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Excerpt
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A Grand Tour of the Heavens

ORIGINS

We comment on "Origins" and "Structure and Evolution" as organizing themes.

Astronomy is in a golden age, filled with the excitement of new discoveries and a deeper understanding of the Universe, our home – and what an enthralling universe it is!

We have explored most of the planets in the Solar System, revealing an astonishingly wide variety of terrains and moons. We have discovered planets orbiting other stars, increasing our confidence that life exists elsewhere. We have solved many of the mysteries surrounding stellar birth and death, revealing among other things how the chemical elements inside our bodies, like calcium and oxygen, formed inside stars. With the Hubble Space Telescope, the Chandra X-ray Observatory, and the Spitzer Space Telescope we have examined galaxies shortly after their birth, deducing important clues to the origin and evolution of our own Milky Way Galaxy. (When we refer to our Milky Way Galaxy, we say "our Galaxy" or "the Galaxy" with an uppercase "G." When we refer to other galaxies, we use a lowercase "g.")

We have witnessed explosions of stars halfway across the visible Universe whose power is so tremendous that it rivals a galaxy containing ten billion normal stars. Indeed, we are lucky that none have recently occurred too close to Earth, for we wouldn't survive. We have detected black holes – strange objects whose gravitational pull is so strong that nothing, not even light, can escape. And, most recently, we have found strong evidence that what we thought was "empty space" actually contains a dark, gravitationally repulsive kind of energy that is causing the Universe to expand faster and faster with time. The origin of this "dark energy" is a complete mystery, but an understanding of it may revolutionize physics.

AIMS

1. Survey the Universe and the methods astronomers use to study it (Sections 1.1, 1.2, and 1.4).
2. Learn the measurement units used by astronomers (Section 1.1).
3. See how the sky looks in different seasons (Section 1.3).
4. Understand the value of astronomy to humans (Section 1.5).
5. Assess the scientific method and show how pseudoscience fails scientific tests (Sections 1.6 and 1.7).

The study of astronomy enriches our view of the Universe and fills us with awe, increasing our appreciation of the Universe's sheer grandeur and beauty. We hope that your studies will inspire you to ask questions about the Universe all around us and show you how to use your detective skills to search for the answers. Get ready for a thrilling voyage unlike any that you've ever experienced!

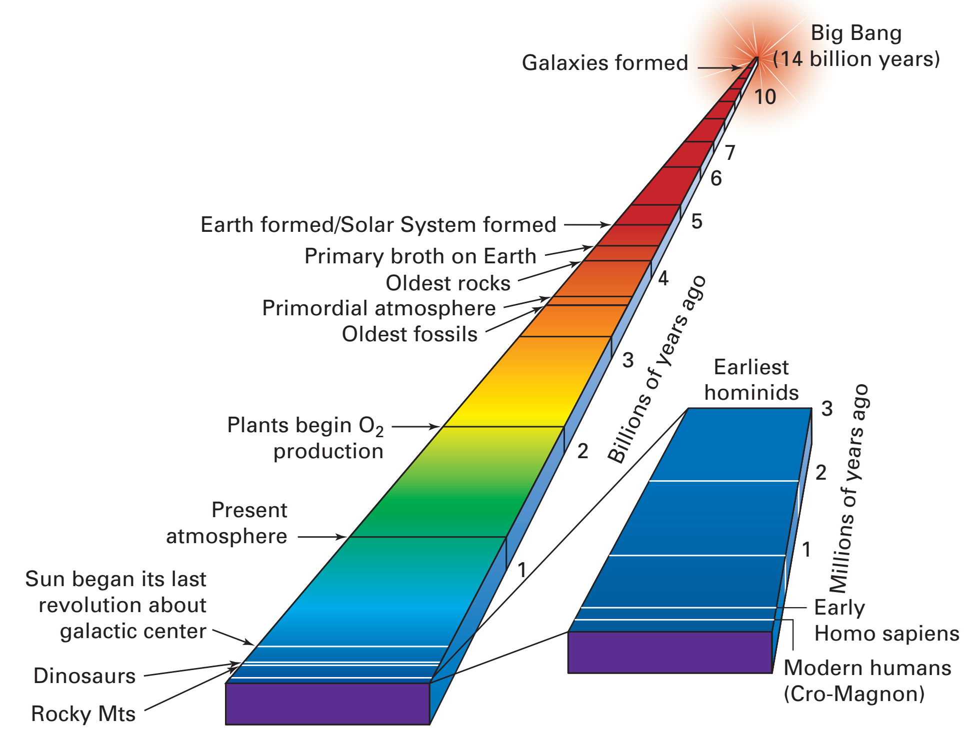
1.1 PEERING THROUGH THE UNIVERSE: A TIME MACHINE

Astronomers have deduced that the Universe began almost 14 billion years ago. Let us consider that the time between the origin of the Universe and the year 2013, or 14 billion years, is compressed into one day. If the Universe began at midnight, then it wasn't until slightly after 4 p.m. that the Earth formed; the first fossils date from 6 p.m. The first humans appeared only 2 seconds ago, and it is only 1/300 second since Columbus landed in America. Still, the Sun should shine for another 9 hours; an astronomical timescale is much greater than the timescale of our daily lives (■ Fig. 1–1).

One fundamental fact allows astronomers to observe what happened in the Universe long ago: Light travels at a finite speed, 300,000 km/s (equal to 186,000 miles per second), or nearly 10 trillion km per year. As a result, if something happens far away, we can't know about it immediately. Light from the Moon takes about a second to reach us (1.3 seconds, more precisely), so we see the Moon as it was roughly one second ago. Light from the Sun takes about eight minutes to reach us. Light from the nearest of the other stars takes over four years to reach us; we say that it is over four "light-years" away. Once we look beyond the nearest stars, we are seeing much farther back in time (see *Figure It Out 1.1: Keeping Track of Space and Time*).

The Universe is so vast that when we receive light or radio waves from objects across our home, the Milky Way Galaxy (a collection of hundreds of billions of stars bound together by gravity), we are seeing back tens of thousands of years. Even for the most nearby other galaxies, light has taken hundreds of thousands, or even millions, of years to reach us. And for the farthest known galaxies, the light has been travelling to us for billions of years. New telescopes on high mountains and in orbit around the Earth enable us to study these distant objects much better than we could previously. When we observe these farthest objects, we see them as they were billions of years ago. How have they changed in the billions of years since? Are they still there? What have they evolved into? The observations of distant objects that we make today show us how the Universe was a long, long time ago – peering into space, we watch a movie of the history of the Universe, allowing us to explore and eventually understand it.

Building on such observations, astronomers use a wide range of technology to gather information and construct theories to learn about the Universe, to discover what is in it, and to predict what its future will be. This book will show you how we look, what we have found, and how we interpret and evaluate the results.



■ **FIGURE 1–1** A sense of time.

FIGURE IT OUT 1.1 Keeping Track of Space and Time

Throughout this book, we shall generally use the metric system, which is commonly used by scientists. The basic unit of length, for example, is the meter, which is equivalent to 39.37 inches, slightly more than a yard. Prefixes are used (Appendix 1) in conjunction with the word "meter," whose symbol is "m," to define new units. The most frequently used prefixes are "milli-," meaning 1/1,000, "centi-," meaning 1/100, "kilo-," meaning 1,000 times, and "mega-," meaning one million times. Thus 1 millimeter is 1/1,000 of a meter, or about 0.04 of an inch, and a kilometer is 1,000 meters, or about 5/8 of a mile.

As we describe in *Figure It Out 1.2: Scientific Notation*, we keep track of the powers of 10 by which we multiply 1 m by writing the number of tens we multiply together as an exponent; 1,000 m (1,000 meters), for example, is 10^3 m, since 1,000 has 3 zeros following the 1 and thus represents three tens multiplying each other.

The standard symbol for "second" is "s," so km/s is kilometers per second. Astronomers measure mass in kilograms (kg), where each kilogram is 10^3 grams (1,000 g).

We can keep track of distance not only in the metric system but also in units that are based on the length of time that it takes light to travel. The speed of light is, according to Einstein's special theory of relativity, the greatest speed that is physically attainable for objects travelling through space. Light travels at 300,000 km/s (186,000 miles/s), so fast that if we could bend it enough, it would circle the Earth over 7 times in a single second. (Such bending takes place only near a black hole or cluster of galaxies, though; for all intents and purposes, light near the Earth goes straight.)

Even at that fantastic speed, we shall see that it would take years for us to reach the stars. Similarly, it has taken years for the light we see from stars to reach us, so we are really seeing the stars as they were years ago. Thus, we are looking backward in time as we view the Universe, with distant objects being viewed farther in the past than those nearby.

The distance that light travels in a year is called a **light-year**; note that the light-year is a unit of *length* rather than a unit of time even though the term "year" appears in it. It is equal to 9.53×10^{12} km (nearly 10 trillion km) – an extremely large distance by human standards.

A "month" is an astronomical time unit, based on the Moon's orbit, and a "year" is an astronomical time unit, based on the Earth's orbit around the Sun. The measurement of time itself is now usually based on processes in atoms, which are used to define the second. So the second from atomic timekeeping is slightly different from the second that we think of as a sixtieth of a minute, which is a sixtieth of an hour, which is a twenty-fourth of a day, which is based on the rotation of the Earth on its axis. For some purposes, weird stars called pulsars keep the most accurate time in the Universe. In this book, when we are talking about objects billions of years old, it won't matter precisely how we define the second or the year.

1.2 HOW DO WE STUDY THINGS WE CAN'T TOUCH?

The Universe is a place of great variety – after all, it has everything in it! At times, astronomers study things of a size and scale that humans can easily comprehend: the planets, for instance. Most astronomical objects, however, are so large and so far away that we have trouble grasping their sizes and distances. Many of these distant objects are fascinating and bizarre – ultra-dense pulsars that spin on their axes hundreds of times per second, exploding stars that light up the sky and incinerate any planets around them, giant black holes with a billion times the Sun's mass.

In addition to taking photographs of celestial objects, astronomers break down an object's light into its component colors to make a **spectrum** (see Chapter 2), much like a rainbow (■ Fig. 1–2). Today's astronomers, thanks to advances in telescopes and in devices to detect the incoming radiation, study not only the visible part of the spectrum, but also its gamma rays, x-rays, ultraviolet, infrared, and radio waves. We use telescopes on the ground and in space to observe astronomical objects in almost all parts of the spectrum. Combining views in the visible part of the spectrum with studies of invisible radiation gives us a more complete idea of the astronomical object we are studying than we could otherwise have (■ Fig. 1–3). Regardless of whether we are looking at nearby or very distant objects, the techniques of studying in various parts of the spectrum are largely the same.

The tools that astronomers use are bigger and better than ever. Giant telescopes on mountaintops collect visible light with mirrors as large as 10 meters across (■ Fig. 1–4). Up in space, above Earth's atmosphere, the Hubble Space Telescope sends back very clear images (■ Fig. 1–5). Many faraway objects are seen as clearly with Hubble as those closer to us appear with most ground-based telescopes. This accomplishment enables us to study a larger number of distant objects in detail. (But ground-based astronomers have developed methods of seeing very clearly, too, over limited areas of the sky in certain parts of the spectrum.) The Chandra X-ray Observatory produces clear images of a wide variety of objects using the x-rays they emit (■ Fig. 1–6).

FIGURE IT OUT 1.2 — Scientific Notation

In astronomy, we often find ourselves writing numbers that have strings of zeros attached, so we use what is called either scientific notation or exponential notation to simplify our writing chores. Scientific notation helps prevent making mistakes when copying long strings of numbers, and so aids astronomers (and students) in making calculations.

In scientific notation, which we use in *A Closer Look 1.1: A Sense of Scale*, included in this chapter, we merely count the number of zeros, and write the result as a superscript to the number 10. Thus the number 100,000,000, a 1 followed by 8 zeros, is written 10^8. The superscript is called the exponent. (In spreadsheets, such as Microsoft Excel, the exponent is written after a caret, ^, as in 10^8.) We also say that "ten is raised to the eighth power."

When a number is not an integer power of 10, we divide it into two parts: a number between 1 and 10, and an integer power of 10. Thus the number 3645 is written as 3.645×10^3. The exponent shows how many places the decimal point was moved to the left.

We can represent numbers between zero and one by using negative exponents. A minus sign in the exponent of a number means that the number is actually one divided by what the quantity would be if the exponent were positive. Thus $10^{-2} = 1/10^2 = 1/100 = 0.01$. As a further example, instead of working with 0.00256, we would move the decimal point three places to the right and write 2.56×10^{-3}.

Powers of 1,000 beyond kilo- (a thousand) are mega- (a million), giga- (a billion), tera- (a trillion), peta-, exa-, zetta-, and yotta-. It has been suggested, not entirely seriously, to use groucho- and harpo-, after two of the Marx Brothers, for the next prefixes.

1.3 FINDING CONSTELLATIONS IN THE SKY

When we look outward into space, we see stars that are at different distances from us. But our eyes don't reveal that some stars are much farther away than others of roughly the same brightness. People have long made up stories about groups of stars that appear in one part of the sky or another. The major star groups are called **constellations**. These constellations were given names, occasionally because they resembled something (for example, Scorpius, the Scorpion), but mostly to honor a hero or other subject of a story.

The International Astronomical Union put the scheme of constellations on a definite system in 1930. The sky was officially divided into 88 constellations (see Appendix 6 with definite boundaries, and every star is now associated with one and only one constellation. But the constellations give only the directions to the stars, and not the stars' distances. Individual stars in a given constellation generally have

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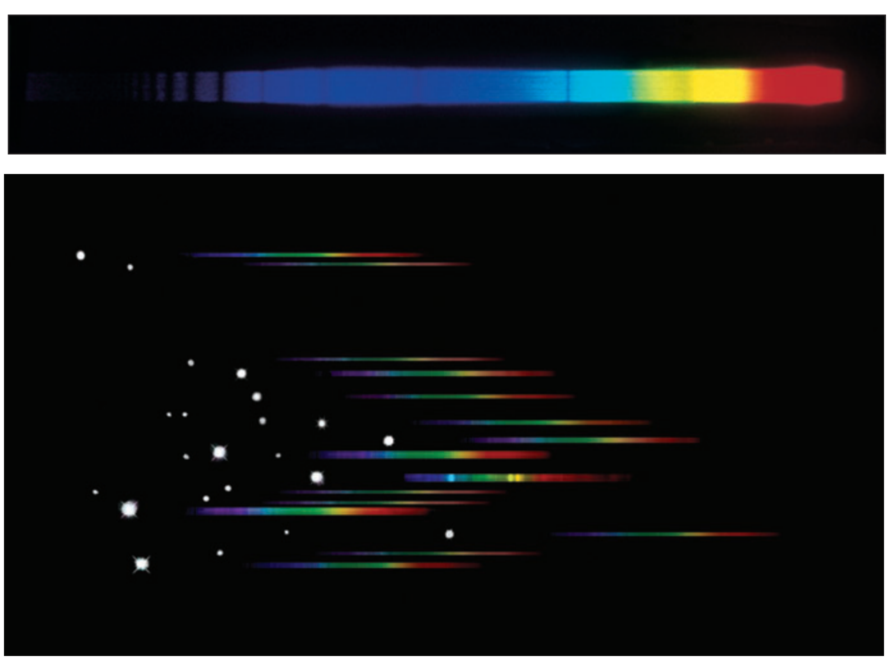
(b)



(a) National Optical Astronomy Observatories/Kitt Peak; (b) Harry Roberts, Australia

FIGURE 1–2 (a) The visible spectrum, light from the Sun spread out in a band. The dark lines represent missing colors, which tell us about specific elements in space or in the Sun absorbing those colors. (b) Spectra of all the stars in a cluster of extremely hot stars, including even a so-called Wolf-Rayet star whose spectrum shows some bands of emission as opposed to the usual absorption; a drawing.

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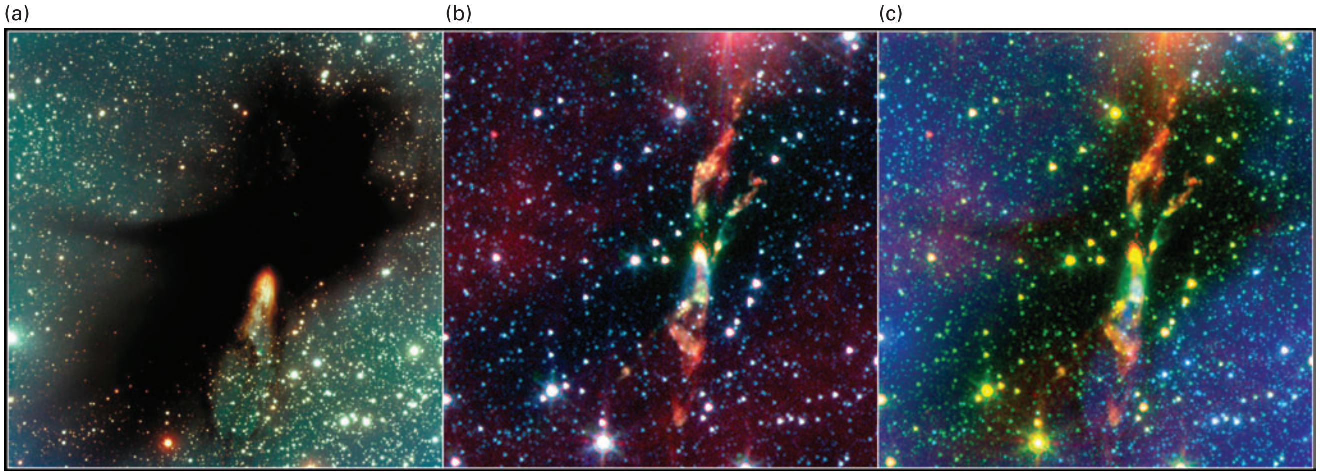
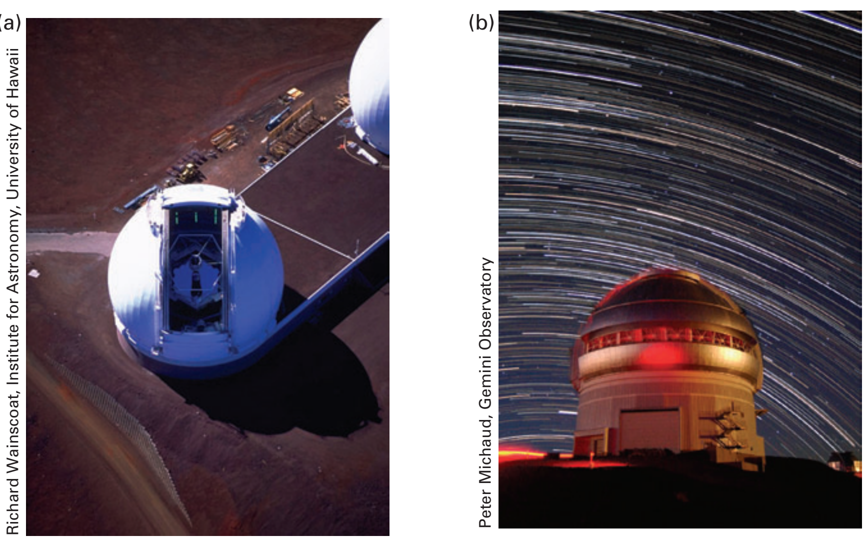
(a) (b) (c)



Spitzer infrared data: NASA/JPL-Caltech/I. Bourke (Harvard-Smithsonian CfA) and c2d Legacy Team; VLT visible light data: J. Alves (ESO), E. Tolstoy (Groningen), R. Fosbury (ST-ECF), and R. Hook (ST-ECF)

FIGURE 1–3 Objects often look very different in different parts of the spectrum. At left we see a visible-light image of the nebula BHR 71, obtained with the Very Large Telescope in Chile; a large amount of dust makes it opaque. The center panel shows the same view at infrared wavelengths, obtained with the Spitzer Space Telescope and displayed in false color; a jet from a protostar deep in the nebula appears, and many other stars can be seen as well. At right the images have been combined, again using false color.

(a) (b)



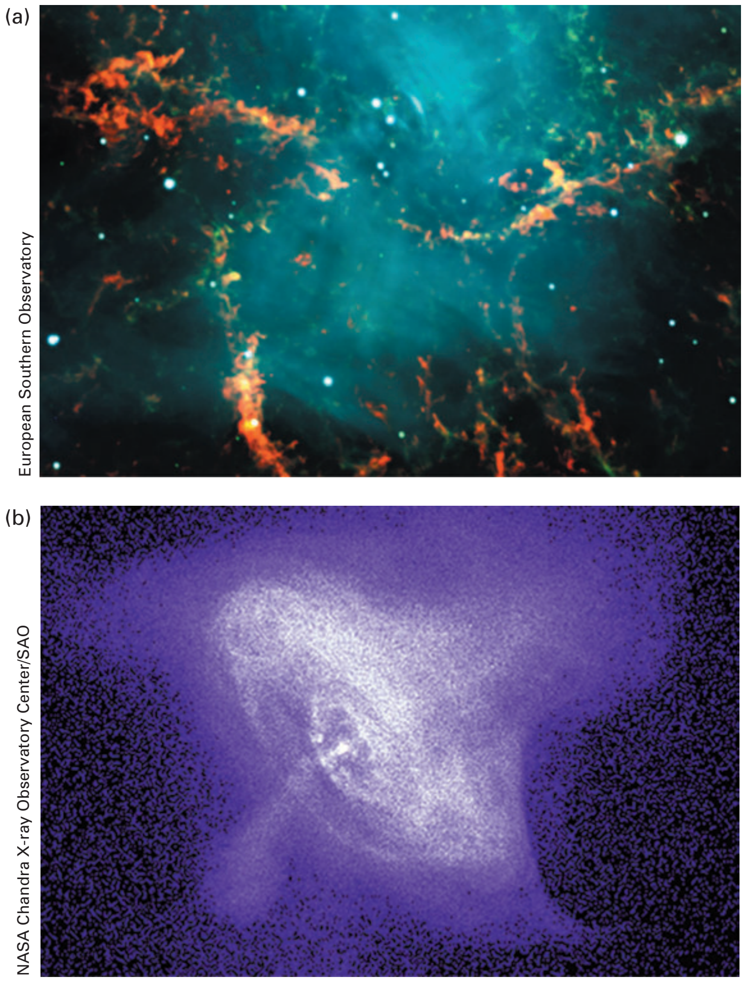
Richard Wainscoat, Institute for Astronomy, University of Hawaii

Peter Michaud, Gemini Observatory

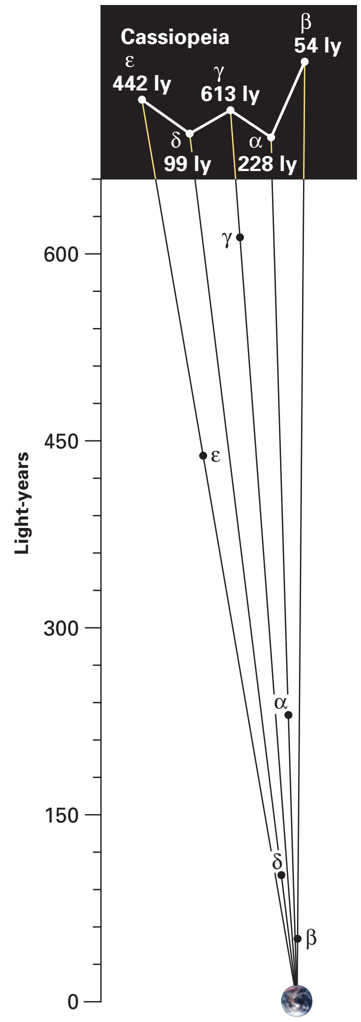
FIGURE 1–4 Near the twin 10-m Keck telescopes (a), we find the 8.2-m-diameter Gillett Gemini North telescope (b) on Mauna Kea volcano in Hawaii. The Giant Magellan Telescope is to be erected in Chile out of several 8-m mirrors in order to have the equivalent of a 21-m-diameter telescope. A Thirty-Meter Telescope is also planned, and the European Southern Observatory is building its 39-m European Extremely Large Telescope (E-ELT); both are based on the Keck design consisting of many relatively small hexagonal segments.

ESA/NASA, ESO, and Danny LaCru

FIGURE 1–5 An image of part of a small, neighboring galaxy to our own, the Tarantula Nebula in the Large Magellanic Cloud. It was taken with the Hubble Space Telescope and a European Southern Observatory ground-based telescope. It was mosaicked and processed by a 23-year-old amateur astronomer using publicly available software. Shock waves from exploding stars have compressed the gas into the visible filaments and sheets.



■ **FIGURE 1–6** (left) The center of the Crab Nebula, the remnant of a star that exploded almost 1,000 years ago, in visible light. This highly detailed image was taken with the Very Large Telescope in Chile. (right) An x-ray image of the heart of the Crab Nebula taken with the Chandra X-ray Observatory. The image reveals tilted 1-light-year rings of material lighted by electrons flowing from the central pulsar, plus jets of gas extending perpendicular to the rings.



■ **FIGURE 1–7** The stars we see as a constellation are actually at different distances from us. In this case, we see the true relative distances of the stars in the "W" of Cassiopeia, as determined from the Hipparcos spacecraft. The stars' appearance projected on the sky is shown in the upper part.

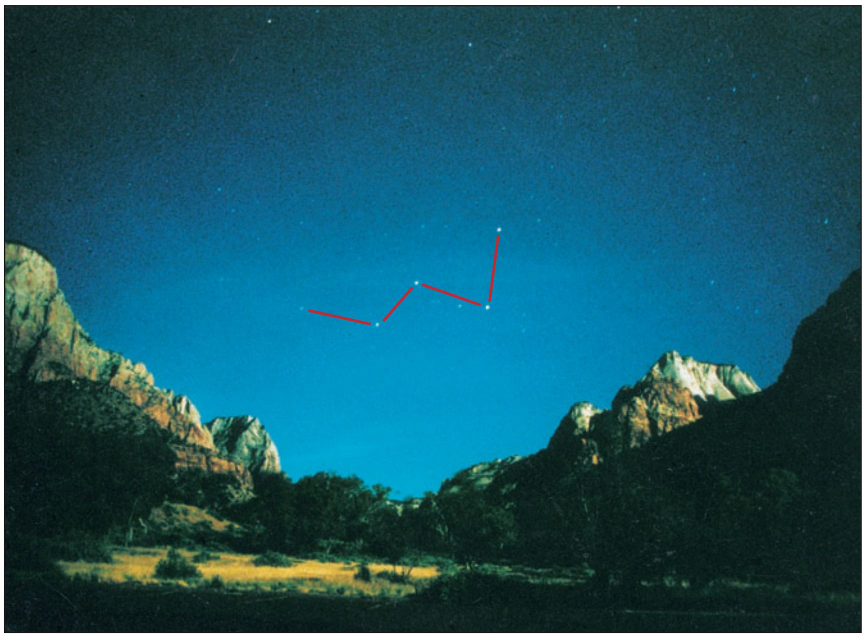
quite different distances from us (■ Fig. 1–7); these stars aren't physically associated with each other, and they were born at different times and locations.

Thus, the constellations show where things appear to be in the sky, but not what they are like or what they are made of. In most of this book, you will study the "how and why" of astronomy, not merely where things are located or what they are called. Still, it can be fun to look up at night and recognize the patterns in the sky.

Some groupings of stars are very familiar to many people but are not actually constellations. These configurations, made of parts of one or more constellations, are known as **asterisms**. The Big Dipper, for example, is an asterism but isn't a constellation, since it is but part of the constellation Ursa Major (the Big Bear). As we will see further in Chapter 4, some asterisms and constellations are sufficiently close to the celestial north pole in the sky that they are visible at all times of year, as seen from the United States. The Big Dipper is an example. But other asterisms and constellations, farther from celestial north, are visible at night for only part of the year. Let us now survey some of the prominent asterisms and constellations that you can see in each season; see also *Star Party 1.1: Using the Sky Maps*. (Amateur astronomers often hold viewing sessions informally known as "star parties," during which they observe celestial objects. Likewise, the occasional "Star Party" boxes in this text highlight interesting observations that you can make.)

1.3a The Autumn Sky

As it grows dark on an autumn evening, you will see the Pointers in the Big Dipper – the two end stars – point upward toward Polaris. Known as the "north star," Polaris is not one of the brightest or nearest stars in the sky, but is well known because it is close to the direction of the celestial north pole. As we will see in Chapter 4, that means it uniquely appears almost motionless in the sky throughout the night, and provides a bearing that can help you get safely out of the woods. Almost an equal distance on the other side of Polaris is a



Clifford Holmes

FIGURE 1–8 The constellation Cassiopeia is easily found in the sky from its distinctive "W" shape, marked in red on the photograph.

"W"-shaped constellation named Cassiopeia (Fig. 1–8). In Greek mythology, Cassiopeia was married to Cepheus, the king of Ethiopia (and the subject of the constellation that neighbors Cassiopeia to the west). Cassiopeia appears sitting on a chair.

As we continue across the sky away from the Pointers, we come to the constellation Andromeda, named for Cassiopeia's daughter in Greek mythology. In Andromeda, on a very dark night you might see a faint, hazy patch of light; this is actually the center of the nearest large galaxy to our own, and is known as the Andromeda Galaxy. Although at about 2.4 million light-years away it is one of the nearest galaxies to us, it is much farther away than any of the individual stars that we see in the sky, since they are all in our own Milky Way Galaxy.

Southwest in the sky from Andromeda, but still high overhead, are four stars that appear to make a square known as the Great Square of Pegasus. One of the corners of this asterism is actually in the constellation Andromeda.

If it is really dark outside (which probably means that you are far from a city and also that the Moon is not full or almost full), you will see the hazy band of light known as the "Milky Way" crossing the sky high overhead, passing right through Cassiopeia. This dim band with ragged edges, which marks the plane of our disk-shaped galaxy (see Chapter 16), has many dark patches that make rifts in its brightness.

Moving southeast from Cassiopeia, along the Milky Way, we come to the constellation Perseus; he was the Greek hero who slew the Medusa. (He flew off on Pegasus, the winged horse, who is conveniently nearby in the sky, and saw Andromeda, whom he saved.) On the edge of Perseus nearest to Cassiopeia, with a small telescope or binoculars we can see two hazy patches of light that are really clusters of hundreds of stars called "open clusters," a type of grouping we will discuss in Chapter 11. This "double cluster in Perseus," also known as h and χ (the Greek letter "chi") Persei, provides two of the open clusters that are easiest to see with small telescopes. (They already appeared in Figure 1–3.) In 1603, Johann Bayer assigned Greek letters to the brightest stars and lowercase Latin letters to less-bright stars (Fig. 1–9), but in this case the system was applied to name the two clusters as well.

Along the Milky Way in the other direction from Cassiopeia (whose "W" is relatively easy to find), we come to a cross of bright stars directly overhead. This "Northern Cross" is an asterism marking part of the constellation Cygnus, the Swan (Fig. 1–10). In this direction, spacecraft detect x-rays whose brightness varies with time, and astronomers have deduced in part from that information that a black hole is located there. Also in Cygnus is a particularly dark region of the Milky Way, called the Northern Coalsack. Dust in space in that direction prevents us from seeing as many stars as we see in other directions of the Milky Way.

Slightly to the west is another bright star, Vega, in the constellation Lyra (the Lyre). And farther westward, we come to the constellation Hercules, named for the mythological Greek hero who performed twelve great labors, of which the most famous was bringing back the golden apples. In Hercules is an older, larger type of star cluster called a "globular cluster," another type of grouping we will discuss in Chapter 11. It is known as M13, the great globular cluster in Hercules. It resembles a fuzzy mothball whether glimpsed with the naked eye or seen with small telescopes; larger telescopes have better clarity and so can reveal the individual stars.

1.3b The Winter Sky

As autumn proceeds and winter approaches, the constellations we have discussed appear closer and closer to the western horizon for the same hour of the night. By early evening on January 1, Cygnus is setting in the western sky, while Cassiopeia and Perseus are overhead.

STAR PARTY 1.1 Using the Sky Maps

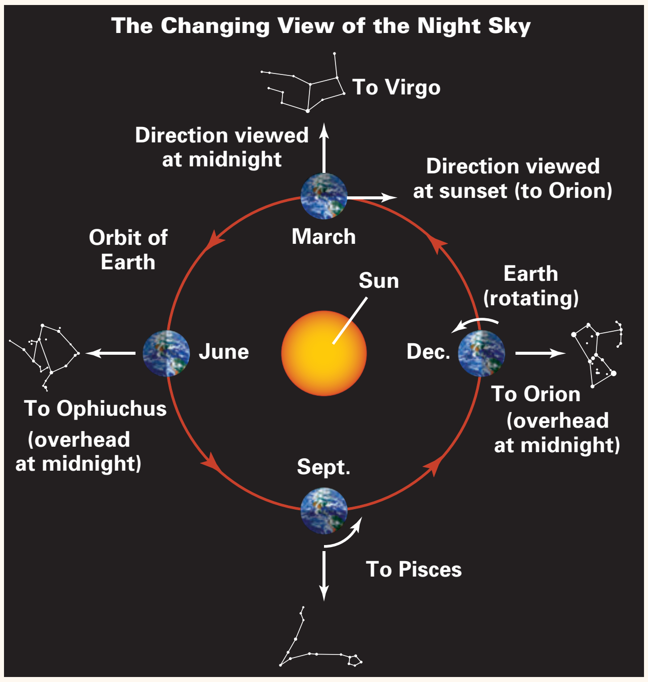
Because of Earth's motion around the Sun over the course of a year, the parts of the sky that are "up" after dark change slightly each day. A given star rises (and crosses the meridian, or highest point of its arc across the sky) about 4 minutes earlier each day. By the time a season has gone by, the sky has apparently slipped a quarter of the way around at sunset as the Earth has moved a quarter of the way around the Sun in its yearly orbit. Some constellations are lost in the afternoon and evening glare, while others have become visible just before dawn.

In December of each year, the constellation Orion crosses the meridian at midnight. Three months later, in March, when the Earth has moved through one-quarter of its orbit around the Sun, the constellation Virgo crosses the meridian at midnight, when Orion is setting. Orion crosses the meridian at sunset (that is, 6 hours earlier than in December – consistent with 4 minutes/day × 90 days = 360 minutes = 6 hours). Another three months later, in June, Orion crosses the meridian an additional 6 hours earlier – that is, at noon. Hence, it isn't then visible at night. Instead, the constellation Ophiuchus crosses the meridian at midnight.

Because of this seasonal difference, inside the front and back covers of this book we have included four Sky Maps, one of which is best for the date and time at which you are observing. Suitable combinations of date and time are marked. Note also that if you make your observations later at night, it is equivalent to observing later in the year. Two hours later at night is the same as shifting later by one month.

Hold the map above your head while you are facing north or south, as marked on each map, and notice where your zenith is in the sky and on the map. The horizon for your latitude is also marked. Try to identify a pattern in the brightest stars that you can see. Finding the Big Dipper, and using it to locate the pole star, often helps you to orient yourself. Don't let any bright planets confuse your search for the bright stars – knowing that planets usually appear to shine steadily instead of twinkling like stars (see Chapter 4) may assist you in locating the planets.

Come back and look at Sections 1.3a–d at the appropriate time of year – even after you have finished with this course.



To the south of the Milky Way, near Perseus, we can now see a group of six stars close together in the sky (■ Fig. 1–11). The tight grouping tends to catch your attention as you scan the sky. It is the Pleiades (pronounced "plee´a-deez"), traditionally the Seven Sisters of Greek mythology, the daughters of Atlas. (We can usually see six stars with the unaided eye now, so either one of the stars has faded over the millennia or it was never visible and the association with the Pleiades myth was loose.) These stars are another example of an open cluster of stars. Binoculars or a small telescope will reveal dozens of stars there, whereas a large telescope will ordinarily show too small a region of sky for you to see the Pleiades well. So a bigger telescope isn't always better.

Farther toward the east, rising earlier every evening, is the constellation Orion, the Hunter (■ Fig. 1–12). Orion is perhaps the easiest constellation of all to pick out in the sky, for three bright stars close together in a line make up its belt. Orion is warding off Taurus, the Bull, whose head is marked by a large "V" of stars. A reddish star, Betelgeuse ("bee´tl-juice" is an acceptable pronunciation, though some say "beh´tl-jouz"), marks Orion's armpit, and symmetrically on the other side of his belt, the bright bluish star Rigel ("rye´jel") marks his heel. Betelgeuse is an example of a red supergiant star; it is hundreds of millions of kilometers across, far bigger itself than the Earth's orbit around the Sun!

Orion's sword extends down from his belt. A telescope, or a photograph, reveals a beautiful region known as the Orion Nebula. Its general shape can be seen in even a smallish telescope; however, only images that have detected much light clearly reveal the vivid colors – though whether it is reddish or greenish in an image depends on what kind of filters were used. It is a site where new stars are forming right now, as you read these words.

Rising after Orion is Sirius, the brightest star in the sky. Orion's belt points directly to it. Sirius appears blue-white, which indicates that its surface is very hot. Sirius is so much brighter than the other stars that it stands out to the naked eye. It is part of the constellation

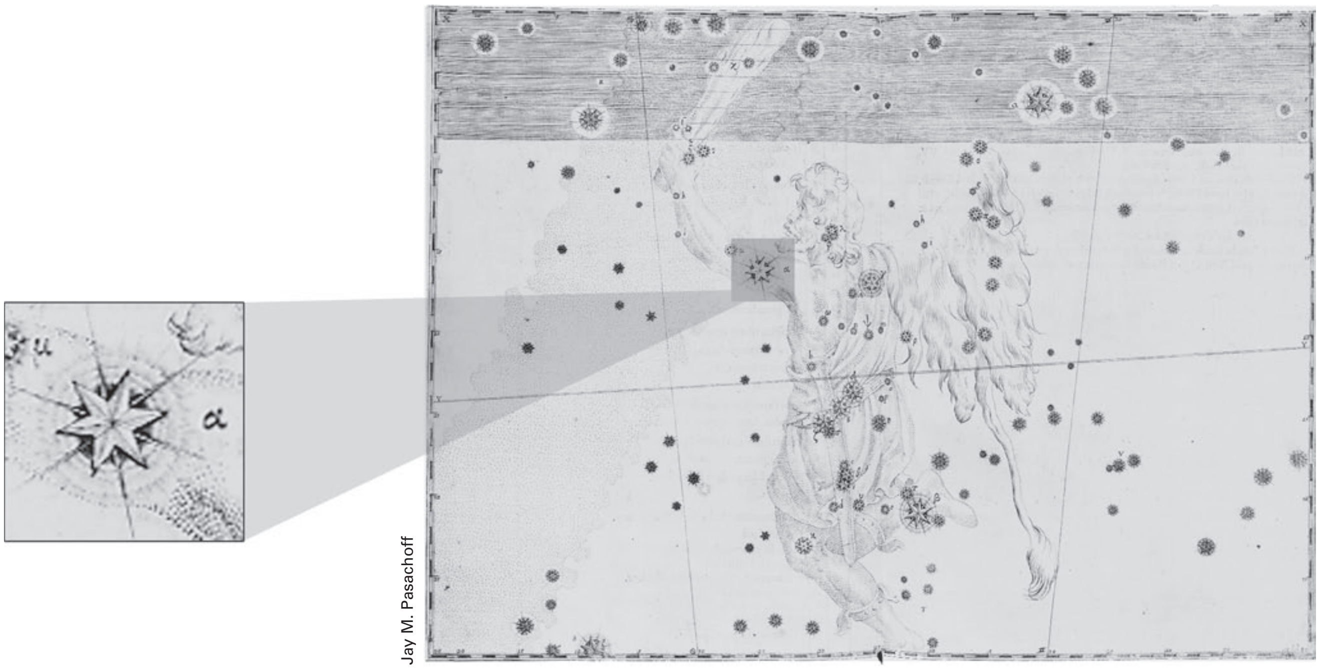


FIGURE 1–9 Johann Bayer, in 1603, used Greek letters to mark the brightest stars in constellations; he also used lowercase Latin letters. Here we see Orion, the great hunter. The inset shows the red-supergiant star Betelgeuse, α Orionis (that is, alpha of Orion), marking Orion's shoulder.

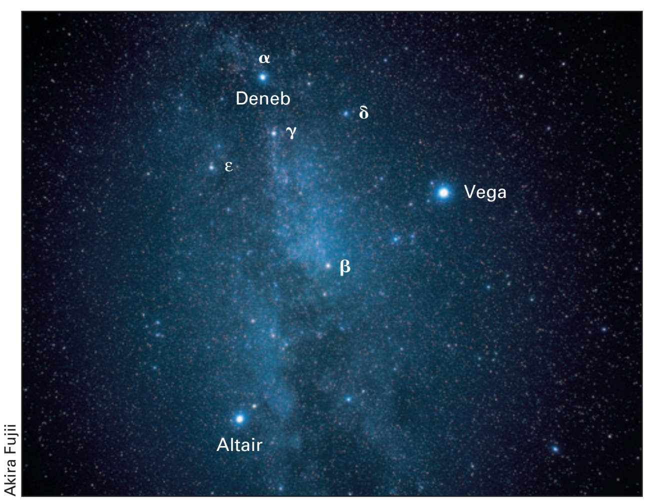


FIGURE 1–10 The Northern Cross, composed of the brightest stars in the constellation Cygnus, the Swan. Deneb, also called alpha (a) Cygni, gamma (g) Cygni, and beta (β) Cygni make the long bar; epsilon, gamma, and delta Cygni make the crossbar. The bright star Vega, alpha in Lyra, is nearby. Also marked is the bright star Altair, alpha in Aquila, the Eagle. These stars lie in the Milky Way, which shows clearly on the image.

FIGURE 1–11 The Pleiades, the Seven Sisters, in the constellation Taurus, the Bull. It is a star cluster, and long exposures like this one show dust around the stars reflecting starlight, preferentially the bluish colors. When the Pleiades and the Hyades, another star cluster, rose just before dawn, ancient peoples in some parts of the world knew that the rainy season was about to begin.

Canis Major, the Big Dog. (You can remember that it is near Orion by thinking of it as Orion's dog.)

Back toward the top of the sky, between the Pleiades and Orion's belt, is a group of stars that forms the "V"-shaped head of Taurus. This open cluster is known as the Hyades ("hy´a-deez"). The stars of the Hyades mark the bull's face, while the stars of the Pleiades ride on the bull's shoulder. In a Greek myth, Jupiter turned himself into a bull to carry Europa over the sea to what is now called Europe.

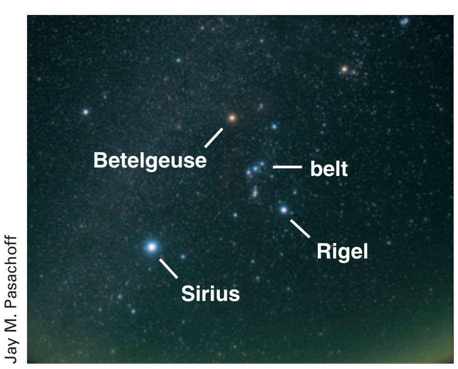


FIGURE 1–12 The constellation Orion, marked by reddish Betelgeuse, bluish Rigel, and a belt of three stars in the middle. The Orion Nebula is the reddish object below the belt. It is M42 on the Winter Sky Map at the end of the book. Sirius, the brightest star in the sky, is to the lower left of Orion in this view.

1.3c The Spring Sky

We can tell that spring is approaching when the Hyades and Orion get closer and closer to the western horizon each evening, and finally are no longer visible shortly after sunset. Now Castor and Pollux, a pair of equally bright stars, are nicely placed for viewing in the western sky. Castor and Pollux were the twins in the Greek pantheon of gods. The constellation is called Gemini, the twins.

On spring evenings, the Big Bear (Ursa Major) is overhead, and anything in the Big Dipper – which is part of the Big Bear – would spill out. Leo, the Lion, is just to the south of the overhead point, called the zenith (follow the Pointers backward). Leo looks like a backward question mark, with the bright star Regulus, the lion's heart, at its base. The rest of Leo, to the east of Regulus, is marked by a bright triangle of stars. Some people visualize a sickle-shaped head and a triangular tail.

If we follow the arc made by the stars in the handle of the Big Dipper, we come to a bright reddish star, Arcturus, another supergiant. It is in the kite-shaped constellation Boötes, the Herdsman.

Sirius sets right after sunset in the spring; however, a prominent but somewhat fainter star, Spica, is rising in the southeast in the constellation Virgo, the Virgin. It is farther along the arc of the Big Dipper through Arcturus. Vega, a star that is between Sirius and Spica in brightness, is rising in the northeast. And the constellation Hercules, with its notable globular cluster M13, is rising in the east in the evening at this time of year.

1.3d The Summer Sky

Summer, of course, is a comfortable time to watch the stars because of the generally warm weather. Spica is over toward the southwest in the evening. A bright reddish star, Antares, is in the constellation Scorpius, the Scorpion, to the south. ("Antares" means "compared with Ares," another name for Mars, because Antares is also reddish.)

Hercules and Cygnus are high overhead, and the star Vega is prominent near the zenith. Cassiopeia is in the northeast. The center of our Galaxy is in the dense part of the Milky Way that we see in the constellation Sagittarius, the Archer, in the south (■ Fig. 1–13).

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■ **FIGURE 1–13** The Milky Way – the band of stars, gas, and dust that marks the plane of our disk-shaped Galaxy – is easily recognized in a dark sky. It is shown here with Halley's Comet (left, middle, with a tail) passing by.

Around August 12 every summer is a wonderful time to observe the sky, because that is when the Perseid meteor shower occurs. (Meteors, or "shooting stars," are not stars at all, as we will discuss in Chapter 8.) In a clear, dark sky, with not much moonlight, one bright meteor a minute may be visible at the peak of the shower. Just lie back and watch the sky in general – don't look in any specific direction. The rate of meteors tends to be substantially higher after midnight than before midnight, since our part of Earth has then turned so that it is plowing through space, crossing through the paths of pebbles and ice chunks that streak through the sky as they heat up. Although the Perseids is the most observed meteor shower, partly because it occurs at a time of warm weather in North America and Europe, many other meteor showers occur during various parts of the year.

The summer is a good time of year for observing a prime example that shows that stars are not necessarily constant in brightness. This "variable star," δ (delta) Cephei, appears in the constellation Cepheus, which is midway between Cassiopeia and Cygnus. δ Cephei varies in brightness with a 5.4-day period. As we will see in Chapters 11 and 16, studies of its variations have been important for allowing us to measure the distances to galaxies. This fact reminds us of the real importance of studying the sky – which is to learn what things are and how they work, and not just where they are. The study of the sky has led us to better understand the Universe, which makes astronomy beautiful and exciting to so many people.

1.4 HOW DO YOU TAKE A TAPE MEASURE TO THE STARS?

It is easy to see the direction to an object in the sky but much harder to find its distance. Astronomers are always seeking new and better ways to measure distances of objects that are too far away to touch. Our direct ability to reach out to astronomical objects is limited to our Solar System. We can send people to the Moon and spacecraft to the other planets. We can even bounce radio waves off the Moon, most of the other planets, and the Sun, and measure how long the radio waves' round trip takes to find out how far they have travelled. The distance (d) travelled by light or by an object is equal to the constant rate of travel (its speed v) multiplied by the time (t) spent travelling ($d = vt$).

If we were carrying on a conversation by radio with someone at the distance of the Moon, there would be pauses of noticeable length after we finished speaking before we heard an answer. This is because radio waves, even at the speed of light, take over a second to travel each way. Astronauts on the Moon had to get used to these pauses when their messages travelled by radio waves to people on Earth, and spacecraft roaming Mars have to be autonomous to travel safely over rocky fields at any reasonable speed.