Night Observing Project I

OBSERVING THE NIGHT SKY – THE CONSTELLATIONS

Note - bring a pencil, eraser, a star chart/wheel/planisphere, and this exercise packet.

A. Objectives

- Learn to identify the major constellations that are visible.
- Learn how to use a star chart to identify the brighter stars, and constellations.
- Learn about the coordinates astronomers use to navigate the night sky. Learn how to locate Polaris.
- Using a pair of binoculars or a small telescope, and your hand as a measuring device, find a few of the brighter star clusters, galaxies and double stars, etc.
- Learn of the lore of some of the names of the constellations. These tales are the link between the sky and our cultural heritage.
- Calculate your latitude by measuring the Altitude of Polaris above the northern horizon.
- Measure the Declination and Hour Angle of a few bright stars and planets.
- Verify that the apparent movement of the star parallels the passage of time.

B. Introduction

With even the simplest of equipment, it is possible to measure one's position on the Earth and to mark the passage of time. Indeed, these were the first chores of early astronomers. The movement of celestial objects across the sky defines our concept of time: the Sun rises in the East in the morning and sets in the West in the evening. The sky acts as a giant clock, marking the passage of days and the progression of the seasons. We all *know* that the stars appear to move across the sky as the Earth rotates, but too few people actually have *watched* this happen. One purpose of this exercise is to use simple measurements of the nighttime sky to deduce your location on the Earth and to see the celestial sphere move overhead.

The Celestial Sphere

Ancient astronomers believed that the Earth was at the center of an enormous *Celestial Sphere,* to which the stars, Sun, Moon and planets were fixed. For purposes of finding one's way around the sky, this simple *model* for the universe is still quite satisfactory, and most modern astronomical coordinate systems are based on this ancient concept.
Thus, celestial globes, the planetarium and the "celestial pipes" in our observatory are all convenient spherical representations of the sky as seen from the Earth.

In order to specify the location of a star on the celestial sphere, it is necessary to establish a suitable coordinate system. Astronomers most frequently use the **Equatorial System**, in which the East-West position of a star is given by the **Right Ascension** and the North-South position by

Declination. This system closely resembles the latitude and longitude system of terrestrial coordinates and specifies the position of a star relative to all the other stars.

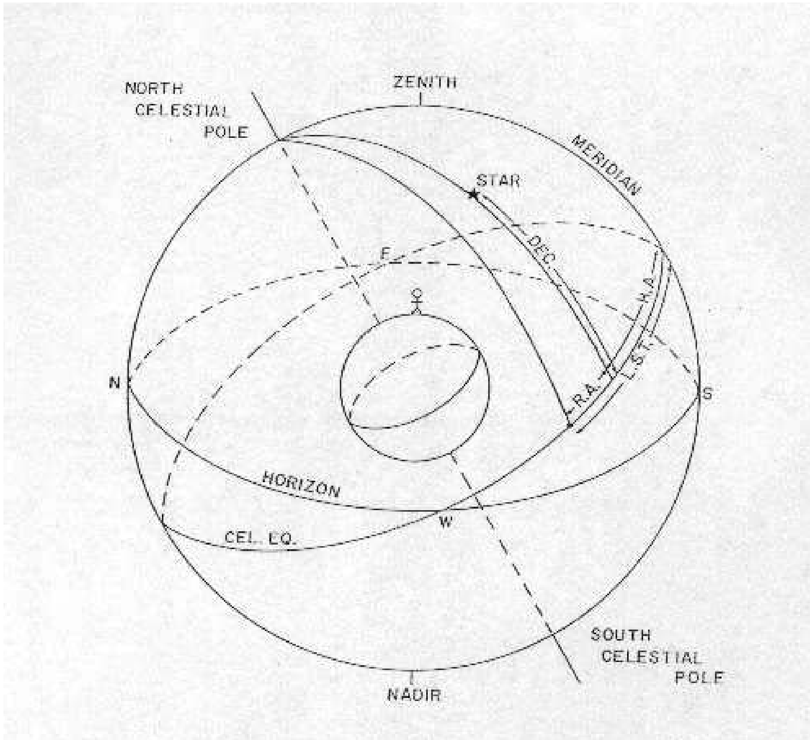

Figure 1 – Equatorial Coordinates

Finding stars on the celestial sphere is complicated by the fact that the Earth is continuously rotating, which causes the stars to move. We need an additional coordinate for measuring time. This is created by constructing, in our imagination, a line on the celestial sphere that joins the **North** and **South Celestial Poles** through the **Zenith**. This imaginary circle, called the **Meridian,** is fixed relative to any one observer, and the stars pass across the meridian as time progresses. Thus, the sky becomes an enormous clock. Our concept of time is based on the daily motion of the Sun, Moon and stars across the sky.

The celestial sphere with the equatorial coordinate system as seen by an observer at about 40° North latitude on the Earth is shown in Figure 1. The various terms used in Figure 1 are defined in the following paragraphs.

a. Celestial Equator - The great circle on the celestial sphere that is a projection of the Earth's equator. It passes through the **Zenith** for any observer on the Earth's equator.

b. Celestial Poles - The projection onto the celestial sphere of the North and South poles of the Earth mark the axis about which the celestial sphere appears to rotate.

c. Declination - This is the angle between the celestial equator and any star measured North or South along a line of constant right ascension.

d. Horizon - The great circle on the celestial sphere which divides it into two hemispheres, the upper, visible hemisphere and the lower one hidden by the Earth.

e. Hour Angle - This is the angle between a celestial object and the **Meridian,** measured along the celestial equator. The Sun's hour angle is the measure of ordinary time shown on clocks.

f. Local Sidereal Time - The sidereal time is defined to be the hour angle of the **Vernal Equinox**. This is equivalent to saying that the sidereal time equals the right ascension of the stars just crossing the meridian. The sidereal time can be used to find the location in the sky of any object if its right ascension is known, through the formula:

H.A. = L.S.T. - R.A.

H.A. = hour angle,
L.S.T. = local sidereal time,
R.A. = right ascension

g. Meridian - This great circle passes through the North and South celestial poles and the observer's **Zenith**. It is fixed relative to the observer; the celestial sphere appears to rotate past it.

h. Right Ascension - The East-West position of a star, measured eastward along the celestial equator from the **Vernal Equinox,** is the right ascension.

i. Vernal Equinox - This is the starting point on the celestial equator of the measurement of right ascension. One could start measuring R.A. anywhere along the celestial equator (at a bright star, for example), but the vernal equinox also happens to be the location of the Sun on the first day of spring. The date on which this occurs (usually March 21) is also called the vernal equinox.

j. Zenith - The point in the sky directly above the observer is the zenith.

k. Nadir - The point in the sky directly below the observer is the nadir, thus the opposite of the zenith.

l. Great Circle – A plane defined to slice any sphere in two and also pass through the sphere's center.

The **altitude** of the North Celestial Pole (NCP), that is, the angle the NCP makes with the horizon, is equal to your latitude on the Earth. At the present time, the star Polaris is close to the NCP (less than 1° away) and provides a convenient reference point for measuring latitude.

The measurement of a person's longitude on Earth is substantially more complicated. Until the 17th century, mariners had to rely on guesswork and dead reckoning to estimate how far they had traveled in an East-West direction. When good clocks were built, sailors could set the clock to the time at their home port, and then by measuring the *observed* time of local noon (i.e., when the Sun crosses the celestial meridian), the difference between the local time as measured by the

Sun and the standard time reveals the longitude difference between their present location and their home port.

Many of these concepts can be demonstrated using the celestial pipes located on the deck next to the rooftop observatory. When you stand under the celestial pipes, you should first identify the small cross-bar on the North to South pipe representing the celestial meridian. This cross-bar locates the north celestial pole, and Polaris should be very close to it. Looking in the opposite direction you should be able to identify the pipe representing the celestial equator. Note that every 10° of declination is marked on the meridian pipe and every hour of hour angle on the celestial equator pipe. With this simple arrangement, it is possible to estimate the approximate positions of stars and planets.

The Constellations

The place to begin your study is to look at the sky the way ancient astronomers did, by fitting the stars into patterns that can be used to delineate regions of the sky from one another. The constellation of Pegasus makes a nice square, though a rather poor representation of a winged horse. It takes some imagination to turn Cassiopeia from a W-shaped figure into a queen. Most of the constellations we now recognize were familiar to the Greeks of 2000 years BC; Ptolemy in his great treatise (the *Tetrabiblos*) identified 48 constellations. The most important of these were the 12 constellations of the zodiac, which is the path the Sun and planets follow around the sky.

The constellations were organized into a series of star charts by Bayer in 1603 in his *Uranometria*, which consisted of a series of maps of the sky, with magnificent drawings of the figures of the constellations overlying the stars. In addition to its artistic value, the *Uranometria* served as a star chart suitable for locating stars in the sky. Bayer also introduced another new idea, labeling the brighter stars in each constellation with letters of the Greek alphabet. Thus the brightest star in each constellation he called α (alpha), the second brightest, β (beta), and so forth. These designations have been retained, so that the star Sirius is also called α Canis Majoris, since it is the brightest star in the constellation Canis Major (the Great Dog).

Bayer regarded the constellations as convenient designations for various regions of the sky. Modern astronomers continue to do so for the same reason, dividing the sky among constellations. The International Astronomical Union, the principal association of the world's astronomers, recognizes 88 “official” constellations across the entire sky. The IAU boundaries of the constellations are strictly defined, so that every star is assigned a specific constellation.

The circumpolar constellations - You may begin your exploration of the constellations in the North, starting at the North Star, Polaris. This is a moderately bright star located at the end of the “handle” of the Little Dipper (or **Ursa Minor**) and is less than one degree from the North Celestial Pole. An easy way to find Polaris is to start with the familiar constellation of **Ursa Major**, better known as the Big Dipper. The two stars that mark the far side of the bowl, on the side away from the handle, point almost directly to Polaris, at a distance about 5 times the distance between the two “pointer stars.”

The Big Dipper may not be observable from our urban observatory throughout the year, so we need another guidepost to locate Polaris. Opposite the Big Dipper from Polaris, you will find the well-known constellation **Cassiopeia**, which has the appearance of a giant "W" in the sky. Use the bright, inner stars of Cassiopeia's "W" to sweep out an arc pointing to Polaris, approximately 6 times the distance between those inner, bright stars.

Proceeding counterclockwise around the pole from Cassiopeia, you will find **Cepheus** and then **Draco**, both rather large constellations, but with no distinctive pattern of bright stars, then Ursa Major (the Great Bear) of which the Big Dipper is the most prominent part, and finally **Camelopardis**, another poorly defined constellation.

Constellations of Autumn - Overhead in the late summer and early fall you will find the prominent constellations **Cygnus** (sometimes called the Northern Cross or the Swan) and **Lyra**, dominated by the bright star Vega. Somewhat to the South of these two is **Aquila** (the Eagle) with the bright star Altair. Vega, Altair and Deneb (the brightest star in Cygnus) form the "Summer triangle."

Rising in the East is **Pegasus**, part of which appears as a large square. However, the northeastern most star of the square is actually the beginning of the **Andromeda** constellation, which extends northward and eastward. If you observe Andromeda from a truly dark location, you will just be able to see a fuzzy spot that is the great galaxy of Andromeda - the only object viewed with only your eyes outside of the Milky Way! Located in the cradle of the constellation's bright stars, the Andromeda galaxy is large member of our Local Group of galaxies. To the Southeast is the constellation **Aquarius**.

The Winter constellations - As we move into the winter sky, we find what is perhaps the most recognizable of constellations - **Orion**, the hunter. Orion dominates the southern sky through the winter into the spring. It is identifiable because of the three bright stars in a row, considered to be the belt of the hunter. To the north and a little east of Orion's right shoulder, is the bright star Betelguese, which is distinctly red in color. Below the belt and to the west is another very bright star, Rigel, which is almost blue in color. The Orion nebula, a giant gas cloud within which hundreds of stars are forming, is easily visible using a small telescope or binoculars.

To the southeast of Orion is the brightest star in the sky, Sirius, the Dog Star. Sirius was sacred to ancient Egyptians, because when the star is first seen every year rising in the East just before the Sun (an event which takes place in July) it was a signal that the Nile river would soon flood, bringing needed nutrients and moisture to their farms. Sirius is usually represented as the eye of the great dog (**Canis Major**). Above Sirius is another rather bright star, Procyon, located in the constellation **Canis Minor**, the little dog.

To the west of Orion and a little North, is another reddish star surrounded by a number of rather faint stars in a "V" shape. (In the city, it may take a pair of binoculars to see these faint stars). This star, Aldebaran, is the eye of **Taurus**, the bull, one of the most important of ancient constellations. The faint stars surrounding Aldebaran form the star cluster called the Hyades, the nearest star cluster to our solar system. Another important, and probably better known, star cluster is located in Taurus - the Pleiades, commonly known as the seven sisters. A traditional test of eyesight is to try to see seven of the Pleiades – a challenge in our urban environment

Considerably to the North of Taurus is another bright star, Capella, located in the constellation **Auriga**, the charioteer. To the west of Auriga is the weakly defined, but large constellation of **Perseus**. Perseus was famous in Greek legends for slaying the Gorgon Medusa, and rescuing the beautiful Andromeda, whom he found chained to a rock about to be eaten by a sea-monster.

To the East and a little South of Auriga is the constellation **Gemini**, the Twins. This constellation is delineated by a pair of bright stars, Castor and Pollux (which are also the names of the two twins who were sons of Jupiter).

Less obvious constellations visible in the winter sky are **Cancer** the crab, **Lynx**, the river **Eridanus** and **Monoceros** the unicorn. These will require binoculars to find!

Even in Boston, you should be able to identify quite a few constellations with the help of the instructor and a star chart. When you try to find a constellation, it isn't necessary to pick out all the stars - simply trace out the basic pattern made by the more prominent stars. A few of the brighter objects can be seen without a telescope in a dark location, but in modern cities, even the brightest of star clusters and nebulae require some optical aid. However, with a pair of binoculars, there are a number of clusters, nebulae and a few galaxies that can be seen, even in the city.

Table 1 - Celestial Objects visible with Binoculars

Object	Constellation	Season	Description
Messier 31	Andromeda	Autumn	Nearest major galaxy
Messier 15	Pegasus	Autumn	Globular star cluster
h and χ	Perseus	Autumn	Double open star cluster
Messier 34	Perseus	Autumn	Open star cluster
Messier 36	Auriga	Winter	Open star cluster
Messier 42	Orion	Winter	Gaseous nebula
Hyades	Taurus	Winter	Open star cluster
Pleiades	Taurus	Winter	Open star cluster

It is possible, even without any optical aid, to deduce something about the physical properties of stars. If you look carefully at some of the brighter stars, you will see that they differ in color - some stars have a distinctly reddish color, while others will appear almost blue-white. The color effects are the result of temperature differences among stars. A star like the sun will appear yellow in color, whereas a cooler star will appear somewhat red, and a very hot star will appear a brilliant white or almost blue-white. Astronomers have developed quantitative ways of measuring the colors of stars and relating those colors to their surface temperatures. Thus by examining the colors of stars, you are doing a simple analysis of their surface temperatures.

C. Procedure

1. Orient yourself - Begin your survey of the sky by locating the North Star (Polaris). Your instructor will demonstrate the celestial pipes to you. The use of this instructional tool and your hand at arm's length as a measuring device will assist you in locating objects in the night sky.

Once you have located Polaris, you can orient your star maps to find other objects.
Indicate on your diagram the approximate altitude of Polaris above the northern horizon.

On your data page, sketch the Big Dipper including the pointer stars as they appear in relation to Polaris at the present time. If the Big Dipper is not visible due to its low altitude, use the constellation of Cassiopeia instead.

2. Constellations - Your instructor will lead you in a tour around the sky, pointing out the locations of the principal constellations and describing some of the folklore and astronomical points of interest about each.

List the constellations your group is able to locate on your record sheet. In the second column, list which prominent stars and other objects you observed for each constellation. Be sure to note the weather conditions at the top of the first data page.

If the night is clear, and you are diligent, you may be able to find some of the less prominent constellations that are located between the major constellations. Be sure to make use of the binoculars available to assist you in seeing the fainter stars.

3. Determine Limiting Magnitude - Your instructor will point out a constellation with a large variety of stellar magnitudes. The constellation should be located high above the horizon, where Earth's atmosphere cannot dim the star's brightness. Your task will be to determine which star is the faintest you can see for the evening. Identify the star, its magnitude, and constellation then note the information on the data page. Use the proper name, Bayer letter (a Greek letter identity) or Flamsteed number to identify the star.

4. Optical Observations - Observe as many objects as time and circumstances allow.
Some observations may not be possible because of weather conditions, or due to the object simply not appearing above the horizon at lab time.

i) There will be several pairs of binoculars available for you to use to examine the sky. With the help of the instructor, try to locate a few such objects. The instructor will guide you to the objects by *star hopping* from bright stars and patterns to the place the fainter object is located. Remember this *path* to the object. List objects you have seen on your record sheet, and record their appearance. Use the opposite side of the data sheet if you need more space for your observations.

ii) In addition to the binoculars, there will be several telescopes pointing to various planetary bodies, the Moon, and other objects. Look through them and list the objects you observed and note their appearance.

iii) Indicate in which general area of the sky each object is located and determine the constellation for each. Note distances between the objects, as described above.

iv) Indicate, in the appropriate places in your data page, which objects you were *not* able to observe.

The Moon – If it is up in the sky during your rooftop visit, compare the view near the lunar **terminator** (the day/night boundary of the Moon) with that near the **limb** (the daylight edge of the Moon). Examine the view with different magnifications by viewing alternately through the telescope and the finder telescope (the smaller spotting scope mounted on the side of the main telescope). Write appropriate comments on the data page comparing and contrasting your observations.

Planetary Observations - Can you see any surface detail on the planet? What is the dominant color of the planet? Are there any satellites visible? How do there appear? Sketch the satellites in relation to the parent planet.

Star Clusters - Estimate the number of stars in the cluster. Think about what makes the faintest stars in the cluster different from the brightest ones. What is the shape of the object? Can you resolve many stars or does the object look like a fuzzy blur? Are the stars evenly distributed across the cluster or is there clumping? Write comments on data page.

Nebulae, Galaxies - Use the lowest magnification possible for observing nebulae and galaxies. Describe the shape of the object. Can you see any spiral structure? Can you see any colors? Is it uniformly bright or are there brighter regions than others? Write comments on data page.

Other Objects - From time to time there may be other objects of interest to view - Comets, asteroids, novae are all possibly visible. Orbiting satellites, airplanes, and even birds cross your field of view when observing. If there are any such serendipitous objects, be sure to observe them and record what you see. Write comments on data page.

5. Determine the position of a Planet or the Moon - Stand under the celestial pipes, making certain that you are exactly in the center of the structure.

Locate a bright star near the celestial equator, the Moon or a planet, if any are visible. Estimate its hour angle, declination and the *time* of the observation. (Don't forget to record what kind of time it is, e.g., EST or EDT). Note the objects' positions on your data page.

Try to determine in which constellation the object is located. (If the night is too hazy, this may not be possible - if so, indicate this on the data page.)

6) Determination of latitude - Use a quadrant to measure the altitude of Polaris above the northern horizon. You will need the assistance of a partner for this part of the exercise.

A quadrant is a device that measures the altitude of an object. The quadrant consists of a protractor with the base affixed to a long stick. From the apex of the protractor hangs a weighted string, which serves to measure angles.

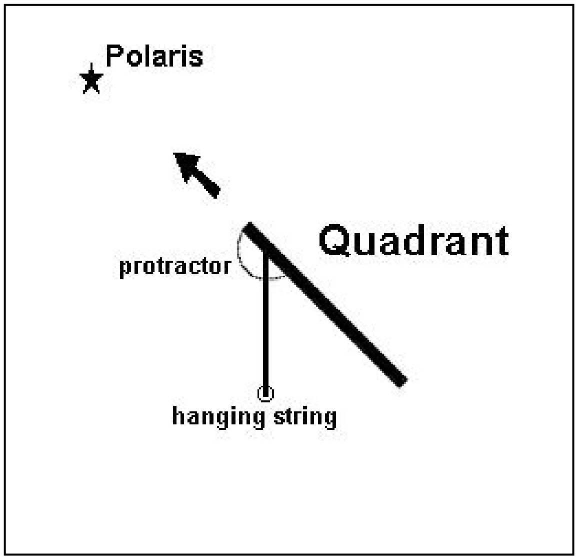

Figure 2 – Quadrant

Hold the quadrant so that the protractor's scale is directed towards the ground as the weighted string swings across the protractor's scale. The straight edge of the stick or the base of the protractor should be directed at the object of interest. As one person sights along the straight edge of the quadrant's stick towards Polaris, the partner steadies the swinging string against the protractor's scale. After the string is steady and not swinging, measure the angle on the scale. Remember, we wish to measure the angle formed between the straight edge and the vertical string. Note that there are two scales on the protractor. We are measuring an angle less than 90° that being the angle formed along the straight edge and the hanging string. The altitude of the object is the co-angle, which is 90° minus the measured angle.

Write down the angle measured in the data page. Repeat this measurement several times, switching partners between measurements. Remember to find the altitude of the object for each measure (subtraction involved) and then average the results to get a final answer.

7. In-depth study of a constellation - Choose one constellation for further study (presumably one of the brighter, well-defined ones).

Draw a *careful* sketch of the constellation, using a pair of binoculars if necessary to pick out the fainter stars. A convenient and effective way to gauge the relative separations of stars is to hold your hand out and use your fingers, your fist or the palm of your hand as a ruler. Note the scale of your constellation drawing by sketching a small hand in the corner of your figure.

Mark the locations of any non-stellar objects, such as star clusters, nebulae or planets located within the constellation. Be sure to indicate the direction to Polaris (North) on your chart. It is best to use a pencil with a good eraser for this sketch.

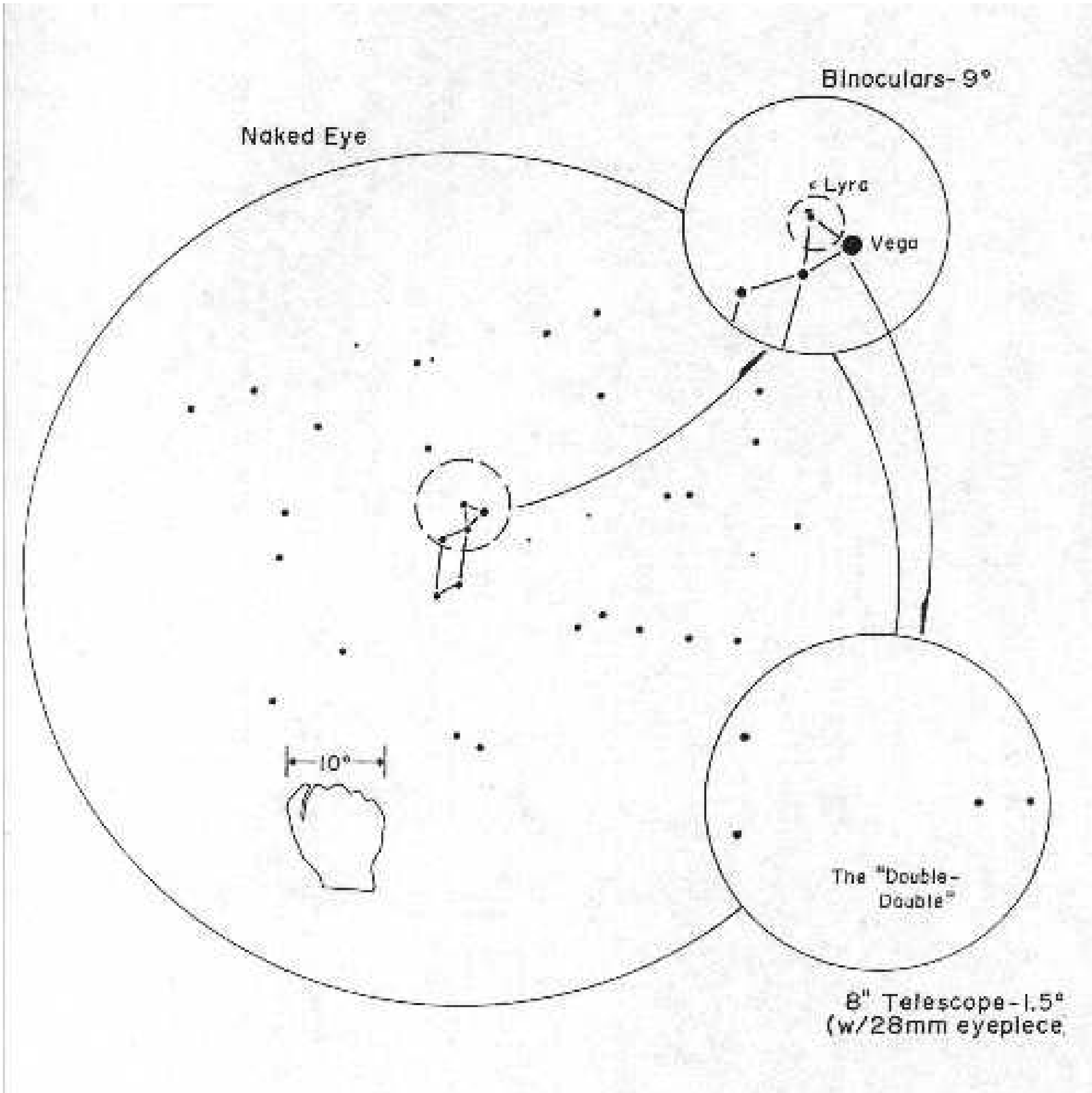

Figure 3 - Field of View Comparison, Lyra (Fall)

Data Page - Constellations - Night Project #1

Only hand in the following stapled pages for credit.

Instructor's Initials	Your Name	Date	Section/TF

Observing Conditions:	
Starting Time	
Ending Time	
Wind	
Temperature	
Sky Conditions (clear, cloudy, hazy, etc.)	
The Moon (phase and location)	
Additional Comments	

1) Stars around Polaris:

Polaris

Northern Horizon

Data Page 2 – Constellations

2) List of constellations located:

Name of Constellation	Prominent Stars and Objects
•	•
•	•
•	•
•	•
•	•

3) Limiting magnitude:

- Constellation –
- Faintest Star –
- Magnitude –

4) Optical observations:

Object Name	Naked Eye (N), Binoculars (B), or Telescope (T)	Constellation	Description
1.			
2.			
3.			
4.			
5.			

5) Determine the position of a planet or the moon:

	Object	Declination	Hour Angle	Time
1.				
2.				
3.				

6) Determination of your latitude:

Altitude of Polaris	First Measure	
	Second Measure	
	Third Measure	
	Fourth Measure	
	Fifth Measure	
	Average	

Data Page 3 – Constellations

7) Constellation Map:

Constellations – Questions

1) Were you able to locate any stars that show a distinct color? List some of the colors seen.

2) Which color of star corresponds to cooler stars, and which to hotter ones? Explain your reasoning.

3) In what way did, or would, the presence of the Moon affect your observations?

4) Did the sky conditions influence the Moon’s appearance? Explain how.

5) What was the phase of the Moon? (You must answer this question even if you did not view the Moon during the exercise.)

6) Sketch a polar view diagram (i.e., as if looking down on the Solar System) showing the Sun, Earth and Moon’s orbital positions with respect to each other for your particular observing session.

7) When did or will the Moon rise?

8) In which constellation was each observed planet located?

9) Did you notice any color or hues to the planets with your naked eye? Did you notice colors or hues when you used a telescope or binoculars? What were they?

10) How were the planets similar to the stars? How were they different from the stars?

11) What was the altitude of Polaris during your observing session?

12) If you lived in Honolulu (+19°50’ latitude, 155°28’ West longitude), what would the altitude of Polaris be?

13) If you lived in Buenos Aires (-34°37’ latitude, 58°21’ West longitude), what would the altitude of Polaris be?