PART ONE

Getting started

1 First night out

Of all my childhood memories, the time my uncle pulled up to our house one afternoon in August of 1960 stands out. In his hands was a long box. In our living room he opened it: Inside were three cast-iron tripod legs, a platform, and a long tube. As he and Dad went about putting the pieces together, I looked on amazed at this surprise gift of my first telescope. 'We were going to wait till your Bar Mitzvah', Uncle Sidney said about the event that was still an eternal nine months off, 'but your parents told us how anxious you are to have a telescope'.

A few hours later, my parents and I were outside in the warm August evening, with my new telescope. Its name is Echo, I announced, saying that it was in honor of the bright new satellite that the US had launched a few days earlier. With a new telescope and a clear sky, the first item of business was deciding what to look at first. We had no idea what star to look at first. We had no guide – no star chart, no magazine, to show us where to look. So, in an effort to make simplicity the mother of invention, I decided to point Echo toward the brightest star in the sky. There were two stars that night brighter than all the rest, and both were just clearing the tops of the tall willow tree to the south.

I turned Echo toward the brighter of the two, and focused it as I had learned that afternoon. As the image grew sharper, I could tell that this was obviously not a star. What started as a round, flat blob of light with a hole in the middle was shrinking to a beautiful sunlit world with bands of dark clouds and three nearby stars which, I knew from my reading, could only be moons of the first distant planet I had ever seen. My parents and I stood there, utterly fascinated, as we gazed on a world half a billion miles away.

We went even farther the next night. Turning the telescope toward the second brightest star in the sky, we tuned in on Saturn and its exquisite system of rings. We could not believe that something that lovely could exist right above our home.

1.1 Discover the sky

Ours was the perfect way to befriend the sky. No star charts, no guides; just the three of us, a small telescope, and a clear evening. You do not have to wait for someone else to show you the stars. A simple walk outside, with a few questions, is enough to get started. Why do the stars rise and set? And why do they rise a few minutes earlier each night? Are the stars all white, for example, or do some show subtle hints of red or blue? Are some parts of the sky more crowded than others? Do some of the brightest stars shine with a steadier light than the shimmer of the rest?

Although these seem to be elementary school type questions, their answers are profound. The stars rise and set because our planet is spinning eastward on its axis at something like 1000 miles per hour. The stars rise a few minutes earlier each night because our vantage point for viewing is changing as the Earth hurtles round the Sun at some 18½ miles per second. Our entire solar system, by the way, is also moving along in the general direction of the constellation of Hercules; it is a part of an arm of the galaxy as it rotates once in 220 million years. Our galaxy is part of a small group of 20 or so galaxies, and that group is part of a massive concentration of galaxies called the Local Supercluster. This supercluster is carrying us away from all the other superclusters at an incredible velocity. All these motions are very complex, and involve both space and time, and are all happening outside your window. You can go outdoors and try to appreciate all these motions, and the ages of the stars as shown by their colors – all information available to you from in front of your home, and without need of a telescope – but you do not have to address these questions. You can just go outside and enjoy the sky.

The stars, you will find, are not all white. The ones you see with reddish tinges are cooler than our Sun, and quite probably older than it is. Bluish stars are hotter, and younger. The stars are definitely not distributed evenly. We are a part of a galaxy so large that it contains several hundred billion suns, and it takes us some 220 million years to travel around its center. The galaxy is shaped like a flat disk, and we are near the edge of one side. So when we look into the disk of our galaxy, the stars will be much more thickly distributed than they are when we look away from it.

1.1.1 Aspects of the Sky

Imagine the sky as a city, with roads, streets, and intersections, and neighborhoods. To identify what you are seeing, you need two things: a star chart to find your way, and a sense of where you are, a perspective from which you can view this 'city' we call the sky.

Latitude Depending upon where you live, different parts of the sky will be visible. If you are at the latitude of Montreal, for example, the Big Dipper is always there. We say that the Dipper is circumpolar. If you look toward the North, and if you have a good horizon toward the northeast and northwest, you should have no trouble finding the Big Dipper at any hour of any night of the year. In autumn and winter the Dipper is low in the sky during the evening hours; the rest of the year it will be high in the sky.

At lower latitudes, like in southern California, the Dipper is not circumpolar. It rises in the northeast and sets in the northwest, and during fall and winter evenings it does not rise far enough above the horizon to be easily seen. The farther south you are, the less visible the Dipper is. In Peru, the Dipper hangs upside down low in the northern sky for a short time each night, and further south it does not rise at all.

Longitude Latitude has a tremendous effect on what stars you see. Longitude, however, does not. From Tucson at 8 p.m. local time, you should see much the same sky as you see from Tel Aviv at 8 p.m. Israel time.

Time of night Because the Earth rotates eastward the time of night is important in understanding what you will see. We live by that maxim by day – the later the hour of day, the further west the Sun is in its diurnal, or daily, apparent motion. The stars appear in the same manner.

Time of year Because the Earth also moves in its orbit around the Sun each day, the stars rise and set an average of 3 minutes and 56 seconds earlier each night. This does not seem like much, but the time adds up quickly – a half hour each week, two hours each month!

Phase of the moon Even in the light-polluted sky of a big city, there is a difference between what one can see at new and full moon. The full moon is very strongly illuminated, and it swamps out light from all but the brighter stars, whether you see them from city or country sky.

Weather conditions There is the amusing tale of the dissatisfied customer who demanded his money back because he could not see the stars through his telescope, despite the fact it was raining! Even a thin layer of cirrus cloud can disrupt a night's viewing. Remember warm clothing for cold nights, and wear a hat for added protection. And don't forget insect repellant for warm summer nights.

1.1.2 Magnitudes

The reckoning of different brightnesses of stars probably comes from biblical times. In ancient Jewish practice, the Sabbath or other festival does not end until sunset, but how does one ensure that the Sun has actually set, and is not still up behind a distant mountain? To solve this problem, ancient Jewish scholars proposed that no festival is considered over until three stars are sighted in the evening sky. However, since bright stars or planets can technically be seen before sunset, a simple magnitude system was created whereby the stars were divided into three groups, bright, medium, and faint. The three stars should not be in the bright category, since that could be too soon, nor in the faint grouping, since that is too faint. Thus, the earliest known magnitude scale came into being to solve a practical problem.

Our system of magnitudes dates back to the second century BC Greek astronomer Hipparchus, who divided the stars into six brightness groups with the 20 brightest stars first magnitude and the faintest stars sixth magnitude. In 1856, Norman Pogson of Radcliffe Observatory had quantified this relationship, making a first magnitude star 100 times brighter than the faintest star visible without a telescope, a second magnitude star 2.5 times fainter than a first magnitude star, a third magnitude star, in turn, 2.5 times fainter again. Vega, the brightest star in the summer triangle, is a zero magnitude star. Pogson defined Polaris, the North Star, as being second magnitude. Most of the stars in the Big Dipper are also about second magnitude. Most of the stars in nearby Cassiopeia are a magnitude fainter.

1.2 The Big Dipper key

If you live in the Northern Hemisphere, you can use the Big Dipper to get started on constellations all over the sky. Here are some examples:

Polaris The two stars at the end of the Big Dipper's bowl opposite the handle can be joined with an imaginary line. If you extend that line about five times the distance between the pointer stars, you find Polaris, the North Pole Star.

This star lies at the end of the tail of the Little Dipper, a constellation we know as Ursa Minor, and whose faint stars are not easy to find in a city sky.

Arc to Arcturus Follow the curved line of the Big Dipper's three-starred handle away from the Dipper until you reach Arcturus, the bright orange star in Bootes. Light from this star, by the way, tripped a photocell that turned on the lights for the Chicago World's Fair in 1933. After cogitating that thought for a second or two, continue following the same curve and speed to Spica, the bluish-white star in the constellation of Virgo.

The Summer Triangle Vega, Deneb, and Lyra, the queens of the summer sky in the Northern Hemisphere, virtually dominate a large section of sky. By joining the two inner stars of the Dipper's bowl and extending the line northward, you will eventually reach these three major stars. Vega is the blue-white diamond at the heart of Lyra, the Lyre. Deneb is at the tail of Cygnus, the Swan, and Altair is at the heart of Aquila, the Eagle.

Scorpius and Sagittarius A line drawn from Gamma Ursae Majoris, the star at the bottom of the Dipper's Bowl on the handle side, through Eta, the star at the far end of the Dipper's handle, will point across the sky toward Antares, a bright red star that's the heart of Scorpius. It looks alternately like the scorpion of mythology, or a more popular dandelion. To the east is Sagittarius, the Archer. These are Northern Hemisphere summer constellations.

The stars of autumn Fall in the Northern Hemisphere is the one season where the Dipper probably won't be too helpful, since it is either low in the sky or not visible at all. If you do see the Dipper low in the north, then use its two pointer stars to go to the pole and an equal amount past the pole until you reach the famous W of Cassiopeia. The Ethiopian Queen, Cassiopeia is close to Cepheus, her King, and proud of the beauty of her daughter, Andromeda. The Queen's incessant boasting angered Neptune, the god of the sea, who sent Cetus the whale to destroy the young princess. Neptune had the terrified Andromeda chained to a rock, to await amid the crashing waves for the arrival of Cetus. At the last minute, Perseus came charging to her rescue on Pegasus, the winged horse, who carried Andromeda, still in chains, into the sky.

Consisting of four second magnitude stars, the Great Square of Pegasus occupies an otherwise vacant area of sky at this time of year. The star at the square's northwest corner forms a triangle with two other nearby stars. The star on the square's northeast corner is actually a part of the horse's famous rider Andromeda. Swinging to the square's northeast, Andromeda can be found by joining the southwest and northeast stars of the square and extending the line the same distance. Extending it the same distance again will take you into Perseus. To find Cepheus, the King, join the two bright stars at the west end of Cassiopeia and extend the line about three times that distance.

A line through the northeast and southeast corner stars of the square, and extended the same distance, will take you through the 'Circlet' of faint stars belonging to Pisces, the Fish. Extending the line the same distance again will lead you to the faint stars of Cetus.

The stars of winter The key to the entire winter sky is mighty Orion. Its three belt stars, surrounded by four other stars, make up a marvelous figure virtually impossible to miss on a clear night. But Orion is only part of a much larger figure consisting of several first magnitude stars that utterly dominate the Northern Hemisphere's winter sky. This figure is called the *Heavenly G*. It begins with Aldebaran, the brightest star in Taurus, and circles through Capella, Castor, Pollux, Procyon, Sirius, and Rigel. The line then turns inward to Betelgeuse to complete the shape of the G.

For those observers fortunate enough to see the sky from the Southern Hemisphere, exquisite Carina is a part of the sky not to be missed. A line stretching from Betelgeuse through Kappa Orionis can be extended about twice that distance to reach the star Canopus, the brightest star in the constellation of Carina, the keel of the mythological ship Argo. This constellation extends entirely to the east of its brightest star. Stretching eastward from Carina lie the fantastic foursome of the Southern Cross, and eastward still, the bright two stars of Centaurus, whose Alpha is the closest star system to the Sun.

The Big Dipper and Orion are two small parts of the sky. But they are so familiar, and so easy to find, and they lead us to many other parts of the sky. Your journey to the stars can be a long one, but using these two constellations as keys, it can start to be productive sooner.

1.3 The Milky Way

One of the most beautiful things in the sky, and one of the most confusing, is the Milky Way. Invisible from most city locations, and bright as cloud in a dark sky, the Milky Way arches through the sky like a subtle feather. Actually, the Milky Way does not look like a cloud at all when seen through binoculars, which reveal it for what it is, a swarm of faint stars. Here's where most of the stars in our galaxy lie; when we look at the Milky Way we look along the plane of our Milky Way galaxy.

We believe our galaxy to be shaped like a giant pinwheel: flat, with arms that spiral out from the center. If we look at our galaxy from a great distance, we would have no difficulty understanding and seeing its shape. You do this any night by looking at the Andromeda galaxy. But with our galaxy, we see it from within. Figuring out the shape of our galaxy was a task that occupied the minds and eyes of astronomers through several decades of the twentieth century. A team led by William Morgan at Yerkes Observatory produced strong evidence for our galaxy's spiral shape early in the 1950s. Since then, astronomers have come up with evidence for spiral arms in the constellations of Orion and Perseus. Even so, determining the shape of our galaxy is like trying to visualize what a house looks like from the outside when we see it only from the inside. It is our galaxy's flattened shape that causes the Milky Way to appear as a single swarm that stretches from one part of the sky to the other. Moreover, we are off in the boondocks in one of the galaxy's spiral arms.

If you want to see the galaxy's center, look towards Scorpius and Sagittarius. On a dark night you'll notice that the Milky Way widens and brightens there, for that is where the center is. The Milky Way is not a smooth band of light, you'll quickly notice. It is thicker and brighter in some parts of its train than in others. In Aquila, it splits into two, a division so apparent that we call it the Great Rift. The rift consists of large amounts of gas and dust that make the Milky Way appear to have an irregular shape.

1.4 The planets

Just when you're sure you have the brightest stars memorized, a bright interloper will come along and confuse the star pattern. Chances are, it's a planet. If you have a telescope, any telescope, set it up and see what it does to the planet. It may show it in a phase like the Moon, or it may show that the planet is itself surrounded by a retinue of moons. The planet may even have rings. If you're seeing rings around it, the planet you're watching is Saturn. Planets will have high priority on your observing list. Among other activities suggested in the next chapter, following the planets on their annual treks among the constellations can be an engrossing activity.

1.5 Celestial co-ordinates and measurements

Leslie C. Peltier, one of the most famous amateur astronomers of the twentieth century, once wrote of going from the excitement of figures on a printed page to a comet in the sky. To share that excitement, we need co-ordinates to read the road map of the sky. Like the Earth, the sky has been

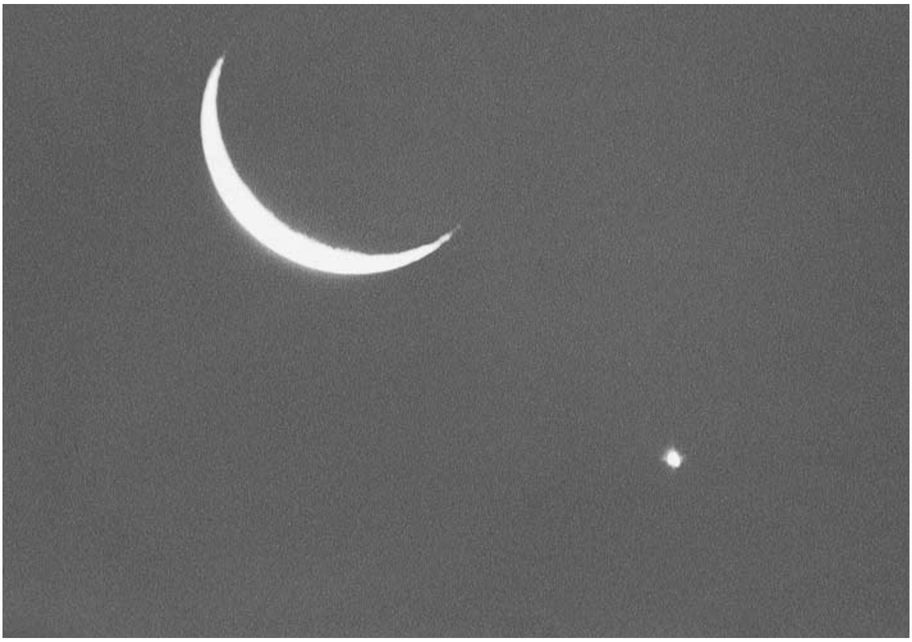

Figure 1.1. The Moon and Venus. Photograph by David H. Levy.

outfitted with a set of co-ordinates called right ascension, corresponding to longitude, and declination, corresponding to latitude. Although you do not really need to know about these to get started on astronomical observing, an understanding about how they work will aid your searching for new objects, especially when you use star atlases.

Right ascension (RA) is simply an extension of longitude into the sky. Just as there are 24 time zones on Earth, all measured according to longitude, the sky has been artificially divided into 24 hours of right ascension, and each hour successively divided into minutes and seconds. Thus, one coordinate of an object might be listed as RA 18 hours 47 minutes 22.7 seconds.

The sky is also divided into degrees of declination with zero at the celestial equator and continuing northward to plus 90, and southward to minus 90. Each degree is divided into 60 minutes, and each minute into 60 seconds, so that an object's declination could be 13 degrees 14 minutes 43 seconds. At the equator, a degree of declination is exactly the same as four minutes of right ascension; you can test that by looking at a star on the celestial equator with an eyepiece that gives a one-degree field. It will drift through your eyepiece field of view in four minutes. However, if the star is not near the celestial equator, the four minutes it drifts will not correspond to what to what you see in your eyepiece field of view. Remember that minutes and seconds of right ascension (minutes and seconds of time) take about 15 times more sky than do those of declination (minutes and seconds of arc).

When you see these co-ordinates printed in the sky atlas, you'll also see a year attached to them – usually 2000 or 1950. This is the *equinox* to which the charts are set. It's not something you need to worry about unless one of two things happen: one, you get a telescope mount with setting circles; and two, you try to locate a newly discovered comet in your telescope using the printed positions provided by a magazine, or from a computerized star chart.

Equinox 2000.0 means that the charts are exactly right for the year 1999.95 to 2000.05, a period of time lasting about three days. They change slightly because of a slow wobble that the Earth has, a wobble caused by the constant pull of the Moon's gravity on the Earth. It is the same effect that causes the apparent position of the celestial poles to change over very long periods. When the northward pointing edges of the Egyptian pyramids were aligned towards the pole, 26 500 years ago, Thuban in the constellation of Draco was at the pole. Thousands of years from now, Vega will be our pole star.

If you use your telescope setting circles, they will be accurate to the date of your observations. For atlases set to 2000.0, the correction is very small and not really to be worried about. If your atlas is set to another of the popular equinoxes, like 1950 or 1855, the correction is far larger, a matter of degrees. Moreover, this correction is not always the same. It depends upon how far you are from the North celestial pole, and typically could be a couple of degrees every 50 years.

When a newly found comet or nova is announced, its positions are published to a particular equinox, like 1950.0 or 2000.0. Say that on March 23rd, 2000, for example, you observe a new comet at right ascension 19 hours 40.8 minutes, and declination −15.6 degrees. If your atlas is also set to equinox 2000.0, you have no adjustment to make; simply mark the position of the comet on the page of your atlas using the co-ordinates, and look for the comet. But if your atlas is set to 1950, the positions will be off by a couple of degrees. It is far easier to have everything in the same equinox.

1.6 The star charts

The following charts are designed to point out the basic constellation patterns for someone just getting started in a celestial journey. As you get more familiar with the sky, you'll benefit from one of the many fine star atlases commercially available.

Figure 1.2. Northern winter evening sky as seen from a suburban location. Stars shown to magnitude 4.5.
These star charts were created by the author using Epoch 2000 Sky Software, and are included by kind permission of Meade Instruments Corporation.
To use these charts, face the southern horizon and hold the chart over your head. North is at the top, East at the left.