the best
ASTRONOMICAL
events
THROUGH 2010

CELESTIAL delights

FRANCIS REDDY and GREG WALZ-CHOJNACKI

Celestial Delights

The Best Astronomical Events through 2010

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and
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Cover photo: Curtains of red and green aurora—also known as the Northern Lights—dance above Hatcher Pass in Alaska's Talkeetna Mountains. On October 25, 2001, twisted magnetic fields on the sun suddenly released their energy and sent an enormous bubble of solar material racing toward our planet. The cloud swept past us on October 28, disrupting the Earth's magnetic environment and triggering vivid auroral displays from Alaska to areas as far south as North Carolina. (Photo by Wayne Johnson)

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To my parents, Elizabeth and Francis,
who introduced me to the Cape Cod sky.

—FR

To my mother, whose love has been a
guiding star to all her children.

—GWC

Preface

There is a widespread impression that the scientific appreciation of the universe must be left wholly to those who have had years of formal training or who devote a large part of their free time to science as a hobby. Everyone takes a moment to sky-gaze now and then—admiring the colors of a sunset, noticing the Man in the Moon, or playing connect-the-dots with the Big Dipper—but there is a sense that astronomy is best left to those with expensive equipment and lots of time for observing the heavens.

That's far from the truth. Although the skies under which most of us live are awash with the tawny glow of city lights, they are surprisingly well suited for observing the motions and arrangements of the solar system's brightest members—the sun, moon, and planets. Their ever-changing configurations fascinated and puzzled skywatchers for the first few thousand years of human civilization, a time when the human eye was the primary observing tool. Tracking their wanderings through the sky requires nothing more than good weather and some guidance on when and where to look.

This book is designed both as an introduction to astronomy and as a calendar of upcoming celestial events. Our first aim is to share the simple beauties of the sky as seen by our ancestors. By using the moon and brighter planets as celestial signposts, the tables and charts in this book serve as a guide to every planet that can be seen with the unaided eye. Separate chapters detail upcoming eclipses, introduce the major constellations, describe the best meteor showers, and explore other more challenging, if less predictable, phenomena. Appendix A provides an almanac of easy-to-see astronomical events from 2003 through 2010, all organized by date and time and cross-referenced with diagrams and tables found elsewhere in the book. For convenience, we have also collected some of this information in additional appendices.

Our secondary goal is to explore how we see the sky from the perspective of our spacefaring culture—which has literally touched some of the worlds that humankind has watched, prayed to, and feared for ages. An exciting burst of planetary exploration is currently under way—plans include spacecraft visits to Mercury, Saturn, Mars, and a couple of comets—and with the unprecedented communications ability afforded us by the World Wide Web, the discoveries of such missions have become more quickly and completely available than ever before. We also have attempted to share something of the excitement felt and the challenges faced by those who continue to delve into the long-observed phenomena that this book describes.

Observant readers will notice that in some diagrams the labels for east and west are reversed from their expected placement on a map of the Earth. Terrestrial maps plot the world as if we are looking down on the Earth from above, but in charting the sky we're looking in the opposite direction. The east-west reversal occurs in our illustrations of the paths of Venus across the sun (chapter 3), the path of the moon through the Earth's shadow in lunar eclipses (chapter 4), and the star charts (chapter 7).

It's our hope that you will come to enjoy the beauty of the heavens that is everyone's heritage, and we encourage you to participate in this centuries-old delight. All we ask is that you occasionally look up and wonder, "What is that bright star?"

This book would not be possible without the assistance of many others. Our own eclipse maps are based on data made available by Fred (Mr. Eclipse) Espenak of NASA's Goddard Space Flight Center. Our friend Robert Miller graciously created custom software for us, and for this new edition he also offered to improve on our maps illustrating the Mars, Jupiter, and Saturn retrograde loops. The wonderful photographs of António Cidadão, Robert Miller, and Bill Sterne enhance the book; we thank them for their help. Geoff Chester, Doug Caswell, Bill Cooke, Audouin Dollfus, Michael Rappenglück, David Pankenier, Peter Schultz, Ewen Whitaker, and Donald Yeomans were all generous with their time and knowledge. Judith Heymann translated the writings of eighteenth-century astronomer J. J. Lalande for us. Of course, the authors alone are responsible for any errors in the text and illustrations.

Judy Young, director of The Sunwheel Project at the University of Massachusetts, gave us encouragement from an unexpected quarter. We thank Ken Crossen of TechView Corp. in Carrboro, North Carolina, for our long and productive relationship with the technical drawing program TechEdit. We also thank Paul Wessel and Walter Smith, University of Hawaii, for the Generic Mapping Tools (GMT) software package and Alan Cogbill of Los Alamos National Laboratory for his continued ports of GMT. Other software we found helpful includes Dance of the Planets 2.71, from ARC Science Simulation Software; Project Pluto's Guide 7.0; and Shinobu Takesako's EmapWin 1.21 eclipse simulator. NASA's ADS Abstract Service, the Jet Propulsion Laboratory's Horizons ephemeris computation service, and the supportive staff of the Newberry County Library in Newberry, South Carolina, all proved immensely helpful. And we gratefully acknowledge the Rector and Visitors of the University of Virginia for permission to use excerpts from their electronic text collection.

Last but not least, we are grateful to our copyeditor, Kristi Hein, and the folks at Celestial Arts for their support in creating this new edition: Joann Deck, publisher; our editors, Brie Mazurek and Justin Wells; and designers Toni Tajima and Jeff Brandenburg.

Contents

1 The Meaning of the Sky

The movements of the heavenly bodies are an admirable thing, well known and manifest to all peoples. There are no people, no matter how barbaric and primitive, that do not raise up their eyes, take note, and observe with some care and admiration the continuous and uniform course of the heavenly bodies.

—Bernabé Cobo, *History of the New World,* 1653

The heavens were once seen as the exclusive domain of supernatural beings, but over the past two generations we mortals have moved in. We have created machines that enable astronauts, albeit briefly, to take up residence in orbit around our world. Hundreds of miles above us, construction proceeds on the third major space station, a growing research laboratory that is sometimes plainly visible to the unaided eye. The space near Earth has become a valued resource: the "high ground" for global communications, military reconnaissance, and the scientific study of the Earth itself. From this increasingly crowded realm we can view the sun, the planets, and the wider universe unfiltered by Earth's atmosphere and unaffected by weather. Beyond it lies the moon, where footprints still attest to brief human visits, and the planets, asteroids, and comets that to date have been explored only by our mechanical surrogates. Farther still, and for now beyond our immediate technological grasp, shine the nearest stars and the vast interstellar frontier of the Milky Way galaxy. With vision extended by telescopes in low earth orbit and on mountaintop observatories, astronomers now catalogue the alien worlds that circle some of the nearest stars. We have taken millennia to unravel the basic structure of our own planetary system. Now we begin the task of comparing it to others, probing for clues that will tell us, among other things, whether our home planet is as unique as we suppose.

As citizens of the twenty-first century, nearly all of us are somewhat familiar with the basic layout of our solar system and the physical laws that govern the universe. But knowing that the planets circle the sun is one thing—recognizing how that movement expresses itself in the sky above us can be quite another. Our ancient forebears may not have understood why the sky worked the way it did, but they certainly knew it better. We have the advantage, though, because the basic motions that beguiled and bewildered our ancestors remain on display. The enjoyment of seeing becomes the deeper pleasure of understanding what we see.

Skywatching and Skywatchers

The single most striking observation of the sky is one so obvious we might at first overlook it entirely. It is that of the daily motion of the sun, moon, planets, and stars as they appear to rise in the eastern sky and set in the west. Extended, methodical observation reveals other motions superimposed on this basic east-to-west movement.

The sun has always been recognized as vitally important and was viewed by many ancient cultures as the greatest deity. Even the most primitive peoples appreciated the life-giving powers of what we now regard as our star. The reverence shown to the sun was reflected by the astronomical functions adopted by ancient priests. The diurnal cycle is even more basic than the motion of the sun, yet even the most casual observers are aware that the length of our days and nights varies as the year passes. The first astronomers noticed that these variations were linked to annual variations in the sun's position throughout the year. The changing apparent position of the rising or setting sun stops and reverses course at two extremes, called solstices, that occur in summer (near June 21) and winter (near December 21). (Note: Unless specified otherwise, all references to seasons and corresponding months apply to the northern hemisphere; they are, of course, reversed in the southern hemisphere.) The longest day occurs at the summer solstice, the date on which the sun rises and sets at its northernmost point and makes its highest arc through the sky. The days then slowly grow shorter until the sun reaches its winter solstice position, when it rises and sets at its southernmost point and traces its lowest arc through the sky. The daylight hours then gradually increase again until they reach another maximum at the following summer solstice. As the sun oscillates from one solstice (literally "standing sun") position to the next, it passes through the point midway between them twice each year. This point is called the equinox ("equal night"), the date on which the hours of daylight equal the hours of darkness. The sun's spring, or vernal, passing of the equinox occurs about March 21; it returns to this point in autumn around September 23. The appearance of the sun at a solstice or an equinox defines the formal start of that season. With this fundamental knowledge, ancient sunwatchers could track the march of the seasons and guide essential activities, such as planting and harvesting, and the festivals and other cultural activities that became associated with them.

We can track this motion easily at sunset (or, for early risers, sunrise). The sun's apparent motion is fastest in spring and fall so the changes are most easily seen then, but the starting date doesn't really matter, as the motion itself is continuous. A few observations of the setting sun's place on the western horizon, spaced over a few weeks, reveals the trend. The direction of sunset creeps along the horizon: southward from July to December, northward the other half of the year. The farthest positions north and south correspond to the summer and winter solstices, respectively, and the point midway between them marks the sun's position at the equinox.

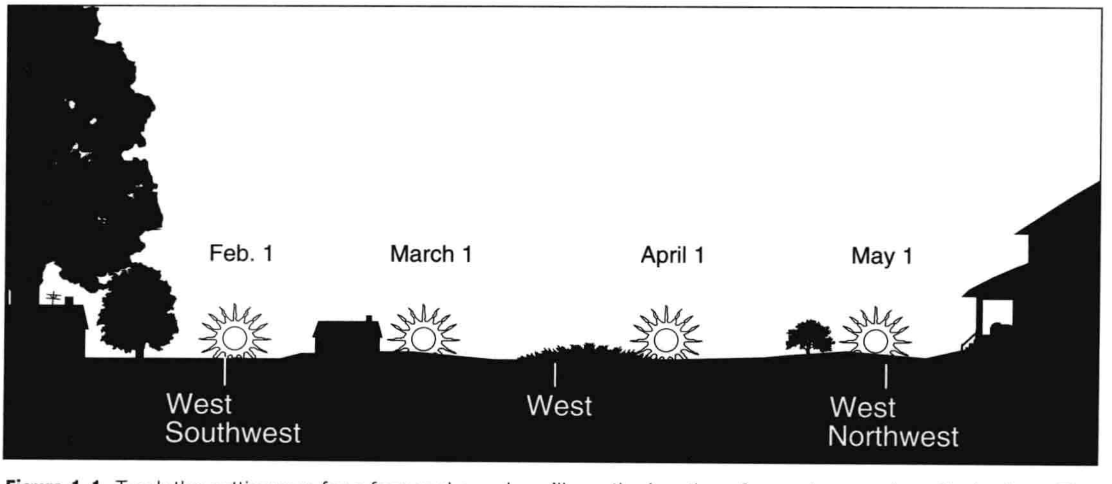

Figure 1-1. Track the setting sun for a few weeks and you'll see the location of sunset move along the horizon. The sun slides northward from late December to late June, then reverses direction and heads south for the rest of the year. This diagram shows how the sunset point travels between February and May for observers in middle northern latitudes.

Timeworn structures—from England's Stonehenge, to the passage tombs of Ireland, to the pyramids of Mexico—incorporate clear knowledge of the sun's movements. These were sacred places consecrated by the astronomical alignments that connected them to the seasonal signposts in the sky.

Even today, many of our holidays and holy days reflect the seasons. The dates of Easter and Passover, for example, are tied explicitly to the spring equinox. Scholars tell us Christ was born in the spring, yet Christmas falls near the winter solstice—that hopeful date after which the days begin to lengthen, promising greater warmth and sunshine to come. The date of the winter solstice was set at December 25 on the calendar reformed by Julius Caesar in 46 B.C. This was also the date for the festival of Sol Invictus (the Unconquerable Sun), a sun cult introduced to Rome in the first century A.D. that became the state religion in A.D. 274. The sun was seen as the divine source of light and order for the universe; the emperor, as the font of Roman civilization, fulfilled a complementary role on earth. Sol Invictus was also associated with Mithras, central god of a mysterious cult that was especially popular among soldiers. There is no date recorded for Christ's birth, but December 25 was selected by the early Church in part for the ease with which it meshed with long-established customs. The Roman world was already celebrating on that date, and the underlying symbolism of the Unconquerable Sun could be suffused with a new Christian meaning.

It's worth noting that the sun's solstice and equinox positions could just as easily be reckoned as marking the height of each season, rather than its start, and there are cultural traditions that acknowledge this. The European holiday of Midsummer in fact falls near the summer solstice. Many observances occur midway between solstice and equinox, an echo of the ancient importance of these midseason dates that reverberates even today. February opens with Candlemas and Groundhog Day, derived from the Celtic festival of Imbolc. May brings us both the bonfire festival of Beltane and its descendant May Day, as well as the witch-vigil of Walpurgisnacht in Bavaria. The Irish feast of Lammas and the Celtic festival of Lughnasa occur at the start of August. The end of October sees the Celtic new year's festival of Samhain and its descendant Halloween, as well as All Saint's Day and the Mexican celebration of Dia de los Muertos. These examples come from Euro-American culture, but independent traditions also acknowledge the dual approach. What ties them together is recognition of the sun's continued journey as vital to the maintenance of the natural order and as something in which humankind must participate, either by encouraging the sun—like spectators cheering on a marathon runner—as it treks through times of special risk, or by celebrating the sun's victorious arrival at its annual stations.

Seen from the tropics, the sun attains another position of importance easily overlooked by those located elsewhere on the globe. Within the band of latitudes bounded by the Tropic of Cancer and the Tropic of Capricorn, the sun passes through the zenith—the point directly overhead—at noon

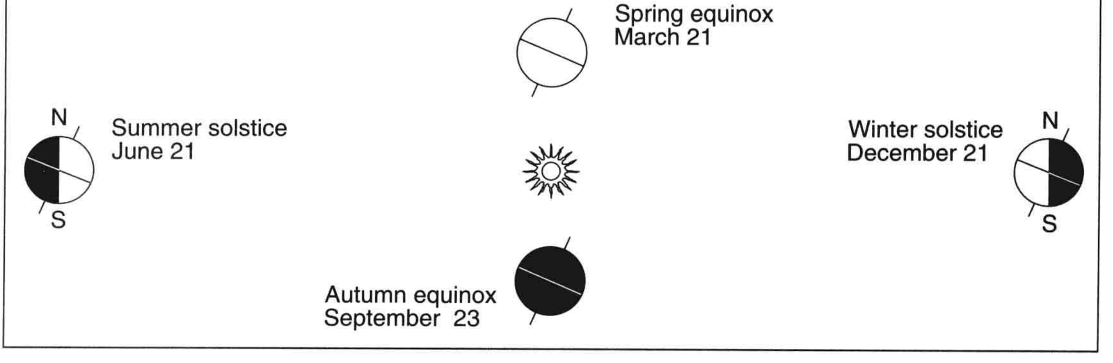

Figure 1-2. Earth's tilt with respect to its orbit (23.45°) creates the seasons. On June 21, the start of northern summer, the northern hemisphere angles into the sun most directly and the sun arcs highest in the sky, rising and setting at its northernmost points. Six months later, on December 21, northern observers see the sun make its lowest track through the sky, rising and setting at its southernmost points.

on certain dates. Each zenith passage occurs on well-defined dates for any particular location. Historical and archaeological evidence from Mexico to South America shows that many peoples observed and celebrated one of the sun's zenith passages as the start of the new year.

Today, the moon, a lesser light, is what first draws our attention to the night sky. Early calendars were based on the motions of the moon, mainly because its cycle is shorter, more obvious, and therefore more accessible than that of the sun. The priest-astronomers of ancient Mesopotamia and Greece determined the start of a new lunar month by watching for the first appearance of the moon's slender crescent in the evening twilight. In Egypt the month began with the disappearance of the waning crescent moon from the predawn sky. The system of marking time by the moon doubtless goes back millennia. Suggestions of some sort of lunar time-reckoning can be found among the 17,500-year-old cave paintings of Lascaux in France, and Paleolithic bone artifacts found throughout Europe bear carved tally marks that may represent even older lunar scorecards. But the moon's convenience as a short-term timekeeper is offset by the unpleasant mathematical problem of reconciling its cycle with that of the sun and the seasons. The solar year cannot be reduced to a whole number of lunar months. Ancient calendar-keepers thus needed some way to recalibrate the two cycles if a lunar calendar was to stay in step with the seasons. They did this either mathematically, by inserting days at culturally acceptable times, or empirically, by observing the sun and stars and synchronizing the cycles anew each year.

The Lure of the Planets

Long before skywatching became part of a formalized time-keeping system, ancient observers must have realized that the sun and moon weren't the only objects moving through the heavens. Unlike most moderns, the diligent starwatchers of ancient times also noticed five peculiar "stars" that wander independently among the constellations, each moving at a different speed. Like the sun and moon, they follow roughly the same path through the sky and usually move eastward relative to the stars. But now and then these wanderers slow down, stop, loop west for a time, stop again, and then resume their eastward journey. Today we know these objects as the planets, a word that derives from the literal Greek description of their peculiar astronomical behavior (*planetes,* "wanderers"). Ancient astronomers knew of only five planets: Mercury, Venus, Mars, Jupiter, and Saturn. Although under ideal conditions Uranus can be seen without some sort of optical aid, evidently it didn't catch the attention of early skywatchers; like the still fainter Neptune and Pluto, Uranus remained undiscovered until long after the invention of the telescope.

In their wanderings through the sky, one or more planets may appear to pass close to another, forming captivating and sometimes striking arrangements. The diagrams in this book illustrate many of these through 2010. The greater the number of planets involved, the greater the time between successive displays, so gatherings of all five visible planets are the least common. These events were characteristically regarded as messages from the heavens—blessings or warnings for the state and its ruler. Nowhere was this more true than in early China. There the planets were viewed as the ministers of Shangdi, the Lord on High, and their gatherings were seen as a congress of sky spirits called only when the celestial realm was deliberating major changes in policy. The emperor was the chief shaman, his role on earth a heavenly appointment, and early in the second millennium B.C. observation of the heavens became his greatest responsibility. It was the emperor's divine obligation to ensure that all human activity conformed as closely as possible to Shangdi's desires. This precept, which became more formalized over time and was first explicitly stated in early writings of the Zhou Dynasty (1046–256 B.C.), is referred to as the "Mandate of Heaven" *(tian ming)*. Chinese rulers believed that the will of Shangdi could be determined by detailed skywatching, with particular importance given to rare and unusual happenings. Astronomical or meteorological events could indicate displeasure with the way affairs on earth were being conducted.

David Pankenier of Lehigh University has shown that tight five-planet clusters are closely associated with dynastic transitions and with the development of the Mandate of Heaven in ancient China. A deliberation of Shangdi's ministers suggested that the current ruler had fallen out of favor and sent a signal throughout the land to would-be political challengers. Official records credit close planetary groupings as heralds of the Zhou, Han, and Song dynasties; astronomical and historical evidence suggest that the Shang and Xia dynasties also began with tight conjunctions. Driven by their heavenly mandate, Chinese rulers created the world's longest continuous record of astronomical observation, one that remains an important source of historical data today.

Belief in planet power is persistent. Jupiter and Saturn appear close together about every twenty years, infrequently enough that their conjunctions were regarded as particularly ominous. In 1348, King Philip VI of France asked physicians at the University of Paris to report on the origin of the terrible plague then sweeping across Europe. Their *Paris Consilium* proposed that the Black Death was in part the result of the conjunction of Jupiter, Saturn, and Mars in Aquarius three years earlier. Most of the Jupiter-Saturn pairings between 1345 and 1538 occurred within astrological signs connected with water. Broadsheets and pamphlets circulated throughout Europe as each conjunction approached, their authors warning of poor harvests and terrible weather culminating in horrific, even biblical, floods.

There is a long and singularly unsuccessful record of apocalyptic predictions associated with planetary groupings, and the phenomenon is still with us. In the past few decades, several planetary gatherings made headlines as mystics and doomsayers foretold of approaching disaster. Mixing such well-worn topics as Nostradamus, pyramid mysteries, and lost continents, as well as a pinch of science here and there, with each event doomsayers concocted a recipe of coming chaos, economic ruin, and geological upheaval. As of this writing, our most recent appointment with doom by planetary alignment was one scheduled for May 2000; just as with similar gatherings in 1962 and 1982, nothing extraordinary happened.

The earth-shattering interpretation of planetary conjunctions reaches back at least to the writings of Berosus, a Babylonian astrologer who brought the astrology and mythology of his homeland to the Greek world around 300 B.C. As transmitted to us through much later writings, he believed that the world is alternately destroyed and recreated—first by fire, then by water—and that the planets hold the key to the timetable. Seneca, in his *Natural History,* summed it up this way:

> For all earthly things will burn, he contends, when all the planets which now maintain different orbits come together in the sign of Cancer and are so arranged in the same path that a straight line can pass through the spheres of all of them. The deluge will occur when the same group of planets meets in the sign of Capricorn.

It's remarkable to us that anyone would look upon a gathering of planets as a harbinger of anything, good or ill. Yet we can sympathize with

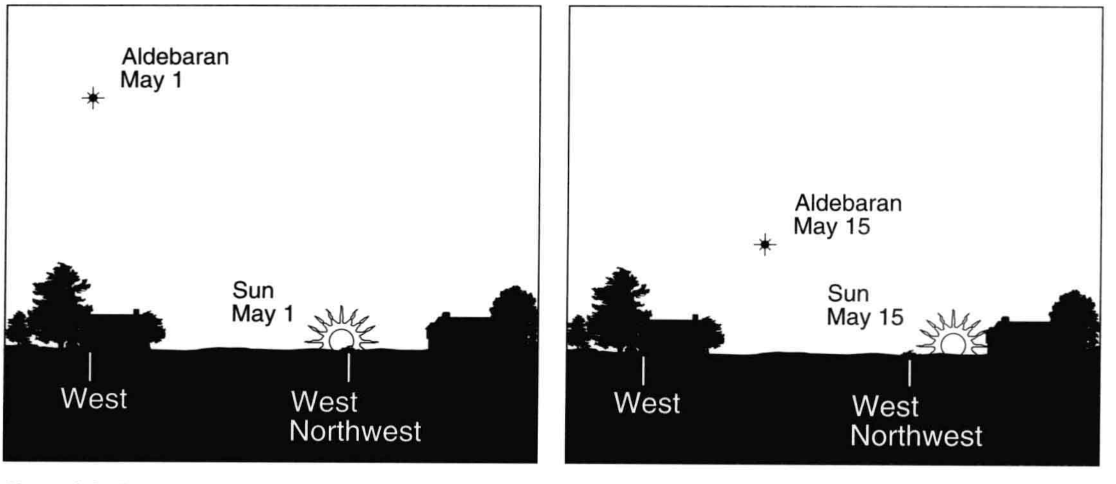

Figure 1-3. The sun appears to drift eastward among the stars, making one complete circuit through the sky each year. Throughout May, for example, the setting sun creeps ever closer to the bright star Aldebaran.

both the impulse to discern order in the universe and the yearning to achieve some of that predictability in the often tumultuous human experience. So perhaps it was natural for our ancestors to attempt to glimpse some guidance in celestial rhythms.

Astronomy and astrology began to part company in the seventeenth century. A continuing thread of late-twentieth-century science is the recognition that other bodies in the solar system truly can affect life on Earth—by impacts or through the long-distance interactions of gravity—in ways explainable by physical laws determined from observation and mathematics. Ancient observers, whose motivations were very different from those of modern scientists, nevertheless recorded data that provide important insights in many astronomical investigations today. Their interpretations, however, have been left behind in the rise of science.

Or so astronomers would like to think. A 1998 Harris poll found that 37 percent of adult Americans professed a belief in astrology; the figure rose to 41 percent in 2000. Gallup polls over the last decade show somewhat lower numbers but a similar trend of an increase of a few percentage points, with 28 percent of American adults agreeing in 2001 that "the position of the stars and planets can affect people's lives." Unfortunately, these surveys provide no measure of the depth of astrological belief.

In 1999, Michael De Robertis and Paul Delaney attempted to fill this void by surveying first-year students at York University in North York, Ontario, about their attitudes toward astrology and astronomy. Over 51 percent of both science majors and other students indicated that they subscribed at least somewhat to astrological principles. Still, only about 15 percent of both groups indicated that they made "many conscious decisions" based on horoscopes. The authors conclude, as have others, that the widening acceptance of astrology is part of a larger problem with the development of critical thinking skills in schools. They also recognize that the need to believe plays an important role in forming and maintaining the very attitudes such surveys measure. And there's the difficulty, for it means that changes to the curriculum that address only science literacy and critical-thinking skills cannot resolve the problem.

Star Light, Star Bright

We see the travels of the sun, moon, and planets against the backdrop of the starry sky, so it should not be surprising that some of the world's oldest surviving literature contains references to the same conspicuous objects and patterns we see there today. Homer's *Iliad,* the epic Greek poem about the Trojan War, can be traced back to at least 700 B.C. In Book 18, Hephaestus fashions and decorates the shield of Achilles with emblems of our winter sky:

> And first Hephaestus makes a great and
> massive shield . . .
> There he made the earth and there the sky
> and the sea
> and the inexhaustible blazing sun and the
> moon rounding full
> and there the constellations, all that crown
> the heavens,
> the Pleiades and the Hyades, Orion in all
> his power too
> and the Great Bear that mankind calls the
> Wagon:
> she wheels on her axis always fixed,
> watching the Hunter,
> and she alone is denied a plunge in the
> Ocean's baths.

The inspirations for these adornments are still in our night sky: the familiar stars of Orion the Hunter, the bright clusters of the Pleiades and the Hyades in Taurus and Ursa Major (the Great Bear, whose brightest stars form the Big Dipper). Homer's observation that the Great Bear "wheels on her axis always fixed" and is "denied a plunge in the Ocean's baths," is a clear reference to the fact that these stars circled about the northern sky and never set below the horizon—a fact of the middle northern latitudes that is as true for us today as it was for the ancient Greeks.

A few generations later, the Greek poet Hesiod wrote *Works and Days.* A kind of *Farmer's Almanac* from 650 B.C., *Works and Days* is a poem about peasant life that weaves an astro-agricultural calendar into a framework of mythology and the virtues of labor. The key dates for the calendar were determined by the rising and setting of certain stars just before sunrise or just after sunset.

When the Pleiades, daughters of Atlas,
are rising,
begin the harvest, the plowing when they set.
Forty nights and days they are hidden
and appear again as the year moves round,
when first you sharpen your sickle.

The Pleiades rose just before the sun in May, heralding the proper time to begin the harvest of what we call winter wheat. In November these stars slipped beneath the western horizon as the sun rose, the signal for farmers to prepare their fields and sow their grain. Five months later the stars were lost in the sun's glare, but they returned the following May, just preceding the dawn and commencing another yearly cycle.

Hesiod relates other aspects of everyday life to the schedules of the stars. The first appearance of Arcturus in the evening, together with certain animal signs, announces the coming of spring. Sirius rising just before dawn is a sign of midsummer, when "goats are plumpest and wine sweetest," while the morning rising of Arcturus signals the best time for picking grapes.

We can watch the motion of the sun among the stars Hesiod describes by locating a bright star in the south or west as evening twilight fades. A good example is Aldebaran, the brightest star in the winter constellation of Taurus the Bull, gleaming low in the western sky in late spring. If we check on the star after a week or two, we'll see that it has drifted slowly westward from its original position, gradually appearing lower in the sky. Continued observation reveals that it moves ever closer to the sun, sliding westward until it is eventually lost in the glow of evening twilight. This westward drift of the stars can be interpreted in another way: as an eastward drift of the sun through the starry background. Figure 1-4 illustrates how the movement of the Earth along its yearly orbit places the sun closer to our line of sight with Aldebaran. Eventually both sun and star lie roughly along the same line of sight and the star is lost in the sun's brilliant glare. When Aldebaran emerges from twilight on the opposite side of the sun, it will be visible just before sunrise.

As Hesiod's descriptions of the Pleiades bear out, ancient observers had noticed that the sun makes a complete circuit through the stars once each year. The path traveled by the sun through the stars became known as the ecliptic; the twelve constellations along the ecliptic gave rise to the famous astrological "signs of the zodiac."

While there can be no question that the sky played an important role in the great cultures of the past, we take for granted the vestiges of its significance remaining in today's societies. Our week has seven days—the time it takes the moon to go through one-fourth of its phases. Seven is also the number of seemingly independent lights known to wander through the sky—the sun, moon, and five planets—and we have given their names to the days of the week. Sunday derives from the Roman *dies Solis*, "day of the sun"; Monday comes from *dies Lunae*, "day of the moon"; Saturday is Saturn's Day. The remaining celestial connections come to us obscured by the names of figures from the Nordic pantheon. For now, it's enough to realize that Tuesday is named for Mars, Wednesday for Mercury, Thursday for Jupiter, and Friday for Venus. We'll have more to say about the mythology associated with each planet later on.

The objects in the sky have one more obvious attribute that we have not yet discussed: brightness. The maps and diagrams throughout this book indicate the brightness of the stars and planets by the size of the dots that represent them. This follows a numerical scale of brightness that owes its essential form to the Greek astronomer Hipparchus. Chief among his contributions is a catalog of stars visible from his home, with notes on their position and brightness (129 B.C.). His notation was a model of clarity: the brightest stars were of the first magnitude, the next brightest were second magnitude, and so on, down to sixth magnitude, into which he grouped the faintest stars visible to the unaided eye. Although the brightness scheme makes sense when described this way, those new to astronomy are often puzzled to learn that a star with a higher magnitude number is actually fainter than one with a lower value. It helps to think of the word "magnitude" as meaning "class": "first-class" (first magnitude) stars are brighter than "second-class" (second magnitude) stars, and so on.

When the brightness scale was later precisely codified, it became clear that some of the stars Hipparchus had classified as first magnitude were in fact considerably brighter than others. Astronomers therefore found it necessary to extend the magnitude scale down to zero and lower. Sirius, the brightest star, has a magnitude

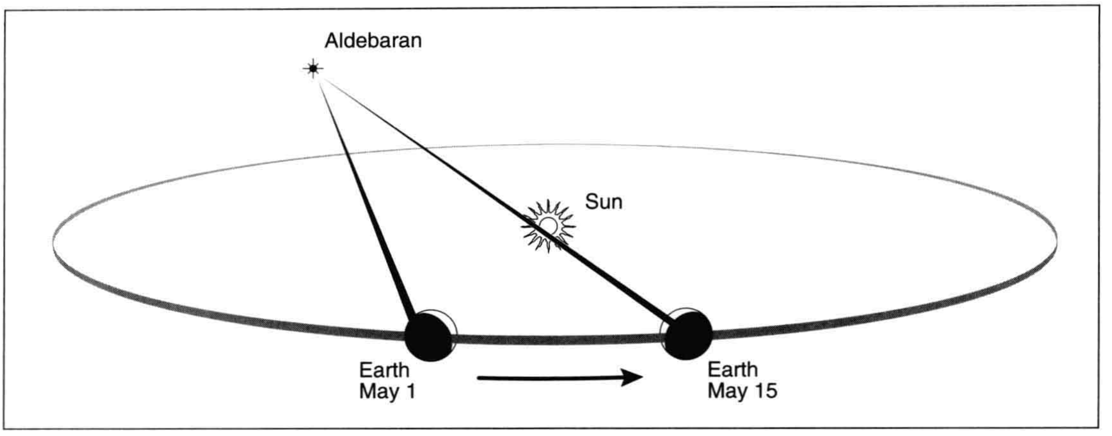

Figure 1-4. The sun's apparent eastward drift among the stars reflects the movement of Earth along its orbit. Once each year, for instance, Earth's motion in space brings the sun close to our line of sight with distant Aldebaran.

of –1.4. And when we apply this scale to objects within the solar system, the numbers look peculiar indeed. Mars can attain a brightness of –2.9, Venus at its brightest is magnitude –4.7, the full moon ranks as –12.7, and the sun naturally tops the scale at –26.8.

Loss of the Night

For about two-thirds of the world's population, the night sky isn't what it used to be—namely, darker—since, out of economic necessity, we moderns spend much of our lives deep within the artificial skyglow of major cities. This was part of our motivation in writing *Celestial Delights:* we chose to examine astronomy using the brightest objects in the sky because they are still available to everyone, even most city-dwellers.

Thanks to the dramatic increase in skyglow over the past decade, it's a challenge to view even Mars and Saturn when they are not at their brightest. Anyone who has taken an evening flight from a large city airport has seen the lattice of orange and green streetlights and the gleam of decorative lighting on buildings far below. Our artificial constellations far outshine the stars. The fact that we can see these lights from high overhead underscores the problem. Most streetlights are intended to illuminate the ground directly below, but a considerable amount of their light spills sideways and upward. Light going where it is neither useful nor wanted creates the washed-out sky of the city and the suburbs—a phenomenon that astronomers refer to as "light pollution."

Light pollution is only beginning to be recognized as a serious environmental problem. Setting aside the aesthetic, ecological, and astronomical concerns, consider the problem from a purely economic perspective. A portion of the energy required to operate a streetlight is wasted if part of that light is thrown directly into the sky. Greater energy demand requires more electrical power and, in turn, the burning of more oil and coal to generate it. Energy use translates to energy cost—wasted light burns money. In 2001 the International Dark Sky Association, a group that supports legislative efforts to limit light pollution, estimated the cost of wasted light at $1.5 billion per year in the United States alone.

The extent of the problem can be seen from the orbital perch of satellites. Pierantonio Cinzano and Fabio Falchi of the University of Padova in Italy and Chris Elvidge of the U.S. National Oceanic and Atmospheric Administration have produced the first world atlas of artificial night sky brightness, using images from the Defense Meteorological Satellite Program. The atlas reveals that 99 percent of the U.S. population and two-thirds of the world's population live in areas where the night sky can be considered polluted. For about half of the world's population, including all but a few percent of U.S. residents, artificial light pollution makes the sky brighter on a clear moonless night than the sky at the darkest observatory sites when illuminated by a first quarter moon. For two-thirds of the United States and one-fifth of the world population, the faint band of the Milky Way is lost in the skyglow. More troubling still, the night sky is now so bright for one-sixth of the world's people that their eyes cannot complete the dark adaptation required for full night vision. "Mankind is proceeding to envelop itself in a luminous fog," the study's authors conclude.

Californians in the Los Angeles area experienced their darkest sky in decades with the power outages that followed the 1994 Northridge earthquake. The city's Griffith Observatory logged hundreds of calls from people wondering why the stars were so bright and concerned over the nature of the unusual "silver cloud" (the Milky Way).

Our loss of the night denies us a wellspring of human inspiration. It disconnects us from a natural resource that binds cultures of the past to cultures of the present. It reinforces the thoroughly modern illusion that we are somehow apart from nature.

There is cause for encouragement. The sky-brightness atlas revealed Venice as the only city in Italy with a population greater than 250,000 from which observers in the city's center could see the Milky Way's subtle glow. The reason? Venice strives for a romantic image and preserves its ambiance by using unobtrusive outdoor lighting, providing an example in which an emphasis on quality, rather than quantity, meets public needs without excising the stars. Solutions that work do exist and cities all over the world are beginning to address the issue. In February 2002, the Czech Republic became the first country to enact a national light-pollution law. It obligates citizens to "take measures to prevent the occurrence of light pollution," which it defines as "every form of illumination by artificial light which is dispersed outside the areas it is dedicated to, particularly if directed above the level of the horizon."

All ancient peoples made some sort of connection with the sky. To them, it was a place where powerful beings worked and played—at times helping, at others hindering humanity. To us today, it is important as a new frontier, a place where a few of us now live and work and which all our minds can explore. We'll conclude this chapter by amending the epigram we began with: There are no people, no matter how sophisticated and technological, who do not profit from observing the night sky.