return of old favorites to the skies. Each hour of the night and each season of the year new stars come into view.

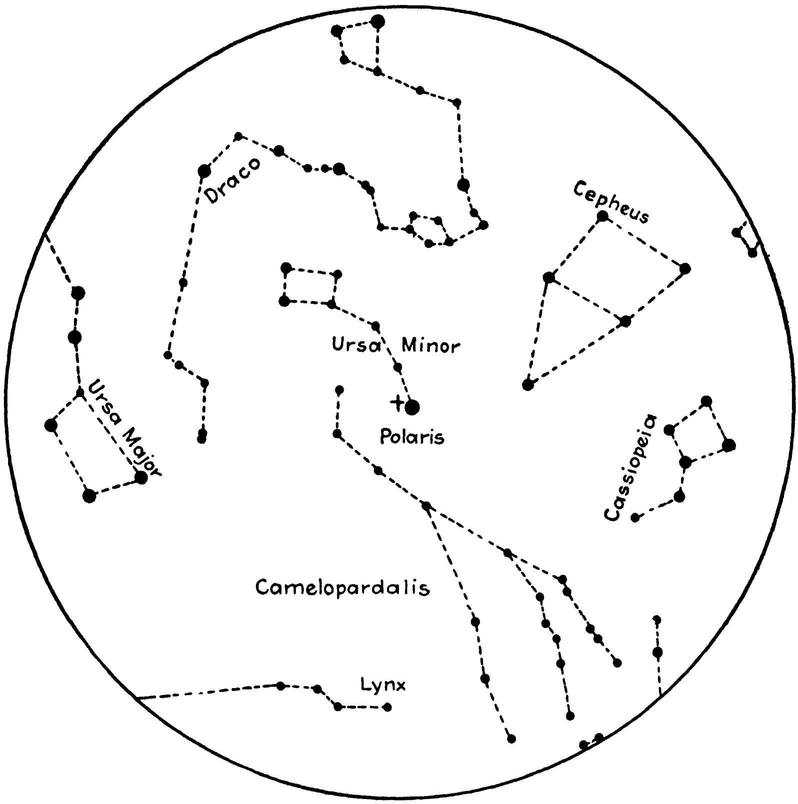
Exploring on one's own, one finds among the star groups or constellations imaginary pictures outlined by the stars. Some are so ancient that they are found on Babylonian stones; others so modern they include an air pump. Perhaps the best known of the constellations are the zodiacal groups which form a backdrop of stars along the path which the sun, moon, and planets always seem to follow. In this historic region of the sky three new planets have been discovered by the watchful eyes of astronomers. There shines Venus, a blaze of glory in the morning or evening sky; and in the same path ringed Saturn creeps, spending two years in one constellation. The moon, too, wends its way among the animals of the zodiac.

In one night of watching the stars we may become familiar with many of them. We may learn to know many of the constellations at sight. But then we have learned only the stars visible at that time. There are hundreds more. Later in the month or even later that same evening new stars will have risen above the horizon. In one night we may see several planets. But there are others. In one night we may find fifty markings on the surface of the moon. But there are thousands.

So all the nights of a lifetime are not enough to discover even half the secrets of the skies. We can learn only a few; always there remains something new, something unknown to lure us on. Perhaps some one of us may find something that has never been noticed before!

It may be this book will reveal to you the fascination of the stars. To that end it is written.

Stars of the North Polar Skies



DAILY swinging around the north celestial pole, never setting for observers in the latitudes of New York, are the keystones of constellation study, the circumpolar stars. Forming an easy guide to the location of other groups, they are in themselves of extreme interest.

Most easily recognized and most important of all these constellations is the Big Dipper. Ursa Major, as it is known to astronomers, means Greater Bear, but no name could suit this group better than the "Dipper" for it looks exactly like one.

Four stars form the bowl and three the handle; and the resemblance is the more perfect since all but one of the stars are of the same magnitude.

In this dipper the second star from the end of the handle is an object that carries us back to the days of the early Arabs. This is the star Mizar and its faint companion Alcor which form a naked-eye double. So difficult is it to see Alcor that this was the standard eyesight test given to recruits for the Arabian army.

Although to the casual observer the bowl of the dipper may seem almost devoid of stars, a careful count with the naked eye on a clear night will reveal ten or twelve faint ones. In this area are located several famous telescopic objects.

It is with the use of the Big Dipper, more widely known than any other group, that the Pole Star is found. By following a line drawn through the pointers of the bowl (the two stars directly opposite the handle), and continuing through the top of it one comes to Polaris, the North Star, guide of mariners for untold generations.

Polaris, which is about twice the moon's apparent diameter from the true north celestial pole, does not stand alone in the sky; instead it is the brightest star of the Little Dipper, or Ursa Minor. This group is more difficult to make out than is its larger brother, for the stars are fainter and of varying degrees of brightness. Two, which occupy a position in the bowl similar to that of the pointers in the larger constellation, are fairly bright and are easily found on a clear night. They lie between the pole and Draco, and because they seem ever to be on guard against an attack by the dragon upon Polaris, they are known as the guardians of the pole.

Draco itself starts in a rather faint star which is slightly nearer to the pointers than to Polaris and winds its serpentine length in a rough half circle around the Pole Star. Then, at a sharp angle to its former path, it rears its head, marked by a pair of prominent stars which might be taken for eyes, at Hercules. The Dragon provides a not-too-difficult group to hunt for and one which, as it gradually unwinds to the beginner, becomes more and more interesting.

Polaris now is the North Star, but it was not always so. Owing to a "wobbling" of the earth's axis the north pole of the sky is constantly changing its position with respect to the constellations. Thousands of years ago Alpha Draconis, one of the dimmer stars in Draco, was the Pole Star, and at some date far in the future the bright star Vega, which now shines in the summer skies, will be near the pole.

Across the pole from Ursa Major, and equally distant from Polaris, lies a group of stars that resembles a big chair. This is Cassiopeia, better known as the Seated Lady. Its startling resemblance to a W is enhanced by the fact that nearly all the component stars are approximately of the same brilliance.

Cassiopeia, like all the constellations, is more than an outline of bright stars visible to the naked eye. It encompasses a sky area in which are numerous stars of various degrees of brilliance. All the stars are classified according to their brightness and grouped in magnitudes. A star of the first magnitude is 2½ times brighter than one of the second magnitude, and this proportion is used throughout the scale. Stars brighter than first magnitude are reckoned below zero, given proportional negative values, and designated by a minus sign. Thus the highest number represents the least brilliance and Sirius, our brightest star, is -1.58. At the other extreme are the faint sixth-magnitude stars beyond which the unaided eye cannot see.

Telescopes have revealed objects down to the twenty-first magnitude and they have also revealed in many cases two or more stars where only one was visible to the unaided eye. Such a double star is Eta (η) Cassiopeiae, so called after the common practice of using Greek letters to designate the different stars in the constellations. Even stars so well known as to have proper names of their own are also given Greek-letter designations; thus Sirius is Alpha (α) Canis Majoris.

Perseus is interesting because it is the radiant point for the August meteor shower that bombards the earth with countless shooting stars each year. It is only partly circumpolar for these latitudes, for here a greater part of it dips below the horizon for a short time every day. To be entirely circumpolar an object must have a polar distance that is less than the observer's latitude. Wherever one is on the earth's surface, his celestial pole is as far above the horizon as his latitude. Thus a person in the latitude of New York, 41°, would count circumpolar all stars within 41° of the north celestial pole.

Perseus contains two stars which vary in brightness within the limits of naked-eye observation. One is Rho (ρ) Persei, which ranges through a whole magnitude in about a month, and the other is Beta (β), the famous Algol, or Demon Star, which changes as much in a few days.

Between Perseus and Cassiopeia lies one of the most interesting objects for amateur observation found within the circumpolar boundaries. This is the double star cluster Chi-h (χ-h) Persei. Faintly visible to the naked eye under good conditions, it becomes an object of beauty when seen through an opera glass.

Two other less prominent constellations fall into the circumpolar group, Cepheus and Camelopardalis. Cepheus may be located by continuing the line from the pointers of Ursa Major through the Pole Star and extending it on for about once again its own length. This will take the beginner to a previously unexplored sky region, and in it he will find a rude lantern composed of third- and fourth-magnitude stars. The Milky Way runs through Cepheus, and in the constellation are found several interesting double stars. Among these is Delta (δ), which is not only a yellow-and-blue double but also a famous variable star after which the Cepheid type of variable was named.

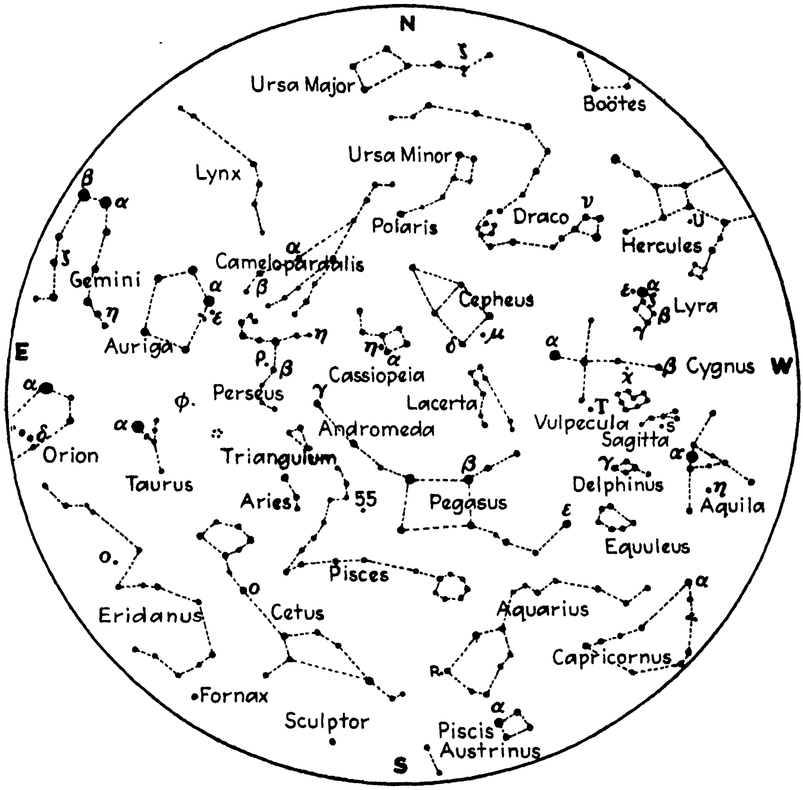
Lacerta, Lynx, and Camelopardalis are real challenges to the sky explorer, for they are all composed of exceedingly faint stars which are not arranged in any striking formations. In an effort to build Camelopardalis up from nothing, locate Alpha and Beta, and from these, with the aid of the connecting lines on the charts, the rest of the stars can be found. But even this elusive group can be observed on any very clear moonless night during the year and so it should soon become as well known as its more prominent neighbors.

Stars of the Autumn and Winter Skies

The map above shows positions and accepted geometric patterns for all the constellations visible at 9 P.M. November 1 in latitude 40° north. Identification of the star groups may be made by comparison with the chart on the opposite page.

In use, this map should be held overhead and oriented according to the compass points indicated. It will then show the stars as they appear in the sky. The stars visible here at 9 P.M. November 1 will also be visible at 7 P.M. December 1 and at 11 P.M. October 1 as explained in the chapter on "Autumn and Winter Skies."

Chart of Autumn and Winter Skies



The map above shows the accepted geometrical patterns of all the constellations visible at 9 P.M. November 1 in latitude 40° north. All the stars listed for study in the chapters on "Double Stars" and "Variable Stars" are indicated, as are the first-magnitude stars, which are the following:

α Geminorum—Castor	α Tauri—Aldebaran	α Aquilae—Altair
β Geminorum—Pollux	α Lyrae—Vega	α Piscis Austrini—Fomalhaut
α Orionis—Betelgeuse	α Cygni—Deneb	α Aurigae—Capella

Autumn and Winter Skies

DURING the cold winter months the display of brilliant stars dotting the night skies is at its best. But really to learn the winter constellations one must start in autumn and continue on into the season of snow and ice, thereby gaining an understanding of the transitions that take place in the heavens.

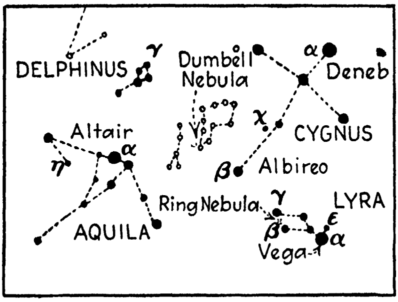
Early in the evening, just around the time that autumn is officially ushered in, we find the impressive Northern Cross, embodied in the constellation of Cygnus, directly overhead. With its first-magnitude star Deneb, the Cross is easily traced among the stars, and at its base is found the beautiful double star Albireo.

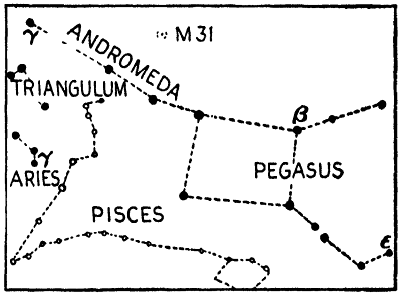
Near Cygnus is the small constellation Lyra, which contains within its borders the blue-white star Vega. Both Vega and Deneb will be setting in the west later in the evening at this time of the year, for they belong with the summer stars. The brightest of the summer stars, Vega, as it sets will be superseded by the even more brilliant Sirius, rising in the east.

Aquila, the Flying Eagle, is southwest of Cygnus and in it there is the first-magnitude star Altair. This is a white star, and it may be distinguished in that it makes a triangle with Vega and Deneb.

Northeast of Aquila is a small and not so important constellation, Delphinus, the Dolphin, or Job's Coffin. In this is a cluster which is estimated to be 220,000 light years away—one of the most distant objects known until recently. The limit of visibility now extends 2,000 times this distance and objects may be photographed which are 500 million light years away.

Somewhere about halfway between Cygnus and the eastern horizon a great square of bright stars fills the sky. This is Pegasus, the Wingéd Horse, and the area within the boundaries





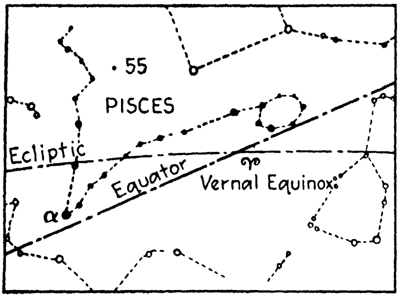
of the square presents a challenge to the observer. Under ordinary conditions only a small number of stars can be seen, but under ideal conditions as many as eighty have been identified with the naked eye.

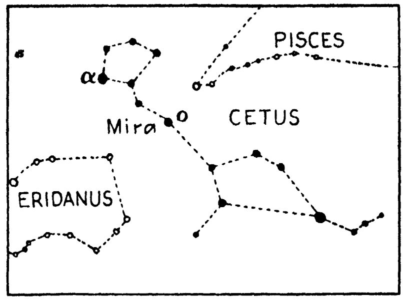
Extending from the northeast corner of Pegasus is part of Andromeda, which contains the only spiral nebula in the whole sky visible to the naked eye. The nebula is marked M 31 in the accompanying diagram. Between Andromeda and the horizon is a little triangular group of fainter stars appropriately named Triangulum. Directly south of Triangulum lies Aries, the first zodiacal constellation.

Looking along the zodiac to the west of Aries, we find the stars of Pisces. The rather faint stars are difficult to identify but the constellation is an important sky mark, for in it is located the vernal equinox, a reference point for the positions of all celestial objects.

Somewhat toward the south and coming up on the eastern horizon is Cetus, the Whale. In this larger group is found the famous variable star Mira which is at times as bright as Polaris, then fades to the limit of naked-eye visibility, and finally drops from view except in a telescope. Stars of this type, which vary in brightness, are discussed more fully on page 88.

The Pleiades, in Taurus, the Bull, consist of seven stars, almost universally known. To the Babylonians they were "the many little ones"; to the Greeks, "the seven sisters"; to the American Indian "the seven brothers"; and so on. Actually, there are about 250 stars in the cluster, but even on a very clear night only seven can be distinguished without optical





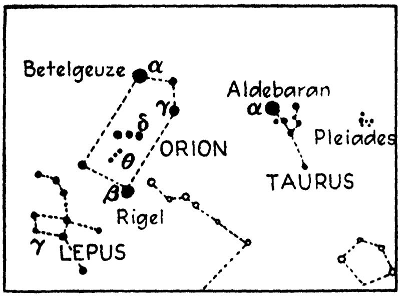
aid. Sometimes it is hard even to see the seventh star, which is called the "lost" sister.

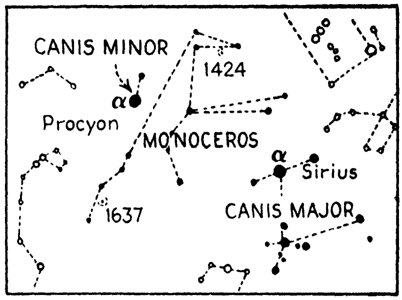
The month of November is known as the Pleiad month because the Pleiades are prominent in the eastern sky early during the evening. Later the same evening the stars will climb toward the south, reach their highest point, and sink in the west, retracing the path laid by the sun twelve hours before. The westward motions of sun and stars are apparent; the true motion is that of the earth as it turns eastward on its axis every twenty-four hours. Thus new objects are coming into view on the eastern horizon all night long.

The rising and setting of the stars are also affected by the earth's yearly revolution around the sun. As a result, in every two hours of watching on any night observers may see objects visible one month later during the two preceding hours. For example, a person observing between the hours of 10 and midnight on July 4 will see the stars visible from 8 to 10 on August 4. Similarly, on any morning from 3 to 6 A.M. one can see the evening stars of the coming season.

Another group of stars found in Taurus is the Hyades—almost as well known as the Pleiades. This is a V-shaped cluster with the first-magnitude star Aldebaran at the lower end. Aldebaran is a fiery-red star visible for eight months of the year. It is frequently obscured from our view by the passage of the moon between it and the earth. This occultation, as such a happening is called, is striking to watch.

Fomalhaut moves across the southern evening sky during the autumn months, but when winter begins it is no longer





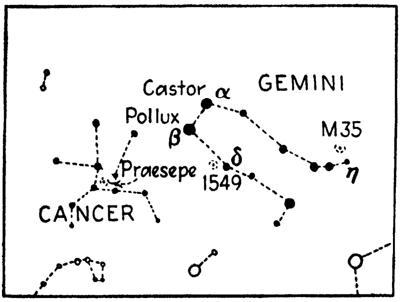
visible. It is the brightest star in Piscis Austrinus, a constellation composed of faint stars. This group can hardly be traced in outline from these latitudes, although Fomalhaut is of the first magnitude and is a conspicuous sky mark.

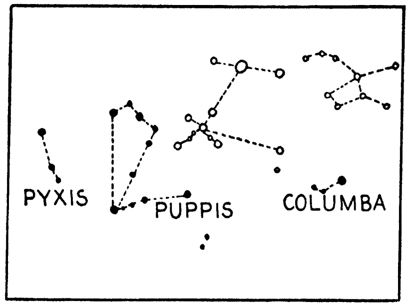
One of the most striking of the constellations, Orion, lies just below the horizon, soon to reveal itself. Toward the end of October it can be seen rising at 9 o'clock. As it comes into view, the groups of Hercules and Ophiuchus are sinking in the west, and Fomalhaut has traveled two-thirds of the way across the southern sky.

Betelgeuse forms the right shoulder of Orion and is one of the few stars mentioned by name in the Bible. Bellatrix, neither so well known nor so bright, forms the left shoulder, while Rigel, blue-white and a star of the first magnitude, lies at the left foot of the hunter or warrior depicted by the group.

Orion can easily be found in the sky by looking for three stars, all of the second magnitude and in a straight line, which make up the belt. In the sword attached to this belt is a beautiful nebula, one of the two in the northern skies that can be seen without optical aid. Of the three objects in the sword, it is the central one, Theta (θ) Orionis.

Almost squarely beneath Orion's feet is little Lepus, the Hare; and Eridanus, the River, also has its source in this region. Beginning at the blue-white star Rigel, it passes below Taurus and winds beneath Cetus, the Whale. No very conspicuous stars mark these two constellations but they are interesting to find, as is near-by Columba.





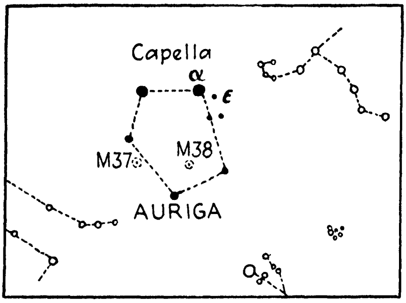
When Gemini, located to the northeast of Orion, rises entirely, it appears as a long, rectangular group of stars. The constellation is commonly known as the Twins because of its two important stars, Castor and Pollux. Pollux, a slightly yellowish star, is the brighter of the pair but this was not always so, for at one time Castor was the brighter.

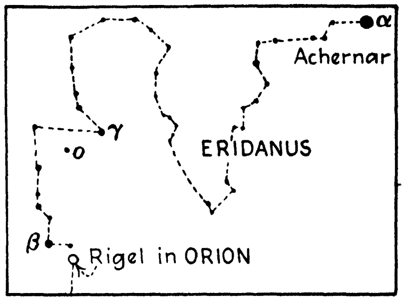
The Twins, of second and first magnitude, respectively, are only about 4½° apart and therefore easy to locate in the sky as a pair. An interesting thing about Castor is that it is a magnificent double star, whose white components are of nearly equal magnitude. These two stars can be separated easily with the use of a small telescope.

The Twins lie in the zodiac between the star groups of Taurus and Cancer. This zodiacal constellation is a very interesting region of the sky, for near Eta Geminorum, Uranus was discovered by Herschel in 1781, and near Delta Geminorum, Pluto was identified by the Lowell Observatory staff in 1930. The moon and the planets traverse this region constantly and are often found within the rectangle.

South of Gemini lies the first-magnitude star Procyon, the brightest star of the diminutive constellation Canis Minor, or the Little Dog. Between it and the horizon is its big brother Canis Major, the Big Dog, containing the brightest star in the heavens, the brilliant blue-white Sirius.

Between Canis Major and Canis Minor is Monoceros, the Unicorn, composed of faint stars. This can be located with the aid of the star maps as can Puppis which is almost touching the bottom of the Dog Star group. It formerly was the poop of



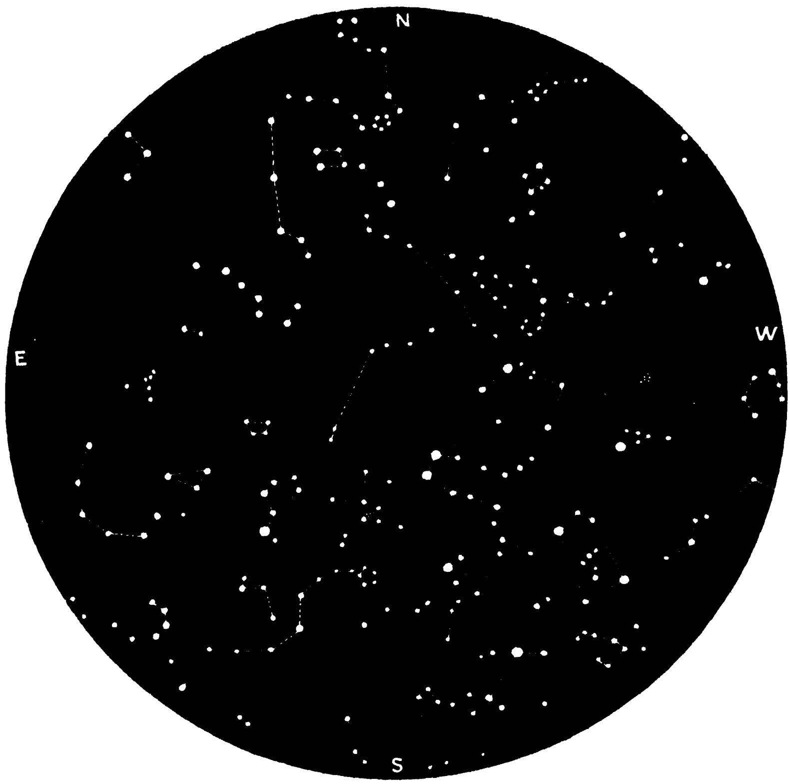


the great ship Argo Navis, which has been split up into several sections, of which Puppis is the most prominent to be seen from our latitude.

Cancer, the Crab, is the next zodiacal constellation to come up over the horizon after Gemini, and in it is the famous Bee Hive cluster, Praesepe, which is visible to the naked eye. A diagram of Cancer with the location of Praesepe appears on page 16. A zodiacal group, Cancer acts as host to many of the planets and the moon.

Almost overhead at 9 o'clock on early February evenings is Auriga, the Charioteer. With its extremely bright yellow Capella it is easy to locate. This group, rich in clusters, is right in the middle of the Milky Way. It narrowly missed being circumpolar and has some stars within the boundaries of the circumpolar groups.

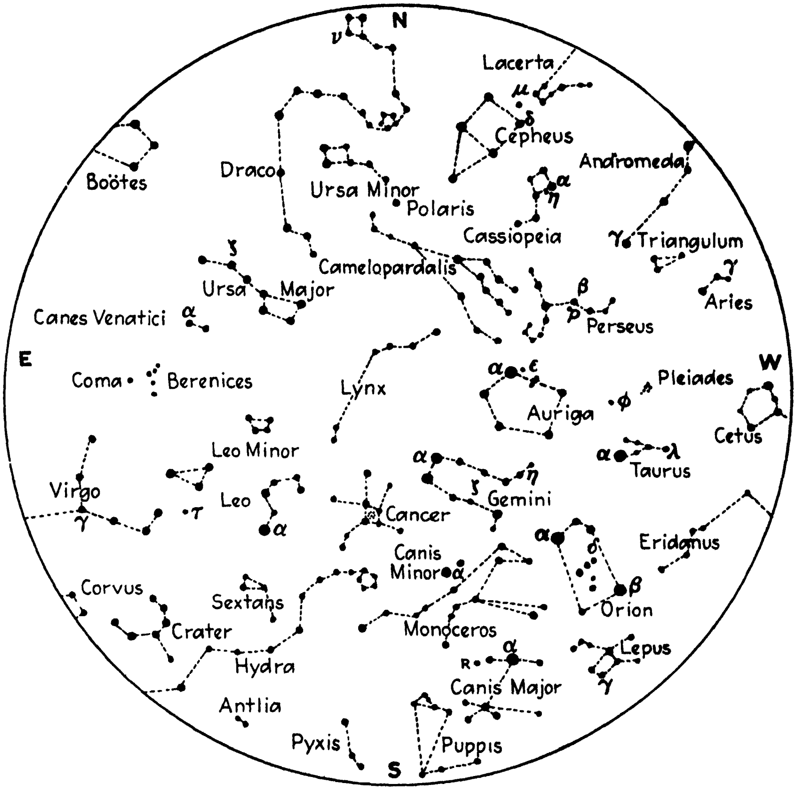
Stars of the Spring Skies



The map above shows positions and accepted geometric patterns for all the constellations visible at 9 P.M. March 1 in latitude 40° north. Identification of the star groups may be made by comparison with the chart on the opposite page.

In use, this map should be held overhead and oriented according to the compass points indicated. It will then show the stars as they appear in the sky. The stars visible here at 9 P.M. March 1 will also be visible at 7 P.M. April 1 and at 11 P.M. February 1.

Chart of the Spring Skies



The map above shows the accepted geometrical patterns of all the constellations visible at 9 P.M. March 1 in latitude 40° north. All the stars listed for study in the chapters on "Double Stars" and "Variable Stars" are indicated, as are the first-magnitude stars, which are the following:

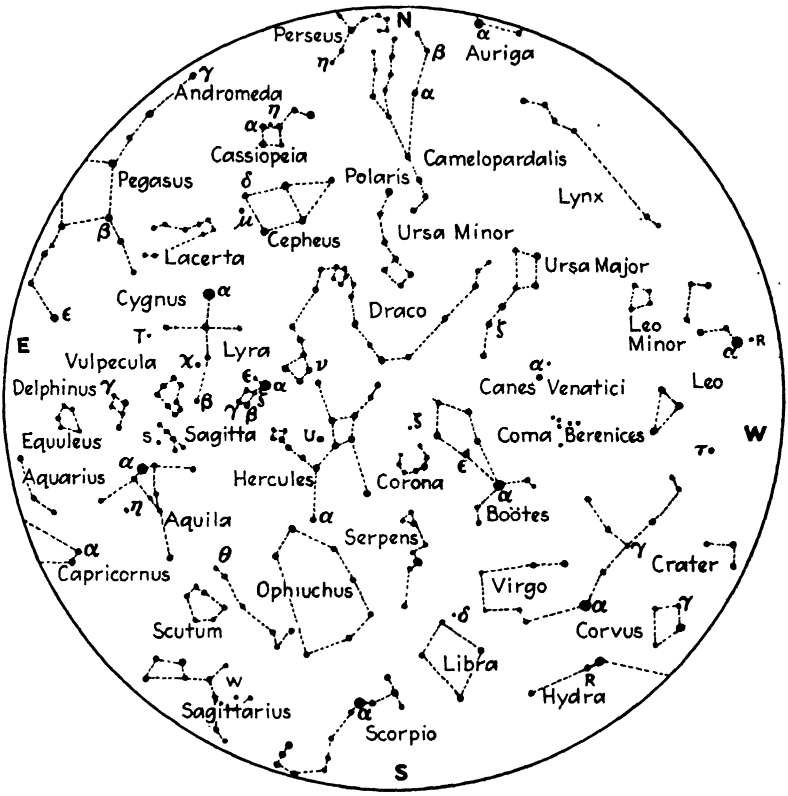
α Aurigae—Capella	α Geminorum—Castor	β Orionis—Rigel
α Leonis—Regulus	β Geminorum—Pollux	α Canis Majoris—Sirius
α Tauri—Aldebaran	α Orionis—Betelgeuse	α Canis Minoris—Procyon

Stars of the Summer Skies

The map above shows positions and accepted geometric patterns for all the constellations visible at 9 P.M. July 1 in latitude 40° north. Identification of the star groups may be made by comparison with the chart on the opposite page.

In use, this map should be held overhead and oriented according to the compass points indicated. It will then show the stars as they appear in the sky. The stars visible here at 9 P.M. July 1 will also be visible at 7 P.M. August 1 and at 11 P.M. June 1.

Chart of the Summer Skies



The map above shows the accepted geometrical patterns of all the constellations visible at 9 P.M. July 1 in latitude 40° north. All the stars listed for study in the chapters on "Double Stars" and "Variable Stars" are indicated, as are the first-magnitude stars, which are the following:

α Aurigae—Capella	α Aquilae—Altair	α Boötis—Arcturus
α Cygni—Deneb	α Leonis—Regulus	α Virginis—Spica
α Lyrae—Vega		α Scorpii—Antares

Spring and Summer Skies

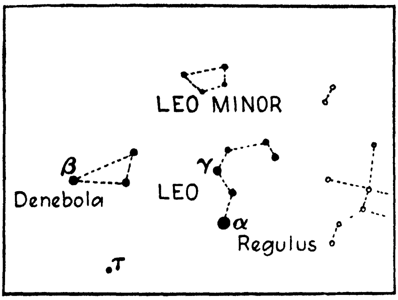
An ever-changing vista of constellations moves across the darkened night skies as the earth pursues its yearly course around the sun. From Orion, setting in the western sky in the early evening on May 1, around again to Orion rising in the east on November 1, an amazing display of objects outlined in the stars is revealed to the eye.

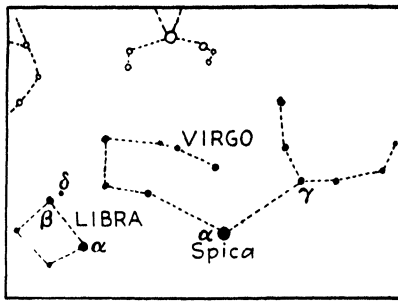
Let us look at the heavens on an evening early in spring at about 9 o'clock. In the west Orion is about to set, and Sirius will also be sinking in the southwest, while Perseus and Cassiopeia are in the northwest. Auriga, Taurus, Gemini, Canis Major, and Canis Minor, all among the autumn-winter stars, still stud the western half of the heavens.

Turning from these groups toward the south, and looking up at a point nearly overhead, we see Leo, the brilliant Lion. Worshiped by the ancient Egyptians because the sun entered it about the time of the inundations of the Nile, Leo is one of the oldest of constellations. Regulus, the Little King, brightest star in the group, has a history of its own since it was by measurements of the longitude of this star that, thousands of years ago, the precession of the equinoxes was discovered. Eleven times as bright as the sun, Regulus is a double star but its eighth-magnitude component is unfortunately not easy to observe with a small telescope.

Gamma (γ) Leonis, second brightest star in the Sickle of Leo, is one of the finest double stars in the sky. Although it cannot be seen with a field glass, it can be resolved in a 3-inch telescope on clear nights. The colors are yellow and green.

The Leonid meteor shower appears to emanate from this constellation, radiating from a point within the sickle. The planet Neptune, moving through the zodiac, has been in Leo for a number of years and it is gradually working its way eastward.



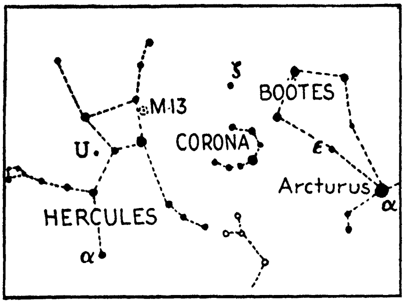


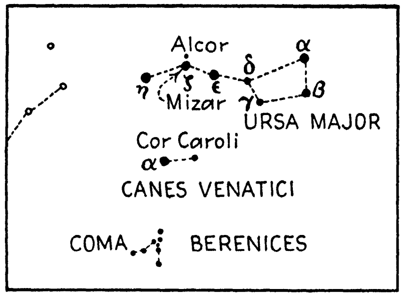
Following Leo across the heavens is Spica, the brightest star in the constellation of Virgo. A large and perfectly shaped Diamond of Virgo is formed in the sky by the stars Spica, Denebola, Cor Caroli, and Arcturus. Big though it is, Virgo contains few brilliant stars, and its chief interest is to the telescopist who can find in it many nebulae. Since the group is one of the zodiacal constellations, it contains within its borders at various times all the planets, the moon, and the sun.

Marked by the blazing Arcturus, Boötes is located a short distance northeast of Virgo. It is surrounded by the stars of Corona to the east and Canes Venatici and Coma Berenices to the west. Although its shape suggests a giant kite, Boötes is supposed, in mythology, to represent a farmer behind his plow. Arcturus is the giant yellow sun whose light was used to open the 1933 World's Fair at Chicago.

The constellation Canes Venatici, a misty patch of stars located beneath the handle of the Big Dipper, is known as the Hunting Dogs in mythology. Cor Caroli, third-magnitude and the brightest star in the group, is an interesting object in a small glass. It is a double with a sixth-magnitude companion.

A little group of faint stars romantically named "Berenice's Hair" (Coma Berenices) can be found between Leo and Arcturus. Only five or six of the group are visible to the naked eye and they fail to form any easily recognizable pattern. The number of stars in the constellation takes a startling jump, however, when the region is viewed with a field glass which will show from twenty to thirty stars, including several doubles.



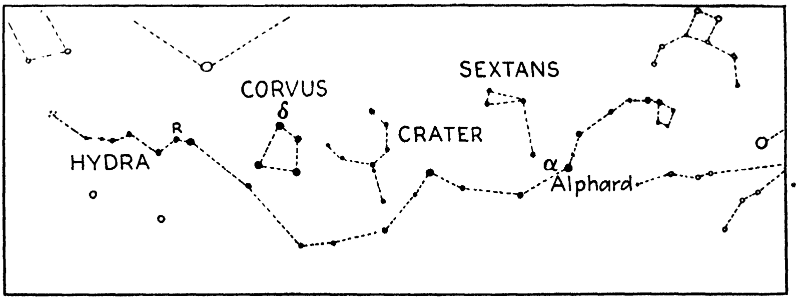


Stretching over a long distance south of Cancer, Leo, and Virgo, lies Hydra with a pentagon of five faint stars marking its head. Although it twists its way southeast among the constellations for a distance equal to one-third the way around the sky, Hydra presents only one bright star to the observer. This is Alphard, a reddish star of second magnitude, which is known both as the Solitary One and as Cor Hydrae, the Heart of the Serpent.

Rivaling in dimness the stars of the Serpent, upon whose back it rests, is the four-star group of Sextans which is so small as to be overlooked. It represents—for it is of modern origin—a scientific instrument, the sextant. Farther back from the head of Hydra, nearly southeast of Regulus, lies Crater, another small and inconspicuous constellation. Because of the fact that its most brilliant star is only of the fourth magnitude, this little group is best observed on a dark, moonless night.

A group closely associated with Crater is Corvus, the Crow, which is near the tail of Hydra. Its stars are somewhat brighter than are those of the groups with which it is identified, and it is arranged in an eye-catching quadrilateral. Delta Corvi is a pretty yellow-and-purple double.

Corona, the Northern Crown, is a small circlet of stars located close beside Boötes. Despite the fact that with the sole exception of Alpha it is composed of fourth-magnitude stars, this little group presents an unusual and striking appearance, similar in a way to a horseshoe, and most people find that having seen it once they look for it continually.

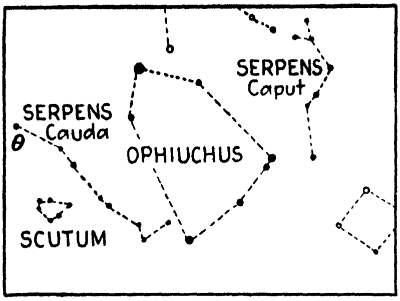


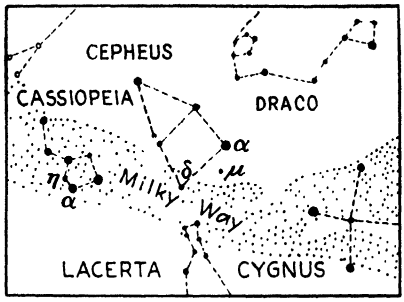
If you should be observing in the middle of July, a great change would greet your eyes. Looking west, you could recognize Spica, Arcturus, Corona, and the Big Dipper, but in the east would be a set of entirely strange constellations.

Vega, most striking of all the newly risen stars, would almost certainly be the first to catch your eye. Surpassed in brightness only by Sirius which rises later in the year, this beautiful blue-white star will be about two-thirds of the way toward the zenith, or overhead point. It marks the approximate point on the celestial sphere toward which the sun, together with the solar system, is speeding at a rate of 12½ miles a second.

A small and faint parallelogram of stars combines with Vega to form the constellation of Lyra. Although they are few, these stars are packed with interest. Epsilon (ε), a naked-eye double to very good eyes, is a quadruple in the telescope; Beta's fluctuations in brightness are visible to the unaided eye; and Delta and Zeta (ζ) are also doubles. Zeta is magnificent in low-powered instruments and Beta, in addition to its variability, becomes a quadruple star when seen with a telescope.

Set in the luminous Milky Way, Aquila, the Eagle, is at this time about halfway between the horizon and Vega. Altair, its brightest star, forms a triangle with Vega and Deneb, of Cygnus, which also lies in the Milky Way. Cygnus, the Swan, is more widely known as the Northern Cross, with Deneb marking the top of the cross and the famous double Albireo the bottom. Glorious star fields pervade this region.





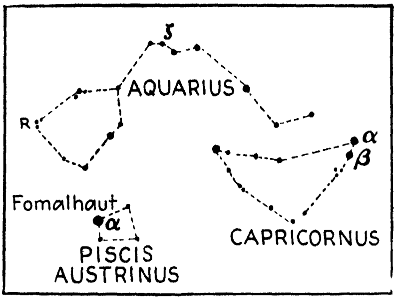
Between Corona and Lyra is the constellation of Hercules. It necessitates gymnastics, but if, when the group is due south, you turn toward the south and then bend your head 'way back, you will see Hercules as the ancients saw him, kneeling with one hand upraised. The group contains the wonderful cluster M 13.

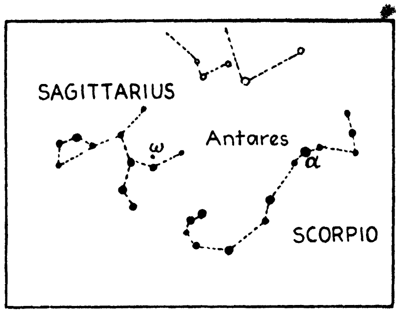
Covering a large portion of the space between Hercules and the southern horizon is an immense pentagon of fairly prominent stars which form the constellation Ophiuchus. The group represents a physician who is holding a serpent, the constellation of Serpens, in his hands.

Ophiuchus just borders on the Milky Way, which may be seen on a clear, moonless night. Starting at its northern end, we find Cassiopeia, and somewhat farther to the south is Cygnus.

Between these two groups is a small house-shaped affair with the top of the house pointing to the pole. This is Cepheus, which contains Mu (μ), the fifth-magnitude Garnet Star, famous for its deep-red color. It makes a startling contrast with the white Alpha Cephei. Delta Cephei is a most interesting type of variable, the first of its kind to be studied. Also in this group is one of the "coalsack" or dark nebulae which are found along the Milky Way. Beyond Cygnus the Milky Way divides into two branches, one going through Sagittarius and the other through parts of Scorpio.

As this striking constellation Scorpio climbs to its greatest height above the southern horizon, its bright-red star passes the meridian. That bright-red star is Antares, the largest





star known, and although it stays close to the horizon now it will, because of the precession of the equinoxes, in a few thousand years climb high into the heavens for these latitudes.

To the east of Scorpio is another important summer group, Sagittarius, the Archer. It boasts no first-magnitude stars, but it lies in the Milky Way with the Scorpion, and both groups therefore contain much telescopic material. They are also distinguished by the fact that both are zodiacal constellations.

Lying along the path of the ecliptic between Scorpio and Virgo is the group of stars called Libra, the Scales. They are supposed to represent the Scales of Justice, and the name also bears some relation to the fact that when the sun is in this portion of the sky the days and nights are of equal length. Of the four bright stars here, two are interesting. Beta has a greenish color unique among naked-eye stars and Alpha is a field-glass double.

On the opposite side of Scorpio and Sagittarius, and also in the zodiac, are Capricornus, the Sea Goat, and Aquarius, the Water Bearer. Both are easily found with the aid of the star maps published here. The faint stars of Capricornus cannot be seen except in a clear sky because they are too dim to penetrate haze and are easily blotted out by the glare of street lights. An occasional passing planet serves to mark the location of this butterfly-shaped group.

Near the end of August, Fomalhaut, first-magnitude star in Piscis Austrinus, and the southernmost first-magnitude star visible from New York, rises above the horizon. It never climbs high, nor does it remain visible for more than a few hours at best, so it must be looked for at the proper time lest it be missed.

In July, late in the evening, Pegasus and Andromeda, two constellations considered as sure harbingers of falling leaves and autumn winds, are beginning to rise. And when, right below Andromeda, Triangulum and Aries come into view, we know that autumn is actually at hand, bringing with it new star groups.

Stars of the Southern Skies

SOUTH of the equator, where the constellation of Orion depicts a man standing on his head, there are dozens of star groups that cannot be seen by observers in northern latitudes.

But in the most southerly parts of the United States, the Southern Cross (Crux) rises above the horizon for a short time, and Canopus, the second brightest star in the heavens, is visible, shining with a peculiar intensity.

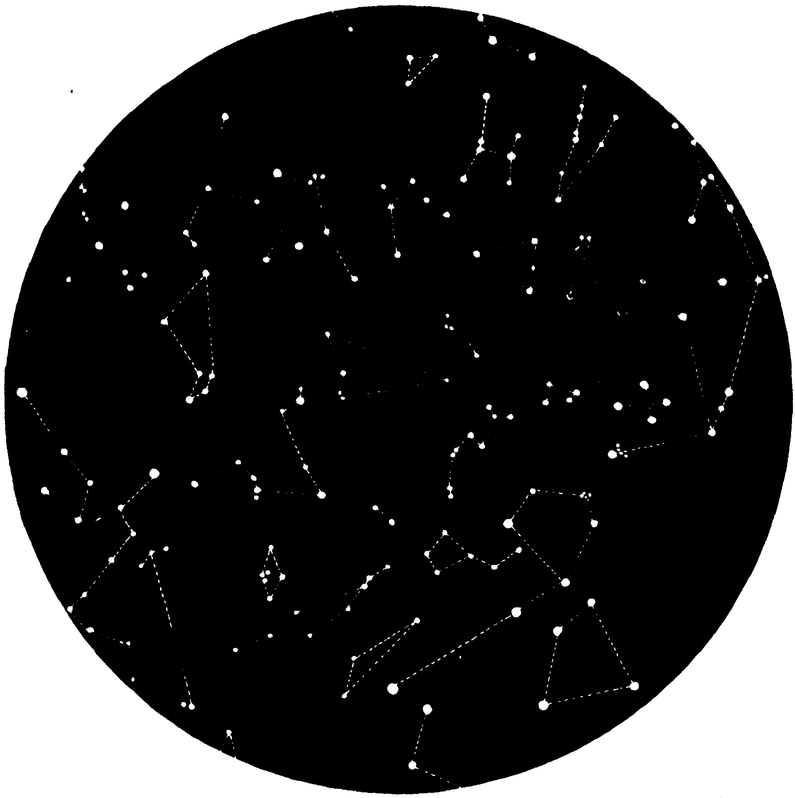
The Southern Cross is preeminent. To persons below the equator it takes the place of Ursa Major and provides a celestial timepiece, reaching its highest southern point—on the meridian—at 9 P.M. on May 15, when it is almost perfectly erect, leaning very slightly to the east.

Crux is clearly outlined by four stars of almost equal brilliance, and its likeness to a cross, therefore, is much more distinct than is that of its northern counterpart. Gamma is at the top of the cross, Alpha at the foot; Beta and Delta form the arms. No star marks the intersection of the arms although within the boundaries of the constellation there are about thirty-two stars visible to the naked eye.

Its beautiful ruddy hue makes Gamma striking to the eye but negligible on an ordinary photographic plate. Because of its color it does not photograph well except on red-sensitive plates, and this is the reason for the usual disappointment people experience when examining pictures of the Southern Cross. Kappa (κ) Crucis, also deep red, is in the midst of a fine cluster of about 130 stars, which are tinted in practically all the colors of the rainbow.

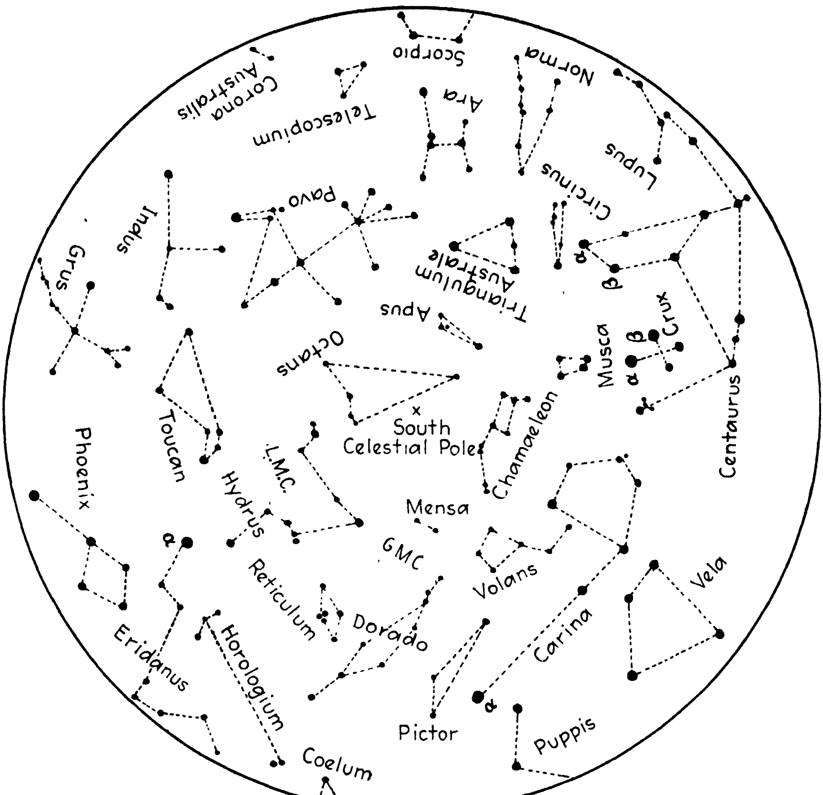
A very interesting feature of the Cross is a coalsack nebula which is situated just due east of Alpha and covers a sizable constellation area. It is known as the Black Magellanic Cloud and is in that part of the Milky Way which runs through the Cross.

Stars of the Southern Skies



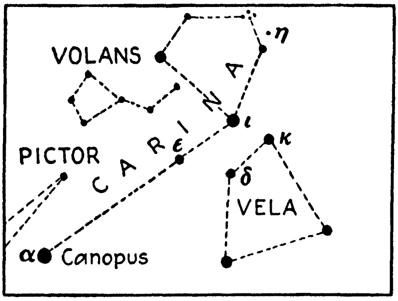
The map above shows the positions and accepted patterns for the constellations within 50° of the south celestial pole. Identification of the star groups may be made by comparison with the chart on the opposite page.

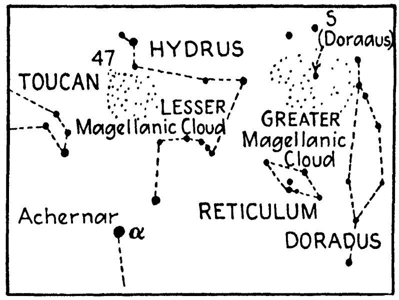
Chart of the Southern Skies



The map above shows the accepted geometrical patterns for the constellations within 50° of the south celestial pole. All the stars listed for study in that chapter are indicated, as well as the first-magnitude stars, which are:

α Carinae—Canopus	β Centauri
α Eridani—Achernar	α Crucis
α Centauri	β Crucis



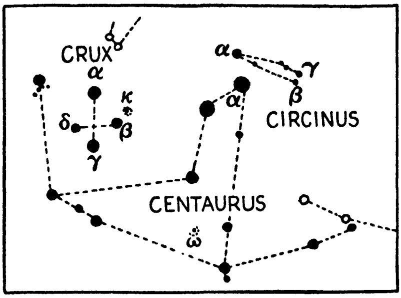


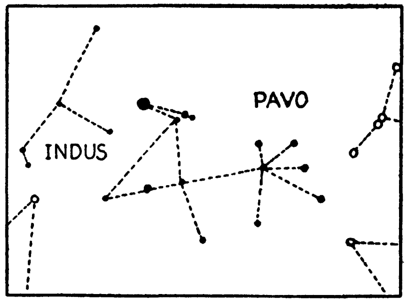
Drawing a line from Delta and extending it through Beta Crucis, one encounters Beta and Alpha Centauri. Centaurus, the Centaur, is one of the largest constellations in the southern sky, measuring in length about 45° or half the distance from the horizon to the overhead point, the zenith.

The two brightest stars in Crux are the second and fourth brightest stars in the southern sky. Alpha Centauri, one of the most widely known stars in the whole heavens, is the third brightest of the naked-eye stars. Before the year 3000 B.C. Egyptian temples were oriented to it. It is a double star, our second nearest neighbor in the stellar universe. Its faint companion, Proxima Centauri, is the nearest star to the sun, having a distance of 4.16 light years. This indicates that it takes light, traveling at 186,000 miles per second, 4.16 years to bridge the distance between the star and the earth.

The most beautiful star cluster in the entire heavens is located just about 18° northeast of Alpha Centauri. This globular cluster, known as Omega (ω) Centauri, is a gorgeous object even with field glasses. It contains 5,000 stars, including over 130 variables; and according to Professor Shapley it is the nearest globular cluster, at a distance of 21,000 light years. If the sun were removed to that distance, it would appear as a star of the twelfth magnitude.

East of Crux and near Centaurus is Circinus, the Compass, outlined by four stars. Alpha Circini is at the joint of the Compass, Beta and Gamma at the two points. Triangulum Australe, the Southern Triangle, is neighbor to the Compass. It is formed by one second and two third-magnitude stars.





The faint constellation Norma, the Level, is just north of the Triangle; Apus, the Bird of Paradise, is south. Ara, the Altar, lies near the tail of the Scorpion and is composed mostly of third-magnitude stars.

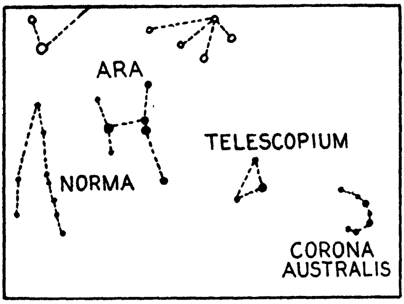
Now returning to the base of the exploring expedition, the Southern Cross, the journey will continue west. The constellation Carina, the Keel and Hull of the Ship, and Vela, the Sails, are due west of Crux. Carina has a surprising number of ruddy and variable stars.

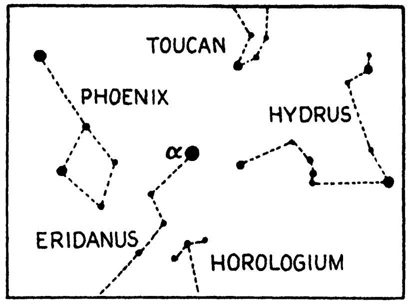
A great number of travelers to the south are confused by the False Cross, which is almost the exact replica of Crux although it is slightly larger. This False Cross is composed of Delta and Kappa Velorum and Epsilon and Iota (ι) Carinae.

Eta Carinae is an irregular variable star in the midst of a wonderful nebula. A glance at its remarkable history reveals that, although it was fourth magnitude in 1677, it rivaled Sirius in 1842. It later became invisible to the naked eye and is today a telescopic object of nearly eighth magnitude.

About 90° west of the Southern Cross lies the second brightest star in the whole heavens—Canopus, Alpha Carinae. Its magnitude is -0.9, and it is one of the very few super-giant stars. This extraordinary star shines with a white light slightly tinted with yellow, and although it is over 400 light years away it appears bright to us because it radiates about 45,000 times as much light as the sun!

Eighteen degrees nearly southwest of Canopus is the Great Magellanic Cloud (Nubecula Major) and about 70° due west of the Great Cloud is the Lesser Magellanic Cloud. The Greater

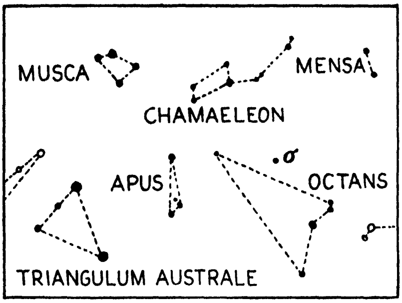


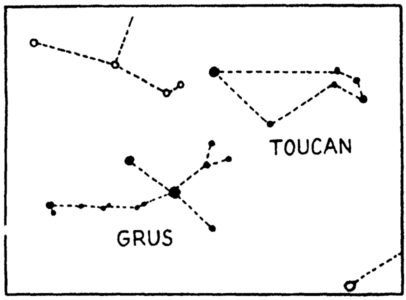


Cloud is about 7° in diameter or fourteen times that of the full moon, and is situated on the border of Dorado, the Swordfish, and Mensa, the Table Mountain. The Lesser Cloud, which is less than 4° in diameter, lies in Tucana, the Toucan. Their brightness, according to Sir John Herschel, "may be judged from the effect of strong moonlight, which totally obliterates the lesser, but not quite the greater." These great objects are made up of star clusters and nebulae. One of the members of this cloud is the super-giant variable S Doradus which, at its maximum, is half a million times brighter than the sun. The actual diameter of this immense object is about sixty million miles and it is intrinsically the brightest object known.

About the same distance from the south pole as Crux but on the opposite side of the heavens is the constellation Eridanus, the River Po, with its bright star Achernar. Eridanus flows in a long winding course from Rigel in Orion over to Cetus, past Fornax and Phoenix to Hydrus, ending in Achernar. The total length of this "Mississippi of the Sky" is about 130°. The constellation is composed mostly of fourth-magnitude stars with Achernar standing out by virtue of its brilliance.

Omicron (*o*) Eridani is a beautiful triple star in which the two faint companions are over 43 billion miles from their primary. In this region is located a planetary nebula described by Lalande as the most extraordinary object of its kind he had ever seen. It consists of an eleventh-magnitude star surrounded by a circular nebula, and this set against a larger,





hazy cloud. Gamma Eridani is a fine contrasting double star, magnitudes 2.5 and 10, separation 51 seconds. It is not in the circumpolar section, however.

Eridanus is surrounded by nine constellations: Hydrus to the south; Phoenix, Fornax, and Cetus to the west; Taurus on the north; Orion, Lepus, Coelum, and Horologium on the east.

In the southeast corner of Toucan lies the Lesser Magellanic Cloud, which is visible to the naked eye. Near by is the famous globular cluster, No. 47 Tucanae, whose 22,000 stars blend into a single star of the fourth magnitude when seen without optical aid.

Directly south of this group is the constellation nearest the south celestial pole, Octans, the Octant. Sigma (σ) Octantis, sixth-magnitude, may be called the Polaris of the south; it is just a little less than 1° from the true south celestial pole.

Most of the names assigned to the constellations in this region of the heavens are of modern origin because the greater number of ancient astronomers lived in northern climes and few ever went south to continue their work. Among the comparatively recently named constellations there appear Antlia, the Air Pump; Chamaeleon; Circinus, the Compass; Columba, the Dove; Crater, the Cup; Crux, the Cross; Fornax, the Furnace; Horologium, the Timepiece; Indus, the Indian; Mensa, the Table Mountain; Microscopium; Musca, the Fly; Pictor, the Easel; Pavo, the Peacock; Telescopium; and Volans, the Flying Fish.

Within 40° of the south pole there are stars representing twenty-seven constellations, while in the same area around the northern pole only fifteen are represented. There are five first-magnitude stars in this southern area and none in the northern. The southern sky has about ten second-magnitude stars, the northern about thirteen. So from studying both northern and southern circumpolar skies it may be concluded that the south circumpolar sky has the more brilliant constellations and individual celestial objects.

But when the heavens 50° south of the equator are compared with those 50° north, both sides come out just about even in brilliance and interest. In all, 6,000 stars are visible to the naked eye and they are shared almost equally by both hemispheres.

Exploring among the Planets

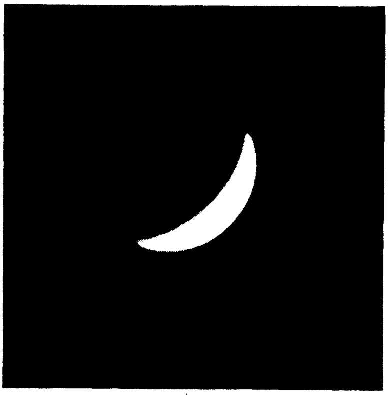
CIRCLING forever about the sun, the planets move against the background of constellations that form the zodiac. Day after day they speed on their way, each a fascinating world revealed to us only by reflected sunlight, for the planets are dark and cold and borrow their brilliant, steady light from the sun.

Quickest of them all and closest to the sun is little Mercury, which completes a revolution—its year—in about eighty-eight days. With the same face always toward the sun because its rotation period is equal to that of its revolution, one-half of the planet is constantly scorched by the sun's rays while the other side is locked in the perpetual cold and blackness of an eternal night. However, owing to the constant rotation and the slightly varying orbital speed (because of its elliptical path), there is a fairly wide zone on Mercury along the twilight line where the sun alternately rises and sets.

Even here the rugged surface is unprotected by an atmosphere and as a result drastic changes minimize the possibilities of life on the planet.

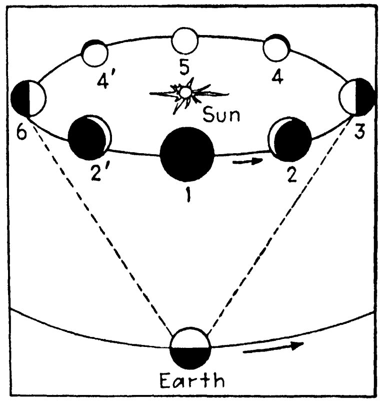
Because of its nearness to the far more brilliant sun—it is on the average only 36 million miles distant—this speeding little globe is seldom seen. There are six two-week periods during the year when it is well situated for observation. These occur at the times of greatest elongation, or when the planet is at its farthest distance from the sun as seen from the earth. At the time of greatest eastern elongation, Mercury sets soon after the sun and is seen in the west as the so-called "evening star." About two months later, reaching greatest western elongation, it will rise in the eastern sky soon before the sun and be known as the "morning star."

Although visible only for an hour or so on each of the days near elongation, Mercury shines with a brightness which varies between that of Aldebaran and Sirius In a 2- or 3-inch tele-



Yerkes Observatory

VENUS. The planet Venus in crescent phase, as she appears to the great 40-inch refracting telescope at Yerkes. She shines most brilliantly at such times because of her nearness to the earth, although but a fraction of her illuminated surface is visible. It is when the planet is but a slim crescent that she is sometimes bright enough to cast a shadow.



PHASES OF MERCURY AND VENUS

1	Inferior conjunction
2 and 2'	Greatest brilliance
3	Greatest elongation west (a morning star)
4 and 4'	Gibbous phase
5	Superior conjunction
6	Greatest elongation east (an evening star)

scope, it appears as a pale yellow globe without surface detail, but it displays phases similar to those of the moon, the causes of which are shown in the diagram above.

Yellowish-white Venus at her best is more than fifteen times as brilliant as Sirius, the brightest star in the heavens. She takes about 225 days for her journey about the sun, traveling along an orbit that is almost a perfect circle. Of all the planets, she is the one most nearly comparable to the earth, for her diameter of 7,575 miles is about equal to the earth's.

Venus has been observed to have a very dense atmosphere which, however, contains practically no oxygen. It is possible, however, that what has been observed is merely an outer layer of atmosphere above a blanket of dense clouds which surround the body. This suggests the possibility of oxygen beneath the clouds sufficient to sustain life.

Like Mercury, Venus is never very distant from the sun. For certain periods of time she is invisible to the naked eye, although her periods of invisibility are not so frequent as those of Mercury. She can be seen at the time of dawn or sunset, but for no more than four hours at a time. However, Venus can at times be seen in daylight with the naked eye.

Using a small telescope, we can watch Venus go through phases just like those of Mercury. When the planet is farthest from the earth, on the opposite side of the sun, she is "full"; when nearest the earth she is in crescent. The planet apparently changes in size as it goes from crescent to full and back to crescent, and its apparent diameter is six times as great in crescent as when it is full. At its maximum brilliance, which occurs 36 days before and after inferior conjunction, it is only a crescent. It is then plainly visible and sometimes even bright enough to cast a shadow.

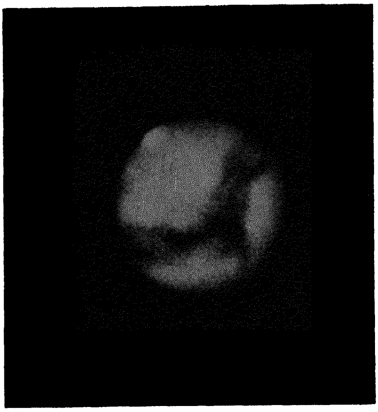
Little of the surface has ever been seen except under very fortunate and perhaps unique observing conditions. For this reason the rotation period or day of the planet has not yet been satisfactorily determined.

Both Mercury and Venus are visible for the greatest lengths of time before sunrise and after sunset when they are at their greatest western and eastern elongations, respectively. The planets are brightest as they pass near the earth between the elongations.

Traveling outward in the solar system, we pass the earth and arrive at the ruddy Mars, which because of its color has long been symbolic of the war god. It is only 4,230 miles in diameter—the smallest planet in the solar system except for Mercury.

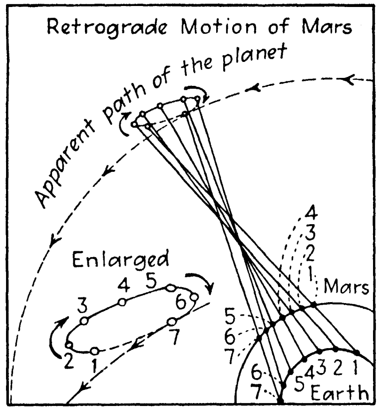
Mars goes through seasons similar to the earth's because its axis is inclined to its orbit at an angle similar to that of the earth's. Its day, $24^h\ 27^m$, is also comparable with the earth's, but its year is nearly twice as long, for it takes 687 days to complete its journey around the sun.

Aided by nearly perfect seeing conditions, several widely known observers of Mars have distinguished linear markings or "canals." At first they were attributed to the handiwork of an advanced race of human beings who dug them to bring water down from the poles, but this sensational idea has been more or less abandoned. Indeed, the best observers are quite



Yerkes Observatory

MARS. Prominent in this photograph of Mars is the south polar cap, which changes in size with the seasons. Syrtis Major, the wedge-shaped area extending toward the north, changes color to correspond with the variations in the polar cap and some astronomers say it is a vast area of vegetation.



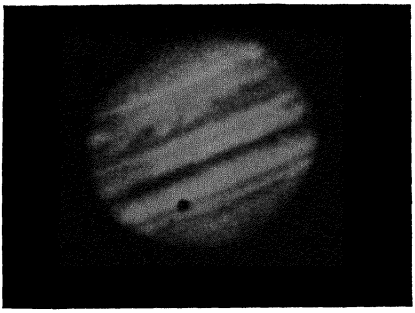
When the planets are in position 2, Mars appears to be moving normally as seen from the earth. But gradually the earth passes Mars and the red planet seems to move more slowly. In position 3 it apparently starts to move backward and it continues so in 4 and 5. In 6 it once again moves forward.

in disagreement as to whether the canals actually exist, for it is a question of seeing detail at the extreme limit of visibility.

Easily picked up and observed when visible, Mars shows a reddish surface with grayish or greenish markings. Even with a small telescope some surface detail is visible. Because of the great transparency of the Martian atmosphere, the polar caps can generally be seen, except when they melt away during the long summer. The pole caps are believed to be either frozen water or carbon dioxide. Extensive reddish areas, the continents of the early observers, and green or gray regions or lakes are plainly visible with sufficient magnification.

For Martian observations with a small instrument a magnification of 200 to 350 diameters is required before one begins to see surface detail; with magnification of 300, one begins to see polar caps, Syrtis Major, and other dark areas.

The red planet is attended by two moons, Phobos and Deimos, neither more than 10 miles in diameter. They are so close to the planet and so small that they cannot be picked up with anything but the largest instruments. Phobos, the inner



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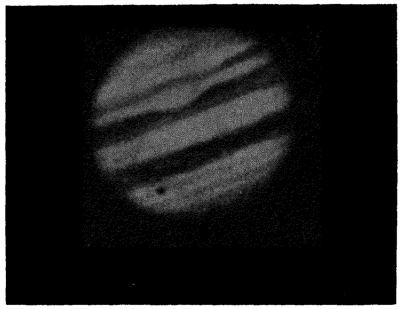


B

Mt. Wilson Observatory

JUPITER. Ganymede, largest moon of Jupiter, throws its shadow on the belted surface of the planet just before the satellite itself crosses in transit. The shadow is more easily observed than the satellite which is soon lost on the planet's disk.

moon, speeds about the planet in less than one-third of a Martian day and, interestingly enough, it rises in the west and sets in the east.

Man has let his imagination run away with him in contemplating the possibility of life on Mars. Whether the canals, which some astronomers claim they have seen, are really waterways and whether Syrtis Major is really a vast area of vegetation remain unanswered questions. And the ideas of writers which picture the Martian man as anything from a creature resembling an octopus to a highly intelligent being are never ending.

Beyond Mars lie the diminutive asteroids, which are discussed separately elsewhere, and outside this belt of minor planets is Jupiter, the largest planet in the sun's system. Pacing slowly and majestically through the heavens, this great cooled-off mass measures 82,880 miles from pole to pole. It is outshone only by Venus and occasionally by Mars and appears as a star much more brilliant than Sirius.

The amateur with his small telescope sees on Jupiter soft shades of red, yellow, tan, and brown and a wealth of other telescopic detail. Exceptional sight is not required to get a clear view of the surface markings, and often a slight haze or smoke in the air will steady the image. Barring the belts which stretch in parallel lines across the disk, the chief marking is—or was—the much-talked-of "red spot" of Jupiter.

First discovered on the Jovian surface in 1857, it has disappeared and reappeared during the years. A curious feature of this floating beauty mark is that it leaves behind it a hollow space to mark its position each time it vanishes.

Of Jupiter's nine moons, four are visible even in a field glass. Their positions in relation to the primary vary from night to night, and indeed from hour to hour. Readily identified, they may be watched through many interesting hours as they speed in front of Jupiter, throwing their shadows on the planet, or vanish behind its giant disk or plunge suddenly into its immense shadow. With care, it is possible to follow the transits of their shadows, and to time their passages behind the planet. A record kept of the moons from night to night gives a graphic picture of their whirlwind paths about Jupiter.

The system of Jupiter and its moons presents a miniature solar system, orderly and regular in manner. Each satellite has a definite period (which you may time for yourself and then check with an ephemeris); each has a definite path; each travels in a set direction about the planet. Of the five satellites that are not visible with small instruments, the outermost two revolve about Jupiter in retrograde direction from east to west. Discussion has arisen from this fact as to whether they might not be captured asteroids and therefore not originally members of Jupiter's system.

Saturn, the next planet beyond Jupiter, was the last known to the ancients who were unequipped with telescopes. And without telescopes, these ancients missed the most wonderful sight to be found in the entire heavens. For Saturn, with his beautiful rings, deserves that title; it presents a magnificent spectacle.

The ring, for it appears as a single flattened object in a small instrument, is poised high over the planet's equator, its inside edge about 7,000 miles above the cloud surface. At different times it appears to us inclined upward or downward and it may even disappear for a time, because, when it is viewed edge on, it actually is invisible. The rings are really inclined at an angle of 27° and remain that way always; but

Barnard at Yerkes Observatory

SATURN. Saturn's rings, darkened in the rear by the planet's shadow, show up beautifully in this photograph. Cloud belt surface and Cassini division of the rings are defined.

as the planet moves around the sun, we see them at varying angles—from the front, the rear, or the side, according to Saturn's position with respect to the earth.

Twice every thirty years Saturn reaches a place in its orbit where the rings are tilted edge-on to the earth. At this time they disappear when viewed with small telescopes and are seen only in the most powerful ones as a fine needle thrust through the globe. They are made visible at such times only by the sunlight passing through them. The rings reflect so much light that, when they present their broadsides to the earth, the planet appears three times brighter than when the rings are edgewise.

A telescope shows the divisions of the rings clearly. First to be noticed is the Cassini division which divides the system in two, and which is easily seen in a small telescope. Then on the outer ring we may see the faint, gray Encke division. This, however, is illusive and is not always visible. The inner ring gradually shades off on the inner edge to meet the misty gray border, the crepe ring.

The outline of the planet has been vaguely seen through the crepe and outer rings, and stars have been seen through all three, for they are composed of hundreds of tiny moonlets revolving about the planet. The rings throw their shadow on the surface of Saturn as a dark, sharply outlined band. In turn, Saturn throws its shadow across its belt of rings as a black shape outlining one rim of the planet.

As for its surface, the ringed planet is somewhat like Jupiter in that it too seems spanned by cloud belts. Little of these can be seen, however, except under exceptionally fine conditions. Occasionally a spot mars the complexion of Saturn, a spot which is very useful in determining the precise rotation period of the planet. The latest one, discovered in 1933, was called the "white spot" and, although it has since diminished somewhat, it is still faintly visible.

Saturn, too, is blessed with nine moons and so outrivals Jupiter, equaling him in satellites and bettering him in rings. At one time, the planet was thought to possess ten moons, but the tenth has, since its reported discovery, vanished and there is some doubt about its existence. Without a more powerful instrument than a 3-inch telescope it is difficult to make observations of the satellites, although Titan frequently can be seen with such a glass. Care must be taken to distinguish them from the stars, but the moons—Titan, Iapetus, Rhea, Tethys, and Dione—are supposed to be visible in a 4-inch telescope. They are named in the order of their observational possibilities.

Discovered by Herschel in 1781, Uranus is the next planet in order out from the sun. About 30,000 miles in diameter, it can be seen as a sixth-magnitude "star" despite its 1,780 million miles' mean distance from the sun. It can be seen as a naked-eye object by observers gifted with good eyesight.

Through a telescope it appears as a tiny green body with vaguely defined belts stretching across its surface. No permanent markings have been perceived upon it that can be used for the exact determination of its rotation period, but this was spectroscopically determined by Slipher who found the period to be about 10⅔ hours.

Uranus has four satellites, but they are all very faint and cannot be observed except with large telescopes. The chief observations possible for amateurs are the locating of the planet and the mapping of its path among the stars. With the aid of the charts published here, it may easily be followed.

Neptune was not discovered until 1846, but it was not long afterwards that it was found to have one satellite. Although Neptune is larger than Uranus, with a diameter of 31,000 miles, Neptune's greater mean distance from the sun, 2,790 million miles, makes it quite invisible except in a telescope of 2 inches or greater aperture. It is, at its brightest, an object of eighth magnitude, and with a little care it may easily be located. Triton, its one satellite, is out of the reach of a small telescope, but with such an instrument you should make out the greenish color of the planet itself. Very much to be recommended is the reading of the "Hints on Telescope Usage" (page 94), which describes the proper technique for locating this planet and other telescopic objects.

Completely out of the range of small instruments, and indeed not easy for a 15-inch refractor, is Pluto, found after years of search in January, 1930. It is so far distant from the sun that it takes 248 of our years to complete one revolution and consequently spends 20 years within the boundaries of one zodiacal constellation. It is still near its discovery point at Delta Geminorum. We know little more about it than that it is about one-half the size of the earth and has no satellites yet discovered.

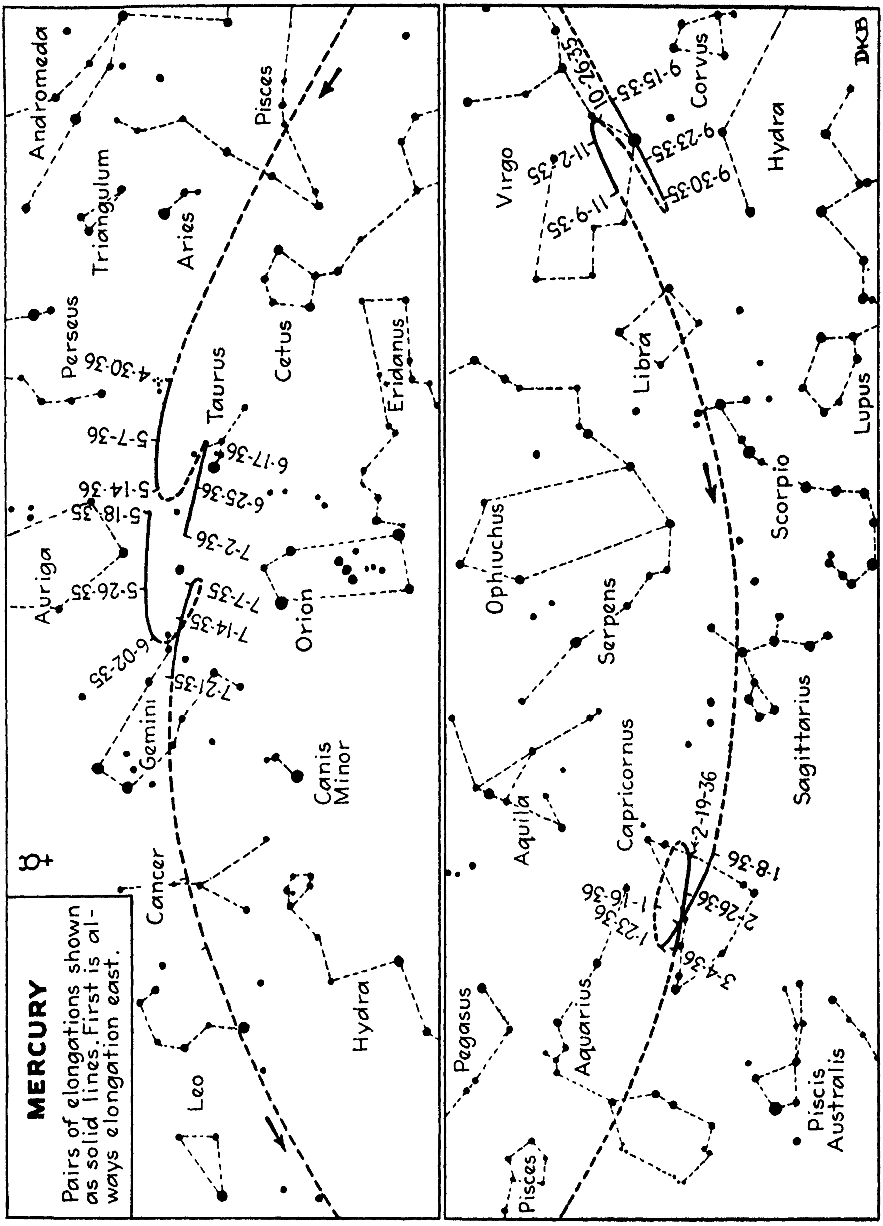
An excellent piece of naked-eye observation of any one of the planets is the mapping of its path among the stars. Sooner or later (except in the cases of Venus and Mercury which are invisible at such a time) the observer will notice the retrograde motion of the planet. That is when it seemingly turns around and backtracks along its former path. But before it has gone far it will turn again and proceed in its original direction. This is an interesting phenomenon and is an effect caused by the relative movements of the earth and the planet under observation. The diagram on page 40 shows this for the earth and Mars. In the following planet maps retrograde motion appears in the path of almost every planet during the period covered by the maps.

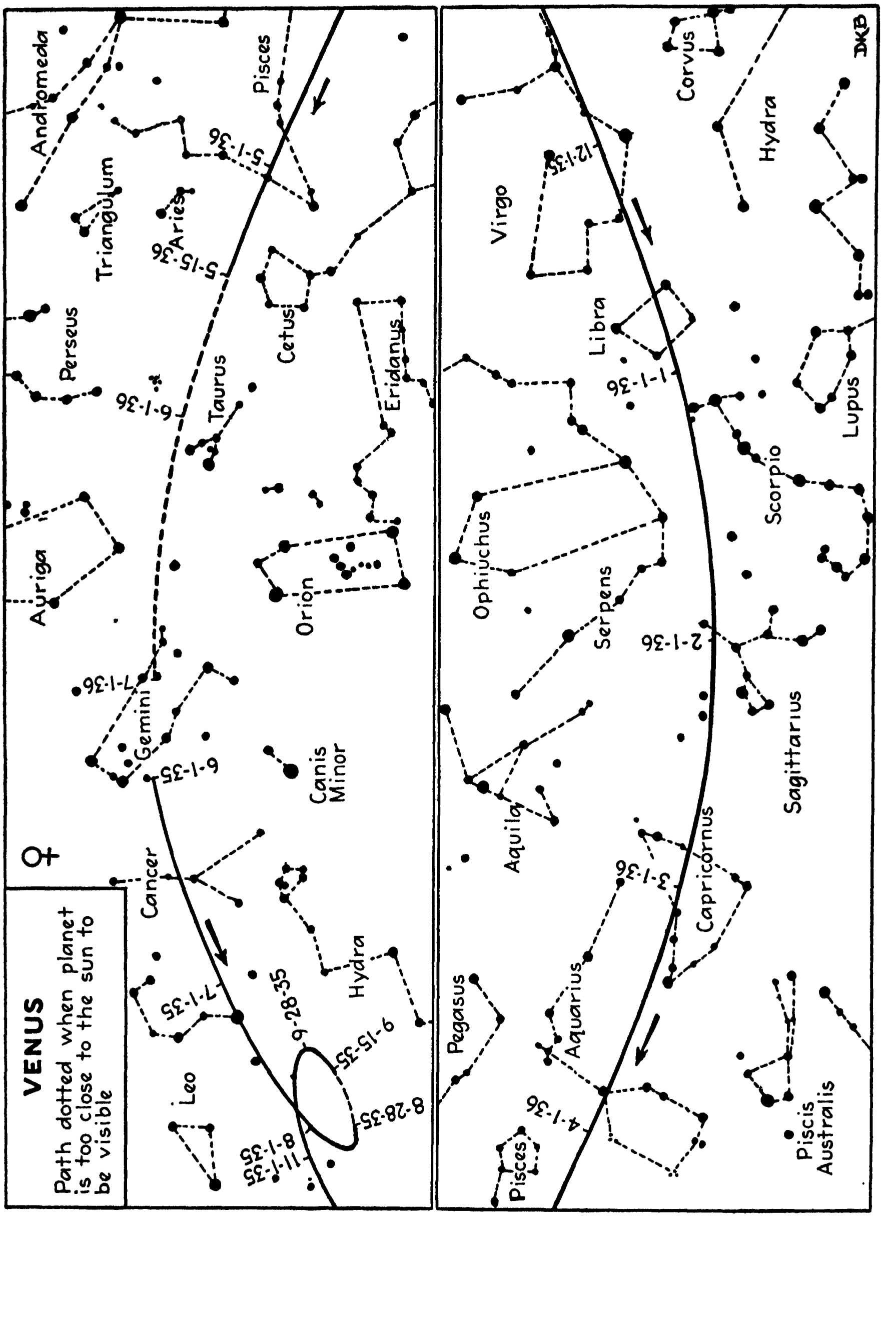
Planet Maps

In the following planet maps, the apparent path of each of the planets is indicated by a long curved line. The dates locate the position of the planet at different times during the year.

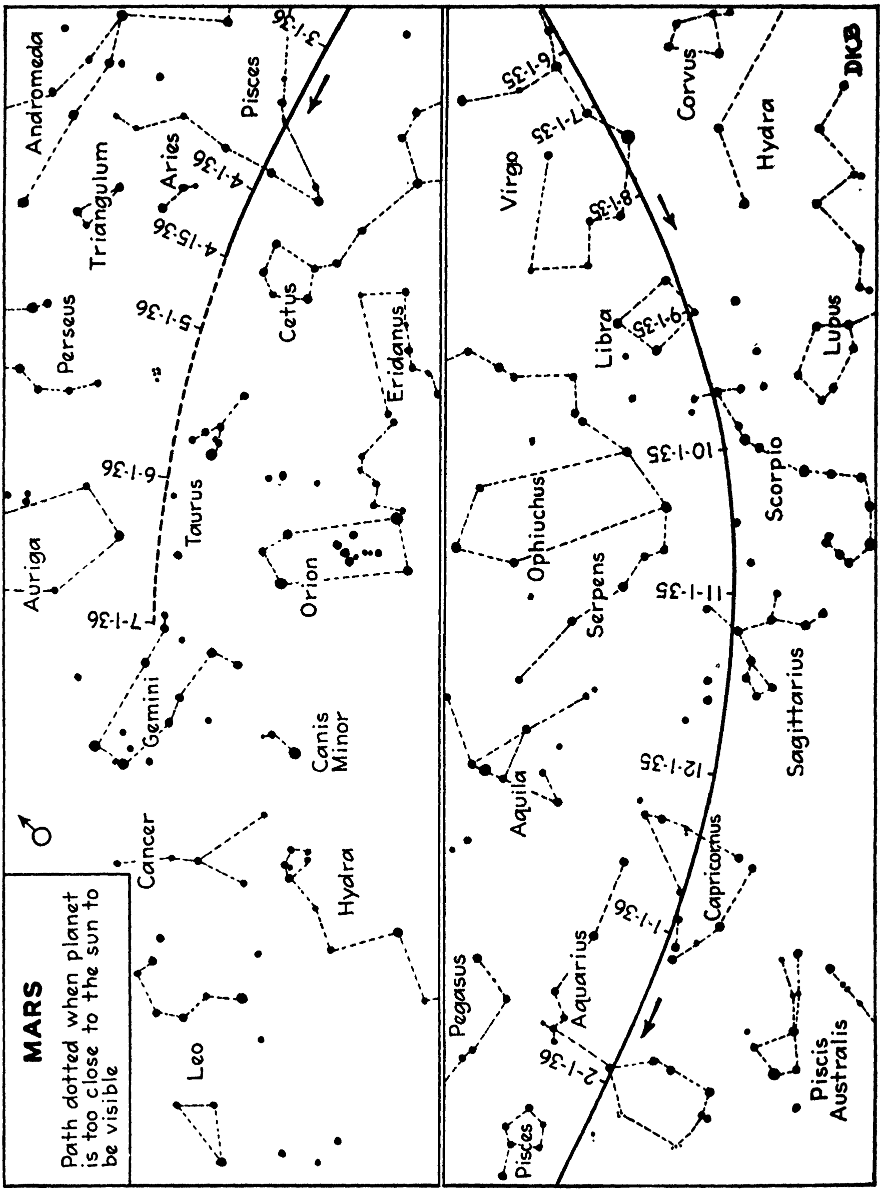
To learn whether Venus, for instance, is a morning or evening star, refer to these maps to learn in which constellation it is located at the time. If the path is dashed in the maps of Mercury, Venus, and Mars, the planet is invisible. If it is visible, refer to the constellation maps to learn when and in what part of the sky the group containing the planet may be seen.

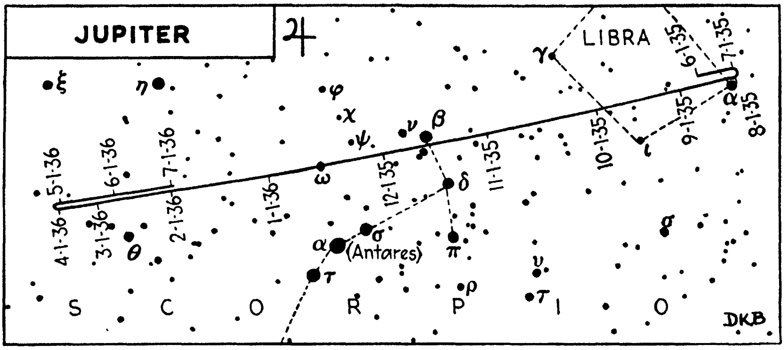
The charts for Jupiter and Saturn show stars to the limit of naked-eye visibility. The charts for Uranus and Neptune show stars down to $9^{\mathrm{M}}.3$. Only the naked-eye stars are labeled on these two charts. Uranus is on the limit of naked-eye visibility and hence its magnitude is close to that of the three BD stars (see the *Bonn Durchmusterung*, Argelander's great atlas and catalog of stars to declination $-2°$). Neptune is much fainter, somewhat brighter than the fainter stars shown.


MERCURY
Pairs of elongations shown as solid lines. First is always elongation east.
☿
Andromeda
Triangulum
Pisces
Aries
Perseus
Cetus
Taurus
Eridanus
Auriga
Orion
Gemini
Canis Minor
Cancer
Leo
Hydra
4-30-36
5-7-36
6-17-36
5-14-36
6-25-36
5-18-35
7-2-36
5-26-35
7-7-35
7-14-35
6-02-35
7-21-35
Virgo
Corvus
Hydra
DKB
9-15-35
10-26-35
9-23-35
11-2-35
9-30-35
11-9-35
Libra
Lupus
Scorpio
Ophiuchus
Serpens
Sagittarius
Capricornus
Aquila
2-19-36
1-8-36
1-16-36
2-26-36
1-23-36
3-4-36
Pegasus
Aquarius
Piscis Australis
Pisces



VENUS
Path dotted when planet is too close to the sun to be visible
♀
Andromeda
Pisces
Triangulum
Aries
Perseus
Taurus
Cetus
Eridanus
Auriga
Orion
Gemini
Canis Minor
Cancer
Hydra
Leo
5-1-36
5-15-36
6-1-36
7-1-36
6-1-35
7-1-35
9-28-35
9-15-35
8-28-35
8-1-35
11-1-35
Corvus
Hydra
Virgo
Libra
Lupus
Scorpio
Ophiuchus
Serpens
Sagittarius
Aquila
Capricornus
Aquarius
Pegasus
Pisces
Piscis Australis
12-1-35
1-1-36
2-1-36
3-1-36
4-1-36
DKB


MARS
Path dotted when planet is too close to the sun to be visible
Andromeda
Triangulum
Aries
Pisces
Perseus
Cetus
Eridanus
Taurus
Auriga
Orion
Gemini
Canis Minor
Cancer
Hydra
Leo
3-1-36
4-1-36
4-15-36
5-1-36
6-1-36
7-1-36
Virgo
Corvus
Hydra
Libra
Lupus
Ophiuchus
Serpens
Scorpio
Sagittarius
Aquila
Capricornus
Aquarius
Pegasus
Pisces
Piscis Australis
6-1-35
7-1-35
8-1-35
9-1-35
10-1-35
11-1-35
12-1-35
1-1-36
2-1-36
DKB


JUPITER
LIBRA
(Antares)
S C O R P I O
5·1·36
6·1·36
7·1·36
4·1·36
3·1·36
2·1·36
1·1·36
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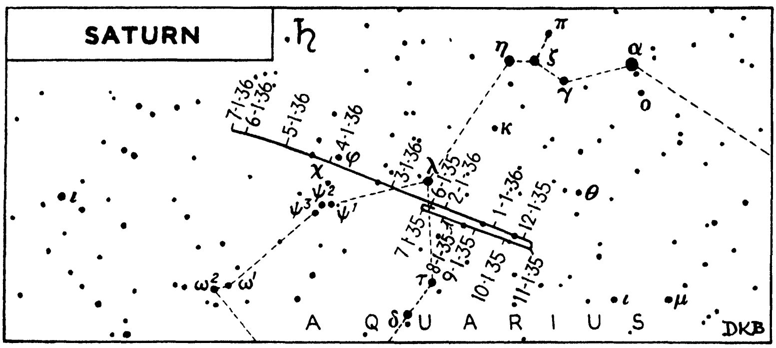
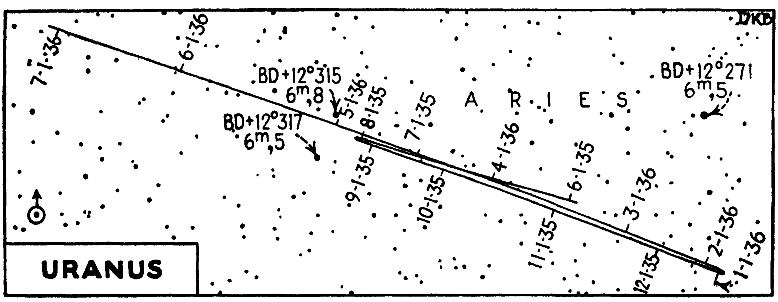
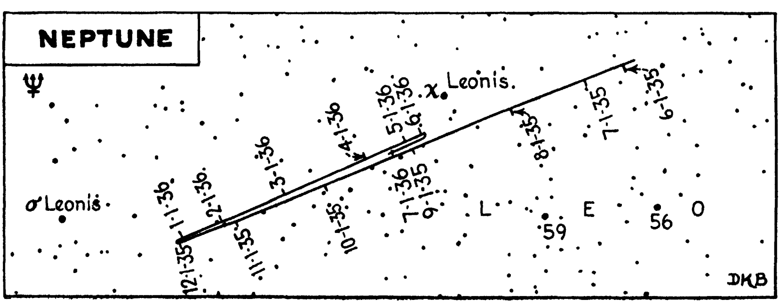
8·1·35
7·1·35
6·1·35
DKB


SATURN
7·1·36
6·1·36
5·1·36
4·1·36
3·1·36
2·1·36
1·1·36
12·1·35
11·1·35
10·1·35
9·1·35
8·1·35
7·1·35
6·1·35
A Q U A R I U S
DKB


URANUS
BD+12°315
6m,8
BD+12°317
6m,5
BD+12°271
6m,5
A R I E S
7·1·36
6·1·36
5·1·36
8·1·35
7·1·35
9·1·35
10·1·35
4·1·36
11·1·35
6·1·35
3·1·36
12·1·35
2·1·36
1·1·36
DKB


NEPTUNE
χ Leonis.
σ Leonis
L E O
59
56
1·1·36
2·1·36
3·1·36
4·1·36
5·1·36
6·1·36
7·1·36
7·1·35
6·1·35
8·1·35
9·1·35
10·1·35
11·1·35
12·1·35
DKB

Exploring on the Moon

SLOWLY the sun rises over the barren, sandy wastes and the great jagged mountain peaks that form a conspicuous part of the moon's surface. Slowly it reveals to the patiently waiting astronomer the landmarks that make the moon the most interesting planetary object for amateur observation. The amateur astronomer finds that the moon's topography, studied even with a small telescope, field glass, or the unaided eye, is far more fascinating than the earth's.

But, just as terrestrial geography is systematic, so is lunar topography, and to make a good beginning it is wise to learn the maria, or seas, so named by the early lunar observers. These great areas are really dark-colored and comparatively smooth plains. The first large one visible as the moon swings around the earth after its "new" phase, and one that is easily recognizable by its isolation, is Mare Crisium. As the moon waxes, the next to appear are, in order: Mare Foecunditatis, Mare Nectaris, Mare Tranquilitatis, and Mare Serenitatis. When all these are in view, the moon has reached its first quarter.

It will then seem to grow to a full moon, become again a quarter, then a crescent, and finally disappear from view. To the observer of lunar surface markings the phases are significant because the best place to observe a lunar feature is at the time of sunrise or sunset on that object. It is then brought into sharp relief by the shadow it casts and is located on the terminator—where sunlight ends and shadow begins. The terminator is constantly shifting across the moon with the changing phases.

The diagram on page 53 illustrates these phases and their cause. The inner circle shows how the moon really is as it revolves around the earth; the outer circle, how the lighted half of the moon appears to us. The phase varies with the angle from which we observe the parts of the moon lighted by the sun. At times a portion of the moon (not lighted by the sun) appears faintly illuminated. This is "earthshine" —the light which the earth has reflected to the moon—which makes visible, areas of the moon which would otherwise be dark and invisible. Sometimes in a clear atmosphere one can distinguish with the naked eye the seas lighted by earthshine and with a telescope certain other of the major details.

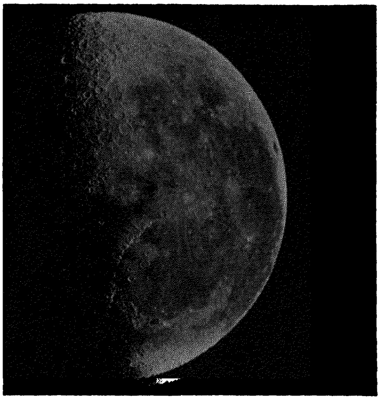
Nightly observations of the moon reveal that, on the average, it rises about 50 minutes later each evening. This is because the moon, in its monthly revolution around the earth, moves approximately 13° eastward through the zodiac in a day. As a result, should the moon rise at 10 P.M. on one evening it would still be below the horizon at the same time next night, and 50 minutes would have to elapse for the earth to rotate enough to allow the satellite to appear over the eastern horizon.

Between first quarter and full moon Mare Vaporum, Mare Frigoris, Mare Imbrium, Mare Nubium, Mare Humorum, and lastly the great Oceanus Procellarum, the Ocean of Storms, appear. This last is the most easily visible to the naked eye.

On the northwestern edge of Mare Tranquilitatis, near the Mare Crisium, will be found the Palus Somnii, the Marsh of a Dream. On the northern "shore" of Mare Imbrium will be found two promontories, Promontory Laplace and Promontory Heraclides, enclosing the semicircular Sinus Iridum, the Bay of Rainbows. Some of the mountains bordering on this bay are said to have peaks towering to 20,000 feet.

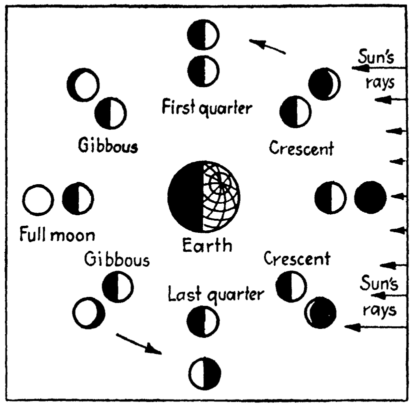
Connecting with the side of the Mare Imbrium is the Sinus Aestuum, the Bay of Hearts, and still farther south and almost in the center of the visible hemisphere of the moon is the appropriately named Sinus Medii. To the west of Mare Imbrium can be found the Palus Nebularum, the Marsh of Clouds, and the Palus Putredinus (between Imbrium and Serenitatis). The inconspicuous Sinus Roris is north of Procellarum and connects with Mare Frigoris.

Once these maria, marshes, swamps, etc., have been discerned, it is natural for the telescopist to develop a strong



Yerkes Observatory

MOON. Near the sunrise line are the lunar Apennines, brought into sharp relief by the sun's slanting rays. Some of the towering peaks on the dark side are tall enough to be seen while the valley below is in darkness.



THE MOON'S PHASES. The inner circle represents the moon as it appears from a point above the earth's pole; and the outer circle shows it as it is seen in the sky (considered apart from the diagram).

interest regarding the circular, crater-like objects, which, next to the seas, are the most conspicuous objects to be observed on the moon.

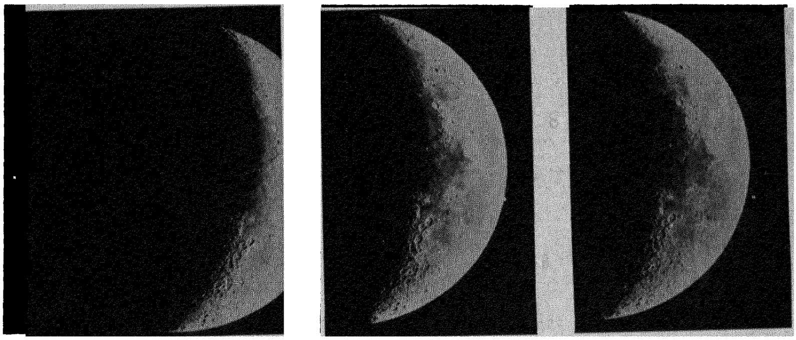
The largest of these crater-like formations are the "mountain-walled plains." They range in size from 60 to 150 miles in diameter. These plains, which closely resemble smaller maria, are encircled by mountain masses of different heights. The interior is much depressed below the level outside the rim, this rim or rampart often rising but little above the surrounding land. Typical of these mountain-walled plains are Clavius (the largest), Schickard, Ptolemaeus, Maginus, and Grimaldi. All of these and numerous other objects appear on the moon map on page 59.

The second group of crater-like features is the "mountain-ringed plains." The ramparts are practically circular, 10 to 60 miles in diameter, with steep inner slopes and gentle outer slopes; the floors are deep depressions; many craters may be discovered on the tops of the walls or on the outer slopes; often there are central peaks: Theophilus, Aristillus, Aristoteles are typical of these. Copernicus and Tycho also belong here and are noted for the striking ray systems radiating from each, these being seen best at the time of full moon. The rays from Tycho extend for hundreds of miles over mountain and plain without interruption. Plato is unique in color and easily located. It was in this crater that Pickering discovered monthly variation, which he supposes is caused by vegetation. Herschel is a small ringed plain north of Ptolemaeus. When on the terminator it can easily be discerned with eighteen-power binoculars and is a beautiful sight, small and round with a very bright inner wall. It thus makes a fine test for low magnification.

The third type consists of the "craters" or "crater rings." These craters proper are but 3 to 10 miles across and are too small to be picked up with low telescopic power. They are almost perfectly circular, very numerous, and of much interest to observers with telescopes using 50 to 500 diameters. They are too small to be indicated on the lunar chart, which shows only the larger and more easily observable objects.

Of the mountain ranges, the more striking ones are named after terrestrial ranges; for instance, the Alps, Apennines, and Carpathians, all of which are part of the irregular border of Mare Imbrium. In these lunar ranges are many hundreds of peaks whose elevations average over 10,000 feet. Some rise higher; Mt. Huygens in the Apennines and Mt. Hadley in the Palus Putredinus rise to heights of 15,000 to 18,000 feet. The Leibnitz range is the highest on the visible lunar surface and some of its peaks are perhaps higher than Mt. Everest, a few being said to attain 30,000 feet. The range is located on the extreme southern limb and so it is seen only in profile. All these ranges resemble earthly mountains, although erosion is commonly supposed to be quite absent; this may not be true, however, as the Riphaen mountains (for example) appear to have suffered much erosion.

The crater Aristarchus is notable as being the brightest object on the moon and by early observers it was often mistaken for an active volcano. The deepest depression to be seen is the small crater Newton. The Straight Wall is a strange object and not very difficult to pick up. When the



Yerkes Observatory

OCCULTATION OF ALDEBARAN. At the left, the star is seen just before it disappears behind the dark limb of the moon. The second picture was made just as it was moving from behind the moon, on the lighted limb, and the third plate was exposed less than two minutes after the star had completely emerged from behind the satellite. The panel is arranged to present the phenomenon as it appears to the naked eye.

light is right there is a bright edge with a narrow black border. It is believed to be a "fault" and is located in the southwestern corner of Mare Nubium. Look also for the Straight Range between Plato and the Promontory Laplace. This formation assumes a nearly uniform, straight line, east and west, about 45 miles long, with at least a dozen peaks discernible with high enough magnification. The central peaks in many of the craters and crater-like objects have been successfully used to account for the lunar formations in both the volcanic and meteoric theories of the moon's origin.

There is no end of interesting material for moon explorations, because more advanced work in observing, besides touching the foregoing types, also brings in isolated mountains, dome-shaped hills, crater chains, crater pits, rills, many twin craters, multiple craters, ruined ring plains, hilltop craters, and other special formations.

In addition to presenting many features of interest in its topography, the moon plays an important part in several spectacular celestial phenomena. Chief among these are occultations and eclipses.

As the moon moves through the sky, it frequently glides in front of a star or planet, blotting it from view. Since the moon always moves eastward in the sky, the object always disappears behind the eastern edge and reappears on the western limb. In an occultation, as it is called, of a star below fourth magnitude a telescope is usually necessary because the moon's light cuts the star from naked-eye view before its disk actually eclipses it. And it must be remembered that an astronomical telescope reverses the object. Therefore a star which, to the naked eye, appears to the left of the moon will seem to be at the right in the telescope.

The most interesting effect is when the dark side of the moon is in the lead (any time before full) and the star disappears without warning. Another unusual sight is the occultation of a double star.

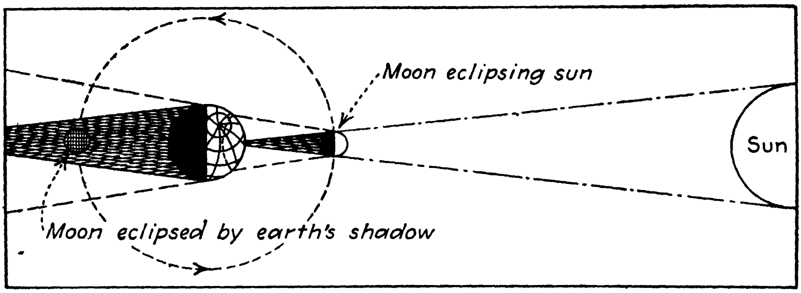
The disappearance of the star in an occultation is instantaneous because of the fact that there is no atmosphere on the moon and because even the brightest stars appear and disappear as mere points of light. The abruptness of these disappearances and reappearances is indeed startling.

The exact place of the moon in the sky can be determined and a knowledge of its motion refined by observations of occultations. It is essential that they be accurately timed if the observation is to be used for this purpose. Of course, it is much more difficult to predict them than to observe or time them. This takes almost an expert but amateurs can do it.

The sight of the moon cutting off the light of a distant star is, however, less spectacular than that of the moon itself dropping from sight in the shadow of the earth. For, as the satellite swings about in its orbit, reflecting the sun's light, it must pass behind the earth and will occasionally be eclipsed.

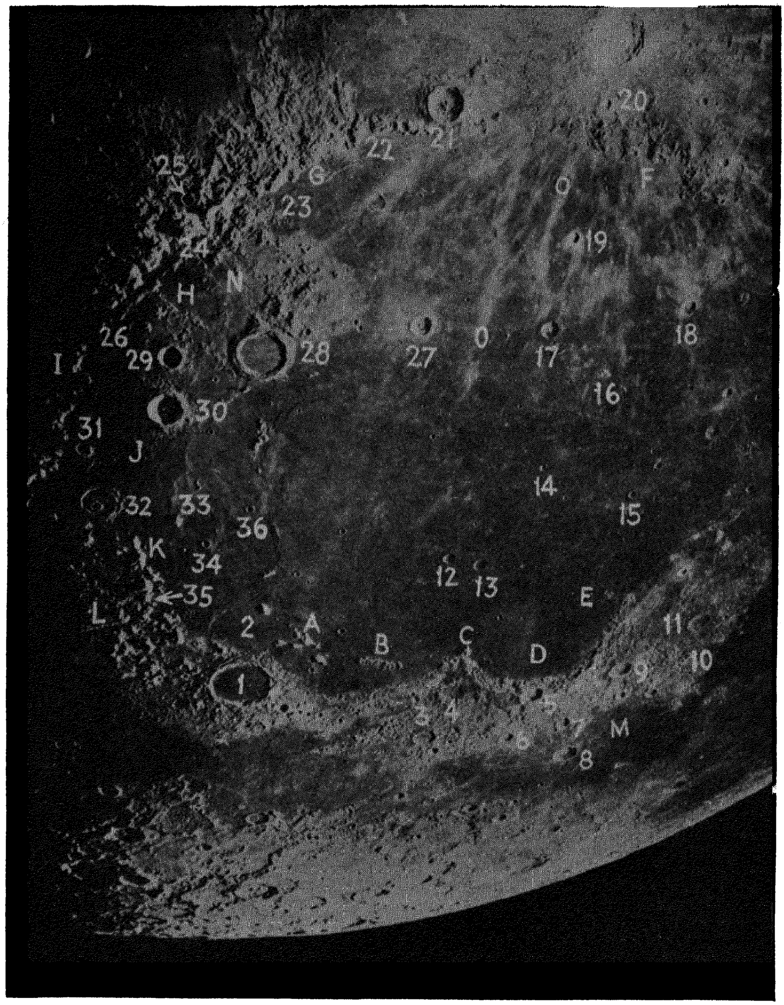
Usually it passes above or below the earth's shadow, but sometimes it does not. And then, with the sun's light shut off, it turns a dull red and becomes nearly invisible. This occurrence, an eclipse of the moon, is illustrated by the diagram on the following page.

In actual observation of a lunar eclipse, even in the midst of totality, it is noted that the moon does not really disappear but only dims and changes color. For even when the moon is



in the midst of the earth's shadow, it does not lose all of the sun's light because some of it is refracted (bent) by the earth's atmosphere. Red, orange, and yellow light pass through the atmosphere most easily and for this reason the moon appears a copper color during the eclipse.

It can be readily seen by the diagrams that eclipses of the moon, when they take place, are visible over half the earth at one time, while eclipses of the sun are visible only in small areas. For this reason, even though eclipses of the sun are more numerous, an observer at a given spot on the earth would see lunar eclipses more frequently than those of the sun. Furthermore he would see the moon eclipsed for a longer time. The moon, therefore, plays a part in two of the most interesting phenomena of the skies.



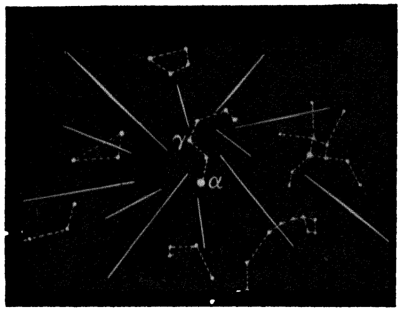
Mt. Wilson Observatory

MARE IMBRIUM REGION OF THE MOON. A portion of one of the finest moon photographs yet made, this beautiful picture shows Mare Imbrium—one of the so-called "seas." It is keyed for study.

1 Plato
2 Pico
3 Condamine
4 Maupertius
5 Bianchini
6 Bouguer
7 Foucault
8 Harpalus
9 Sharp
10 Louville
11 Mairan
12 Leverrier
13 Helicon
14 Carlini
15 C. Herschel
16 Lahire
17 Lambert
18 Euler
19 Pytheas
20 Gay Lussac
21 Eratosthenes
22 Wolf
23 Mt. Huygens
24 Mt. Bradley
25 Conon
26 Mt. Hadley
27 Timocharis
28 Archimedes
29 Autolychus
30 Aristillus
31 Thaetetus
32 Cassini
33 Piton
34 P. Smyth
35 Mt. Blanc
36 Kirch
A Teneriffe Mts.
B Straight Range
C Prom. Laplace
D Sinus Iridum
E Prom. Heraclides
F Carpathian Mts.
G Apennines
H Palus Putredinus
I Caucasus Mts.
J Palus Nebularum
K Alps
L Alpine Valley
M Sinus Roris
N System of clefts southwest of Archimedes
O Rays extending from Copernicus

Yerkes Observatory

METEOR TRAIL. An errant meteor glides into the star field of a Barnard photograph.



METEOR RADIANT. The paths of meteors belonging to a swarm trace backward to a common center.

Composed of stone or metal or a combination of the two, the average meteor probably revolves in an orbit within the solar system and is subject to the gravitational attractions of any large bodies which it may approach.

Many are found in groups which follow nearly regular orbits around the sun. A few of these orbits may be identified as belonging to comets which may no longer exist. It is thought that these meteors are simply the remnants of the comet which has broken up or which is in the process of breaking up.

The débris from the disintegrating comet becomes scattered around its orbit, and when the earth happens to cross one of these orbits, as it frequently does, many more meteors plunge into the atmosphere than do usually. If a large number of meteors are gathered into a central swarm traveling around the sun in the comet's orbit, and the earth intersects this swarm, the meteors can then be counted by the thousands.

This explains the periodic meteor showers and it explains the strange periodicity of the Leonid shower, to take a definite example. Every thirty-three years a big shower is seen, and the display in 1833, previously mentioned, belongs to this group. This unusual shower which greets the earth three times a century occurs when this planet cuts into the main swarm. During intermediate years the earth swings through the meteor orbit without meeting the main condensation, but, nevertheless, hundreds of stray meteors are caught. In some cases, like that of the Perseids, the bodies have become well distributed about the orbit so that one year is about as good as another.

Recently the Leonids have been very disappointing to amateur and professional astronomers who were expecting great displays. Meteor authorities attribute this disappointment to the fact that Jupiter may have drawn the Leonid swarm away from its former orbit so that the earth does not cut through the densest part at the same time it did formerly.

Of course, the best nights on which to watch for meteors are nights on which showers are due, for at these times it may happen that as many as 500 meteors are seen by one observer between midnight and dawn. During a shower the meteors seem to radiate from some particular constellation, and this point is called the radiant. Usually the shower takes its name from the name of the constellation in which its radiant is located.

This radiant point is only an illusion, and the meteors have absolutely no connection with the constellation from which they appear to emanate. This is brought home by the fact that the star group which marks the radiant may be fifty light years away, while the meteors themselves, when seen, are only some fifty miles distant. The illusion of the radiant is caused by the fact that when parallel lines are extended they appear to converge. It is the familiar effect of railroad tracks converging in the distance. Since meteors travel in more or less parallel paths through the atmosphere, the effect is similar.

Amateurs will find much pleasure and enjoyment in observing and recording meteors any night during the year and can be of material assistance to the science of astronomy. Even the record of a single meteor may prove valuable when combined with the reports received from other observers in the region. And the apparently unimportant results of a night's observation may become extremely significant to an expert who can compare them with other reports.

If only one person is observing, it is best to use a star chart and plot the path of shooting stars on it, together with a note of the time, as in the diagram on page 61. When this is done it may be noticed that some of the paths, traced backwards, will indicate a common point of origin. If two people are observing, it is suggested that one person observe and the other record the observations. In this way a constant watch is kept on the sky and no meteors are likely to escape attention.

When more than one person observes the same sky area during the same time, care should be taken not to combine totals, as the unit used in recording and computing meteor falls is the number seen by one observer per hour. If possible, each meteor should be timed separately; otherwise the number seen every five minutes will do.

When measuring paths, trails, or positions of particularly bright meteors, astronomers use the unit of 1°. The distance from the true horizon to the zenith is 90°; it is 5° between the pointers of the Big Dipper; the belt of Orion has a length of 3°. These dimensions can be used to judge other distances.

In estimating the magnitude of a meteor it is best to compare its brightness with that of familiar stars. Capella and Rigel are of the first magnitude; Polaris is a second-magnitude star; the stars in the constellation Delphinus are of the third and fourth magnitude.

The following chart is a suggestion made to expedite the recording of the meteors whether a shower is being observed or whether it is just an average night's fall.

The observer should be warned that only on the nights indicated by asterisks are there actual showers, when large numbers of meteors may be expected. The unstarred nights have been reported as favorable by a large number of observers, and the meteors seem to show some relation to the radiant indicated. However, in the present state of knowledge, it is impossible to prepare a complete list of radiants and showers.

Much research is being done on this problem and a large number of careful observations are necessary to solve it. The American Meteor Society, Upper Darby, Pennsylvania, will give specific directions to those wishing to make observations.

Name Date Sky

Time	Seen		Speed	Color	Magnitude	Remarks
	First	Last				
12:50	Regulus	Horizon	Fast	White	−1	Trail 7°, lasted 2 sec.
12:53	γ Leonis	Spica	Slow	Yellow	2	No trail
12:59	δ Leonis	Polaris	Fast	White	1	Trail, lasted 3 sec.

Calendar of Good Nights for Observation†

Date	Shower	Remarks
June–September	γ Draconids	Slow; with trains
July 18–30	α Capricornids	Very slow; bright
July 25–Aug. 4	α-β Perseids	Swift; streaks
*July 25–30	δ Aquarids	Long paths; slow
*Aug. 10–12	Perseids	Famous shower; swift
Aug. 12–Oct. 2	α Aurigids	Very swift
Aug. 10–20	κ Cygnids	Medium
Aug. 21–23	o Draconids	Very slow
Aug. 21–31	ζ Draconids	Bright
Sept. 7–15	ϵ Perseids	Swift
Oct. 2	Quadrantids	Slow
*Oct. 9	ϵ Arietids	This shower is scheduled to return in 1940
Oct. 12–23	(head of Draco)	Very slow; fireballs
*Oct. 18–20	Orionids	Swift
Oct. 30–Nov. 17	ϵ Taurids	Slow; fireballs
Nov. 3–15	e Taurids	Very slow, bright
*Nov. 13–15	Leonids	Famous shower every 33 years but disappearing
Nov. 17–27	Andromedids	Famous shower disappeared in recent years. Slow, Biela's Comet
*Dec. 10–12	Geminids	Fine shower; white
*Jan. 2–3	Quadrantids	Good; medium speed
Jan. 17	κ Cygnids	Slow; trains
Feb. 5–10	α Aurigids	Very slow; fireballs
Mar. 10–12	ζ Boötids	Swift; streaks
*Apr. 20–22	Lyrids	Swift; streaks
*May 6	γ Aquarids	Very swift; long paths before sunrise
May 11–24	ζ Herculids	Swift; white
May 30	η Pegasids	Very swift; streaks
June 2–17	α Scorpiids	Very slow; fireballs
June 27–30	ι Draconids	Very slow

* The best showers. † Adapted from Norton with modifications approved by Dr. C. P. Olivier.

Comets

ALTHOUGH thousands of comets revolve in regular orbits around the sun, it is seldom that one becomes visible to the naked eye. However, nearly always there is one within reach of observers using a small telescope.

When, from time to time, one of these space wanderers does mushroom into sight, it may grow brighter than Venus and even become visible in the daytime despite the overwhelming brilliance of the sun.

Although tremendous in size, comets are really collections of small particles of matter so widely scattered that stars may be seen through thousands of miles of comet material. The nucleus, when present, is the densest part of the comet and is a meteoric mass at the central part of the head. Enveloping the head and visible in all comets is the coma, a faintly luminous gas cloud which often sends out a series of concentric shells or "envelopes."

The coma is a large mass, nearly synonymous with the head, and the matter it sends out either as envelopes or as plain material seems to move steadily toward the sun. When it reaches a certain limit it seems to be repulsed by the sun, and it is then thrown back to form the tail. This is the most spectacular feature of naked-eye comets, although some do not have tails. When present, the tails always stream out into space away from the sun. Tail, head, and coma are generally composed of hydrogen, hydrocarbons, sodium, and other metallic vapors, together with fine solid materials.

The average diameter of comet heads varies from 10,000 to 100,000 miles, while the range in the length of tails in naked-eye comets is from 5 million to 200 million miles. The tail is shaped somewhat like a horn, and consequently it may be millions of miles wide at its end.

Comets differ more in brightness than do any other celestial bodies. Some have been second in brightness only to the sun and moon, while others are barely seen with powerful telescopes, and there are some that are so dim as to be beyond visibility.

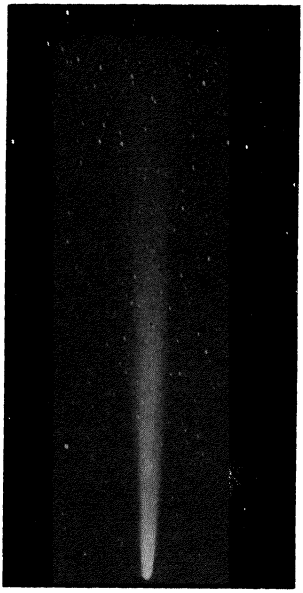
Comets are often discovered by astronomers who continually sweep the skies with their telescopes searching for them. Among these comet seekers are numerous amateurs who add considerably to the total. Many new comets also have been found in recent years by photography. A comet is usually identified only after hours spent in visual or photographic observation of its motion.

When an observer comes upon a *diffuse* object in the field of the telescope, he should first refer to a reliable atlas to eliminate the possibility of its being a nebula or cluster. If it is comparable in brightness with average Messier objects in the surrounding field, the chances are that it is a comet. He should then plot its position with extreme accuracy and telegraph the Harvard Observatory, briefly stating its exact location and appearance. This will assure him of priority of discovery in the event that it is a comet. However, if it is possible to get in touch with an observatory or with an expert who has a list of current comets, it might be best to do this first before telling Harvard.

Perhaps for his first adventure in comet hunting the observer would prefer to feel more sure of himself before notifying the observatory. If this is the case, he may discover some displacement of the object from the original position by observing it on subsequent evenings. The evidence of any motion in relation to the neighboring stars leaves little doubt that it is a cometary object of which the observatory should be notified.

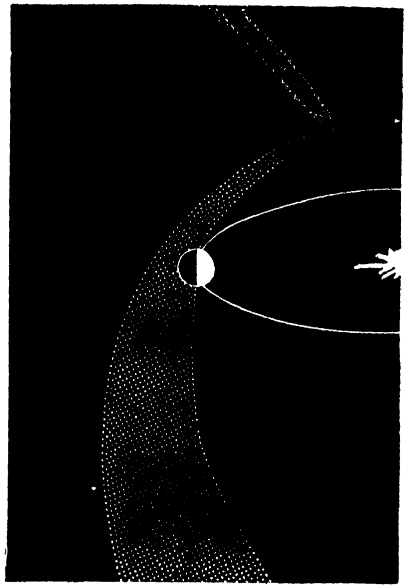
Of course, this may be a known comet for which he cannot claim the credit of discovery, but he will at least have experienced the thrill of discovering it for himself.

Unusually brilliant comets are frequently given the name of their discoverers, as, for instance, Donati's Comet. A comet is also technically designated by the year in which it is discovered, followed by an *a* if it is the first to be found in a



Mt. Wilson Observatory

HALLEY'S COMET. Halley's Comet photographed during its visit to the earth in 1910. One of the most spectacular of the naked-eye comets, and the last great comet to be seen to date, it will not be visible again until 1986.



COMET DEBRIS. As a comet disintegrates, it leaves behind it widely scattered meteoric material which continues to follow the comet orbit. When the earth meets such a swarm, we have a "meteor shower."

given year, a *b* if it is the second discovered, etc. Another method of classification is the year followed by a Roman numeral giving the order of perihelion (point nearest to the sun) passage, as Comet 1816 II. Both designations are used, the latter being applied after all the year's comets' perihelion passages have become known, while at first only the order of discovery can be used.

Comets travel in three types of orbits: elliptical, parabolic, and hyperbolic. Those which follow hyperbolic and parabolic orbits will never again swing around the sun, once they have made this curve. Instead they continue on and on, far out beyond the solar system.

But those whose orbits take the shape of ellipses do revolve about the sun in periods that vary according to the individual comet. About fifty are known to have periods of less than

100 years, while some are thought to take 10,000 years to complete one revolution. The Comet 1864 II had a period of 2,800,000 years and its aphelion distance was 40,000 astronomical units, or 3,720 trillion miles.

Short-period comets are those which have periods of just a few years, and of these thirty-six complete a revolution in from five to seven and one-half years. They form a definite group, all moving in similar orbits, all being quite faint, and most of them having no tails. The aphelion (farthest distance from the sun) of each of these comets is very near to the orbit of Jupiter, and so it has been suggested that these comets, formerly traveling in parabolic orbits, were drawn into their present paths by Jupiter's gravitational attraction.

Most comets move just as they would be expected to in free space under the laws of gravitation, but there is one striking exception. This is Encke's Comet, which has the shortest period known—3.3 years. The period of Encke's Comet is observed to be shortening steadily, and this phenomenon is difficult to explain. It is believed that the comet meets with some unknown resistance in its path. This resistance causes a greater relative gravitational effect from the sun, and so the comet falls toward the latter more, shortening the orbital path and therefore its period of revolution.

The long-period comets show little evidence of having been captured by any of the planets. They are often of great brilliance, while those of shorter period are usually very faint.

Double Stars

Two tiny points of brilliant light, one a rich gold and the other a deep blue, glowing in a field of coal-black sky—the double star Albireo, seen through a 3-inch telescope!

It can be seen with a field glass or a small telescope, and it leaves an impression on the memory as clear as that left on a photographic plate. Albireo is the star Beta Cygni, the fourth brightest star in the constellation of the Northern Cross, which begins to rise in early May evenings.

Albireo is only one of thousands of stars of its type which stud the heavens, their concealed beauties unsuspected until they are viewed with the telescope. These thousands of "double stars," as they are called, are for the most part binary systems. That is, they are two stars which, although not actually in contact, have a physical connection with each other, for they rotate about a common center of gravity. Albireo is thought to be such a system.

But there is another variety of double star in which the components are not connected but are simply so situated along the line of sight that they appear to be together, although one may be hundreds of light years behind the other. These stars must usually be within a half minute of arc of each other to be considered as "optical doubles."

Then, too, there are the "naked-eye doubles" which seem to the unaided eye to be very close together but which generally have no physical connection. Of these Mizar (Zeta Ursae Majoris) and its near neighbor Alcor in the Big Dipper are the most famous. As they are brought under the telescope, one of the pair suddenly becomes a double in its own right, so that three stars appear in the field. Other naked-eye doubles include Alpha Capricorni and Epsilon Lyrae.

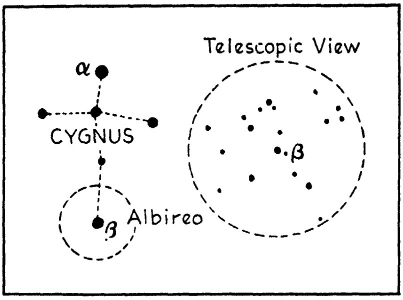
As previously mentioned, the majority of the twenty thousand or so close visual doubles actually revolve about a common center of gravity and are called physical doubles. Some of these binary systems have periods of revolution of five to ten years, although many of them have far longer periods. The motion as we see them from the earth are in some cases so slow that it takes centuries to establish an orbit. Until comparatively recent times, all double stars were thought to be composed of two stars that were nearly in the observer's line of sight.

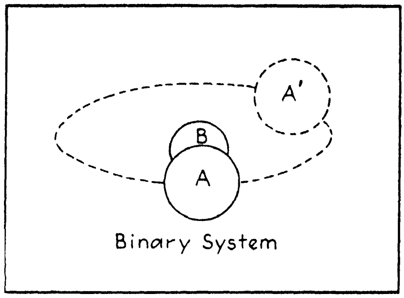
It was Sir William Herschel who accidentally stumbled upon the fact that in most cases the two stars actually do revolve around each other. He had, in 1789, turned his telescope to the task of observing a double with the intention of measuring the distance between the brighter star and the supposedly far more distant dimmer one. Instead, he made a new discovery—that in most cases components of a double star actually revolve about each other, or rather about a common center of gravity. Herschel's catalogues contain about 700 double stars, including many important binary systems.

The photographs on page 73, taken over a period of twelve years, clearly demonstrate this discovery of Herschel's. In them is shown the rotation of the two components of the binary Krüger 60.

The discovery of new double stars is made by simple telescopic observation, a departure from the usual lines of research. Professional hunters of doubles find that they need suitable atmospheric conditions, a trained eye, a telescope of good optical quality and large aperture, and a micrometer. The Lick 36-inch refractor, used in a recent search through a limited portion of the sky, revealed more than 4,300 new pairs. Work now in progress in the southern skies is expected to disclose thousands more.

Yellow and purple, a magnificent combination of colors seen at its best in the natural setting of the stars, form the scheme of the star Eta Cassiopeiae, a double that can be found without difficulty. Also among the circumpolar star groups are the previously mentioned Mizar and Alcor, which appear as double to the naked eye and triple in a telescope.





But this three-star view approaches no limit, for deep in the Nebula of Orion is imbedded a jewel among star sights, Theta, a quadruple whose components form the Trapezium. Its stars, ranging in magnitude from 4.7 to 8, are white, lilac, garnet, and reddish. Although this quartet can be observed with a 3-inch glass, a larger glass reveals it in even more splendor, and more stars can be seen (see Orion, page 81).

It might be well to mention that there is, so far as we know, no relation between double stars and star clusters. The cluster is by no means a further development of the double and multiple stars which we have been considering, for a cluster is a grouping of a considerable number of individual stars which may be in themselves single or double.

In many cases, the component stars of a binary system are so close to each other that the most powerful telescopes in the world today cannot separate them. It is only when they are subjected to the searching eye of the spectroscope, astronomy's second greatest weapon, that they are revealed.

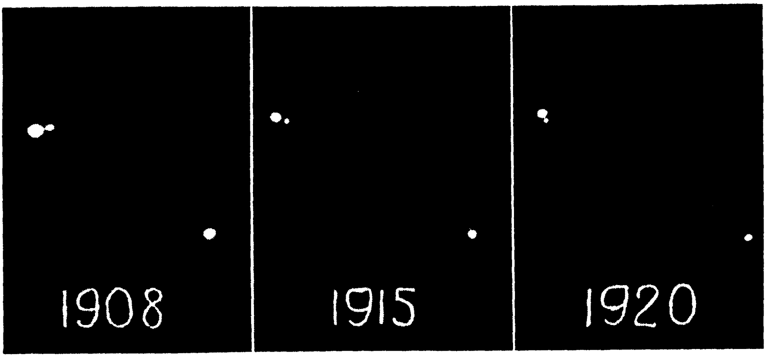
When a star is racing toward the earth, the lines of its spectrum as seen in the spectroscope are displaced toward the violet end of the spectrum; and when it is speeding away, the lines are displaced toward the red. If the spectrum of a star shows that some of the lines are displaced toward the red, while others are moved toward the violet, then we know that there are in reality two stars moving in opposite directions. This telltale split spectrum is a sure sign of a close double, and, as they are known to be twin stars only because of the spectroscope, this type is known as the "spectroscopic binary."

Should the orbital plane of the pair be at right angles to the line of sight, so that neither of the stars appears to be moving toward or away from the earth, the spectroscope is unable to detect their motion, and doubtless many doubles under such a condition are still awaiting discovery. If the orbital plane of the pair passes through the earth, the two stars will eclipse one another, and they are known as eclipsing binaries. Such stars are often variable; see the chapter on "Variable Stars" (page 88).

The great range of colors may best be shown by scanning the following list. Yellow and blue, orange and emerald, topaz and green are only a few of the descriptive comments you see;

A SELECTED LIST OF BEAUTIFUL DOUBLES

Double star	Magnitude	Separation, seconds	Remarks
ζ Ursae Majoris	2– 4	14	Mizar
ν Draconis	5– 5	62	A beautiful object
δ Cephei	3.6– 7.5	41	Yellow and blue (variable)
γ Andromedae	2.4– 5	10	Orange; greenish blue
α Capricorni	3– 4	376	Telescopic double-double
τ Leonis	5 4– 7	90	Contrasting colors
γ Leporis	3.8– 6.4	95	Yellow and garnet
δ Orionis	2.5– 6.9	53	White and violet
ε Pegasi	2.5– 8 5	138	Yellow and violet
η Persei	3.9– 8.5	28	White and blue
β Cygni	3.2– 5.4	34	Gold and blue
ζ Lyrae	4 3– 5.9	44	Topaz and green
ε Lyrae	5– 5	207	Double-double with high power
γ Virginis	3.7– 3.7	6	Both yellow; easy
γ Arietis	4.2– 4.4	8	Good test for small glass
η Cassiopeiae	3.7– 7.6	6	Yellow and purple
α Geminorum	2– 3	6	Both white
γ Delphini	4.5– 5.5	10	Yellow and bluish green
ε Boötis	3– 6.3	3	Orange and green; superb
α Canum Venaticorum	3.2– 5.7	20	Beautiful pair
θ Serpentis	4– 4.2	22	Both yellow; very fine
55 Piscium	5– 8.2	6	Yellow, red or purple
φ Tauri	5– 8	53	Red and blue
ζ Coronae	4.1– 5	6	White; greenish
δ Corvi	3– 8.5	24	Yellow and purple
ζ Aquarii	4– 4.1	3	Easy though close
α Tauri	1–11.2	36	Fine in 4-inch telescope



Yerkes Observatory

DOUBLE STAR KRÜGER 60. Far out in the depth of space two stars swing about each other—and photographer Barnard, at Yerkes Observatory, captures them on his plates. The pictures prove beyond all doubt the rotation of this binary star.

and when one of these pairs bursts upon your field of vision, it finds you totally unprepared for the sight.

Experienced observers find that the clearest nights, when the stars are twinkling excessively, are not the best times for seeing doubles; a calm night with a tranquil atmosphere, not disturbed by wind and layers of air of unequal density and often with something of a mist or haze, helps to keep the stellar image motionless.

A highly corrected telescope objective or a reflecting telescope mirror will show the colors to best advantage in resolving stars. It is advisable to use the lowest magnification that will resolve the stars at the time. Those of very wide separation can be split with field glasses. Some, like Epsilon Lyrae, are double with low power and quadruple with high.

Certain doubles are remarkably beautiful and can be profitably used as special ones for demonstration to new groups of enthusiasts. Such are Albireo, Castor, Gamma Andromedae, Epsilon Boötis, and Epsilon Lyrae. They vary in magnification needed, Albireo using 18 diameters, Epsilon Boötis 150.

The foregoing list is but a suggestion; the heavens containing a vast wealth of material to use any clear night of the year—starry gems that can be revealed only by a good telescope and careful observing.

Solar Observations

WHAT would happen if the sun suddenly ceased to shine, or if it changed its position in relation to the earth, or if it suddenly blazed up to many times its present light and heat?

The results are too horrible to contemplate, but certainly an object that plays so important a part in our lives as does the sun is worthy of a good deal of observation and study.

If you should turn a 2- or 3-inch telescope, carefully equipped with a darkened lens, upon the sun almost any day within the next few years, you might see a few sunspots scattered upon its bright yellow surface between 5° and 40° north and south latitude. They are often grouped in pairs and clusters and seem to move across the disk as the sun turns on its axis. Some last during a full rotation (25 days); a few stay longer, but most have only a few days' existence.

On careful examination these spots would be seen to consist of a dark center surrounded by a lighter area. Although they look so tiny in a small telescope, many of them are really large enough to engulf the earth, and some have been known to reach the size of 150,000 miles in diameter. Another strange thing about these spots is that they appear black when in reality they are white hot.

When one turns a telescope on the sun, one does not always see only full-grown spots, for new magnetic storms are whirling up on the sun as old ones die down. New sunspots may first be detected in the process of formation as small black patches on the visible disk of the sun; or they may start to form on the side that is turned away from the earth, and then they will first be noticed as they round the edge of the sun. In this case they are marked by the bright patches called "faculae" which surround them. The faculae are seen best on the limb of the sun, and they can rarely be seen at the center of the sun's disk.

There are two general methods of observing these spots with the help of a telescope. One is by observing directly through the telescope, but extreme care must be taken to use a sun glass or ray filter.

A second way is by allowing the enlarged image to fall on a piece of paper held at the eye end of the telescope. Rack out the eyepiece a little farther than for normal visual observation. Then move the paper until the image is well projected and sharp. A wire frame can be made to hold it at the correct distance (see page 95). This leaves you free to chart the position of the spots by tracing them as they appear on the paper. It is a good idea to place a black cloth over the wire framework to keep out some of the extraneous light and thus make the image more distinct. A piece of cardboard with a hole in the center, placed on the telescope tube near the rack and pinion, also helps to keep out light. The advantages of this method are that it eliminates danger to the eyes, permits simultaneous observation by a number of observers, and facilitates charting.

And, lastly, some people use a solar eyepiece, equipped with a prism that diverts most of the sunlight and permits a direct view of the sun with the least chance of danger to the eyes. But even with this "Herschel solar prism" a colored sun glass is needed.

At times with even a 2-inch telescope, faculae may be seen in association with the spots. These are lighter areas above the sun's surface, which become more easily visible the nearer they are to the sun's limb.

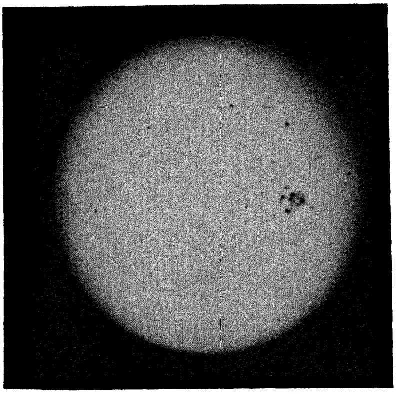
Besides charting the spots there are other statistics that can be gathered concerning them, such as number, speed of rotation, and duration. From your chart you can, of course, get position and grouping. The size, too, is easy to determine. Let the diameter of the sun's image, 4 inches, for example, represent the diameter of the real sun—864,000 miles. If the spot's image is 1/16 inch in diameter (that is, one sixty-fourth of the sun's image), it will be one sixty-fourth of the sun's actual diameter or 13,500 miles. This is an average spot!

Even if you do not have a telescope, you can make observations of the sun, noting the rising and setting points on the horizon and the time of sunrise and sunset over a period of several months. They are dependent both upon the time of year and upon the latitude of the place and they follow definite laws. They affect the "insolation," or amount of sun's rays received and are seasonal variations.

As seen from northern latitudes, at the time of the winter solstice the setting sun is as far south on the horizon as it can get. Day by day it gradually moves northward on the horizon until the time of the summer solstice in June. If you were at the equator, you would find that on December 21 the sun would rise at 6 A.M. about 23½° south of the east point on the horizon and set at 6 P.M. 23½° south of the west point. In our latitudes, 40° north, it rises about 7:30 A.M. 32° south of the east point, on December 21, and sets about 4:30, 32° south of the west point. But at Oslo, Norway, the sun rises about 2:45 A.M. on June 21, at a point 54° north of the east point on the horizon, and does not set until 9:15 P.M. Places with such high latitudes therefore have much more sunlight during the summer months. Above the Arctic Circle, from May until July, it is light almost all the time, but from November to January it is dark nearly all the time. Indeed, all latitudes on the earth's surface have definite times and places for the rising and setting of the sun.

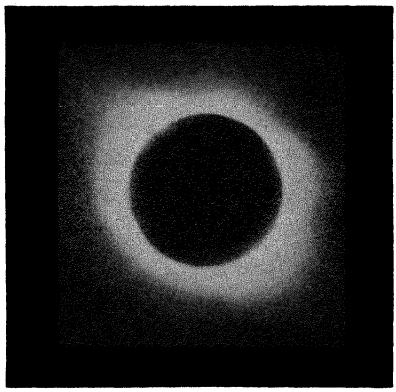
Solar eclipses, although rare for any one section of the earth's surface, have completely captured the layman's fancy and he will travel miles to see one. During the total eclipse of August, 1932, New England was crowded with tourists from all over the United States—indeed from all over the world.

Those travelers who were not "clouded out" felt well rewarded for their efforts. If you have ever seen the moon slowly creep across the face of the sun, steadily covering more and more of it until at last the brilliant sphere disappears and the corona suddenly flashes into view, you will understand why.



Yerkes Observatory

SUN'S DISK WITH SPOTS. A photograph of a portion of the solar surface, showing great groups of sunspots. The dark umbra of each is visible, and the surrounding penumbra as well as the lighter faculae near the edge.



James Clark, AMNH

SOLAR ECLIPSE. A beautiful photograph of the sun's corona, taken during the solar eclipse of August 31, 1932. The equatorial streamers reach a quarter million miles from the solar surface. (*From a motion picture.*)

But the corona, beautiful as it is, is not the only phenomenon visible. The prominences, huge masses of flaming gas thrown out to heights of thousands and hundreds of thousands of miles by eruptions inside the sun, are well worth observing.

The Baily's beads and the "diamond-ring" effect, two other impressive displays seen during a total eclipse, are not, like the corona and prominences, actual parts of the sun which the eclipse makes visible. They are merely lighting effects. Just before the moon, moving across the face of the sun, shuts off the last tiny crescent of light, a few rays shine through the valleys along the edge of the moon. The result is one or several lighted dots along the dark rim of the satellite—the Baily's beads.

Then, just as the beads vanish, the sun's lower atmosphere, the inner corona, comes into view shining brilliantly. At nearly the same instant the pearly outer corona flashes forth. Along the black rim of the moon the reddish prominences lace into the inner corona. But almost as soon as it can be seen, the glorious spectacle has begun to fade.

Just before the sun reappears, its outer corona is blotted out, but the inner corona remains for half a minute as a yellow ring around the sun. When the first speck of the sun returns to view, irradiation makes it seem much larger than it really is, and the total effect is the formation of a diamond ring with the speck of the sun as the diamond and the inner corona as the ring.

The eclipse also has its visible effects on the earth. During the whole time that the moon is creeping toward its central position and away from it, the light shining through the small spaces between tree leaves and through small holes, instead of forming the usual disks on the ground, makes tiny crescents —images of the disappearing sun.

Then, about ten minutes before totality, an eerie darkness begins to be felt. Chickens and other animals become alarmed and the air gets noticeably colder. Shortly before the shadow reaches the observer, rippling shadow bands appear on all light surfaces, and (from the high vantage point of an airplane or even a high hill) the moon's shadow itself can be seen advancing. Finally the moon covers the sun completely, the corona streams out, and the brighter stars and planets are visible.

During a partial eclipse, when the moon is seen moving across the face of the sun although it does not cover it entirely, there are comparatively few observations that an amateur can make. He can time "first contact," when the moon first nicks the edge of the sun, and he can time the last contact (there are only two in a partial eclipse), when the moon finally moves off the face of the sun. At intervals during the eclipse he can estimate the percentage of the surface covered and measure the drop in temperature.

He can also make note of the crescents cast upon light surfaces when the sunlight shines through leaves or small holes. But there is little else that can be attempted during a partial eclipse.

The total eclipse, of course, provides a better opportunity for the observer. He can record all the phenomena mentioned above—the corona, prominences, Baily's beads, diamond ring, temperature drop, effect on animals, shadow bands, etc. He can time four contacts: first, when the moon first touches the sun; second, the instant of beginning of totality; third, the instant at which totality ends; fourth, the moment when the moon moves off the face of the sun. He can count and identify the stars that appear during totality.

If he is equipped with a direct-vision spectroscope, he may watch for the reversal of the spectrum lines from dark to light and light to dark as the flash spectrum of the "reversing" layer becomes visible just before and after totality.

In observing the corona, prominences, and similar phenomena, note their shape and position. In the case of Baily's beads, count the number seen; with the shadow bands, measure their width and the speed and direction in which they move.

Nebulae and Clusters

It is easy to observe bright blue, yellow, and white stars and even the constellations themselves, but nebulae and clusters are quite a different matter. They require a knowledge of star groups, the possession of a field glass or telescope, and perseverance.

At first, of course, it will be rather hard to find most of the nebulae and clusters because they are usually hazy, dim patches of light. Their appearance, which distinguishes them from the stars, makes them difficult to locate in a telescope. But the search becomes easier as time goes on, soon turning into a treasure hunt with a long-sought nebula or cluster as the goal.

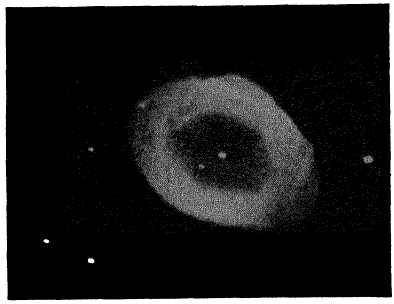
Perhaps the most famous nebula is that in Orion. It is a huge mass of gas in a state of violent agitation, but in a 2- or 3-inch telescope one sees a small, peaceful greenish-white patch of lace. This nebula, in the middle of Orion, is the easiest to locate of them all. It may even be seen with the naked eye as the central star Theta of the easily distinguished sword.

Sharing honors with this colossus is the great spiral nebula in Andromeda, the only nebula of its kind visible to the naked eye. In a field glass or even in a 3-inch telescope it looks like a thin patch of white haze—a wisp of clouds—but in reality is a tremendous galaxy, so big that light (which travels at the rate of 186,000 miles per second) requires 100,000 years to cross it.

The beautiful ring nebula in Lyra cannot be seen with the naked eye but is quite easy to find in a telescope because of the two bright stars Beta and Gamma between which it lies. In a small telescope it appears as a faint, misty, round patch. A 5-inch telescope reveals its annular quality, and it then looks like a smoke ring. It is a fine planetary nebula with a

Yerkes Observatory

ORION NEBULA. The only one of the diffuse nebulae visible to the naked eye, this great nebulous mass is found in the sword of Orion.



Mt. Wilson Observatory

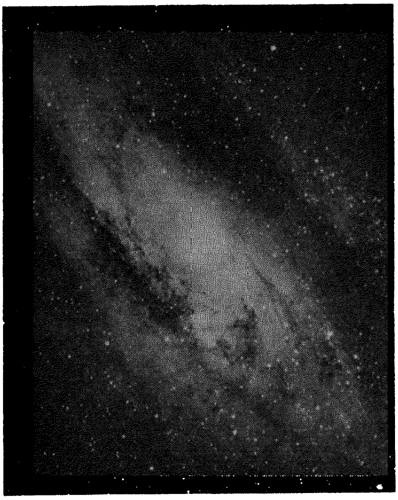
RING NEBULA IN LYRA. A fifteenth-magnitude star at its center lights the Ring Nebula in Lyra, Messier 57.

fifteenth-magnitude star in the center which becomes visible only in a huge instrument.

A planetary nebula consists of a single star surrounded by a hollow sphere of gaseous material. These are comparatively near the earth since they are all within our own "island universe," the Milky Way Galaxy. On the other hand, spiral nebulae like that in Andromeda are in themselves island universes made up of thousands of stars and huge aggregations of gases and cosmic dust. The Andromeda Nebula is the nearest of these huge galaxies, at a distance of 900,000 light years from the solar system. The great Orion Nebula represents a third type, for it is a great cloud of dust reflecting the light of near-by stars which are associated with it. This class of nebula is also found within the confines of the Milky Way Galaxy.

A 3-inch telescope discloses many more of these objects, but to see them at their best the stargazer should use a large home-made reflector of preferably 10- to 12-inch diameter. The larger the aperture of the glass, the more clusters and nebulae are within reach. Any good atlas will indicate the nebulae, many examples of which lie within almost every constellation boundary. Herschel found hundreds between Leo and Virgo, and the amateur is limited only by the power of his instrument.

Although the telescope does aid the eye by gathering the light from a nebula and focusing it at a point, it cannot



Mt. Wilson Observatory

GREAT NEBULA IN ANDROMEDA. This nearest of the spiral nebulae is an island universe similar to the Milky Way Galaxy.

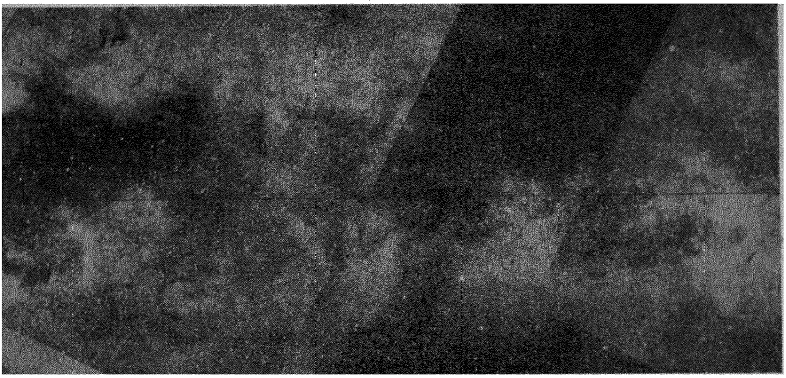
Mt. Wilson Observatory

DARK NEBULA IN ORION. The Horsehead, a gigantic cloud of nebulous matter obscuring the light of the stars behind.

gather enough light at any one instant to make much of the nebulous matter visible to the eye. A photographic plate, on the other hand, can collect the light until enough has been gathered to make a noticeable impression on the plate where none was made on the eye; thus the camera can "see" more of the nebula. A photograph of the nebulous matter around the Pleiades (which combine a cluster with nebulous matter) illustrates this fact, for such a picture shows matter that the eye could never see even with the largest telescope.

Sagittarius, which contains so many objects of note because of its situation in the Milky Way, presents the nebula M 17, known as the Horseshoe Nebula, and also the famous Trifid, M 20. In Aquarius is another planetary nebula, M 2, a fine sight in a 3-inch telescope; and Vulpecula contributes the famous Dumbbell Nebula, which forms a rectangle with Epsilon, Gamma, and Beta Cygni.

There is yet another type of nebula which is interesting mainly because it cannot be seen! This sounds queer at first, but the explanation is simple. These nebulae are the dark nebulae, patches of nebulous matter which are not illuminated



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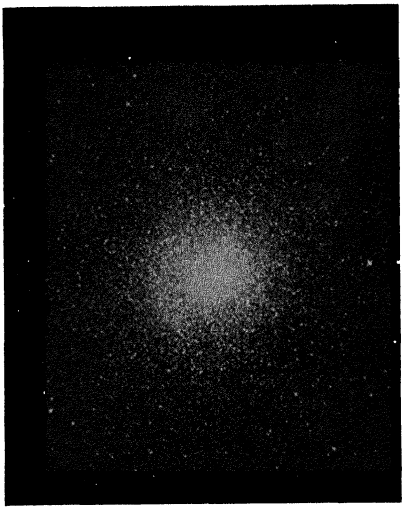
MILKY WAY. A beautiful mosaic of the Milky Way—the view obtained when we look along the plane of our Galactic System.

by near-by stars, and which, in fact, blot out the light of the stars behind them, giving the appearance of a black hole in the sky. Indeed they were once thought to be just that, but the theory has been definitely disproved. There are several dark nebulae in the Milky Way, Orion, Taurus, and Ophiuchus. Those in the last constellation appear as dark lanes running through the group and show up nicely in a photograph taken with a low-power telescope. The most famous dark nebula of all is the Coalsack Nebula in the Southern Cross—a large, round, black patch.

There is one nebula—a spiral one—which, although it is by no means the largest of its kind, can be seen on every clear night. It is the Milky Way, which forms the backbone of the Milky Way Galactic System.

The Milky Way Galaxy is a huge, watch-shaped aggregation of stars, star clusters, and planetary and diffuse nebulae. The sun is one of these stars, as are *all* the stars we see in the sky. When we see the faint band of light called the Milky Way, we are, in reality, looking out into space along the plane of the Galaxy, where the stars are thickest.

The Milky Way is always in some part of the sky. It never sets entirely below the horizon, but sometimes it is so faint that it cannot be seen. The glare of near-by street lights is



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MESSIER 13. The Great Globular Cluster in Hercules, a group of over 50,000 giant suns, known in star catalogues simply as M 13.

Yerkes Observatory

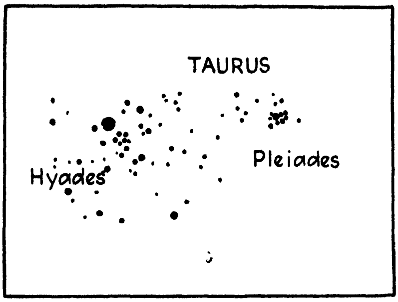
DOUBLE CLUSTER IN PERSEUS. This twin cluster (Chi-h), containing thousands of stars in two open clusters, is a brilliant telescopic object.

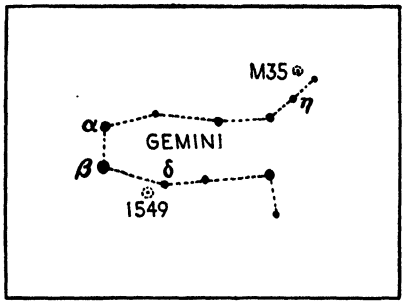
often sufficient to blot it out, and a slight haze or mist in the sky is fatal to the hopes of those who would see it.

Running directly overhead during the winter evenings, the great arc of light begins to drop toward the western horizon in March. Early in May, at about 8 o'clock in the evening, it is almost resting on the edge of the sky; it stretches along the horizon from a point almost due southwest, northward around the compass, to the point that is due east. At this time it provides a filmy lace border to five-eighths of the sky, but it is barely visible because of the thicker layers of atmosphere at the horizon through which the light must pass.

Three hours later part of the Milky Way will have set. But the Milky Way is a great circle of light that extends around the entire sky, and another arc of it has already risen in the east. This continues to climb and late in July, at 8 P.M., it is halfway toward the zenith. By the same time in September—or even at 5 P.M. the following morning—it is overhead again, and it remains so during the evening for the rest of the year.

No one is prepared to say how many stars there are in the Milky Way Galaxy. Every naked-eye star in the heavens





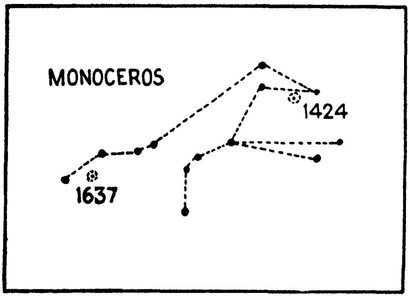
belongs to it, and the river of light that earned it its name contains millions of dim stars. Modern estimates place the number of suns in this Galaxy at more than a hundred thousand million.

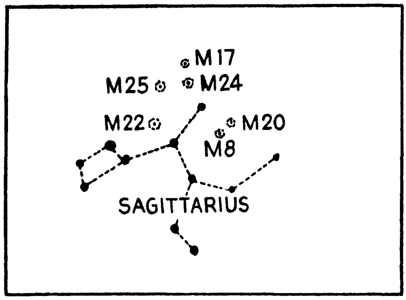
The diameter of this Galaxy is probably about twice that of the Andromeda Nebula. It rotates constantly about the center of the system, which is believed to lie near the constellation of Sagittarius. The sun, located about one-half of the way out from the center of the galaxy, requires something more than 200 million years to perform a complete revolution, although it is traveling around the axis of the system at about 200 miles a second.

Few nebulae are visible with low power as compared with the huge number of clusters or groups of stars that can be seen and studied with little optical aid. Some are very small, consisting of less than a hundred stars, while others range up into the thousands. Of course, with a field glass or 3-inch telescope, one can view only the larger ones.

The best known of these vast swarms of stars are the Pleiades and the Hyades, both in the constellation of Taurus, the Bull. They are examples of loose clusters in which the stars are moving in the same direction at approximately the same speed. Even with low power they are a wonderful sight, and as the magnification increases the number of stars that can be seen also increases. We may never be able to plumb the greatest depths of these vast swarms.

The Hyades to the naked eye look like a V of faint stars, with the first-magnitude star Aldebaran in their midst. Here





is a good region to test eyes, field glass, and telescope and to see how many objects may be counted with each.

The Pleiades are a loose cluster of stars; six stars (seven with very good eyesight) can be seen with the naked eye, arranged in the form of a dipper. In exceptionally clear skies, such as those of Arizona and New Mexico, as many as eighteen have been seen with the naked eye. Great magnification reveals countless stars in the region, and long-time exposure shows nebulosity enveloping the major stars in the group.

Praesepe, the cluster in Cancer, contains 85 stars down to tenth magnitude and 358 down to eighteenth. Beyond that they have not been counted but there are probably many hundreds more. An interesting thing about this Bee Hive cluster is the fact that it is so faint that the slightest wisp of cloud will obscure the cluster.

In Perseus is the double cluster Chi-h set in a rich region of the sky "sown with scintillating stars." On exceptionally clear nights the pair are faintly visible to the naked eye. In a field glass they appear to be two interesting patches of innumerable stars; the number seen is a good test of the aperture of the glass and "seeing" conditions of the atmosphere.

The region enclosed by Auriga's pentagon has several clusters. Two are visible with a field glass, while a 3-inch telescope discloses seven. M 37 and M 38 are especially interesting. Of course, one must not expect to see separate pin points of light, for only patches of haze will greet the eye and it is necessary to have a large telescope to resolve the haze into separate stars (for their location, see page 91).

Gemini offers M 35, one of the most beautiful clusters in the sky. In a 3-inch telescope it is exquisite, for the red star in its center is visible. It is very near Eta, and, close by, Uranus was first sighted by Herschel. Just beside Delta is 1549—another challenge for the cluster hunter—and near by, in the head of Monoceros, is 1424, while near the tail of the same group is 1637.

Last but not least is the cluster M 8 in Sagittarius, which is in the midst of a rich and gorgeous field where many interesting objects can be found with a 2- or 3-inch telescope. On an exceptionally clear night one cluster, M 22, can be seen with the naked eye about 3° northeast of Lambda (λ). M 24 and M 25 should be found as well as M 17 and the Trifid Nebula M 20.

There are many other clusters which can be easily seen with a 3-inch telescope but which are not unusual enough to be separately named and discussed. A good atlas will show clusters in almost every constellation. Portions of the sky which contain a great number of these make up very fine star fields. The region east of Leo, for instance, contains many hundreds of small clusters which appear as hazy specks of light when viewed with a 3-inch telescope.

Variable Stars

THE observation of variable stars is a field of astronomical research that is left almost entirely to the amateur and he can handle the assignment quite well, because no complicated or expensive instruments are needed in order to work with the brightest stars. A small telescope—a 3-inch refractor, for instance—makes a good instrument, and it is sometimes possible even to use the naked eye. However, there are variables of all magnitudes, and some of them need a 5- or 8- or 10-inch instrument.

A fact that adds to the interest of variable-star observing is that the cause of the light fluctuations of many variables is still a mystery, and only through hundreds of very accurate observations can a solution be reached.

A variable star is one whose magnitude changes from time to time, these changes in some instances being slight but in others very great. Variables are generally classified as "short period" when the cycle is completed in a few days or so and "long period" when the cycles are much longer—in some cases even years.

Short-period variables may be subdivided into two classes. In one, variations are caused by a partial eclipse of the brighter star by a companion star of lesser brightness (see diagram on page 71). Algol, in Perseus, is a good example of this type. For the other subdivision, the variations are caused by some change in the stars themselves. They alternately blaze up and die down for some reason which is still a mystery. The variables of this class are known as Cepheids because the first of the type was discovered in Cepheus. These Cepheids were the first stars used to help measure Galactic distances.

The cause for variation in the long-period variables is not known, but one theory states that spots, corresponding to our sunspots, may have cycles of more or less than 11 years and may cover a larger area of the star.

Some stars of this class, such as R Coronae, are ordinarily bright and then darken for a few weeks; others are dark most of the time but then occasionally rise in brilliance; still others rise to unheard-of brightness and then fade and remain out of naked-eye vision for years. This type has been found only in the southern hemisphere.

On the whole, long-period variables are irregular and range from two or three months to two or three years in period. They seen to "scorn" constancy, and the maximum of one rise may fall far short of the previous brilliancy. The change of brightness in these stars is often great; the range from minimum to maximum is sometimes over a hundred, even a thousand, times. They are giant red stars, with low density and great luminosity—many times the brightness of our sun.

Novae, new stars, which flare up where no star was visible before and then gradually fade away, are usually classed as variables. In late 1934 a new star appeared in Hercules. Nova Herculis, as it was known, rose from twelfth magnitude to first, and then quickly faded from naked-eye view. A completely satisfactory explanation of this type of star is still lacking.

The best known of the long-period variables probably is Mira, or Omicron Ceti. It has a wide range, from magnitude 1.7 to 9.5, and goes from maximum to minimum in about 331 days. Slight irregularities in its variation increase the interest of this star for the amateur, and it can be observed throughout its entire period with a 3-inch glass. This great giant has a diameter of perhaps 260 million miles and could, therefore, contain the whole orbit of the earth, and much more, within its vast bulk.

For those amateur astronomers who do not have telescopes there are many variables that can be observed through their whole cycle with the unaided eye. Algol, Beta Persei, is the most interesting of these. Its short period, $2^d\ 20^h\ 48^m$, is known with great accuracy. It is an eclipsing binary, ranging from magnitude 2.3 to 3.5.

The star Rho Persei is another variable whose period is very irregular. It should prove interesting to compile a list of observations of this star which undergoes a change of about a magnitude in five or six weeks.

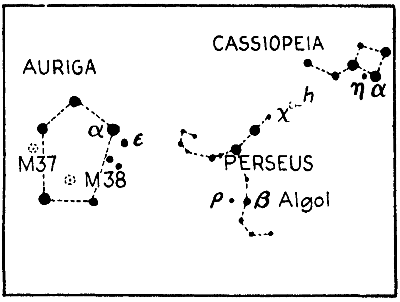
Before entering the subject of how to observe variable stars, it is interesting to note that our own sun is a long-period variable. In this case the chief variation is brought about by the eleven-year sunspot cycle.

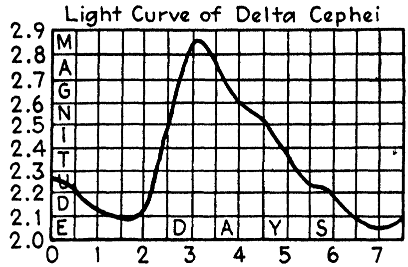
In observing and recording the actual amount of a star's variation, bear in mind these facts: first, the human eye without long training cannot estimate accurately divisions smaller than one-third of a magnitude; and, second, the method to be used depends entirely upon the star in question.

The first method employs comparison with stars in the vicinity of the variable. Take two which are about two magnitudes different in brightness, rather near each other, and which encompass the entire range of variability. Try to estimate the brilliancy of the variable as accurately as you can. If these stars are less than two magnitudes apart, do not attempt such fine estimation as tenths. For example, supposing them to be at least two apart, if the variable in question were, as nearly as you could tell, the same brightness as the fainter of the two stars, it would be recorded 0.0. If it were halfway between, it would be recorded 0.5. If you have no comparison stars conveniently near, the best method is to estimate the brilliancy in relation to any standard star. The disadvantage of this method is that the sky may be hazy at a point where the standard star is located, thus introducing an error.

The observation of telescopic variable stars is one of the most fascinating bits of work that a telescopist can undertake. Patience and perseverance are the only requirements needed aside from the small telescope.

These pulsating stars are designated both by the Harvard designation number and by letters. The numbers consist of





six digits, divided into three units: the hour and minute of right ascension and the degrees of declination for the year 1900. If the last two digits are underscored or italicized, southern declination is indicated. Thus, 094211 would be the designation number of R Leonis: $9^h\ 42^m$ right ascension and $+11°$ declination.

An outline of the procedure to be followed in the observation of variables may be secured from the American Association of Variable Star Observers as well as star charts especially devised for this work. In using charts at the telescope, it must be remembered that the astronomical telescope shows the stars in an inverted field. Therefore the chart must be inverted, unless prepared to represent them as they appear in the field of view.

If the telescope in use is not equipped with declination circles, it will be necessary first to plot the position of the variable on a star map and then to pick up the field by guiding from some bright star in the vicinity of the variable.

It is useful to determine the diameter of the "field of view" of the telescope. To find this diameter, focus the telescope on a star which is as close to the celestial equator as possible and time its passage from one side of the telescope field to the other. This time interval, in minutes, divided by 4 is equal to the diameter of the field in degrees of arc—exactly what is required.

In actually locating the variable we wish to observe, in this example, R Leonis, let us suppose the diameter of the telescope field is 1° and that the telescope is focused on Omicron Leonis. It would be seen by examining a chart of the naked-eye stars near R Leonis that it (R Leonis) is just about 1½° east and 1½° north of Omicron. So the first movement is to move the telescope east just two diameters of the field. This brings the point that is 1½° east of Omicron into the center of view.

From this point the telescope is moved north 1½°, and now you should be able to recognize the field from the chart and pick out the variable. Two bright stars, pointing southeast, with a little equilateral triangle south of them would be seen. The variable star is one of the members of the little triangle and by proper orientation of the chart you should be able to identify it quite easily. Of course, all variable fields are not so easily found, but by clear thinking and patient work they may be located if within range of the telescope in use.

Now that we have tracked down the variable, our next task, of course, is to estimate its magnitude. Other stars in the field whose magnitudes are known are used for estimating, as has been explained. Suppose, for example, the brightness seems to be just about between 9.0 and 9.6 (using the other two stars in the little triangle for comparison). R Leonis is then recorded to be 9.3 magnitude at that particular date and time. This method is only a slight departure from the procedure previously outlined, but it serves to show how circumstances may alter that procedure somewhat. No absolutely definite rule can be laid down in this work because all working conditions cannot be foreseen. The method given, however, can with little adaptation be used in almost every case.

To aid the observer to get more accurate results it may prove expedient to push the eyepiece just a little out of focus, getting little lighted disks instead of mere pin points of light. Disks of light are much easier to compare for brightness than points of light.

The method of recording variables is simple; merely construct a graph. Along the top record the time, usually in days (fractions may be estimated), and along the side place the magnitude (see diagram). Consult a star catalogue and find the actual magnitudes.

Below are listed several of the many variable stars which furnish excellent observational material throughout the year.

Star	Magnitude range	Period
α Cassiopeiae	2.2– 2.8	Not periodic
o Ceti	1.7– 9.5	331^d, irregular
ρ Persei	3.4– 4.2	33^d, very irregular
β Persei	2.3– 3.5	$2^d\ 20^h\ 48^m$
λ Tauri	3.8– 4.1	$3^d\ 22^h\ 52^m$
ε Aurigae	3.0– 4.5	Not periodic
α Orionis	0.7– 1.5	Irregular
R Canis Majoris	5.9– 6.7	$1^d\ 03^h\ 15^m$
η Geminorum	3.2– 4.2	231^d
ζ Geminorum	3.7– 4.5	$10^d\ 03^h\ 41^m$
T Vulpeculae	5 5– 6.5	$4^d\ 10^h\ 27^m$
μ Cephei	4.0– 5 5	430^d
δ Cephei	3.6– 4.3	$5^d\ 08^h\ 47^m$
β Pegasi	2.2– 2.7	Irregular
R Aquarii	5.8–11.0	387^d
R Leonis	5.0–10.8	310^d
S or 10 Sagittae	5.4– 6.1	8.4^d
δ Librae	4.8– 6.2	2.3^d
U Herculis	4.8– 5.3	2.05^d
α Herculis	3.1– 3.9	Irregular
β Lyrae	3.5– 4 1	12.91^d
η Aquilae	3.7– 4.5	7.18^d
W Sagittarii	4.3– 5.1	7.59^d
χ Cygni	4.2–13 7	409^d
R Hydrae	3.5–10.1	406^d

The A. A. V. S. O. was formed in 1911 to relieve professionals of the work of observing variables. This association has members all over the world, and some of the most active ones make thousands of observations in the course of a year. The data are published in *Popular Astronomy*. If one really becomes interested enough in observing variables and wishes to take up the work as a form of research, it is advised that he write a letter of inquiry to Leon Campbell, Recorder of the A. A. V. S. O., Harvard College Observatory, Cambridge, Massachusetts.

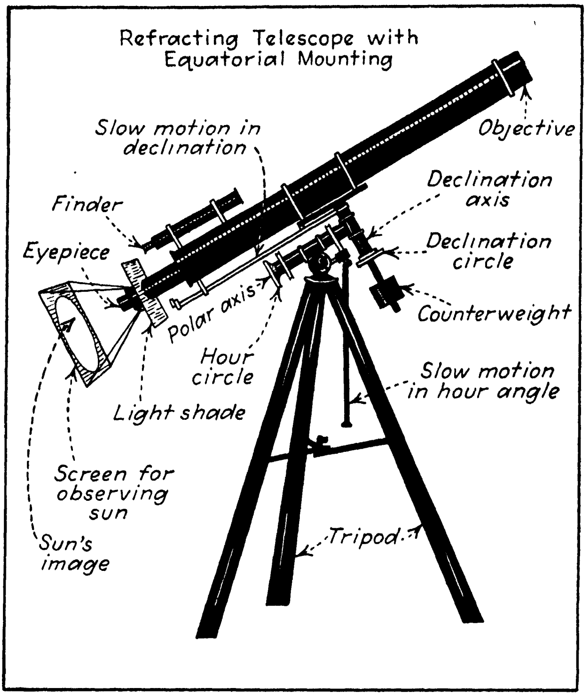
Hints on Telescope Usage

MOST of the material in this handbook is made very much more interesting when the observer is aided by a telescope or field glass, whether small or large. But even with one of these instruments to help him, he may miss a great deal of importance through lack of knowledge of how to use it.

When the purchase of a telescope is considered, it is well to remember that refracting telescopes are superior to reflectors in certain respects. They are less liable to be damaged by inexperienced handling or from neglect, and they offer a wider field with good definition. Reflectors are much cheaper, when taken aperture for aperture. But it is necessary to resilver reflector mirrors every few weeks and this is troublesome, expensive and requires much skill. So while the initial cost may be greater for a refractor, it obviates this perpetual annoyance of reconditioning (including frequent centering of prism, mirror, etc.). However, a new aluminizing process which makes the mirror surface both permanent and washable is now within the amateur's budget.

In selecting a telescope it is preferable to get a smaller aperture and good lens, with a good mounting, than to get a large telescope with an unsteady mount or poor lens.

The highest magnification that a good telescope can stand depends upon (1) quality of objective, (2) quality of eyepiece, (3) condition of mounting, (4) state of atmosphere. Moreover, the highest magnification is seldom used, each celestial object and condition of atmosphere determining the proper power to use at the moment. The magnifying power of a telescope is determined by the focal length of the object glass divided by focal length of ocular used at the time. (Larger lenses admit more light and make the image brighter.) But if one were to take two telescopes, one with an objective 1 inch in diameter and the other with an objective 40 inches in diameter, one



would find that they had the same magnifying power, provided their focal lengths were the same. However, there would be a great difference in the images.

Telescopes themselves, no matter how fine the lenses, are made less efficient through lack of good mountings. In fact the mounting is an integral part of the telescope. And the first requisite of a good mounting is *firmness*. There must be no looseness at the connection between tripod and instrument which will result in "dancing stars."

The simplest mounting is the type known as the altazimuth found almost universally in small telescopes. Although it is efficient up to a certain point it is not easily adapted to certain types of work. The altazimuth mount may consist, in one form, of nothing more than a universal joint which permits movement in any direction, horizontally, vertically, or diagonally. Variations are numerous, but, broadly speaking, this mounting is one which allows free motion of the telescope in any direction.

The greatest weakness of the altazimuth mounting lies in the fact that when the earth rotates, carrying the instrument with it, the star moves out of the field of view and the telescope must be moved in two directions, or their resultant, to find it again. This inconvenience and waste of motion are also met with when first locating an object.

All observatories and many amateurs have their instruments mounted on an equatorial. With this mounting they overcome the inconvenience of the altazimuth and derive several additional advantages. But equatorials are more difficult to construct and much more costly to buy. Briefly, the equatorial mounting consists of a polar axis and a declination axis at right angles to each other, as shown in the diagram on page 95. The polar axis is adjusted to the latitude of the observer so as to point toward the celestial pole, and as a result it is parallel to the earth's axis. The circle in the diagram graduated in hours and minutes of hour angle, and known as the hour circle, is attached to the polar axis. As may readily be seen, it will be parallel to the earth's equator.

The polar axis is set quite firmly on the tripod or pier which supports the mount. Fixed to one end of it at a right angle is the declination axis, and at the other are a graduated declination circle and a counterweight. The declination circle and the counterweight also appear in the diagram.

Having once pointed a telescope so mounted at a star, only one motion is necessary to follow it, that is, motion in hour angle. The declination axis is not touched, only the polar axis is moved, and this in a direction opposite to that of the earth's rotation. Since the polar axis is parallel to that of the earth, its movement counteracts that of the earth, and the star under observation remains constantly in the field of view.

Equatorial telescopes have accessories, and one of the most important is the driving clock. This clockwork mechanism turns the polar axis at a steady rate of speed, relieving the observer of this work. But relatively few private telescopes are so equipped and most of them are guided by hand. The equatorial also eases the task of "picking up" an object invisible to the naked eye. Having obtained, from the *Nautical Almanac*, an atlas, or ephemeris, the right ascension and declination of an object (see the "Observational Scrapbook," page 115), one needs also to know the sidereal time. The sidereal clock which is rated to gain 1 second in every 6 minutes of ordinary time is an invaluable accessory for this work. If one does not have a real sidereal clock or watch, he may use an ordinary timepiece, computing sidereal time from solar time by using the *Nautical Almanac*. When right ascension and declination and sidereal time are known, the circles of the equatorial mounting may be set so that the telescope will point directly at the as-yet-unseen object.

With the aid of an equatorial mounting which follows the stars steadily, it is possible to make fine pictures of star fields, planets, etc. Details will be found in the chapter on "Amateur Astronomical Photography" (page 109).

A zenith prism is an almost essential piece of equipment for observing objects nearly overhead. It makes for far greater comfort by throwing the image off at right angles to the telescope so that the observer does not have to maneuver his head into a position directly at the end of the tube. But while the image, when seen through an astronomical refractor with an ordinary eyepiece, is inverted or turned upside down, it suffers a worse fate when observed through a zenith prism. It is then reversed in such a way that certain objects, say the moon, cannot be checked easily, for the observer cannot turn the moon chart in any position to coincide with the telescopic view unless he looks through the back of the paper. Whereas, when looking straight through a refractor, he turns the chart upside down, if indeed it may not already be published so, with north at the bottom, etc. However, ordinary field glasses and terrestrial telescopes do not have inverted but erected images.

Should you desire to determine the colors of a double, put the image out of focus so that the stars appear as blurred disks. The color will be more readily apparent, at least according to some observers, as the eye is more sensitive to the color of a disk than to that of a point of light. But an important point here is the quality of the telescope's objective, for it should be free as much as possible from chromatic aberration which causes colors to form around a brilliant object. The "apochromat" lens is superior to all others in this respect. And, of course, for all colored objects the refracting telescope cannot rival the reflector. No color estimate can accurately be made, if the object under observation is within 10° of the horizon, because absorption, among other things, causes it to change color rapidly.

When attempting to find Neptune, an asteroid, or other telescopic objects, the first task ahead is really not telescopic at all. If you have not a chart showing the object's position for the night on which you are observing, you must make one. This is no small task, as you must use charts with stars below the magnitude of the object observed and go through computations to allow for precession, also interpolations so as to do the plotting. Include in the map all the stars near the object under observation, so as to make identification of the field easier.

The *Handbook of the Heavens* eliminates much of this work by including maps of the planetary positions. In the actual observing of the object, first locate the nearest naked-eye star, and then work from that in the telescopic field, identifying the fainter stars on the charts, until the object of the search has been found. If any question as to its identity remains, if it is an asteroid, comet, or planet, keep watching it until it has undoubtedly changed its position with relation to the other stars on the chart. It will do so in a night or more if the search has been successful.

As a general rule, it will be found more convenient to use low-power magnification on these objects particularly because it gives a wider field. The high powers will cause the object to pass rapidly out of the field and will exaggerate imperfections of the object glass and "jiggling" of the mounting, if it is not a very good one. They will also exaggerate the atmospheric irregularities, such as rising heat waves, dust, differences in temperature within and without the telescope tube, and will always magnify tremors due to wind.

When using a flashlight in observation work, cover it or mask it with red tissue paper or cloth, so that the glare does not affect the eye. Should the mounting be unsteady in itself (not because of the wind), point the telescope ahead of the object under observation. Then, by the time it moves into the field, the movements in the mounting will have had a chance to settle down.

When cleaning lenses, always use the softest tissue obtainable and rub gently. Have a dew cap constantly over the objective when it is not in use. A person who is not experienced in handling telescopes would best let alone the silver of a mirror or the cell of an object glass.

Telescopes of 3-inches or greater aperture should be equipped with a small finder, which is a little telescope attached to the tube of the large one and mounted parallel to it. It saves much time when locating star fields in which any object is to be found. It would take some ingenuity to make one of these at home, although it has often been done. Try to get an achromatic 2-inch lens objective, 8 to 10 inches in focus, and a 1-inch ocular (Huygens type) and make a miniature telescope or the instrument may be purchased complete.

In observing comets, star clusters, nebulae, and other faint objects, it is best to look somewhat away from the object if the latter be very faint. Objects viewed in this manner appear brighter than when seen by looking squarely at them. This is known as averted vision; by looking as suggested one frequently finds many small stars that were invisible when observed straight on.

When observing double stars, use, if possible, the approximate magnification suggested for them in the chapter on "Double Stars" (page 69). After you have graduated from the outstanding examples presented in this handbook, you will have had enough experience to judge for yourself the magnification. A general rule for finding the resolving power of your telescope would be to divide $4''.56$ by the diameter of its objective or mirror in inches. Thus a 2-inch telescope cannot resolve doubles closer than 2.″28; therefore, all doubles are notoriously easier to separate when a large glass is used in preference to a small one, because the aperture increases resolution.

A "moon glass," to use the Zeiss term, a neutral glass tinted very slightly, will make observations of the moon less tiring to the eyes especially when using a telescope of large aperture. A "sun glass" is a transparent heavily tinted glass for the ocular.

Really to enjoy stargazing beyond the beginner's stage, one will want a good star atlas. Norton's, Schurig's, and Stuker's are suggested.

Asteroid Hunting

IN THE vast gulf of space between the orbits of Mars and Jupiter lies the asteroid zone. In this broad zone, circling perpetually around the sun in giant ellipses, may be found between one and two thousand diminutive worlds. These are called not only the asteroids but the minor planets; in fact their name, literally translated into English from several other languages, means "little planets." For they are just as much planets as are Mercury and Mars, only smaller and of less importance.

The following table gives data concerning the first four asteroids discovered, and consequently those best known and easiest to observe.

Asteroid	Discovery	Diameter, miles	Albedo	Average magnitude at opposition
1. Ceres	Piazzi, 1801	480	.06	$7^{M}.4$
2. Pallas	Olbers, 1802	304	.07	8.0
3. Juno	Harding, 1804	120	.12	8.7
4. Vesta	Olbers, 1807	240	.26	6.5

From this table it is seen that they are all very small bodies, astronomically. Many hundreds are smaller than these, with but a few miles of diameter, and some are suspected of being not over a mile in diameter.

The asteroids are probably barren worlds—without water, atmospheres, or living things, and with temperatures far below freezing. Many have rocky or mountainous surfaces as shown by their disproportionate change in brightness with a change of phase.

There are over 1,300 minor planets that are so well known from observations that the elements of their orbits are known and published and ephemerides calculated every year. This laborious work in celestial mechanics is undertaken by the Astronomisches Rechen-Institut, the world's headquarters for asteroids, in Berlin-Dahlem, Germany. Each ephemeris gives the exact right ascension and declination of an asteroid for about 6 weeks around opposition time, when it can be observed best.

Most of the asteroids are of fainter magnitude than the first four in the foregoing table. Brightness varies with the distance of the object from the earth and the phase of the illumination; but there are other variations, and it is likely that they are caused by the combination of rotation of the spheroid, with difference in the reflecting power of different portions of the surface. The brightness of Eros in 1931 was found to have a periodic variation of a few hours, and it is thought that this is to be correlated with its rotation period. The average magnitudes of all the known planetoids go down to 18, and the aphelion magnitudes of some are as faint as 20. These can be observed only in the greatest telescopes, if at all; actually observations are made by the photographic plate exposed a long time. The largest number of asteroids seem to have an average opposition magnitude of 13; there are 404 of them; next comes fourteenth magnitude, with 360 planets. It can readily be appreciated that only a few are within range of a small telescope, and usually one or two are available for observation in a 3-inch instrument.

Asteroid hunting is of two kinds—professional searching with the astrocamera and observation with a small telescope. Professional asteroid work is done in a large observatory specializing in this field. There the method consists of exposing a plate in an "astrographic camera" for sometimes as much as two or three hours. When the plate is held, by guiding, on the stars, the asteroids leave short trails. But if the plate is moved during exposure to correspond with the motion (with respect to the stellar background) of an average asteroid for the particular region, then the planet appears as a small point. Its image is denser on the negative, from accumulation of light, than it would be as a trail. Very often plates contain images of several planets. These are then "reduced," or the planets' positions determined in the laboratory, and a comparison is made with places of known asteroids. After several observations of one object are made, preferably at intervals of some weeks, the computers are able, as in the case of new comets, to determine the orbit and construct an ephemeris. Such an ephemeris is really a prediction of the exact positions of the asteroid in the sky at stated times.

The second type of observation depends on these ephemerides, for it consists in locating the planet in the telescope from the ephemeris positions. Such is the kind of work outlined in this handbook.

If you are observing, you are commonly using the telescope on dates lying between the ones marked on the charts supplied with the handbook, so that you must obviously mark the position where the asteroid should be at the moment of observation. Then you are ready for observing.

Carry the telescope into a really dark place, open to the constellation containing the asteroid. If it is an astronomical telescope, it inverts the image. If, therefore, you are looking toward the meridian, anywhere near the equatorial regions of the sky, south is at the top, north at the bottom, west on the left, and east on the right in the field of view. As you move the telescope to the west, all these points of direction rotate clockwise; or if you move to the east, they rotate counterclockwise. Hold the chart near the telescope (using a dim light) and tilt it so that the north-south line in the chart is parallel to the hour circle of the field of view and inverted—that is, with the "south" of the chart toward the north celestial pole—not the north horizon. Then after a few moments of being in darkness, you can see the star configurations just as they are in the chart. Locate first the brightest star of the region near the asteroid, and gradually move the field of view to the asteroid, identifying all the stars by their configurations and relative magnitudes as on the diagram. The asteroid should be found in its proper place, according to the date of observation with respect to the dates marked on the chart.

With practice, and good sky conditions, identifications can often be made in a few minutes. At times they have even been made instantly.

It is interesting to follow these objects from night to night. Except at the stationary points in their apparent paths, a movement from night to night can be noticed. Indeed, if after observing a few times an interruption of a few nights takes place, more time will be needed on the next observation to identify the new star fields in which the moving object is now found. With the technique as outlined above, some observers follow asteroids through many weeks' time.

Half of the entire work of picking up asteroids or other objects invisible to the naked eye lies in the plotting of the course. There are other possible ways, but this is the most practicable method, for a month's path is done in an hour or so, and further work is all at the eyepiece of the telescope. Positions are taken from the current ephemeris of the planet to be located. These positions could be plotted at once on a good star chart, if there were no precession of the equinoxes, causing a constant change of reference points. But any one star atlas has fixed coordinates of right ascension and declination. This framework of coordinates is placed in position on the atlas according to the actual positions of the vernal equinox and celestial pole for any specified year. Obviously it cannot be changed to match the equinox of every ephemeris published, without a new edition of the atlas every year. While the yearly change is very small, it is cumulative and throws an object out several minutes for a number of years of equinox change. Now, the star charts have their equinoxes placed to correspond with equinox positions of standard star catalogues. So, in plotting, one must allow for precession.

Reduction for precession is effected by trigonometric formulas, tables, interpolations from precession data on the charts. The result is a new ephemeris to match the equinox of the chart. Then very careful plotting with an accurate scale divided into half millimeters will establish positions for certain dates, for 0^h G.C.T., and through these points a smooth curve must be drawn. (A star atlas that has star magnitudes fainter than the minor planet under consideration must be used.) Comet paths are made similarly. The difficulty involved varies with the place on the celestial sphere where the object is to be found. Plotting star paths is very troublesome as the region approaches a celestial pole and in a way is increased also if the object has a large motion from day to day, like most comets, for then an hour's work will not cover such a long period.

Asteroids are not spectacular in the telescope. They cannot be distinguished by appearance from a star of the same magnitude, except that possibly they sparkle less, and some of them, like Vesta, do have characteristic colors. However, their daily movement against the stellar background is a positive indication of their character. But a telescope user gets much practice and fun, too, and even a thrill from following the movements of these tiny worlds, which may be but 100 miles in diameter and 250 million miles away!

Chart of Vesta

Our large-scale chart of Vesta shows a typical retrograde loop performed by the planet during the latter half of 1935. The continuous line shows the apparent path of the asteroid among the stars for several months, and the planet is expected to be at the exact positions given at 7 P.M. (Eastern Standard Time) on the dates specified. At intermediate times the observer must interpolate the position for himself, which is done before going to the telescope.

In observing, the north-south line of the diagram is oriented to correspond with the actual directions in the heavens, the north pointing to the north celestial pole. If your instrument is a terrestrial glass with an erected image, the field of view will correspond to the chart; if, however, you are using an astronomical telescope with inverted image, invert the chart and have the chart's south pointing to the north celestial pole.

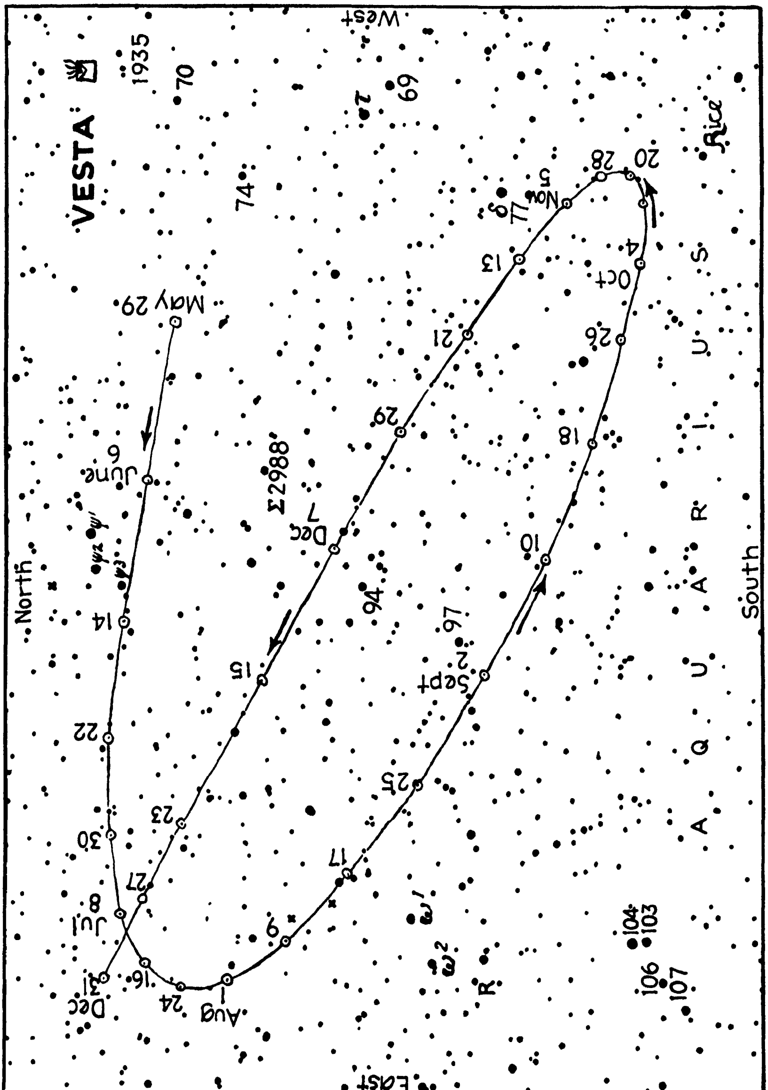
Locate first one of the brightest stars; for instance, if observing in the first half of November, center on the group δ and 77 Aquarii. After these key stars are located in the field of view, the smaller stars and objects can be discerned. Usually the chart will have to be tilted in orientation, and the asteroid will commonly be between the dates marked.

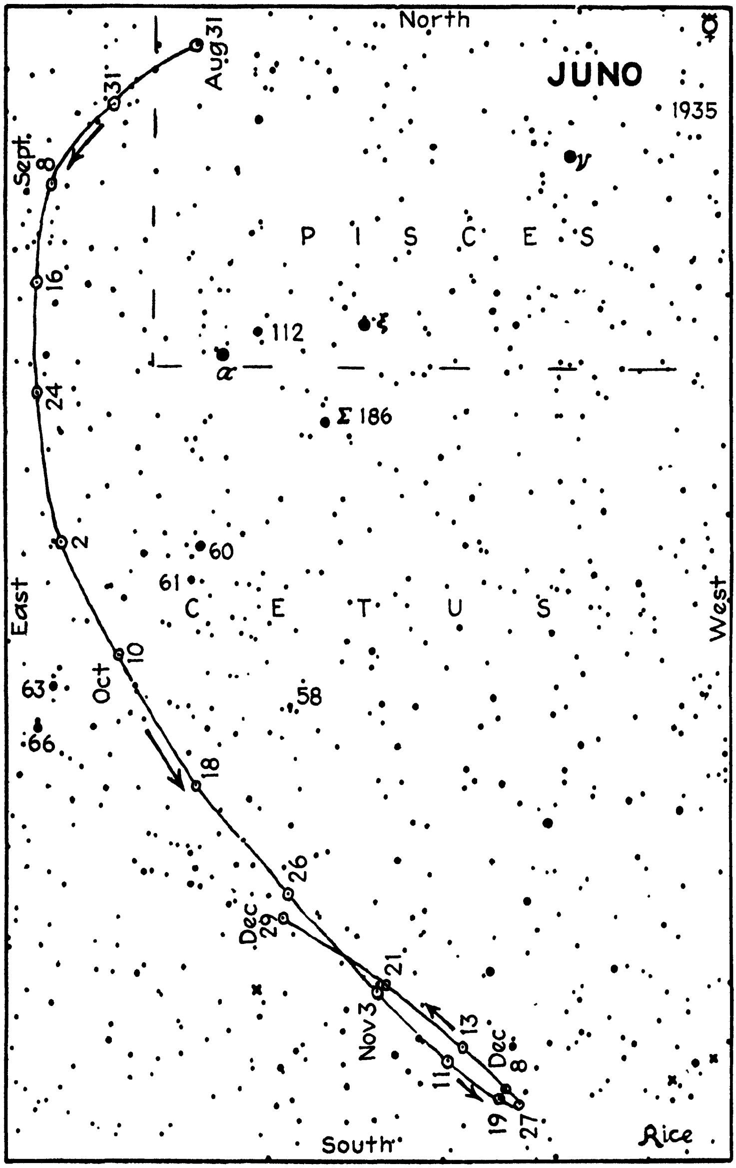
Vesta varies in brightness during the year, its maximum being almost sixth magnitude on September 3. In December it is about 8 and the average for the period is about the same as the star 74 Aquarii. It will be noted that several telescopic stars will be in exceedingly close conjunction with Vesta during this half year, as on August 16. The daily motion of this planet with respect to the stars (not the "diurnal motion" through the sky) can be observed whenever it passes close to a star, at such times the motion can be detected in one night's observation.

Chart of Juno

In Juno's course among the stars for the latter part of 1935, it will be seen to be moving southward until November 27, this direction constituting its retrograde motion. This asteroid is fainter than Vesta. After starting with magnitude 8 in August, it will become brightest in October with magnitude 7.2, which will fall to 7.8 in December.

First pick up α Piscium, a naked-eye star, and then move the telescope field gradually to the asteroid, identifying all the configurations. Juno is more difficult than Vesta to locate at this time, as fewer bright stars lie near Juno's path.


VESTA 1935
North
South
East
West
A Q U A R I U S
Rice



North
JUNO
1935
PISCES
CETUS
East
West
South
Aug 31
31
Sept. 8
16
24
2
Oct 10
18
26
Nov 3
11
19
27
21
13
Dec 8
Dec 29
112
ξ
ν
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Σ 186
60
61
63
66
58
Rice

Amateur Astronomical Photography

Pictures of the great rambling nebulae, globular star clusters, comets, and similar astronomical subjects are used profusely to illustrate books and articles dealing with the stars, and undoubtedly the reader has sometimes wished that he too might make such photographs.

Unfortunately, pictures of this nature require much elaborate apparatus including an expensive telescope and an equatorial mount driven by clockwork. They are not, of course, made primarily to illustrate books but to aid modern astronomical research. The astronomer lets the patient eye of the camera, which never tires and which sees far more than the human eye, do much of his laborious observing for him. Then he examines the plates at his leisure.

Although the apparatus needed for such pictures is far beyond the reach of the beginner, anyone who is the owner of a good camera and has a little knowledge of photography can take pictures that will be satisfactory. Minor equipment is all that is necessary to make pictures of star trails, records of sunspots and the phases of an eclipse; but if an equatorial mounting is obtainable, comets, minor planets, star clusters, and glorious star fields fall within reach. Lunar landscapes do not require much equipment, but considerable care and experimentation are necessary to get sharp, unmoved, and satisfactory images.

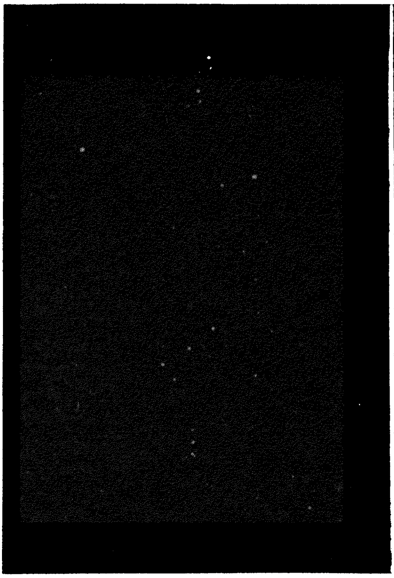
The first experiment in the new field for the amateur should be photographing the stars with a stationary camera. This will result in what are known as star trails (made because of the earth's rotation). These are obtained by lengthening the usual time of exposure considerably. As the earth swings on its axis, it carries the camera with it, and the stars, which remain still, form lines of light on the plate.

Very firmly propped, the camera may be left open for any length of time. Longer exposures, of course, result in longer star trails, but it is not advisable to leave the shutter open more than four hours. The most interesting phase of star-trail photography is making circumpolar trails—trails of the Pole Star and its immediate neighbors. When examined, trail pictures of this region will show a series of small and large concentric arcs, different indeed from the arcs of great circles made by stars directly overhead or by those 90° from the pole.

To take pictures of this type, center the camera on the pole star and focus with a magnifier. It may be somewhat difficult to line up a box camera on Polaris because the star does not show up well in the small finder used with these instruments. Fortunately, this may be done fairly accurately if the observer takes a little care. Carefully avoid having any extraneous light coming into the lens while the plate is exposed. On cool summer evenings dew may collect on the lens and it is necessary that it be wiped off at intervals. The extremely cautious use of a flashlight will help in this, especially since it will provide enough light so that the lens may be cleaned without accidentally moving the camera. During exposure, the shutter should be opened to its widest aperture so that it will record the faintest stars possible, although the widest aperture does not give as good definition of image as a somewhat smaller one does.

The best exposure for obtaining good results on circumpolar trails is from two to three hours. If the shutter be left open longer than this, the trails overlap too much. Pictures of this nature should be taken with a fast plate or film and should be developed for contrast. If the film is sent to a professional finisher for development, it would be wise to include instructions both to develop for contrast and to print the pictures, whether or not they seem to have "turned out." Otherwise the finisher may return the negatives without making prints.

When these circumpolar pictures are examined, it becomes obvious that Polaris is not right at the north celestial pole,



Girard Bloch, J. A. C.

ORION. Orion, king of the winter skies, as photographed by an amateur. Made with long exposure, and with the telescope and camera guided on the stars.

Robert Fleischer, J. A. C.

ON THE TRAIL OF THE SETTING SUN. The moon, with the planet Venus close beside it, dips toward the western horizon. Long exposure with stationary camera.

for it has made a small arc of its own on the plate. By using a lens of large actual diameter and giving the plate a maximum exposure of about three hours, it is possible for you to photograph certain of the faint stars which are nearer the pole than Polaris and which will appear as short concentric arcs within the trail of the pole star.

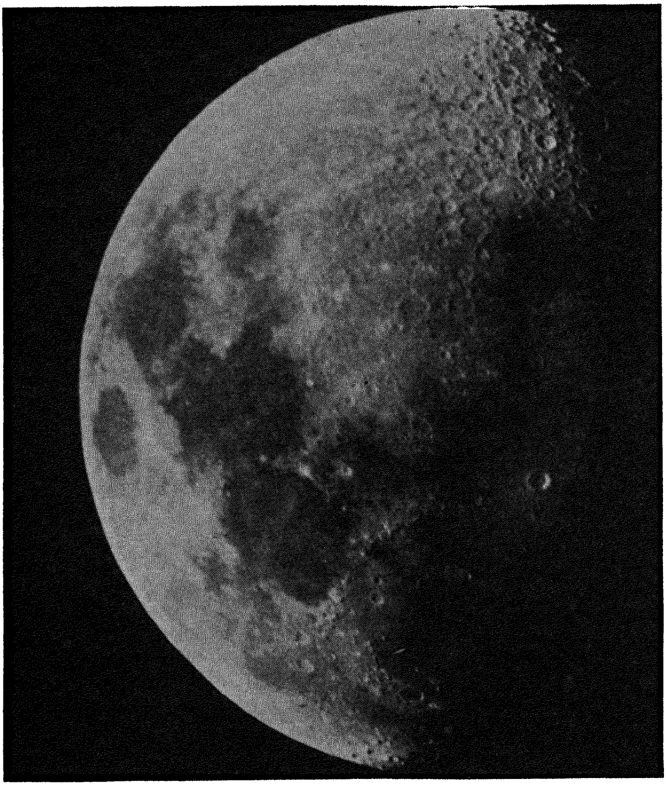
Pictures of the seas, plains, craters, and mountain ranges of the moon may be made with only two pieces of equipment—a telescope and a camera. But what patience and experience are needed! Most cameras of the folding or pocket type are equipped with a lens that can be removed and should be taken off. Rigidly and carefully, the camera should be attached to the eyepiece end of the telescope, with the eyepiece racked out somewhat beyond the normal point.

A ground-glass attachment is a necessary part of the camera's equipment for this work since the moon must be focused accurately with a magnifier. Without such an attachment it is practically impossible to focus the image correctly, although trial-and-error attempts may be made by setting the focus at various points, making pictures and developing to find which is best.

Both instruments must be mounted rigidly in this work, and the greatest difficulty with a small telescope will probably lie in still having it centered on the moon when the picture is taken. A sight along the barrel of the telescope or a smaller finder telescope will help here. The actual exposure of the plates should be about ½ second for the supersensitive panchromatic films or plates that are recommended. A longer exposure blurs the moon's image from the diurnal motion, and with a long-focus telescope objective even the shorter time will "move" the image.

An alternative to the foregoing method is to use the object glass (large lens) of the telescope only, removing the eyepiece and focusing directly on the ground glass. This "primary" image formed by the objective will be much smaller but much more under control. In this case the telescope itself is being used as a camera. Finest grain plates and fine-grain developer are necessary to this method which is used successfully with home-made reflectors. Still a third method is to use the telescope complete and the camera complete, rigidly mounted back of the ocular, with a space of an inch between ocular and camera lens. The image is large and therefore moves rapidly because of the earth's rotation, but this method has proved successful.

Beautiful photographs of constellations, star fields, comets, asteroids, and other special objects can be made if one has an equatorial mounting (described on page 95). Such a mounting can be constructed by anyone who is handy with tools, or one may be occasionally "picked up" here or there for a small sum. In all probability this mounting will not be motor driven, and it will be necessary to operate it by hand. A little practice, however, will enable you to keep the telescope moving so as to counteract the movement of the earth.



Ramiro Quesada, A.A.A.

MOON. Mountain ranges, craters, and so-called "seas" are revealed in this photograph of the moon, taken with a homemade telescope.

The polar axis of the mount must, of course, be lined up accurately with the north celestial pole, and the camera should be fixed firmly to the rest of the instrument. If the mounting is already serving a telescope, the camera had best be placed on top of it and fixed so that its focus is parallel to the telescopic line of sight.

Should there be no telescope on the mounting, a small one must be attached at the same angle at which the camera is tilted. Cross-hairs, placed within the focus of the telescope's eyepiece, will enable the astrophotographer to keep the star or object under observation constantly in the center of the plate. The telescope must be guided throughout the length of exposure and the star must be kept precisely at the cross-hairs every second of the time. High magnification in the telescope will result in more efficient guiding of the mount.

Camera work with comets and asteroids as subjects has an additional obstacle to overcome in that these bodies move noticeably in comparatively short periods of time. Therefore, when working with comets, the observer must guide most carefully on the comet head and, when he has developed his plates, he will find that the stars themselves have trailed. If he had guided on the stars, the comet would have trailed, thus ruining any structural details the picture might have shown.

This same procedure is used in photographing asteroids if a disk is required or if the asteroid is so faint that the advantage of exposure is needed. Otherwise the asteroid will trail and the stars will appear as points of light. Especially in the discovery and recording of asteroids this last method is used.

The equipment used in taking pictures of the moon may also be used to take pictures of sunspots. The only accessory needed is a neutral filter to cut out the overpowering glare of the sun itself (such filters can usually be obtained at stores dealing in photographic goods). The procedure for sunspot pictures is the same as that for the moon landscapes.

With nothing more than an ordinary camera and a little judgment it is possible to take photographs of the brighter planets including Venus, Mars, Jupiter, and sometimes Mercury.

The camera need only be pointed at the subject and given an exposure of a few seconds (three or four) on fast plate or film. If the period of exposure is too long, movement of the subject across the plate will result from the earth's diurnal motion; and if it is too short, faint objects will not show. Six seconds is about the maximum exposure for this type of work with a small camera. The picture taken, of course, will be very small and it will be necessary to make an enlargement to show satisfactory results of your experiments in elementary astrophotography.

Observational Scrapbook

AWAY up in the extreme northern region of the moon, flanking the north border of Sinus Iridum, is located a mountain-ringed plain that contains one of the prime mysteries of lunar observation. There, in the depths of Plato, lies—what?

For years, Prof. William H. Pickering has carefully observed that crater and has watched color changes taking place. These, he suggests, are caused by vegetation. And there is no proof that they are not, for at the bottom of Plato there may be some remnant of oxygen or water to support plant life.

Whatever their cause, the changes continue to occur. They appear as spots and streaks on the crater floor which vary in visibility independently of the sun's altitude and are prominent enough so that they may be seen with the aid of a 6- to 12-inch telescope. The first step is to locate Plato on the moon with the aid of the maps (see page 58). The crater is prominent because of its unusual coloring and will be easy to find.

There are a few elementary but important things to take into consideration in observing the changing conditions in the crater's depths. All observations must be made when the moon is in exactly the same phase, the moon should always be the same distance above the horizon, and the same magnification should be used each time. All these conditions must be equalized, and even then there is a chance of error due to atmospheric irregularities, so that numerous observations should be made before any changes noted can definitely be said to be taking place at the bottom of Plato.

* * * * *

Travel has an interesting effect on the positions of heavenly bodies. In Florida the moon is often seen north of the zenith, its beams shining on the landscape from almost overhead. This naturally is because the moon must follow the zodiac, never straying from its border. The zodiac runs nearly overhead in Florida, but for New York the nearest it comes to the zenith is about 7½°.

As we travel south, some stars climb up before us while others drop to our rear. In Florida the Dipper sets, as do others of our circumpolar constellations, but their loss is more than made up for by many new groups we see. The Southern Cross rises above the horizon for a short time, and Canopus is also visible, shining steadily in the clear air of the peninsula.

At any point situated along the equator, Orion is directly overhead, but much below the equator he stands on his head—because the ancients who figured the group lived in the northern hemisphere.

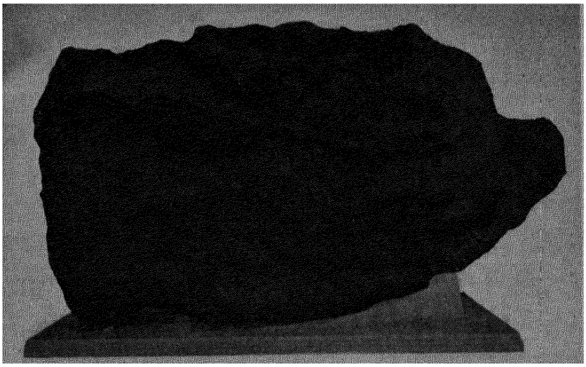
* * * * *

It pays to keep your eyes open in everyday life, and also in astronomy. Know the stars, be familiar with each constellation, at least to the extent of knowing all the prominent stars. And keep watch on them; glance up at the sky on clear evenings and note the new constellations that are rising and those that are setting. Amateurs who have formed this habit are sometimes the ones who first discover the rare variety of stars called novae that spring from obscurity to many times their former brilliance, becoming prominent overnight.

Shining brilliantly among the familiar stars, these novae (new stars) are conspicuous and are noticed immediately by one who is acquainted with the constellations. And they have been first discovered, on several occasions, by an amateur who was armed with no more than a thorough knowledge of the star groups.

* * * * *

Millions of meteors daily meet extinction in their mad flight through the atmosphere, but despite this fact hundreds of them must actually reach the ground. The number which might be found lying about on any given unit of the earth's surface, however, is small because the earth itself is so vast. Frequently amateurs find rocks which, after a casual examination, they take to be meteorites and which usually are merely



American Museum Photograph.

AHNIGHITO. This meteorite, the Ahnighito iron of 37½ tons, is the largest in any museum today. It rests in the American Museum of Natural History, New York. Dark and cold now, its surface was once heated to incandescence by friction generated in a rapid flight through the atmosphere.

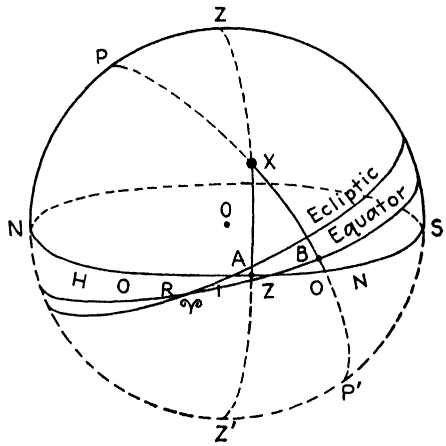
pieces of basalt or some black rock. Persons familiar with rocks may be more certain of a suspected meteorite, for by elimination, if it is not a known rock, it may be a meteorite.

The tentative identification may be checked by considering these points: the outer coating of meteorites often will be fairly smooth as a result of the oxidation caused by friction as they pass through the air; they may be any size, from a pebble to a rock weighing tons; and they may be heavier than other stones when picked up because many contain a large percentage of iron. The final analysis, which must be made in the laboratory for absolute certainty, will tell the true story, leaving no room for doubt.

* * * * *

An amateur astronomer, attempting to find his way in the sky with nothing more than his sense of direction to guide him, would become hopelessly lost in a sea of stars—even as an amateur navigator, with no knowledge of latitude and longitude, would become lost in the limitless wastes of an ocean.

Early astronomers, realizing this, set about the task of providing themselves with a set of coordinates with which they could locate a star. To do this, they evolved a system of reference based on altitude and azimuth.



CELESTIAL COORDINATES

O = observer
Z = zenith
Altitude and azimuth
AX = altitude, 38°
SA = azimuth, 90° +
$ZXAZ'$ = vertical circle

♈ = vernal equinox
X = star

P = north celestial pole
$NPZS$ = meridian
Right ascension and declination
BX = declination, 40°
♈B = right ascension, 3h
PXP' = hour circle
$SZPXB$ = hour angle

The altitude, or elevation of a star above the horizon as measured in degrees of arc, gave the height of a star above the horizon, let us say, 38°. This one direction would be of little help, however, for this star might be located anywhere along a circle running around the sky parallel to the horizon and at an altitude of 38°. The astronomer needed another coordinate.

So he took the distance, measured in degrees westward around the horizon, from the due south point to the point directly beneath the star in question and called it azimuth. Now the star had an altitude of 38° and an azimuth, let us say, of 90°+ to establish its position in relation to the observer.

It is obvious, of course, that such a system is based upon the observer and that he is the primary point of reference. He sets up a framework through which he views the stars. But the stars' positions change their relation to this framework with every moment of time because of the earth's rotation. The background of stars seems to move in relation to the point of reference, therefore, and in the course of an hour a dozen stars might occupy the position of 38° altitude and 90°+

azimuth. Because of this, the altitude and azimuth system is used today for certain limited purposes, as for navigation.

Most generally, astronomers employ that set of constants known as right ascension and declination.

Since there are in the sky both a north and south celestial pole where the axis of the earth, projected, intersects the celestial sphere, one may rightly institute a celestial equator, situated midway between the poles, and everywhere at a distance of 90° from them.

From this sky equator is measured declination—the distance in degrees north or south of the equator, positive (+) if north, and negative (−) if south. It corresponds to latitude as measured on the earth's surface, and it provides the astronomer once again with one of the two coordinates necessary to find the position of an object on the celestial sphere.

The ecliptic, a great circle on the celestial sphere, is formed by the intersection of the plane of the earth's orbit on the celestial sphere. It intersects the celestial equator at two points, the vernal and autumnal equinoxes.

Through the vernal equinox, which lies in the southern part of the constellation of Pisces, astronomers have drawn an imaginary line, a great circle running from pole to pole around the sky for 360°, and they have called it the equinoctial colure. This line, as are all others bisecting the celestial sphere at the poles, is known as an hour circle. And every star has its own hour circle, running through it and through the celestial poles. Right ascension, the second of the two coordinates, is measured in degrees eastward on the celestial equator from the vernal equinox to the point where the star's hour circle cuts the equator.

Under this system when an astronomer wishes to locate a particular object on the celestial sphere, he may use right ascension and declination in a manner similar to that in which latitude and longitude are used by mariners. All standard atlases are based on this system, and it is also employed in the operation of an equatorial telescope. With right ascension and declination tables given, it is possible to locate any celestial object at any time.

Glossary

Aberration, chromatic: The condition of a telescope lens in which all the colors of the image are not brought to one focus.

Aberration, spherical: The condition of a telescope lens in which the marginal and central rays of the image do not come to a focus at the same point.

Aphelion: Point in the orbit of an object farthest distant from the sun.

Apochromat: A lens of the highest possible correction where the different color components of white light all come to a focus in one plane.

Asteroids: The minor planets or planetoids whose orbits lie between the orbits of the planets Mars and Jupiter.

Binary, spectroscopic: A system of two stars revolving about each other in which the separate stars cannot be seen with a telescope although they can be detected with the spectroscope.

Celestial sphere: The infinitely remote imaginary globe suspended around the earth, on which the celestial objects are projected.

Configuration: The grouping of stars and planets in recognizable pattern for identifying. This term is usually used to identify the planet's position.

Coordinate: One of two points of reference on the celestial sphere used to determine the position of an object.

Declination: The celestial coordinate measured north or south of the celestial equator; a star's distance north or south of celestial equator.

Degree: A unit of measurement on the celestial sphere (°) (any circle is 360 degrees) further divided into minutes (′) each of which contains 60 seconds (″).

Earthshine: A slight illumination of the dark portion of the moon by light reflected from the earth.

Eclipse, lunar: A cutting off of the sunlight received by the moon when it passes into the earth's shadow.

Eclipse, solar: A cutting off of the sun's light by the passage of the moon across the sun's disk.

Ecliptic: A great circle made by the intersection of the plane of the earth's orbit with the celestial sphere. The apparent path of the sun through the sky lies along this circle.

Elongation, greatest: The points in the apparent paths of Mercury and Venus where they are at their greatest distance east or west from the sun as seen from the earth.

Ephemeris: Tables of the prediction of the exact location of an object at stated times; *The American Ephemeris* is published by the United States Naval Observatory and contains this for the sun, moon, planets, etc.

Equator, celestial: The earth's equator projected to the celestial sphere. It is a great circle on the celestial sphere, everywhere 90° from the celestial poles.

Equatorial mounting: Type of telescope mounting consisting of a polar axis set parallel to the earth's axis and of a declination axis at right angles to the polar axis. Graduated circles relating to right ascension and declination are attached to the axes.

Equinox, vernal and autumnal: Imaginary points in the sky where the celestial equator and the ecliptic cross. The sun reaches these points on March 21 (vernal equinox) and September 23 (autumnal equinox).

Equinoxes, precession: The slight westward movement of the equinoxes, or the slow conical movement of the earth's axis around a line connecting the poles of the ecliptic.

Equinox of a chart: The exact position of the coordinates of the chart with respect to the background of stars.

Eyepiece: The short-focus lens or combination of lenses which is nearest the eye in a telescope.

Eyepiece, Huygenian: A type of eyepiece invented by the noted astronomer Huygens, sometimes called the "negative eyepiece."

Faculae: The regions surrounding sunspots which are much hotter than the average solar surface and therefore are seen as white spots in contrast to the sun's yellow-white surface.

G. C. T.: Greenwich Civil Time means solar time of the prime meridian at Greenwich, zero hour in all astronomical computations. 0^h G. C. T. = 7 P.M. Eastern Standard Time.

Guiding: The moving of a telescope or of the photographic plate to keep an object exactly in the same place on the plate.

Hour circle: A great circle which passes through a celestial object and through the celestial poles.

Interpolation: The process of deriving from a series of given values, other intermediate values in conformity with the given values.

Magnitude: The brightness of a star or other celestial object.

Maria: The large, darker areas of the moon; the so-called "seas," now known to be arid plains.

Meteor: To the observer a brilliant flash of light in the sky, sometimes called a "shooting star"; actually a bit of solid matter passing through the earth's atmosphere from outer space.

Meteorite: A meteor that has reached the earth's surface.

Meteor shower: A swarm of meteors which returns periodically.

Messier's Catalogue: A very famous catalogue of the most splendid star clusters and nebulae found in the heavens, compiled by Messier. The objects are designated by the initial M and a number (example, M 31—great Andromeda Nebula).

Nebula, dark: Patches of cosmic dust which shut off the light of stars in the background and which do not reflect light.

Nebula, planetary: Disklike masses of nebulosity surrounding a central star.

Nebulae, spiral: (Island universes). Great aggregations of stars, star clusters, lesser nebulae, etc., which have a physical connection.

Nova: A new star seen where none or only a dim star was seen before.

Objective, achromatic: The type of objective usually composed of two lenses, a double-convex lens of crown glass and a plano-concave lens of flint glass, used to correct chromatic and spherical aberration. An ordinary "good" lens.

Objective: The large lens of the telescope, which is used to form the primary image of the object observed.

Ocular: The eyepiece of a telescope.

Occultation: The hiding of one celestial object by another larger celestial object (usually the moon).

Opposition: Position of a superior planet when sun, earth, and planet are in straight lines, and in this order.

Perihelion: Point in the orbit of an object nearest the sun.

Prominence: A large, gaseous, incandescent offshoot of gas seen at the edge of the sun.

Revolution: The motion of one body about another.

Right ascension: The celestial coordinate measured eastward from the vernal equinox along the celestial equator; a star's distance from the vernal equinox measured along the celestial equator to the star's hour circle.

Rotation: The motion of any body on its own axis.

Solstice, summer: The time when the sun reaches its highest *north* declination point. Usually June 21.

Solstice, winter: The time when the sun is at its greatest point of *south* declination. Usually December 22.

Spectroscope: An instrument used to determine the composition of the sun and stars by spectrum analysis.

Star: A great ball of burning gas.

Sun: A star or great ball of burning gas.

Sunspots: Dark areas in the sun's surface, believed to be magnetic storms.

Telescope, reflecting: A type of telescope employing a concave mirror as the main optical part.

Telescope, refracting: A type of telescope employing a compound-convex lens as the main optical part.

Terminator: The boundary between the light and the dark side of a body.

Transit: The crossing of a celestial object in front of the disk of an apparently larger body; or the passing of a celestial body across the field of view of a telescope.

Variable, cepheid: A type of variable star named after the first star of its kind ever discovered, Delta Cephei.

Variable, eclipsing: A binary star, made variable by the eclipsing of one component by the other.

Variable star: A star that changes its brightness.

Zenith: The point exactly overhead.

Zodiac: A band of twelve constellations, 8° either side of the ecliptic; the zone in which the sun, moon, and planets seem to move.

The Greek Alphabet

α Alpha	η Eta	ν Nu	τ Tau
β Beta	θ Theta	ξ Xi	υ Upsilon
γ Gamma	ι Iota	o Omicron	ϕ Phi
δ Delta	κ Kappa	π Pi	χ Chi
ϵ Epsilon	λ Lambda	ρ Rho	ψ Psi
ζ Zeta	μ Mu	σ Sigma	ω Omega

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