Chapter 1

Seeing the Light: The Art and Science of Astronomy

In This Chapter

- Understanding the observational nature of astronomy
- Focusing on astronomy's language of light
- Weighing in on gravity
- Recognizing the movements of objects in space

Step outside on a clear night and look at the sky. If you're a city dweller or live in a cramped suburb, you see dozens, maybe hundreds, of twinkling stars. Depending on the time of the month, you may also see a full moon and up to five of the nine planets that revolve around the sun.

A shooting star or "meteor" may appear overhead. What you actually see is the flash of light from a tiny piece of comet dust streaking through the upper atmosphere.

Another pinpoint of light moves slowly and steadily across the sky. Is it a space satellite, such as the Hubble Space Telescope, or just a high-altitude airliner? If you have a pair of binoculars, you may be able to see the difference. Most airliners have running lights, and their shapes may be perceptible.

If you live out in the country — on the seashore away from resorts and developments, on the plains, or in the mountains far from any floodlit ski slope — you can see thousands of stars. The Milky Way appears as a beautiful pearly swath across the heavens. What you're seeing is the cumulative glow from millions of faint stars, individually indistinguishable with the naked eye. At a great observation place, such as Cerro Tololo in the Chilean Andes, you can see even more stars. They hang like brilliant lamps in a coal black sky, often not even twinkling, like in Van Gogh's *Starry Night* painting.

When you look at the sky, you practice astronomy — you observe the universe that surrounds you and try to make sense of what you see. For thousands of years, everything people knew about the heavens they deduced by simply observing the sky. Almost everything that astronomy deals with

- You see from a distance
- You discover by studying the light that comes to you from objects in space
- Moves through space under the influence of gravity

This chapter introduces you to these concepts (and more).

Astronomy: The Science of Observation

Astronomy is the study of the sky, the science of cosmic objects and celestial happenings, and the investigation of the nature of the universe you live in. Professional astronomers carry out the business of astronomy by observing with telescopes that capture visible light from the stars or by tuning in to radio waves that come from space. They use backyard telescopes, huge observatory instruments, and satellites that orbit Earth collecting forms of light (such as ultraviolet radiation) that the atmosphere blocks from reaching the ground. They send telescopes up in sounding rockets (equipped with instruments for making high-altitude scientific observations) and on unmanned balloons. And they send some instruments into the solar system aboard deep space probes.

Professional astronomers study the sun and the solar system, the Milky Way, and the universe beyond. They teach in universities, design satellites in government labs, and operate planetariums. They also write books (like me, your loyal *For Dummies* hero). Most have completed years of schooling to hold PhDs. So many of them study complex physics or work with automated, robotic telescopes that they have moved far beyond the night sky recognizable to our eyes. They may not have ever studied the *constellations* (groups of stars, such as Ursa Major and the Great Bear, named by ancient stargazers) that amateur or hobbyist astronomers first discover. (You may already be familiar with the Big Dipper, an *asterism* in Ursa Major. An asterism is a named star pattern outside of the 88 recognized constellations. Figure 1-1 shows the Big Dipper in the night sky.)

In addition to the more than 13,000 professional astronomers worldwide, thousands of amateur astronomers enjoy studying the skies, including more than 300,000 in the United States alone. Amateur astronomers usually know the constellations and use them as guideposts when exploring the sky by eye, with binoculars, and with telescopes. Many amateurs also make useful scientific contributions. They monitor the changing brightnesses of variable stars;

discover asteroids, comets, and exploding stars; crisscross the earth to catch the shadows cast as asteroids pass in front of bright stars (thereby helping astronomers map the asteroids' shapes); and join the search for planets orbiting stars beyond the sun.

Figure 1-1: The Big Dipper, found in Ursa Major, is an asterism.

In the rest of Part I, I provide you with information on how to observe the skies effectively and enjoyably.

Understanding What You See: The Language of Light

Light brings us information about the planets, moons, and comets in our solar system; the stars, star clusters, and nebulae in our galaxy; and the objects beyond.

In ancient times, folks didn't think about the physics and chemistry of the stars; they absorbed and passed down folk tales and myths: the Great Bear, the Demon star, the Man in the Moon, the dragon eating the sun during a solar eclipse, and more. The tales varied from culture to culture. But many people did discover the patterns of the stars. In Polynesia, skilled navigators rowed across hundreds of miles of open ocean with no landmarks in view and no compass. They sailed by the stars, the sun, and their knowledge of prevailing winds and currents.

EYES ON THE SKIES

Gazing at the light from a star, the ancients noted its brightness, position in the sky, and color. This information helps people distinguish one sky object from another, and the ancients (and now people today) got to know them like old friends. Some basics of recognizing and describing what you see in the sky are

- Distinguishing stars from planets
- Identifying constellations, individual stars, and other sky objects by name
- Observing brightness (given as magnitudes)
- Understanding the concept of a light-year
- Charting sky position (measured in special units called *RA* and *Dec*)

They wondered as they wandered: Planets versus stars

The term planet comes from the ancient Greek word *planetes,* meaning wanderer. The Greeks (and other ancient people) noticed that five spots of light moved across the pattern of stars in the sky. Some moved steadily ahead; others occasionally looped back on their own paths. Nobody knew why. And these spots of light didn't twinkle like the stars did — no one understood that difference either. Every culture had a name for those five spots of light, what we now call planets. Their English names are Mercury, Venus, Mars, Jupiter, and Saturn. These celestial bodies aren't wandering through the stars; they orbit around the sun, our solar system's central star.

Today, astronomers know that planets can be smaller or bigger than Earth, but they all are much smaller than the sun. The planets in our solar system are all so close to Earth that they have perceptible disks — at least when viewed through a telescope — so we can see their shapes and sizes. The stars are so far away from Earth that even if you view them through a powerful telescope, they show up only as points of light. (For more about the planets in the solar system, flip to Part II.)

If you see a Great Bear, start worrying: Naming stars and constellations

I used to tell planetarium audiences who craned their necks to look at stars projected above them, "If you can't see a Great Bear up there, don't worry. Maybe those who *do* see a Great Bear should worry."

Ancient astronomers divided the sky into imaginary figures, such as Ursa Major (Latin for Great Bear); Cygnus, the Swan; Andromeda, the Chained Lady; and Perseus, the Hero. The ancients identified each figure with a pattern of stars. The truth is, to most people, Andromeda doesn't look much like a chained lady at all, or anything else for that matter (see Figure 1-2).

Today, astronomers have divided the sky into 88 constellations, which contain all the stars that you can see. The International Astronomical Union, which governs the science, set boundaries for the constellations so astronomers can agree on which star is in which constellation. Previously, sky maps drawn by different astronomers often disagreed. Now when you read that the Tarantula Nebula is in Dorado (see Chapter 12), you know that to see this nebula, you must seek it in the Southern Hemisphere constellation Dorado, the Goldfish.

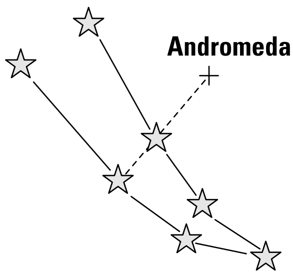


Figure 1-2: Andromeda is also known as the Chained Lady.

The largest constellation is Hydra, the Water Snake. The smallest is Crux, the Cross, which most people call the "Southern Cross." You can see a Northern Cross, too, but you can't find it in a list of constellations; it's an *asterism* (a named star pattern) within Cygnus, the Swan. Although astronomers generally agree on the names of the constellations, they don't have a consensus on what each name means. For example, some astronomers call Dorado the Swordfish, but I'd like to spike that name. One constellation, Serpens, the Serpent, is broken into two sections, which aren't connected. The two sections, located on either side of Ophiuchus, the Serpent Bearer, are Serpens Caput (the Serpent's Head) and Serpens Cauda (the Serpent's Tail).

The individual stars in a constellation often have no relation to each other except for their proximity in the sky as visible from Earth. In space, the stars that make up a constellation may be completely unrelated to one another, with some located relatively near to Earth and others located at much greater distances in space. But they make a simple pattern for observers on Earth to enjoy.

As a rule, the brighter stars in a constellation were assigned a Greek letter, either by the ancient Greeks or by astronomers of later civilizations. In each constellation, the brightest star was labeled alpha, the first letter of the Greek alphabet. The next brightest star was beta, the second Greek letter, and so on down to omega, the final Greek letter of the 24-character alphabet. (The astronomers used only lowercase Greek letters, so you see them written as α, β, . . . ω.)

So Sirius, the brightest star in the night sky — in Canis Major, the Great Dog — is called Alpha Canis Majoris. (Astronomers add a suffix here or there to put star names in the Latin genitive case — scientists have always liked Latin.)

Table 1-1 shows a list of the Greek alphabet, in order, with the names of the letters and their corresponding symbols.

Table 1-1 The Greek Alphabet

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

TIP

When you look at a star atlas, you discover that the individual stars in a constellation aren't marked α Canis Majoris, β Canis Majoris, and so on. Usually, the creator of the atlas marks the area of the whole constellation "Canis Major" and labels the individual stars α, β, and so on. When you read about a star in a list of objects to observe, say in an astronomy magazine (see Chapter 2), you probably won't see it listed in the style of Alpha Canis Majoris or even α Canis Majoris. Instead, to save space, the magazine prints it as α CMa; *CMa* is the three-letter abbreviation for Canis Majoris (and also the abbreviation for Canis Major). I give the abbreviation for each of the constellations in Table 1-2.

Astronomers didn't coin special names such as Sirius for every star in Canis Major, so they named them with Greek letters or other symbols. In fact, some constellations don't have a single named star. (Don't fall for those advertisements that offer to name a star for a fee. The International Astronomical Union doesn't recognize purchased star names.) In other constellations, astronomers assigned Greek letters, but they could see more than 24 stars for 24 Greek letters. Therefore, astronomers gave some stars numbers and letters from the Roman alphabet, such as 236 Cygni, b Vulpeculae, HR 1516, and worse. You may even run across RU Lupi and SX Sex. (I'm not making this up.) But like any other star, you can recognize them by their positions in the sky (as tabulated in star lists), their brightnesses, their colors, or other properties, if not their names.

When you look at the constellations today, you see many exceptions to the rule that the Greek-letter star names correspond to the respective brightnesses of the stars in a constellation. The exceptions exist because

- The letters were based on inaccurate naked-eye observations of brightness.
- Over the years, star-atlas authors changed constellation boundaries, moving some stars from one constellation into another that includes previously named stars.
- Some astronomers mapped out small and Southern Hemisphere constellations long after the Greek period, and the practice wasn't always followed.
- The brightness of some stars has changed over the centuries since the ancient Greeks charted them.

A good (or bad) example is the constellation Vulpecula, the Fox, where only one of the stars (alpha) has a Greek letter.

Because alpha isn't always the brightest star in a constellation, astronomers needed another term to describe that exalted status, and *lucida* is the word (from the Latin word *lucidus,* meaning bright or shining). The lucida of Canis Major is Sirius, the alpha star, but the lucida of Orion, the Hunter, is Rigel, which is Beta Orionis. The lucida of Leo Minor, the Little Lion (a particularly inconspicuous constellation), is 46 Leo Minoris.

Table 1-2 lists the 88 constellations, the brightest star in each, and the magnitude of that star. *Magnitude* is a measure of a star's brightness. (I talk about magnitudes later in this chapter in the section "The smaller, the brighter: Getting to the root of magnitudes.") When the lucida of a constellation is the alpha star and has a name, I list only the name. For example, in Auriga, the Charioteer, the brightest star, Alpha Aurigae, is Capella. But when the lucida isn't an alpha, I give its Greek letter or other designation in parentheses. For example, the lucida of Cancer, the Crab, is Al Tarf, which is Beta Cancri.

Table 1-2 The Constellations and Their Brightest Stars

Name	*Abbreviation*	*Meaning*	*Star*	*Magnitude*
Andromeda	And	Chained Lady	Alpheratz	2.1
Antlia	Ant	Air Pump	Alpha Antliae	4.3
Apus	Aps	Bird of Paradise	Alpha Apodis	3.8
Aquarius	Aqr	Water Bearer	Sadalmelik	3.0
Aquila	Aql	Eagle	Altair	0.8
Ara	Ara	Altar	Beta Arae	2.9
Aries	Ari	Ram	Hamal	2.0
Auriga	Aur	Charioteer	Capella	0.1
Bootes	Boo	Herdsman	Arcturus	–0.04
Caelum	Cae	Chisel	Alpha Caeli	4.5
Camelopardalis	Cam	Giraffe	Beta Camelopardalis	4.0
Cancer	Cnc	Crab	Al Tarf (Beta Cancri)	3.5
Canes Venatici	CVn	Hunting Dogs	Cor Caroli	2.8
Canis Major	CMa	Great Dog	Sirius	–1.5
Canis Minor	CMi	Little Dog	Procyon	0.4
Capricornus	Cap	Goat	Deneb Algedi (Delta Capricorni)	2.9
Carina	Car	Ship's Keel	Canopus	–0.7
Cassiopeia	Cas	Queen	Schedar	2.2
Centaurus	Cen	Centaur	Rigil Kentaurus	–0.3
Cepheus	Cep	King	Alderamin	2.4

Name	*Abbreviation*	*Meaning*	*Star*	*Magnitude*
Cetus	Cet	Whale	Deneb Kaitos (Beta Ceti)	2.0
Chamaeleon	Cha	Chamaeleon	Alpha Chamaeleontis	4.1
Circinus	Cir	Compasses	Alpha Circini	3.2
Columba	Col	Dove	Phakt	2.6
Coma Berenices	Com	Berenice's Hair	Beta Comae Berenices	4.3
Corona Australis	CrA	Southern Crown	Alpha Coronae Australis	4.1
Corona Borealis	CrB	Northern Crown	Alphekka	2.2
Corvus	Crv	Crow	Gienah (Gamma Corvi)	2.6
Crater	Crt	Cup	Delta Crateris	3.6
Crux	Cru	Cross	Acrux	0.7
Cygnus	Cyg	Swan	Deneb	1.3
Delphinus	Del	Dolphin	Rotanev (Beta Delphini)	3.6
Dorado	Dor	Goldfish	Alpha Doradus	3.3
Draco	Dra	Dragon	Thuban	3.7
Equuleus	Equ	Little Horse	Kitalpha	3.9
Eridanus	Eri	River	Achernar	0.5
Fornax	For	Furnace	Alpha Fornacis	3.9
Gemini	Gem	Twins	Pollux (Beta Geminorum)	1.1
Grus	Gru	Crane	Alnair	1.7
Hercules	Her	Hercules	Ras Algethi	2.6
Horologium	Hor	Clock	Alpha Horologii	3.9
Hydra	Hya	Water Snake	Alphard	2.0
Hydrus	Hyi	Little Water Snake	Beta Hydri	2.8

(continued)

Table 1-2 *(continued)*

Name	***Abbreviation***	***Meaning***	***Star***	***Magnitude***
Indus	Ind	Indian	Alpha Indi	3.1
Lacerta	Lac	Lizard	Alpha Lacertae	3.8
Leo	Leo	Lion	Regulus	1.4
Leo Minor	LMi	Little Lion	Praecipua (46 Leo Minoris)	3.8
Lepus	Lep	Hare	Arneb	2.6
Libra	Lib	Scales	Zubeneschemali (Beta Librae)	2.6
Lupus	Lup	Wolf	Alpha Lupus	2.3
Lynx	Lyn	Lynx	Alpha Lyncis	3.1
Lyra	Lyr	Lyre	Vega	0.0
Mensa	Men	Table	Alpha Mensae	5.1
Microscopium	Mic	Microscope	Gamma Microscopii	4.7
Monoceros	Mon	Unicorn	Beta Monocerotis	3.7
Musca	Mus	Fly	Alpha Muscae	2.7
Norma	Nor	Level and Square	Gamma Normae	4.0
Octans	Oct	Octant	Nu Octantis	3.8
Ophiuchus	Oph	Serpent Bearer	Rasalhague	2.1
Orion	Ori	Hunter	Rigel (Beta Orionis)	0.1
Pavo	Pav	Peacock	Alpha Pavonis	1.9
Pegasus	Peg	Winged Horse	Enif (Epsilon Pegasi)	2.4
Perseus	Per	Hero	Mirphak	1.8
Phoenix	Phe	Phoenix	Ankaa	2.4
Pictor	Pic	Easel	Alpha Pictoris	3.2
Pisces	Psc	Fish	Eta Piscium	3.6
Pisces Austrinus	PsA	Southern Fish	Fomalhaut	1.2

Name	Abbreviation	Meaning	Star	Magnitude
Puppis	Pup	Ship's Stern	Zeta Puppis	2.3
Pyxis	Pyx	Compass	Alpha Pyxidus	3.7
Reticulum	Ret	Net	Alpha Reticuli	3.4
Sagitta	Sge	Arrow	Gamma Sagittae	3.5
Sagittarius	Sgr	Archer	Kaus Australis (Epsilon Sagittarii)	1.9
Scorpius	Sco	Scorpion	Antares	1.0
Sculptor	Scl	Sculptor	Alpha Sculptoris	4.3
Scutum	Sct	Shield	Alpha Scuti	3.9
Serpens	Ser	Serpent	Unukalhai	2.7
Sextans	Sex	Sextant	Alpha Sextantis	4.5
Taurus	Tau	Bull	Aldebaran	0.9
Telescopium	Tel	Telescope	Alpha Telescopium	3.5
Triangulum	Tri	Triangle	Beta Trianguli	3.0
Triangulum Australe	TrA	Southern Triangle	Alpha Trianguli Australis	1.9
Tucana	Tuc	Toucan	Alpha Tucanae	2.9
Ursa Major	UMa	Great Bear	Alioth (Epsilon Ursae Majoris)	1.8
Ursa Minor	UMi	Little Bear	Polaris	2.0
Vela	Vel	Sails	Suhail al Muhlif (Gamma Velorum)	1.8
Virgo	Vir	Virgin	Spica	1.0
Volans	Vol	Flying Fish	Gamma Volantis	3.6
Vulpecula	Vul	Fox	Anser	4.4

Identifying stars would be much easier if they had little name tags that you could see through your telescope, but at least they don't have unlisted numbers like an old friend that you're desperate to reach. (For the whole scoop on stars, check out Part III.)

What do I spy? The Messier Catalog and other sky objects

Naming stars was easy enough for astronomers. But what about all those other objects in the sky — galaxies, nebulae, star clusters, and the like (which I cover in Part III). Charles Messier, a French astronomer in the late 18th century, created a list of about 100 fuzzy sky objects and gave them numbers. His list is known as the *Messier Catalog,* and now when you hear the Andromeda Galaxy called by its scientific name, M31, you know what it means. Today, 110 objects make up the standard Messier Catalog.

TIP

You can find pictures and a complete list of the Messier objects at The Messier Catalog Web site of Students for the Exploration and Development of Space at `www.seds.org/messier`. And you can find out how to earn a certificate for viewing Messier objects from the Astronomical League Messier Club Web site at `www.astroleague.org/al/obsclubs/messier/mess.html`.

Experienced amateur astronomers often engage in Messier marathons in which each person tries to observe every object in the *Messier Catalog* during a single long night. But in a marathon, you don't have time to enjoy an individual nebula, star cluster, or galaxy. My advice is to take it slow and savor their individual visual delights. A wonderful book on the Messier objects, which includes hints on how to observe each object, is Stephen J. O'Meara's *The Messier Objects* (Cambridge University Press and Sky Publishing Corporation, 1998).

Astronomers have confirmed the existence of thousands of other *deep sky objects,* the term amateurs use for star clusters, nebulae, and galaxies to distinguish them from stars and planets. Because Messier didn't list them, astronomers refer to these objects by their numbers as given in catalogues made since his time. You can find many of these objects listed in viewing guides and sky maps by their NGC *(New General Catalogue)* and IC *(Index Catalogue)* numbers. For example, the bright double cluster in Perseus, the Hero, consists of NGC 869 and NGC 884.

The smaller, the brighter: Getting to the root of magnitudes

A star map, constellation drawing, or list of stars always indicates each star's magnitude. The *magnitudes* represent the brightnesses of the stars. One of the ancient Greeks, Hipparchos (also spelled Hipparchus, but he wrote it in Greek), divided all the stars he could see into six classes. He called the brightest stars magnitude one or *1st magnitude,* the next brightest bunch the *2nd magnitude* stars, and on down to the dimmest ones, which were *6th magnitude.*

By the numbers: The mathematics of brightness

The 1st magnitude stars are about 100 times brighter than the 6th magnitude stars. In particular, the 1st magnitude stars are about 2.512 times brighter than the 2nd magnitude stars, which are about 2.512 times brighter than the 3rd magnitude stars, and so on. (At the 6th magnitude, you get up into some big numbers: 1st magnitude stars are about 100 times brighter.) You mathematicians out there recognize this as a *systematic progression*. Each magnitude is the 5th root of 100 (meaning that when you multiply a number by itself four times — for example, 2.512 $\times$ 2.512 $\times$ 2.512 $\times$ 2.512 $\times$ 2.512 — the result is 100). If you doubt my word and do this calculation on your own, you get a slightly different answer because I left off some decimal places.

Thus, you can calculate how faint a star is — compared to some other star — from its magnitude. If two stars are 5 magnitudes apart (such as the 1st magnitude star and the 6th magnitude star), they differ by a factor of 2.512^5 (2.512 to the fifth power), and a good pocket calculator shows you that one star is 100 times brighter. If two stars are 6 magnitudes apart, one is about 250 times brighter than the other. And if you want to compare, say, a 1st magnitude star with an 11th magnitude star, you factor a 2.512^{10} difference in brightness, meaning a factor of 100 squared, or 10,000.

The faintest object visible with the Hubble Space Telescope is about 25 magnitudes fainter than the faintest star you can see with the naked eye (assuming normal vision and viewing skills — some experts and a certain number of liars and braggarts say that they can see 7th magnitude stars). Speaking of dim stars, 25th magnitudes are five times 5 magnitudes, which corresponds to a brightness difference of a factor of 100^5. So the Hubble can see 100 $\times$ 100 $\times$ 100 $\times$ 100 $\times$ 100, or 10 billion times fainter than the human eye. Astronomers expect nothing less from a billion-dollar telescope. At least it didn't cost $10 billion.

You can get a good telescope for under $1,000, and you can download the billion-dollar Hubble's best photos from the Internet for free at `www.stsci.edu`.

Notice that contrary to most common measurement scales and units, the brighter the star, the smaller the magnitude. The Greeks weren't perfect, however; even Hipparchos had an Achilles' heel: He didn't leave room in his system for the very brightest stars, when accurately measured.

So, today, we recognize a few stars with a zero magnitude or a negative magnitude. Sirius, for example, is magnitude –1.5. And the brightest planet, Venus, is sometimes magnitude –4 (the exact value differs, depending on the distance Venus is from Earth at the time and its direction with respect to the sun).

Another omission: Hipparchos didn't have a magnitude class for stars that he couldn't see. This didn't seem like an oversight at the time, because nobody knew about these stars. But today, astronomers know that millions of stars exist beyond our naked-eye view, and they all should have magnitudes. Their magnitudes are larger numbers: 7 or 8 for stars easily seen through binoculars and 10 or 11 for stars easily seen through a good, small telescope. The magnitudes reach as high (and as dim) as 21 for the faintest stars in the Palomar Observatory Sky Survey and 30 or maybe 31 for the faintest objects imaged with the Hubble Space Telescope.

Looking back on light-years

The distances to the stars and other objects beyond the planets of our solar system are measured in *light-years.* As a measurement of actual length, a light-year is about 5.9 trillion miles long.

People confuse a light-year with a length of time, because the term contains the word "year." But a light-year is really a distance measurement — the length that light travels, zipping through space at 186,000 miles per second, over the course of a year.

When you view an object in space, you see it as it appeared when the light left the object. Consider these examples:

- When astronomers spot an explosion on the sun, we don't see it in real time; the light from the explosion takes about eight minutes to get to Earth.
- The nearest star beyond the sun, Proxima Centauri, is about 4 light-years away. Astronomers can't see Proxima as it is now, only as it was four years ago.
- Look up at the Andromeda Galaxy, the most distant object that you can readily see with the unaided eye, on a clear, dark night in the fall. The light your eye receives left that galaxy about 2.6 million years ago. If the galaxy disappeared by some mysterious means, we wouldn't even know for over two million years. (See Chapter 12 for more hints on viewing galaxies.)

Here's the bottom line:

- When you look out into space, you're looking back in time.
- Astronomers don't have a way to know exactly what an object out in space looks like right now.

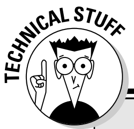
When you look at some big, bright stars in a faraway galaxy, you must entertain the possibility that those particular stars don't even exist any more. Some massive stars only live for 10 or 20 million years. If you see them in a galaxy that exists 50 million light-years away, you're looking at lame duck stars. They aren't shining in that galaxy any more; they're dead.

If astronomers send a flash of light toward one of the most distant galaxies found with Hubble and other major telescopes, the light would take at least 12 billion years to arrive, because the farthest galaxies are at least 12 billion light-years away (furthermore, the universe is expanding, so those galaxies will be farther away by the time the light gets there). Astronomers, however, project that the sun will swell up and destroy all life on Earth a mere five or six billion years from now, so the light would be a futile advertisement of our civilization's existence, a flash in the celestial pan.

Keep on moving: Figuring the positions of the stars

Astronomers used to call stars "fixed stars" to distinguish them from the wandering planets. But, in fact, stars are in constant motion as well, both real and apparent. The whole sky rotates overhead because the earth is turning. The stars rise and the stars set, like the sun and the moon, but they stay in formation. The stars that make up the Great Bear don't swing over to the Little Dog or Aquarius, the Water Bearer. Different constellations rise at different times and on different dates as visible from different places around the globe.

Actually, the stars in Ursa Major (and every other constellation) do move with respect to one another and at breathtaking speeds, measured in hundreds of miles per second. But those stars are so far away that scientists need precise measurements over considerable intervals of time to detect their motions across the sky. So, 20,000 years from now, the stars in Ursa Major will form a different pattern in the sky. Maybe they will even look like a Great Bear.



Hey, you! No, no, I mean A.U.

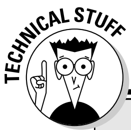
The Earth is about 93 million miles from the sun, or one *Astronomical Unit* (A.U.). The distances between objects in the solar system are usually given in A.U. Its plural is also A.U. (Don't confuse A.U. with "Hey, you!")

In public announcements, press releases, and popular books, astronomers state how far the stars and galaxies that they study are "from Earth." But among themselves and in technical journals, they always give the distances from the sun, the center of our solar system. This rarely matters, because astronomers can't measure the distances of the stars precisely enough for one A.U. more or less to make a difference, but they do it this way for consistency.

In the meantime, astronomers have measured the positions of millions of stars, and many of them are tabulated in catalogs and marked on star maps. The positions are listed in a system called "right ascension and declination" — known to all astronomers, amateur and pro, as *RA* and *Dec:*

- The RA is the position of a star measured in the east-west direction on the sky (like longitude, the position of a place on Earth measured east or west of the prime meridian at Greenwich, England).
- The Dec is the position of the star measured in the north-south direction, like the latitude of a city, which is measured north or south of the equator.

Astronomers usually list RA in units of hours, minutes, and seconds, like time. We list Dec in degrees, minutes, and seconds of arc. Ninety degrees make up a right angle, sixty minutes of arc make up a degree, and sixty seconds of arc create a minute of arc. A minute or second of arc is also often called an "arc minute" or an "arc second," respectively.



Digging deeper into RA and Dec

A star at RA 2h00m00s is two hours east of a star at RA 0h00m00s, regardless of their declinations. RA increases from west to east, starting from RA 0h00m00s, which corresponds to a line in the sky (actually half a circle, centered on the center of the earth) from the North Celestial Pole to the South Celestial Pole. The first star may be at Dec 30° North and the second star may be at Dec 15° 25′12″ South, but they're still two hours apart in the east-west direction (and 45° 25′12″ apart in the north-south direction). The North and South Celestial Poles are the points in the sky — due north and due south — around which the whole sky seems to turn, with the stars all rising and setting.

See the following details about the units of RA and Dec:

- An hour of RA equals an arc of 15 degrees on the equator in the sky. Twenty-four hours of RA span the sky, and $24 \times 15 = 360$ degrees, or a complete circle around the sky. A minute of RA, called a *minute of time,* is a measure of angle on the sky that makes up $\frac{1}{60}$ of an hour of RA. So you take $15° \div 60$, or $\frac{1}{4}°$. A second of RA, or a *second of time,* is 60 times smaller than a minute of time.
- Dec is measured in degrees, like the degrees in a circle, and in minutes and seconds of arc. A whole degree is about twice the apparent or angular size of the full Moon. Each degree is divided into 60 seconds of arc. The sun and the full Moon each are about 32 minutes of arc (32′) wide as seen on the sky, although in reality the sun is much larger than the moon. Each minute of arc is divided into 60 seconds of arc (60″). When you look through a backyard telescope at high magnification, turbulence in the air blurs the image of a star. Under good conditions (low turbulence), the image should measure about 1″ or 2″ across. That's one or two arc seconds, not one or two inches.

A few simple rules may help you remember how RA and Dec work and how to read a star map (see Figure 1-3):

- The North Celestial Pole (NCP) is the place to which the axis of the earth points in the north direction. If you stand at the geographic North Pole, the NCP is right overhead. (If you stand there, say "Hi" to Santa for me, but beware: You may be standing on thin ice; no land covers the geographic North Pole.)
- The South Celestial Pole (SCP) is the place to which the axis of the earth points in the south direction. If you stand at the geographic South Pole, the SCP is right overhead. I hope you dressed warmly: You're in Antarctica!
- The imaginary lines of equal RA run through the NCP and SCP as semicircles centered on the center of Earth. They may be imaginary, but they appear marked on most sky maps to help people find the stars at particular RAs.
- The imaginary lines of equal Dec, like the line in the sky that marks Dec 30° North, pass overhead at the corresponding geographic latitudes. So if you stand in New York City, latitude 41° North, the point overhead is always at Dec 41° North, although its RA changes constantly as the earth turns. These imaginary lines appear on star maps, too, as *declination circles.*

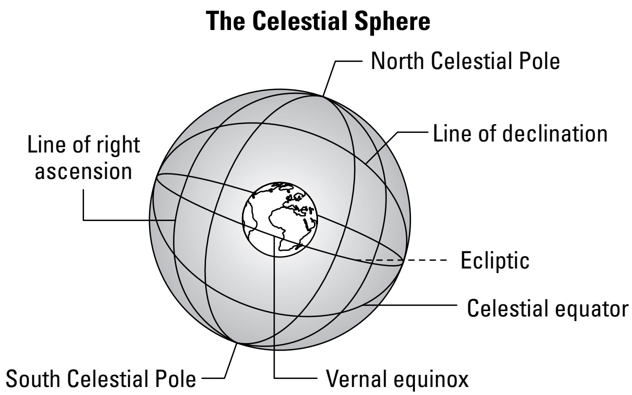


Figure 1-3: Decoding the celestial sphere to find directions in space.

Suppose you want to find the NCP as visible from your backyard. Face due north and look at an altitude of *x* degrees, where *x* is your geographic latitude. I'm assuming that you live in North America, Europe, or somewhere in the Northern Hemisphere. If you live in the Southern Hemisphere, you can't see the NCP. You can, however, look for the SCP. Look for the spot due south whose altitude in the sky, measured in degrees above the horizon, is equal to your geographic latitude.

In almost every astronomy book, the symbol “ means seconds of arc, not inches. But at every university, a student in Astronomy 101 always writes on an exam, “The image of the star was about one inch in diameter.” Understanding beats memorizing every day, but not everyone understands.

Here’s the good news: If you just want to spot the constellations and the planets, you don’t have to know how to use RA and Dec. You just have to compare a star map prepared for the right time of year and time of night (as printed, for example, in many daily newspapers) with the stars that you see at the corresponding times. But if you want to understand how star catalogs and maps work and how to zero in on faint galaxies with your telescope, understanding the system helps.

And if you purchase one of those snazzy, new, surprisingly affordable telescopes with computer control (see Chapter 3), you can punch in the RA and Dec of a recently discovered comet and the scope points right at it. (A little table called an *ephemeris* comes with every announcement of a new comet. It gives the predicted RA and Dec of the comet on successive nights as it sweeps across the sky.)

Gravity: A Force to Be Reckoned With

Ever since the work of Newton (Isaac, not the cookie), everything in astronomy has revolved around gravity. Newton explained it as a force between any two objects. The force depends on mass and separation. The more massive the object, the more powerful its pull. The greater the distance, the weaker the gravitational attraction.

Albert Einstein developed an improved theory of gravity, which passes experimental tests that Isaac’s theory flunks. Newton’s theory was good enough for commonly experienced gravity, like the force that made the apple fall on his head (if it really did hit him). But Einstein’s theory also predicts effects that happen close to massive objects, where gravity is very strong. Einstein didn’t think of gravity as a force; he considered it the bending of space and time by the very presence of a massive object, such as a star. I get all bent out of shape just thinking about it.

Newton’s concept of gravity explains the following:

- Why the moon orbits the earth, why the earth orbits the sun, why the sun orbits the center of the Milky Way, and why many other objects orbit one object or another out there in space
- Why a star or a planet is round
- Why gas and dust in space may clump together to form new stars

Einstein's theory of gravity, the General Theory of Relativity, explains the following:

- Why stars visible near the sun during a total eclipse seem slightly out of position
- Why black holes exist
- Why, as the earth turns, it drags warped space and time around with it, an effect that scientists have verified with the help of satellites orbiting the earth.

You can find out about black holes in Chapters 11 and 13 without mastering the General Theory of Relativity. You can become smarter if you read every chapter in this book, but your friends won't call you Einstein unless you let your hair grow, parade around in a messy old sweater, and stick out your tongue when they take your picture.

Space: A Commotion of Motion

Everything in space is moving and turning. Objects can't sit still. Thanks to gravity, a celestial body is always pulling on a star, planet, galaxy, or spacecraft. The universe has no center.

For example, the earth

- Turns on its axis — what astronomers call *rotating* — and takes one day to turn all the way around
- Orbits around the sun — what astronomers call *revolving* — with one complete orbit taking one year
- Travels with the sun in a huge orbit around the center of the Milky Way; the trip takes about 226 million years to complete once, and the duration of the trip is called the *galactic year*
- Moves with the Milky Way in a trajectory around the center of the *Local Group of Galaxies,* a couple dozen galaxies in our neck of the universe
- Moves through the universe with the Local Group as part of the *Hubble Flow,* the general expansion of space caused by the Big Bang

  The Big Bang is the event that gave rise to the universe and set space itself expanding at a furious rate. Detailed theories about the Big Bang explain many observed phenomena and have successfully predicted some that hadn't been observed before the theories were circulated. (For more about the Big Bang and other aspects of the universe, check out Part IV.)

Remember Ginger Rogers? She did everything Fred Astaire did when they danced in the movies, and she did it all backward. Like Ginger and Fred, the moon follows all the motions of the earth (although not backward), except for the earth's rotation; the moon rotates more slowly, about once a month. And it performs its tasks while also revolving around the earth (which it does about once a month).

And you, as a person on Earth, participate in the motions of rotation, revolution, galactic orbiting, Local Group cruising, and cosmic expansion. You do all that while you drive to work without even knowing it. Ask your boss for a little consideration the next time you run a few minutes late.