Laboratory 3 - Observing the Night Sky and the Celestial Coordinate System

When the Sun goes down, the ancient book of the skies begins to appear. Long before the printing press, before the written word, long before, the stars were the book of the people. The various groupings of stars or constellations reminded the storytellers of the various tales of valor, heroism, terror, and love. Here too were the stories of the Gods, mortals and other beings. Further, if you were only one of the few who knew how to calculate with them, you could navigate a ship on the high seas far from the sight of land and arrive at the right place.

Today, the book of stars is still there, but many people interested in astronomy think that to observe, you need a big telescope. To see some things, to be sure, a telescope is necessary; however if you don't have one, don't think you need to go out and buy one. The best instrument to begin observing the night sky is the eye.

Understanding the night sky's geography and its overall motions are as important in amateur astronomy as knowing how to focus a telescope. You can learn this skill by taking the time to observe the stars and understand what you are seeing.

The point of observational astronomy is not just to look into a telescope eyepiece; it is more a personal discovery of visible space in an orderly process, beginning first with the identification of the Big Dipper and the bright planets. The recognition of the major constellations and brightest stars precedes the ability to identify the less obvious constellations. From this framework, a growing appreciation of the sky's motion due to the Earth's rotation will emerge.

If you had the time and patience (and could stay awake) to watch the night's sky from sunset to sunrise you would see constellation after constellation rising in the east, ascending to zenith and finally setting in the west. They are always there, always in the same place, as if they were plastered on a giant sphere that appears to encircle the earth.

Most of the bright stars (magnitude 2 or brighter, the smaller the number the brighter the star) have names. These names go back before the written word. The names come to us through China, the Middle East, and those writings of the Greeks which survived the burning of the Great Library of Alexandria. So too, have the names for the groupings of the stars, the constellations.

For the most part, we use the Greek names for the constellations and Arabic names for a few of the stars, simply because they were written down and are a part of our history. The Chinese and American Indians had their own constellations, some of which show enough similarity to indicate contact between these civilizations before the dawn of written history.

One constellation which shows both differences and similarities is Ursa Major. Most societies recognize this constellation as the "Great Bear". Within this constellation is an asterism made up of stars that all have about the same magnitude (+2) called (in North America) the Big Dipper. The Chinese identify the same asterism with a wagon or royal coach.

The Big Dipper is such a familiar sight that it is a good place to begin observing the stars. Figure 1 is a sketch of the Big Dipper. The circle is simply to help define what you're looking at; it does not define a scale. The dimensions of the field are given by the scale in degrees of arc.

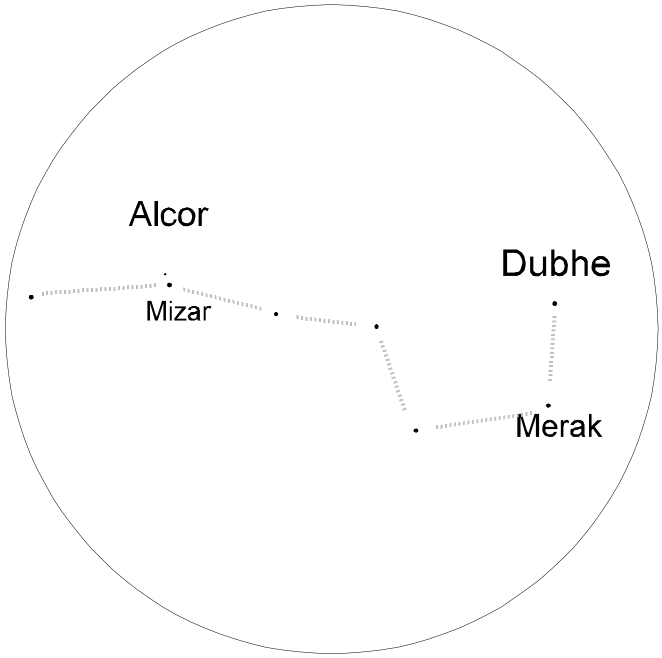

Figure 1 - The Big Dipper in Ursa Major

Most of the stars in the Big Dipper are part of the Ursa Major Cluster, a group of about 101 stars all moving in the same direction and within a sphere with a radius of 6.5 parsecs. Dubhe is not one of those stars, although it lies within that sphere, for it is moving in a slightly different direction from the rest of the cluster.

I've included names for four of the stars simply because the names are handy to use. Find Alcor and Mizar (Native Americans call them horse and rider). If you can see both of these stars, the night is a good night for "seeing" other stars. Mizar (itself a pair of stars only separated with a telescope or spectroscope) is the brightest of the pair at a magnitude of +2. Alcor, it's fainter optical companion, shines at magnitude +4. So, when you go out too look at stars, check this pair first. If you can see both stars clearly, you know you can see one fourth magnitude star, and probably see some fifth (fainter) and possibly even some of the faintest sixth magnitude stars. Stars fainter than sixth magnitude can be seen only with binoculars, telephoto lenses and telescopes.

Incidentally, the distance between Alcor and Mizar is about ten thousand times the distance between the Sun and Pluto. While they may orbit around each other, it would take a few million years for one orbit of Mizar and Alcor. You decide if they constitute a binary star system. Locate the other two named stars in Figure 1 and then locate them in the sky when you go out. Merak and Dubhe are the pointer stars to the North Star, Polaris.

Mentally, draw a straight line from Merak through Dubhe and extend it outward five times the distance between Merak and Dubhe. The only magnitude +2 star that you find in the area is Polaris.

Merak and Dubhe are also two standard stars in the fact that they are just slightly more than five degrees of arc apart. Map 1, from Wil Tirion's "The Bright Star Atlas 2000.0", shows Merak (β UMa) and Dubhe (α UMa) along with many other stars not shown on the normal textbook sky chart. Most of these are fainter than magnitude +6 and are not visible to the naked eye.

Long ago astronomers plotted a network of grid lines on our celestial sphere - or sky - that are similar to longitude and latitude on the earth. Respectively, they are called ***Right Ascension*** and ***Declination***. If you extended the Earth's axis in both directions out to the celestial sphere, the points where they touch become the north and south celestial poles. If you were to stand on the exact point of the Earth's north pole, for example, the north celestial pole would be at your zenith (that is, directly overhead). By similarly extending the Earth's equator out to the celestial sphere you are defining the celestial equator.

Just as there is a celestial equator, there are also corresponding celestial "latitude" circles, representing declination, running parallel to it and numbered the same way as its terrestrial counterparts: 0° of arc at the equator up to 90° of arc at both poles. However, where terrestrial latitude is described in degrees north or south of the equator, declination is expressed in degrees + or - in relationship to the celestial equator.

Each degree of declination is further broken up into 60 arc minutes and each of those minutes is divided into 60 arc seconds. This permits a rather exact means of locating objects on the celestial sphere. To give you an idea of how exact this might be, hold up your index finger at arms length. If held up against the sky the width of the tip of your finger would cover about 1 degree of arc. Now if you chopped your finger, lengthwise, into 60 equal slices, each one would cover 1 arc minute. And finally, slice the slices into 60 equal slivers. Each sliver would cover 1 arc second of sky. If you haven't passed out at the thought of mutilating your finger, you might now realize how small some celestial objects are and that the celestial sphere is extremely large.

Explaining the celestial equivalent of longitude, right ascension, is not quite as simple as the explanation for declination. Terrestrial longitude is measured in degrees ($^\circ$), minutes ($'$), and seconds ($''$) of arc east and west of an arbitrary prime meridian (0°) which runs through Greenwich, England and is numbered up to 180° at a point in the Pacific Ocean on the other side of the Earth that is directly opposite Greenwich. Remember, these are the long lines that run in circles from pole to pole.

Right Ascension, on the other hand, is numbered in _hours_ (^{h}), minutes (^{m}) and seconds (^{s}) of time eastward from the point where the sun crosses the celestial equator at the beginning of northern spring. This point is called the Vernal Equinox and is designated 0^h (zero hours) right ascension. Right ascension hour values are based on star time, or Sidereal Time, which is slightly different than the time on your wrist watch. Sidereal time runs four minutes faster per day than the solar-based civil time we live by. In fact, when the Earth exactly completes one rotation on its axis, it represents the passage of one sidereal day, which is 23 hours and 56 minutes by our watches. However, since the Earth has continued travelling around the sun in its curved orbit during this time, the Sun's position against the sky has shifted slightly eastward - (nearly one degree) - so the Earth must rotate a bit more - the equivalent of four minutes - to present the same face to the Sun again. The extra four minutes added to the sidereal day gives us our 24 hour day.

In any case, these hour circles of sidereal time serve as the celestial equivalent of longitude and are used, along with declination, to precisely specify a celestial body's position in the sky. That is, the position where the two lines intersect is the locating coordinate. For example, the brightest star in our sky, Sirius, is located at $6^h\ 45^m\ 09^s$ right ascension, and $-16^\circ\ 42'\ 58''$ declination. It is located on one of the attached maps. Can you find it?

Now, lets try out your map reading skills. The attached star maps represent parts of the sky that can generally be seen during the spring semester. On Map 1 right ascension is indicated on the top, right and bottom of the map. It is marked off in increments of 5 minutes. Declination is shown on the left side of this map, since almost the entire circle of declination can be seen. Declination is marked off in 1 degree increments only on the line of right ascension located at 6^h. On Map 4, however, right ascension is indicated at the top and bottom of the map, again in 5 minute increments and declination is shown at the left and right side of the map in 1 degree increments. For our purposes, you are asked to give coordinates in hours and minutes of right ascension and to the nearest degree of declination.

The small dotted lines that run in straight lines and make several right angle turns are the ***Constellation Boundaries***. The name of the constellation is printed somewhere within the boundary lines. The larger dotted curved line on Map 4 is the ***Plane of the Ecliptic***. The line of dashes and dots located on both maps represents the ***Galactic Equator***.

The "see through" key provided with this lab contains examples of the dotted lined discussed above, as well as other symbols that you will need to answer the questions. They will help you discover a stars **Magnitude** and **Type**, determine a **Cluster** and **Nebula Type** and identify what a **Galaxy** symbol is.

Question 1: What are the coordinates of the two points where the Galactic Equator crosses Map 4?

Question 2: What are the coordinates of the two points where the plane of the Ecliptic crosses Map 4?

Question 3: What are the coordinates of the center of the Andromeda Galaxy (M31) located in the constellation Andromeda?

Question 4: How many open clusters are located completely or partially in the constellation Cassiopeia?

Question 5: How many stars of magnitude 2 or greater exist in the constellation Ursa Major?

Question 6: What kind of object is located at 11^h 15^m, $+55^\circ$? What is it's name?

Question 7: What type of star is located at 5^h 55^m, $+7^\circ$? What is it's magnitude? What is it's name? What constellation is it in?

Question 8: What are the coordinates of the Great Orion Nebula (M42)?

Question 9: What kind of object exists at 5^h 47^m, 0°? What is it's name? What declination circle is it located on?

Question 10: The Eskimo Nebula is also known as NGC 2392. It is a Planetary Nebula. What are it's coordinates? (Hint: Map 4)

Question 11: What are the coordinates of Merak? (β UMa); of Dubhe? (α UMa)

While it might seem a little more confusing than the Earths Latitude/Longitude system, when we go outside to view some of these celestial objects through the telescope, you will be shown how these coordinates are utilized on modern day telescopic equipment. The term ***Setting Circles*** will be used. There is a setting circle for right ascension and one for declination. Once the telescope is properly aligned to the north celestial pole, and a known star is then centered in the scope, its coordinates will be "dialed in" to the right ascension setting circle. The declination circle should be correct since it is pretty much adjusted during the polar alignment process. Once done, the telescope will be rotated on it's right ascension and declination axes to locate objects visible in the night sky. You will also see why some objects can't be seen at a given time, since the Earth or Sun might be in the way.

The circles below are for you to sketch in two more constellations that appear on the maps. Indicate their names, the names of any prominent stars and a scale to indicate the approximate separation in degrees.

Name ____________________

Date ____________________

Name ____________________

Date ____________________