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STARS

A GUIDE TO THE CONSTELLATIONS,
SUN, MOON, PLANETS,
AND OTHER FEATURES OF THE HEAVENS
a Golden Guide® from St. Martin's Press

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FOREWORD

The artist, James Gordon Irving, worked with skill and imagination. His wife, Grace Crow Irving, assisted in research. David H. Heeschen of the Harvard Observatory and Ivan King of the University of Illinois Observatory helped with data and tables. Paul Lehr, of the National Oceanic and Atmospheric Administration, checked text involving meteorology. Hugh Rice of the Hayden Planetarium gave helpful advice, and our seasonal constellation charts owe much to his projections. Dorothy Bennett, for many years a member of the Hayden Planetarium staff, contributed greatly to our editorial planning. Isaac Asimov, Joe and Simone Gosner are to be credited for intermediate revisions; Mark R. Chartrand prepared the latest revisions. Twelve new illustrations by Howard Friedman have been added for this edition.

Thanks are due the Lowell, Hale (Mt. Wilson and Mt. Palomar), Lick, Yerkes, and National Optical Astronomy observatories and NASA for the use of images.

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This is a book for the novice, the amateur, or anyone who wants to enjoy the wonders of the heavens. It is a field guide, with information to help you understand more fully what you see. Use this book when you are watching the stars, constellations, and planets. Turn through it at odd moments to become familiar with sights you may see; carry it along on trips or vacations.

OBSERVING THE SKY

- Activities for the Amateur
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- Telescopes

STARS

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OBSERVING THE SKY



Egyptian Pyramids

Stars and planets have attracted man's attention since earliest times. Ancient tablets and carvings show that movements of planets were understood before 3000 B.C. Legend says two Chinese astronomers who failed to predict an eclipse correctly in 2136 B.C. were put to death. The Egyptians placed their pyramids with reference to the stars. The circles of stone at Stonehenge may have been used to keep track of lunar eclipses. Astronomy is indeed the oldest science, yet its importance increases as scientists turn to the stars to study problems of physics which they cannot tackle directly in the laboratory.

As far back as history records, there were professional astronomers — long before there were professional zoologists and botanists. The Egyptians, Chinese, and Europeans had countless astronomers. Their work often involved trying to predict future events, but their systems, though considered unscientific today, involved observation and recording of facts about stars and planets. These early astronomers, as well as those of today, made remarkable discoveries that changed man's outlook on the world and himself.

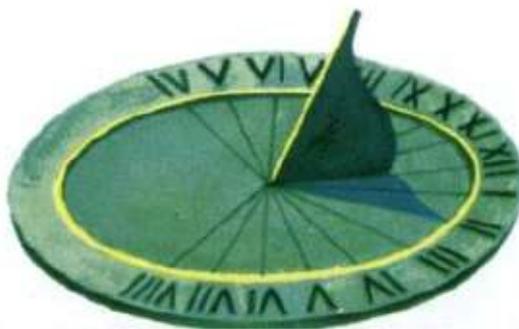
There has always been, too, an army of amateurs studying and enjoying the stars. Some make practical use of their knowledge — sailors, pilots, surveyors — but most study the heavens out of sheer interest and curiosity.

WHY LOOK? The stars can tell you time, direction, and position. These are about their only practical use to an amateur. More important is the satisfaction one finds in recognizing the brightest stars and planets. To see and to recognize Leo in the eastern sky is akin to seeing the first robin. And, as you learn more about the stars and the variety of other celestial objects, the more the wonder of the heavens grows.

WHERE TO LOOK Star-gazing has no geographic limits. Some stars can even be seen from brightly lit, smoky city streets, but the less interference from lights or haze the better. An ideal location is an open field, hill, or housetop where the horizon is not obscured by trees or buildings. However, buildings or a hill may also be used to screen off interfering lights, and although you may see less of the sky this way, you will be able to see that part of it better.

WHEN TO LOOK Only the brighter stars and planets are visible in full moonlight or so

after sunset. At these times the beginner can spot them and learn the major constellations without being confused by myriads of fainter stars. On darker nights, without moonlight, one may observe minor constellations, fainter stars, nebulae, and planets. Stars and planets visible at any given hour depend on time of night and season of the year. As the earth rotates, new stars come into view in the eastern sky as the evening progresses. Late at night one can see stars not visible in the evening sky until several months later. The seasonal star charts [here](#), [here](#), [here](#), and [here](#) and [planet tables](#) show the location of major celestial objects at various times of the year. See [check list](#).



Sundial

HOW TO LOOK First, be comfortable. Looking at stars high above the horizon may cause a stiff neck and an aching back; so use a reclining chair, a couch, or a blanket spread on the ground. Remember — ground and air may be unexpectedly cold at night; warm clothing, even in summer, may be needed. How to look also involves a method of looking. The section on constellations [here](#) gives suggestions. Many observations require knowing a little about angles in the [sky](#); After you have become familiar with the more common star constellations, and planets, a systematic study may be in order — perhaps with field glasses. By that time your interest may lead you to some of the activities suggested on the following pages.

EQUIPMENT You need no equipment, except your eyes, to see thousands of stars. This book will point the way to hours of interesting observation with your eyes alone. Later you will find your enjoyment greatly enhanced by the use of field glasses (6- to 8-power) such as those used in bird study. With these you can see vastly more — details on the moon, moons of Jupiter, many thousands of stars, star clusters, double stars, and nebulae. Larger field glasses (12-, 15-, or 18-power mounted on a tripod) will reveal finer lunar details and more hundreds of exciting stellar objects. Some day you may buy or make your own telescope.



ACTIVITIES FOR THE AMATEUR

ENJOYING THE STARS It is worth repeating that night-by-night observing, studying, and enjoying the stars is the activity that can mean the most to most people. No equipment and little preparation are needed. This [book](#) and sources of [information suggested](#) will help.

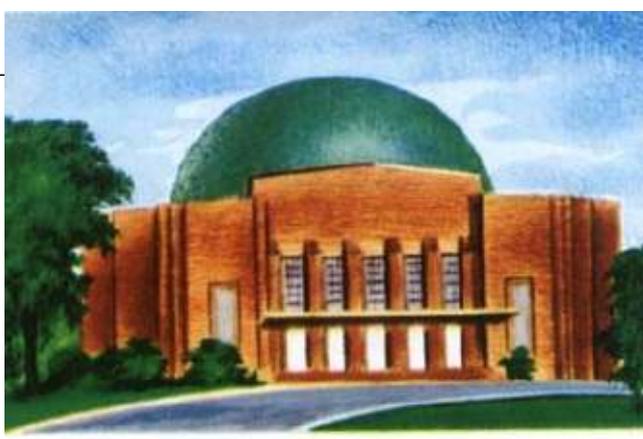


Zeiss Projection Planetarium

IDENTIFICATION The enjoyment of stars involves some practice in identification. Knowing two dozen constellations and a dozen of the brightest stars is often enough. A systematic study of stars, the identification of lesser constellations, and the location and study of clusters and nebulae demand more intensive efforts. A serious amateur will benefit by knowing nearly all the constellations and bright stars before going deeper into any phase of astronomy.

FOLLOWING THE PLANETS The planets, moving along in their orbits, are constantly changing their positions. Even the beginner can become familiar with the movements of planets — can recognize them, and predict which way they will travel. Knowing the planets is as important and as enjoyable as knowing the stars.

MUSEUMS Many museums have astronomical exhibits worth seeing. These may include meteorites, photographs of stars and planets, and sometimes working models of the solar system. Museums may be found at universities, observatories, planetariums, or governmental institutions. Inquire locally or when traveling concerning museums in the area that may offer astronomical exhibits.



Hayden Planetarium

OBSERVATORIES These are the sites of the great optical and radio telescopes where professional astronomers work. When work is going on, astronomers cannot be disturbed. However, many observatories are open for tours at specified hours, and some offer a schedule of public lectures. Some of the major places you can visit are listed here, and others are given in references on [here](#).

- Kitt Peak National Observatory, Tucson, AZ
- National Radio Astronomy Observatory, Greenbank, WV
- Mt. Wilson Observatory, Los Angeles, CA
- U.S. Naval Observatory, Washington, DC
- Allegheny Observatory, Pittsburgh, PA

PLANETARIUMS These “indoor universes” offer the chance to see and learn the sky under the instruction of experts. Sky shows also explain astronomical concepts. In addition to hundreds of small planetariums in schools and smaller museums, among the major planetariums are:

- Hayden Planetarium, New York, NY
- Adler Planetarium, Chicago, IL
- Fels Planetarium, Philadelphia, PA
- Griffith Planetarium, Los Angeles, CA
- Fernbank Planetarium, Atlanta, GA
- Charles Hayden Planetarium, Boston, MA
- Morrison Planetarium, San Francisco, CA
- Davis Planetarium, Baltimore, MD
- Buhl Planetarium, Pittsburgh, PA

CLUBS AND ASSOCIATIONS Amateur astronomers often band together to share their experiences and interests. Clubs are found in most large cities and many smaller ones. At meetings, a lecture or discussion is usually followed by a period of observing through telescopes. Some clubs work on cooperative projects in which the members share some scientific investigation. Visitors are usually welcome, and membership is commonly open to anyone who is interested.

Through such activities anyone from a youth in high school to a retired couple can become

serious amateurs. Such amateurs spend much of their time working on an astronomical hobby. They often become experts; some have made important discoveries. Professional astronomers are glad to have the help of trained amateurs, and several fields of astronomical research are manned largely by them. Amateur activities that demand greater skill and experience offer greater rewards in the satisfaction they provide.



Grinding a Mirror

TELESCOPE MAKING Making a telescope requires time and patience. But in the end you have an instrument costing only a small fraction of its worth, plus the fun of having made it. The telescopes made by amateurs are usually of the reflecting type, with a concave mirror instead of a lens for gathering light. Telescope-making kits, including a roughly finished glass “blank” for the mirror, other telescope parts, and complete instructions, are available from some optical-supply firms.

OBSERVING METEORS [Meteors or shooting stars](#) often occur in well-defined showers. Careful observation and plotting of the paths of meteors yield information of scientific value. A number of groups of amateurs are engaged in observing meteors, and any interested amateur or group of amateurs can join. Contact the American Meteor Society, Dept. of Physics and Astronomy, State University, Geneseo, NY 14454.

Armillary Sphere Once Used to Demonstrate Celestial Motions



OBSERVING VARIABLE STARS Amateurs with telescopes have done unusual work in this advanced field. Studies of these stars are coordinated by the American Association of Variable

Star Observers, 187 Concord Ave., Cambridge, Massachusetts 02138. The director of the Association will be glad to furnish qualified amateurs with details about this work.

STELLAR PHOTOGRAPHY Photographing the stars and other heavenly bodies is not difficult. Excellent pictures have been taken with box cameras set firmly on a table. But pictures of faint objects must be taken with a telescope or with a special camera adjusted to compensate for earth's motion. Photography is an important tool of astronomers — one which the amateur can use to good advantage.

MORE INFORMATION This book is a primer to the sky and can only introduce a story which is more fully told in many texts and popular books on astronomy.

BOOKS:

Abell, George O., *Exploration of the Universe*, 3rd ed., Holt, Rinehart, and Winston, New York, 1975. One of the best college level textbooks.

Bok, Bart J. and Priscilla E., *The Milky Way*, 4th ed., Harvard University Press, Cambridge, 1974. An engaging introduction to our own galaxy by two renowned experts.

Chartrand, Mark R., *Skyguide*, Golden Press, New York, 1982. This excellent introduction to the sky and to astronomy in general bridges the gap between books such as this one and textbooks. It contains seasonal sky maps and detailed charts for all the constellations.

Kirby-Smith, H.T., *U.S. Observatories: A Directory and Travel Guide*, Van Nostrand Reinhold, New York, 1976. Information for visiting observatories and other astronomical sites.

Lum, Peter, *The Stars in Our Heavens*, Pantheon Books, New York, 1948. A delightful recounting of sky mythology from around the world.

Mayall, Mayall, and Wyckoff, *The Sky Observer's Guide*, Golden Press, New York, 1965. An introductory book for the layman with maps of the heavens.

Norton, Arthur P., *Norton's Star Atlas*, Sky Publishing Corp., Cambridge, 1978. An excellent first sky atlas useful with binoculars or a small telescope.

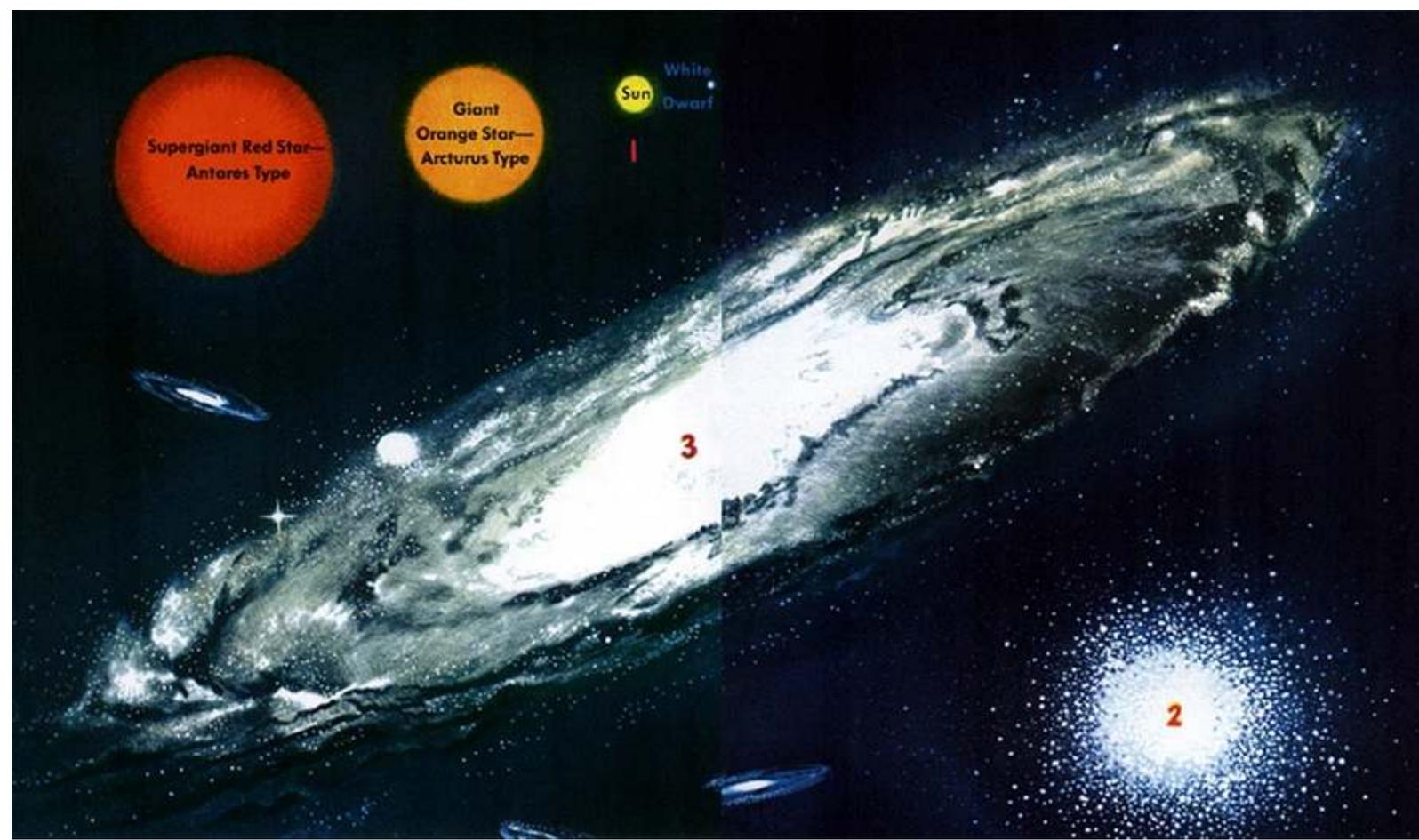
Shipman, Harry L., *Black Holes, Quasars, and the Universe*, 2nd ed., Houghton Mifflin Co., Boston, 1980. An exciting introduction to recent astronomical discoveries.

MAGAZINES:

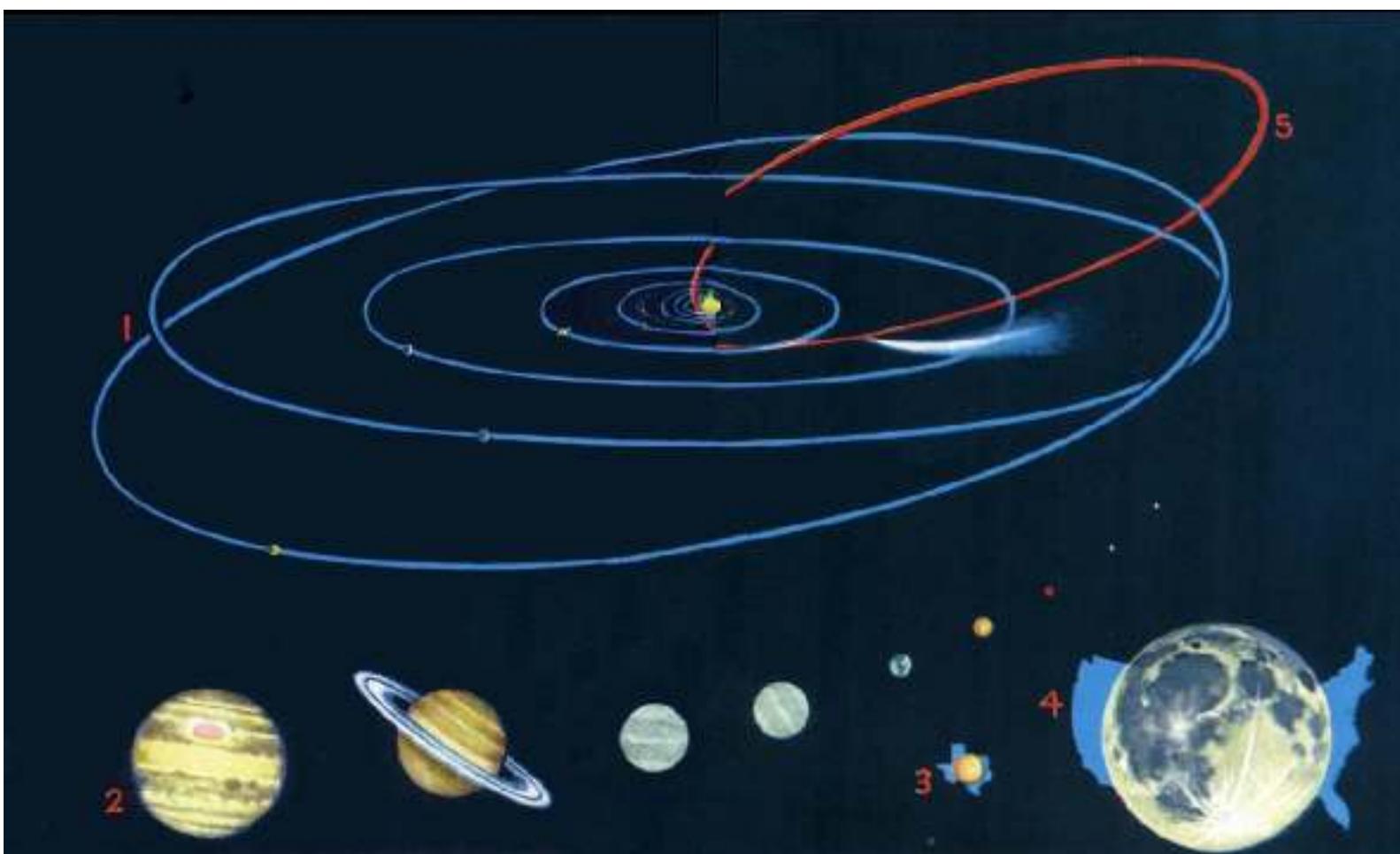
Astronomy, AstroMedia Corp., P.O. Box 92788, Milwaukee, WI 53202.

Mercury, Astronomical Society of the Pacific, 1290 24th Ave., San Francisco, CA 94122.

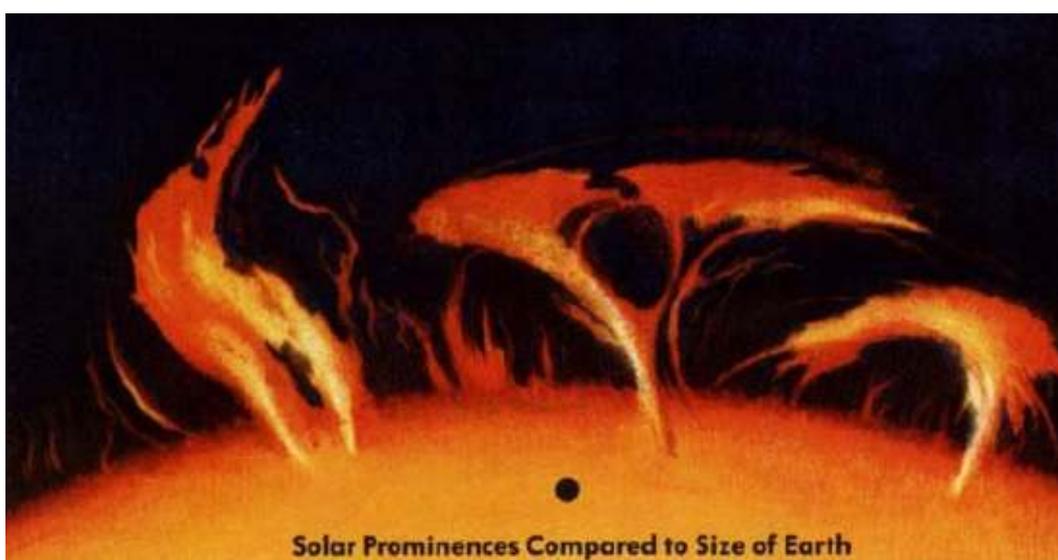
Sky and Telescope, Sky Publishing Corp., 49 Bay State Rd., Cambridge, MA 02138.



OUR UNIVERSE is so vast that its limits are unknown. Through it are scattered millions of galaxies of various sizes and shapes. In a galaxy like one shown here (3), our sun and earth are located [here](#). Galaxies contain hundreds of millions, even hundreds of billions, of stars of many types (1), ranging from red supergiants less dense than the earth's atmosphere to white dwarfs hundreds of times denser than lead. Stars on the average are spaced several light-years apart, but may be closer in some clusters (2). Planets may revolve around many of the stars.



OUR SOLAR SYSTEM is located halfway from the center of our galaxy — the Milky Way. Around the sun revolve the nine major planets with more than four dozen satellites; also hundreds of thousands of asteroids and swarms of meteors. Here we see the planets (1) their orbits around the sun (see [here](#)) and (2) in the order of their size. The asteroid Ceres compared (3) to Texas for size, and the moon is compared (4) to the United States. A comet orbit (5) appears in red. Our solar system may be only one of billions in the universe. So far, life is known to exist only on earth.



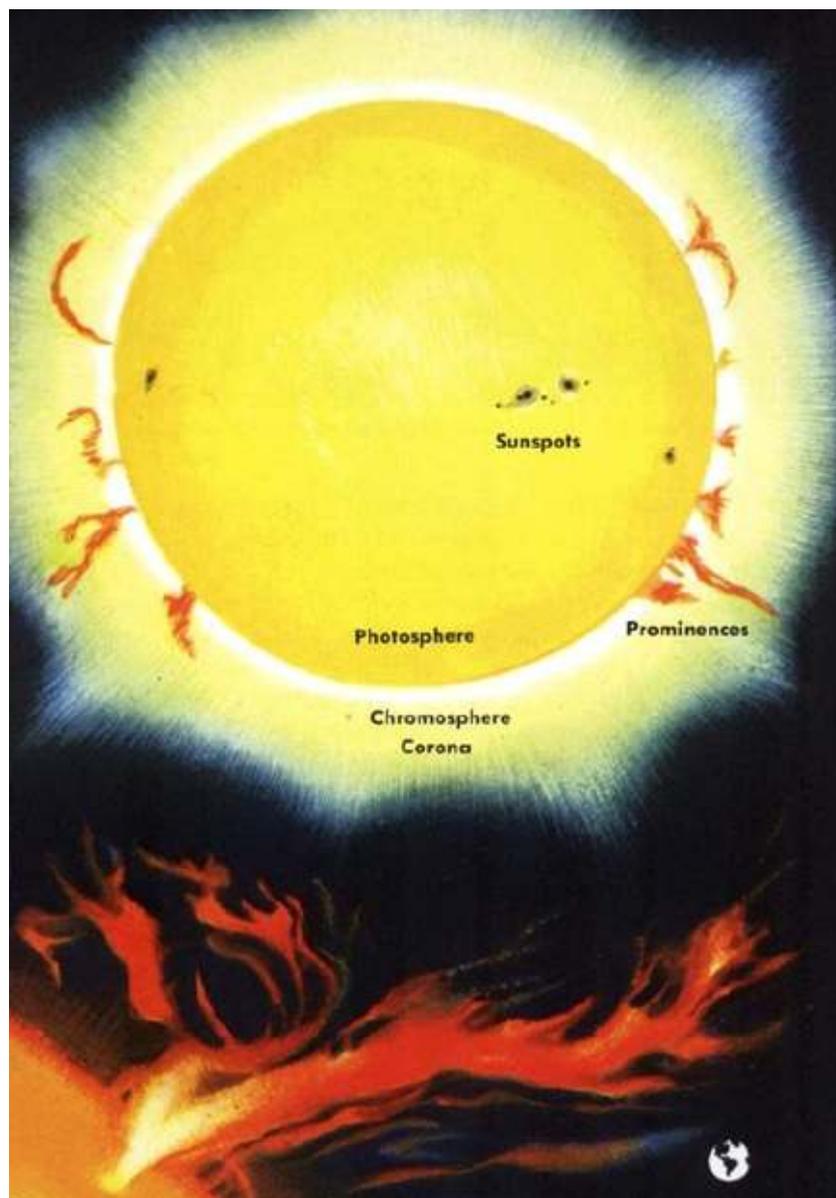
THE SUN is the nearest star. Compared to other stars it is of just average size; yet if it were hollow, over a million earths would easily fit inside. The sun's diameter is 860,000 miles.

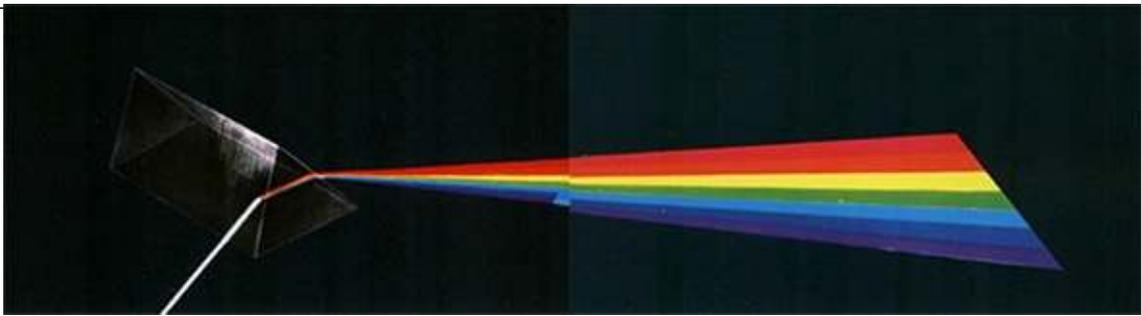
rotates on its axis about once a month. The sun is gaseous; parts of the surface move at different speeds. The sun's density is a little under 1½ times that of water.

The sun is a mass of incandescent gas: its core is a gigantic nuclear furnace where hydrogen is built into helium at a temperature of millions of degrees. Four million tons of the sun's matter is changed into energy every second. This process has been going on for billions of years, and will continue for billions more.

The sun's dazzling surface, the photosphere, is speckled with bright patches and with dark **sunspots**. Rising through and beyond the chromosphere, great prominences or streamers of glowing gases shoot out or rain down. The corona, which is the outermost envelope of gaseous matter, forms a filmy halo around the sun.

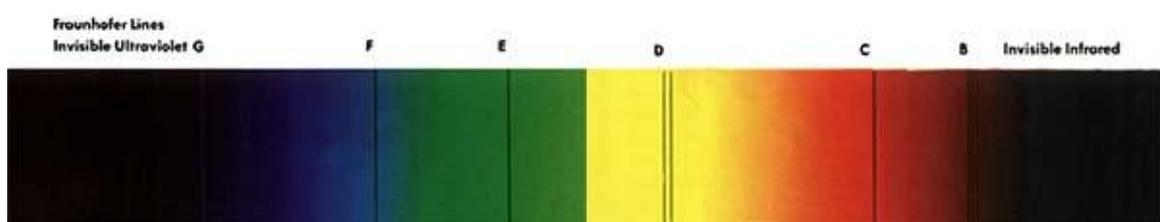
It is unsafe to observe the sun directly with the naked eye or binoculars. Use a special filter, a dark glass, or a film negative to protect your eyes. When a telescope is used, project the sun's image on a sheet of paper.





SUNLIGHT Every square yard of the sun's surface is constantly sending out energy equal to the power of 700 automobiles. About one two-billionth of this, in the form of sunlight, reaches us. Sunlight is a mixture of colors. When it passes through a glass prism, some of the light is bent or refracted more than other portions. Light leaving the prism spreads out into a continuous band of colors called a spectrum. Colors grade from red, which is bent least, through orange, yellow, green, and blue to violet, which is bent most.

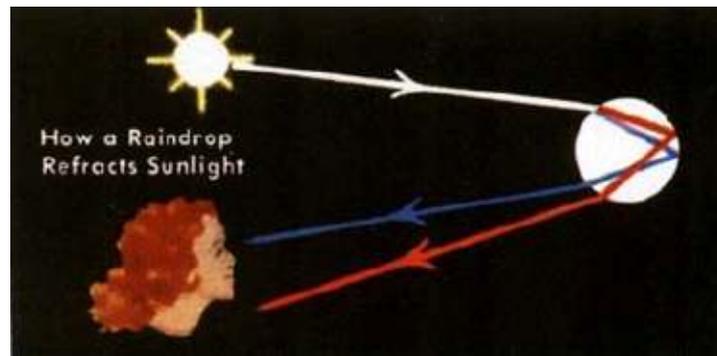
The spectrum is crossed by thousands of sharp dark lines. These indicate that some light was absorbed as it passed through the cooler gases above the sun's surface. These gases absorb that part of the sunlight which they would produce if they were glowing at a high enough temperature. Thus a study of the dark lines in the solar spectrum (called Fraunhofer lines, after their discoverer) gives a clue to the materials of which the sun is made. Of the 92 "natural" elements on the earth, $\frac{2}{3}$ have been found on the sun. The rest are probably present also. From the shifting of spectral lines, astronomers can measure the rotation of the sun and the motions of stars. They can detect magnetic fields from spectral lines and can determine a star's temperature and its physical state. Although astronomers can only see the surface of a star, they can calculate what it must be like deep inside.



A Rainbow Is a Spectrum

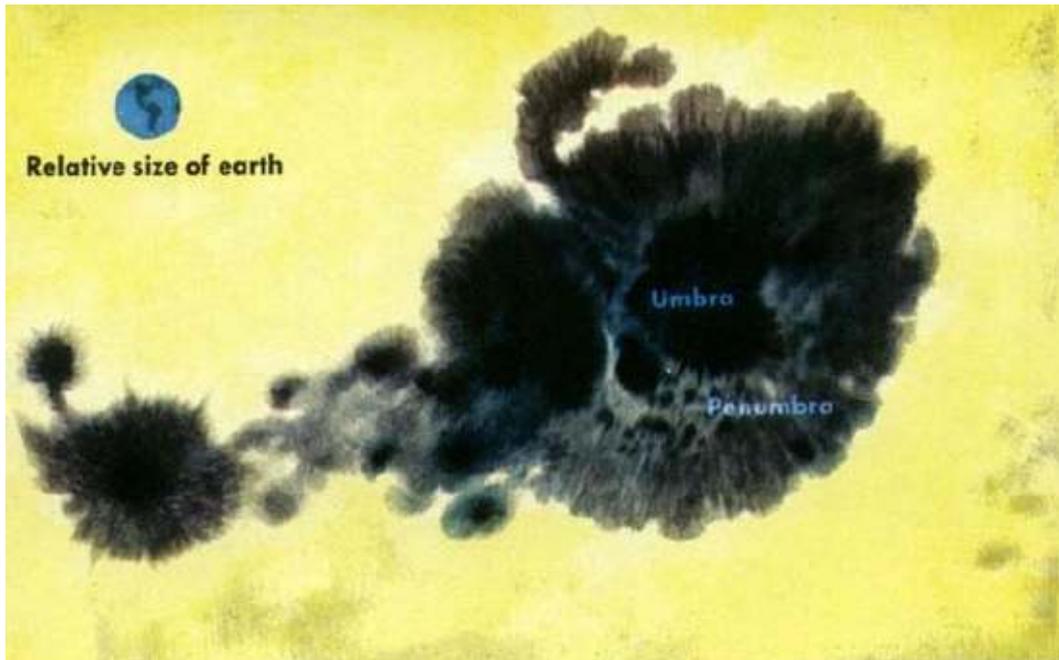
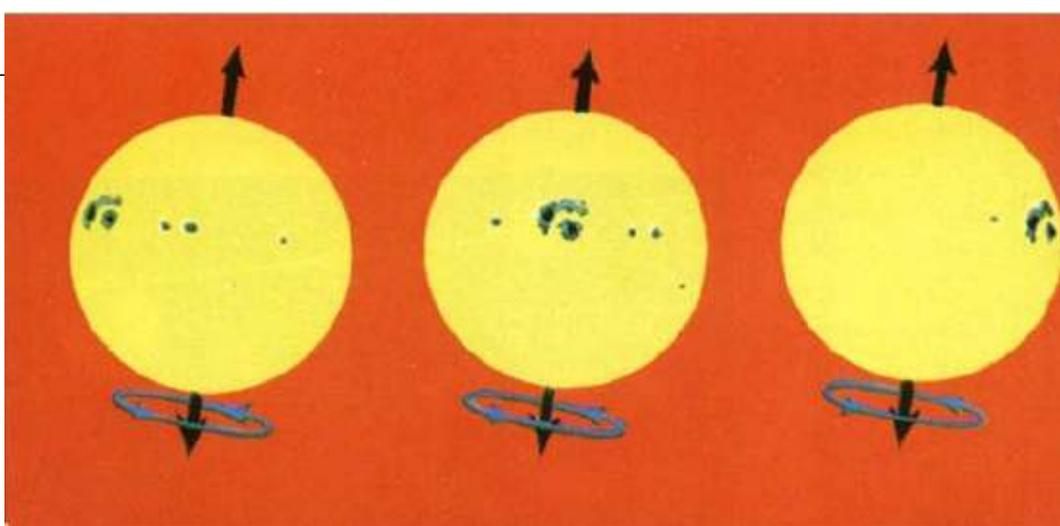
RAINBOWS are solar spectra formed as sunlight passes through drops of water. Rainbows may be seen when a hose is adjusted to a fine spray. The drops act like prisms, refracting sunlight to produce the spectrum.

A single, or primary, rainbow has red on the outside, violet inside. The arc is 40 degrees in radius. The center of the arc is always opposite the sun. When you see a bow, the sun is behind you. Sometimes a secondary rainbow forms outside the primary. It is fainter, with colors reversed — red inside, violet outside. The secondary bow forms from light reflected twice within drops. Light may be reflected more than twice, so occasionally up to five rainbows are seen. Another type of bow — red, or red and green — may appear with primary and secondary bows.



SUNSPOTS often appear on the sun's photosphere — appearing as dark, sculptured "holes" in contrast to the bright white surface. These sunspots are sometimes so large they can be seen with the unaided eye (through a dark glass for protection, of course), and are most easily observed when the sun is low on the horizon. The use of field glasses or a small telescope helps, but the safest method of observation is to study photographs. The dark center, or umbra, of a sunspot varies from a few hundred to over 50,000 miles across. This is surrounded by a less dark area, a penumbra, that often doubles the size of the sunspot. As the sun rotates, new sunspots come into view. Most persist for a week or so, but the maximum duration is from three to four months.

The number of sunspots varies in cycles of about 11 years — first increasing steadily until hundreds of groups are seen annually, then gradually decreasing to a minimum of about 5 groups. At the beginning of a cycle the sunspots appear about 30° north and south of the sun's equator. As the cycle progresses, they develop closer to the equator and the zone of activity extends from 10 to 20 degrees on either side of it. The 11-year cycle is really an average value. Mysteriously waxing and waning, the exact length of the cycle can be as short as nine years or as long as sixteen. The 11-year cycle is part of a larger 22-year cycle in which the entire magnetic field of the sun may reverse itself.



Sunspots seem to be giant magnetic storms on the sun's surface, which may be caused by deeper, periodic changes. They occur in groups which grow rapidly and then slowly decline. The gases in the sunspot (about 8,000°F) are cooler than the rest of the sun's surface (about 11,000°F); hence they appear darker. Actually, if a large sunspot could be isolated in another part of the sky, it would appear as bright as a hundred full moons. Sunspots have strong magnetic fields. Radiation from "solar flares" near them interacts with the upper levels of the earth's atmosphere and interrupts shortwave radio transmission; it is also likely to cause an increase in [auroras](#).

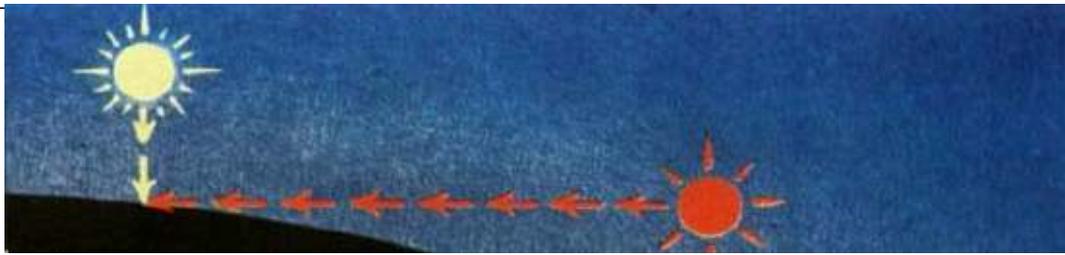


AURORAS OR NORTHERN LIGHTS The shifting, glowing, diffuse light of an aurora is hard to describe. Yellow, pink, and green lights come and go; arcs of light start at the horizon and spread upward; streamers and rays extend toward the zenith. Auroras last for hours, and often all through the night. They are most often seen in the north and middle northern latitudes and in the arctic. A similar display is seen in the southern latitudes. Auroras occur from about 60 to 600 miles up in the air. At these heights, so little air remains that space is almost empty like a vacuum, or the inside of a neon light. The shifting glow of the aurora is essentially electrical and somewhat similar to the light from the neon signs along Main Street.

Atomic particles from the sun hitting the thin gases of the upper atmosphere is what causes auroras. The charged particles come from solar flares near sunspots. The fact that auroras are most frequent near the earth's magnetic poles emphasizes their electrical character. A few days after a large new sunspot group develops, an auroral display is likely to occur.



THE SKY FROM SUNRISE TO SUNSET As the sun's rays pass through the earth's atmosphere, some are scattered, and a play of colors results. Blue rays are scattered most and therefore a clear sky is typically blue. But just after sunrise and just before sunset the sun is reddish. At these times the sharply slanting sun's rays must travel a longer path through the atmosphere, and more of the blue and yellow rays are scattered out of the rays reaching your eye. The red rays, which are scattered least, come through in the largest numbers, giving the sun its reddish hue. If there are clouds and dust in the air, many of the red rays which filter down into the lower atmosphere are reflected, and large areas of the sky may be reddened.

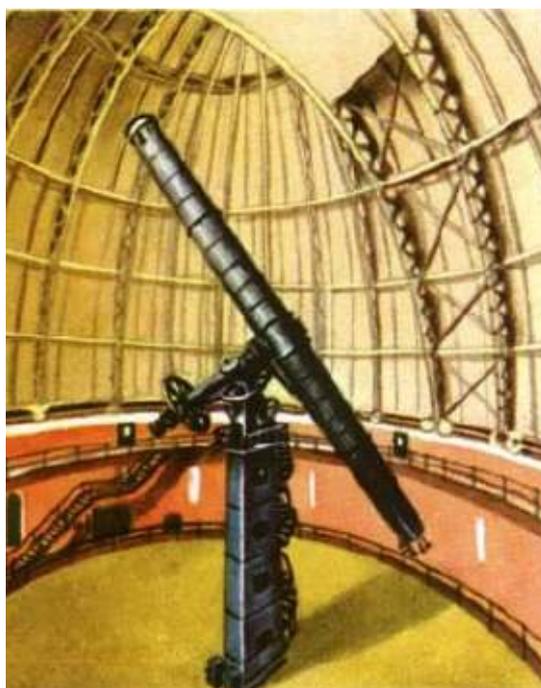


Because of the bending or refraction of light, which is greater when the sun is near the horizon, you can actually see the sun for a few minutes before it rises and after it sets. Daylight is a bit longer for this reason. The closer to the horizon, the greater the refraction at sunrise or sunset. Hence, as refraction elevates the sun's disc, the lower edge is raised more than the upper. This distorts the sun, just as it is rising or setting, giving it an oval or melon-shaped appearance.

Twilight is sunlight diffused by the air onto a region of the earth's surface where the sun has already set or has not risen. Astronomical twilight is defined as the period between sunset or sunrise and the time when the sun is 18 degrees below the horizon — that is, a little over an hour.

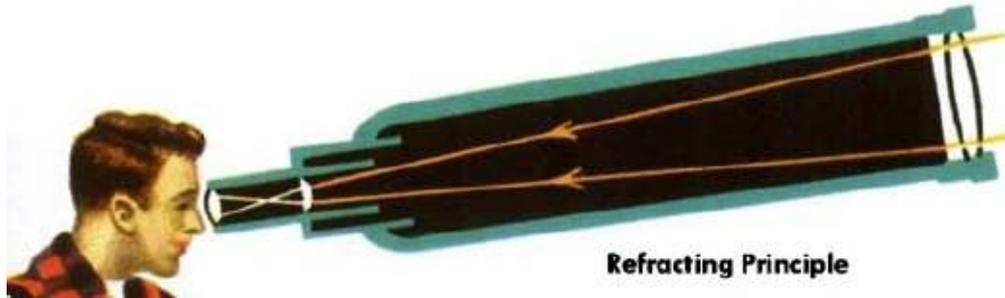
THE TELESCOPE was first put to practical use by Galileo in 1609. Since then, it has extended man's horizons farther and has challenged his thinking more than any other scientific device. The telescope used by Galileo, the best-known kind, is the refracting telescope, consisting of a series of lenses in a tube. In a simple refractor, two lenses are used, but commonly others are added to correct for the bending of light that produces a colored halo around the image. The largest refracting telescopes are one with a 40-inch lens at the Yerkes Observatory in Wisconsin, and a 36-inch one at Lick Observatory in California.

40-Inch Refractor, Yerkes Observatory

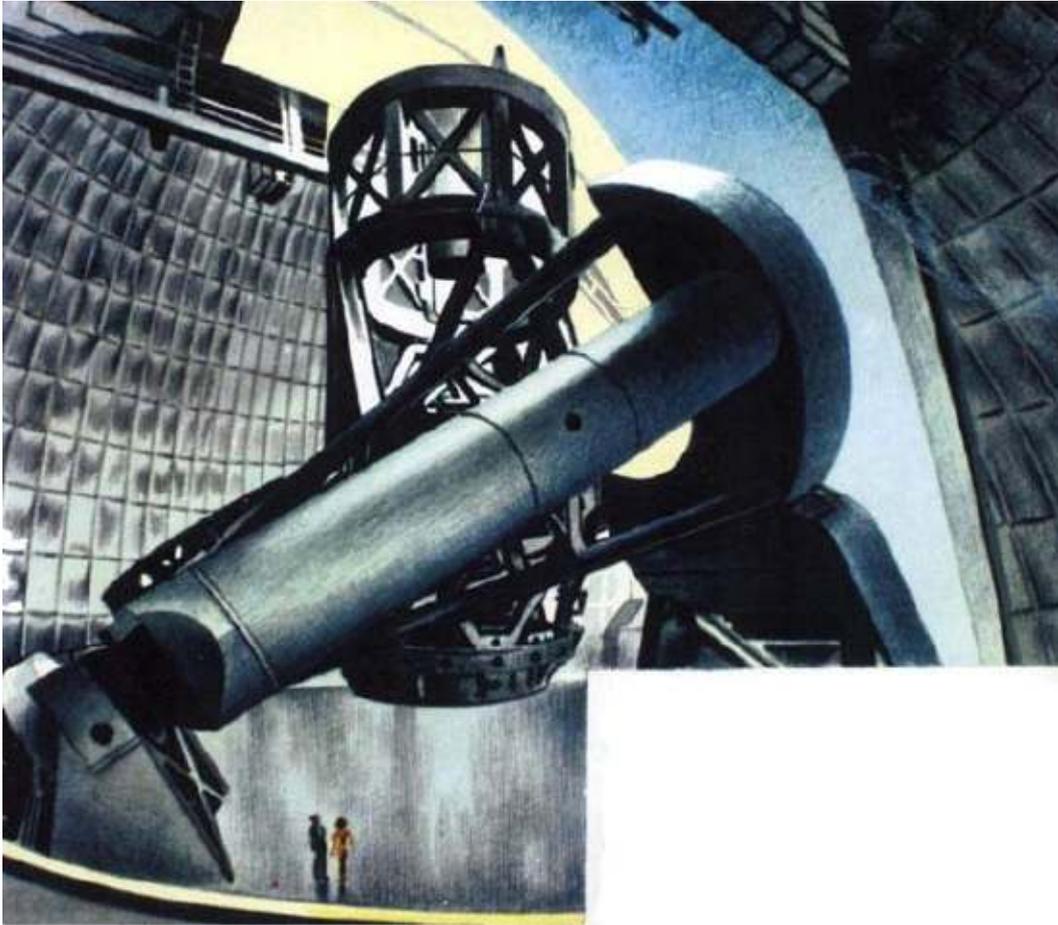


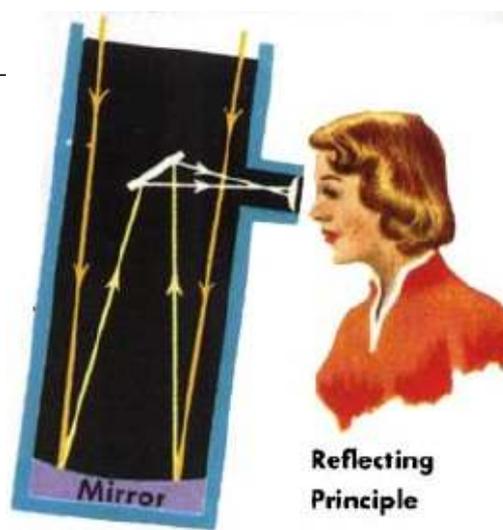
The simple reflecting telescope has a curved mirror at the bottom of the tube. This reflects

the light in converging rays to a prism or diagonally placed mirror, which sends the light to the eyepiece or to a camera mounted at the side of the tube. Since mirrors can be made larger than lenses, the largest astronomical **telescopes** are reflectors. Reflectors with mirrors up to 100 inches in diameter are made by amateurs as the best simple, low-cost telescope. Many astronomical bodies emit invisible radio, infrared, ultraviolet, X-ray, and gamma radiation, as well as visible light; each kind of radiation gives important information to astronomers about the physical state of the source. New types of telescopes, some of them in orbit around the earth, are used to observe these parts of the spectrum.



200-Inch Reflector, Palomar Mountain, Calif.





THE LARGEST TELESCOPE of the reflector type in the United States is on Palomar Mountain, near San Diego, Calif. Its 200-inch (16.6-foot) mirror is a marvel of scientific and engineering skill. The great disc of pyrex glass was cast with supporting ribs to bear its weight. It is 27 inches thick and weighs 14½ tons. Yet because of its design, every part is within two inches of the air — permitting the mirror to expand and contract uniformly with changes in temperature. The great piece of glass has been polished to within a few millionths of an inch of its calculated curve. Despite its great weight it can be tilted and turned precisely without sagging as much as the thickness of a hair. The mirror gathers about 640,000 times as much light as the human eye. With it, astronomers photograph stars six million times fainter than the faintest stars you can see, and galaxies over two billion light-years away.



STARS



Stars are suns: heavenly bodies shining by their own light and generally so far away from us that, though moving rapidly, they seem fixed in their positions. All are composed of at least 99 percent hydrogen and helium.

NUMBERS OF STARS On the clearest night you are not likely to see more than 2,000 stars. With changing seasons, new stars appear, bringing the total visible during the year to about 6,000. A telescope reveals multitudes more. The total in our galaxy runs into billions, but even so, space is almost empty. Were the sun the size of the dot over an “i,” the nearest star would be a dot 10 miles away, and other stars would be microscopic to dime-size dots hundreds and thousands of miles distant.

DISTANCES OF STARS The nearest star, our sun, is a mere 93 million miles away. The next nearest star is 26 million million miles — nearly 300,000 times farther than the sun. For these great distances, miles are not a good measure. Instead, the light-year is often used. This is the distance that light travels in one year, moving at 186,000 miles per second: nearly a million million miles. On this scale the nearest star (excluding the sun) is 4.3 light-years away. Sirius, the brightest star, is 8.8 light-years off. Other stars are hundreds, thousands, and even millions of light-years away.

STARLIGHT All stars shine by their own light. This light is produced by nuclear reactions similar to those of the hydrogen bomb occurring at the centers of stars. When the element hydrogen is transformed into helium, which happens in most stars, about 1 percent of its mass (weight) is changed into energy. This energy keeps the temperature in the star’s interior at millions of degrees. At the surface the temperature varies from about 5,500 degrees F. to over 55,000 degrees, depending on the kind of star. One pound of hydrogen changing to helium liberates energy equal to about 10,000 tons of coal. In a single star the energy released in this way requires the transformation of millions of tons of matter per second.

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