Chapter 1 Charting the Heavens

Our Place in Space

Since man has been around, he has thought of himself in the middle of it all. As time has moved on, we have come to realize that we are on an ordinary planet, just 1 of 9 that orbit our Sun, which is an ordinary star. Our Sun is found 28,000 ly from the middle of our galaxy, which is 1 of billions of galaxies out there.

Our solar system is connected to the rest of the universe due to the fact that most of our solar system is made up of elements that were produced inside of massive stars that ended their lives with huge explosions that spread the material out into space. Eventually material condensed into our solar system some 5 billion years ago.

We now study the *universe* which is all space, time, matter, and energy. Everything! *Astronomy* is the study of the universe. What we know in astronomy has changed as over time due to what? When you go to a dark location, Payson maybe, and you look up and see all those stars, realize that they are all in our galaxy, the Milky Way. There are probably 200 billion stars in the Milky Way. It is 100,000 ly across. A *light year* is a unit of distance; light moves at about 186,000 miles per second. So if you multiply 60sec/hr x 24 hr/day x 365 days/year x186,000 miles/sec you would find that light moves almost 6 trillion miles per year. The Earths 8000 mile diameter is about $1/20^{th}$ of a light second.

Due to the enormous size of the numbers we use, the book will use scientific notation to make it easier. For example, the 200 billion stars of the Milky Way can be written as 200,000,000,000 or $2 \times 10^{11}$.

Scientific Theory and Scientific Method

Our earliest thoughts of the universe were based on mythology and imagination when the ancient people looked into the sky. As people watched more closely, ideas changed and new ideas took their place. People started to search for knowledge of nature. They formed a *theory*, which simply tried to explain why things happened the way they did. If observations and experiments supported the theory, it can be developed further. This eventually ended up as the *scientific method*. This is a way to solve problems in science. Modern theories share several characteristics: testable, continually tested, simple, and elegant (when a theory ties together several phenomena thought to be distinct, it makes it stronger).

The birth of modern science is usually associated with the Renaissance in the $14^{th}$ to the $17^{th}$ centuries. Although one of the earliest documented uses of the scientific method was with Aristotle. He noted that every lunar eclipse he saw the Earth cast a curved shadow on the Moon. He thought the Earth was round from this. This was his *hypothesis*, or one possible explanation. Observation, theory and testing are the cornerstones for the scientific method.

Constellations in the Sky

When we look out into the night sky we see about 3000 stars. The human eye picks out patterns and the sky is no different. Ancient people picked out patterns in the stars and made up stories about them. These patterns are called *constellations*. They are named for mythological gods, heroes, and animals. One of the most easily seen patterns is

Orion.  Page 3  The patterns have a strong cultural bias depending to their ancient stories.  Orion though is seen as the same basic type of being: a warrior by most cultures.  Early astronomers had a good reason to watch the sky; you could navigate by it (Polaris) or it could be used to plant or harvest by the constellations.  As time went on some people thought that knowing where the planets, the Sun, and the Moon were at your birth would predict how you would become.  These people were *astrologers*.  It is from the astrologers that astronomy arose.

As you look at a constellation, you need to understand that what you see are simply stars that are in our line of sight, as shown on page 9 showing Orion.  There are 88 modern constellations in the sky.  Twelve of these constellations are special.  Why?

The Celestial Sphere

Ancients watched the stars move east to west across the sky, but they never changed their position with each other.  This led them to believe that the points of light were attached to a *celestial sphere*.

We know that the movement of the stars is due to the *rotation* of the Earth on its axis.  Currently Polaris points almost due north for us.  If you extend the Earth's poles out into space, the places where they touch the sky are called the *celestial poles*.  In the north, this is where Polaris is.  Half way between the celestial poles is the *celestial equator*.

When we talk about positions in the sky, we talk in terms of *angular positions* and *separations*.

Day to Day Changes

The easiest way to tell time was to use the Sun.  WHAT TIME OF THE DAY WAS THE EAQSIEST TO DETERMINE?  From one noon to the next was called a *solar day*.  The movement of the Sun and other stars across the sky is called the *diurnal motion*.  If you go out over a period of several nights, you will see that the stars are not in the same position in the sky at the same time of night.  A day measured by the stars is called a *sidereal day*.  A sidereal day is 4 minutes shorter than the solar day.  The reason for this is the fact that we *revolve* around the Sun.  How far do we move in 1 day?

Seasonal Changes

As the year goes by, we notice that the stars we see at night changes.  This is due to our motion around the Sun.  These changes are *seasonal changes*.  As we go around the Sun, the Sun appears to line up with different stars throughout the year.  The constellations that the Sun appears to pass through are called the *ecliptic*.  These constellations are important in astrology because they are the signs of the *zodiac*.  The ecliptic appears to be above and below the celestial equator.  This is due to the fact that the Earth tilts at 23.5° on its axis.

The point where the Sun is at its farthest north position on the horizon is called the *summer solstice*.  This is June 21.  We receive the most direct sunlight at this time in the northern hemisphere.  The days are long.  Six months later it will be at its farthest southerly position on the horizon and that is the *winter solstice*.  This is Dec. 21.  We have less direct sunlight and the days are shorter.  The 2 points where the Sun crosses the celestial equator are the *equinoxes*.  This is when we are supposed to have equal day and night.  These dates are Sept. 21 for the autumnal equinox and March 21 for the sparing (vernal) equinox. The time from one vernal equinox to the next is 365.2422 mean solar days or one *tropical year*.

Long Term Changes

We know that we undergo many movements over time in space. Name them. One of these motions is called *precession*. As our Earth rotates, we seem to wobble in space like a top that is slowing down. Our pole points to a different part of the sky. Currently we are pointing towards Polaris, but that will change as time goes on. It takes about 26,000 years to precess once around the sky. This is due to the gravity of the Sun and the Moon on the Earth.

The time the Earth takes to make one complete orbit relative to the stars is called a *sidereal year*, which is 365.256 days. This is about 20 minutes longer than the tropical year. The reason for the difference is precession. As the Earth wobbles, the point of vernal equinox changes slightly and accounts for the 20 minutes. In 13,000 years, the height of summer will be in February.

Astronomical Timekeeping

As we have said, a solar day is from one noon and the next. Well noon is the time when the Sun crosses an imaginary line called the *meridian*. This line goes from the north to the south passing through the *zenith*, which is the point directly over your head. Why is this bad? As we rotate, we revolve. The rotation rate is constant, but our revolution is not. Our orbit is not circular, but rather an ellipse. This means when we get closer to the Sun we move faster. Also since we tilt, the eastward component of our motion depends on the time of year. This means that the day varies by .5 minutes over the year. That is not bad, but it is unacceptable for astronomical work. That is where we determined the *mean solar day*, or the average day length over the course of a year. Since noon is the easiest time of day to set our clocks by, it means that 50 miles from us when we are at noon, they aren't. In 1883 (due to the railroads) *time zones* were introduced. Since 1884 *standard time* has been used around the world. In astronomy we use an even simpler time, *Universal Time,* which is set to Greenwich, England.

Calendars were soon introduced to keep track of time (Why?) and since a calendar can't represent the year correctly, Julius Caesar introduced the *leap day*, an extra day every 4 years. This was the Julian Calendar. Still it wasn't quite right. It was off by about 11 minutes per year. By the time of Pope Gregory XIII the calendar was off by 10 days. In 1582 the 10 days were put back in and the new calendar didn't have leap days if the year was a multiple of 100, but did if it was a multiple of 400. We currently use the Gregorian Calendar. In 1752 the United States and England adopted it. Why did it take so long?

The Motion of the Moon

Lunar Phases

One of the things that we notice is the fact that the Moon seems to change its looks every night. This all occurs due to the fact that the Moon goes around the Earth. The different phases that we see are all due to the orientation of the Earth, Moon and the Sun. GO THROUGH THE LUNAR PHASES Sometimes we can see the side of the Moon that is in shadow. What you are really seeing is *earthshine*. It is light reflected off the Earth onto the Moon so that the dark side isn't quite so dark

Now the Moon has 2 different orbital periods. One is called the sidereal period. This places the Moon back in the exact spot among the stars. It is about 27.3 days. The synodic period is the time it takes from full to full or any phase back to the same phase. It takes about 29.5 days. The difference is due to the fact that the Earth is going around the Sun while the Moon goes around the Earth.

Eclipses

Every once in a while the Moon or Sun gets covered up in what we call an *eclipse*. There are several types of eclipses.

1) Lunar Eclipse—this is when the Moon enters the Earths shadow. Depending on the alignment, you can have a partial eclipse or a total eclipse. DO DRAWING A lunar eclipse may last as long as 100 minutes.
2) Solar Eclipse—This is when the Moon passes in between the Sun and the Earth. The shadow from the Moon is about 138 miles wide and as long as you are in that shadow you will see the Sun go away. Again, depending where you are you may see a partial or a total solar eclipse.
3) Annular Eclipse—this is where the Moon is farther away from us and can't cover up all of the Sun. You will get a ring of Sun here.

During both Total solar and lunar eclipses there are 2 parts of the shadow that you need to be aware of: the *umbra*, which is the darkest part of the shadow and the *penumbra*, which is the lighter part of the shadow.

Eclipse Seasons

We don't have eclipses every month because the orbit of the Moon tilts slightly with the Earth. It only occurs when the Moons orbit crosses the Earth's plane and is lined up with the Sun. These are called the *nodes*. When this occurs, you have a possibility of an eclipse. It happens twice a year and these times are called *eclipse seasons*. On page 24 you will see the eclipses between 2000 and 2020.

The Measurement of Distance

Distance is one of the harder things to measure in astronomy. One way to measure distance is by *triangulation*. This make up the foundation of the *cosmic distance scale*.

Triangulation and Parallax

Triangulation isn't too difficult. You look at an object and then move some measurable distance at 90° to it and measure the angle formed by the object. Then it is just geometry. *Parallax* is similar to that. We look at an object against the background stars and in 6 months we look again and see ho much it has moved. The angle we get is the parallax angle. This allows us to calculate the distance to the star we looked at. There is a problem. What is it? The largest parallax angle that we have measured is from Alpha Centauri and it is .76°. That is really small. The farther away the object is the smaller the angle.

Sizing Up the Earth

Let's look at how a Greek named Eratosthenes in about 200 B.C. determined the circumference of the Earth. He knew that on the summer solstice the Sun shown straight down a well in Syrene. In Alexandria, some 5000 stadia away to the north, the Sun was displaced slightly and formed an angle of 7.2°. He said that the angle was 7.2/360 of a circle. He said: 7.2/360 = 5000 stadia/Earth's circumference. If you get that you will get a diameter of about 250,000 stadia. A stadium was about .16 km, so you get about 40,000km. the correct circumference is 40,070 km.