The Organization of the Sky

1

Astronomy Laboratory Exercise

Learning Objectives

In this laboratory exercise, students will:

- Learn about constellations.
- Learn about the coordinate system used to navigate the sky.
- Learn about the movement of the stars across the sky.
- Learn about the usefulness of the star "Polaris".
- Create their own star chart for use in this exercise and in future exercises.

Definitions:	constellation, celestial sphere, right ascension, declination, North Celestial Pole, South Celestial Pole, Celestial Equator, circumpolar

Introduction

Humans have been gazing up at the night sky for thousands of years. More than 2,500 years ago, the ancient Greeks made attempts at understanding the Universe by organizing the sky and describing its movements. There are many objects in the sky that can be seen on any given night. The stars, planets and the Moon are just a few of the celestial wonders that are on display each night. In an attempt to organize the night sky, ancient cultures recognized that the many stars that are seen are not randomly displayed across the sky, but rather tend to group together in patterns. These patterns are called ***constellations***. Early human cultures began to recognize that the constellation patterns resembled animals, people and objects from their everyday lives, and so they began to name the constellations after what they resembled. Many different cultures saw different things in the patterns of the stars and so named them accordingly. However, today we universally recognize many of the constellation patterns that were named by the ancient Greek and Roman cultures. Today, there are 88 officially recognized and named constellations.

In this exercise, you will explore the nature of how the night sky is organized. The coordinate system that is used by astronomers in order to navigate the night sky will also be explained.

Procedure

First you need to build a star chart that will be used to explore the nature of the night sky.

1. Locate the three pages of star charts that are in Appendix B. Remove these pages from your lab manual. Locate the first star chart and trim the *left* edge of the chart off, trimming all of the paper to the left of the first black line that has "12 hr" under it (if this is not clear to you, BEFORE you trim your paper, ask your instructor for help).

2. Locate the second star chart and trim the *right* edge of the chart off, trimming all of the paper to the right of the last black line that has "12 hr" under it.

3. Tape the two charts together so that the two black lines that have the "12 hr" coincide, creating one long continuous chart that has numbers along the bottom that go from "0 hr" on the far right to "24 hr" on the far left (ask your instructor for help if this step is not clear to you).

There are no modifications necessary for the third star chart. Keep all of these charts handy, you will refer to them later in the exercise.

Navigating the Night Sky

In order to map the locations of objects in the night sky, astronomers devised a system of coordinates that is analogous to the coordinate system that is used to navigate the surface of the Earth. Lets review how the coordinate system on Earth works.

The Earth has three distinct geographic reference points: the *North Pole*, the *South Pole* and the *Equator*. The North and South poles represent the spin axis of the Earth, whereas the Equator represents the halfway point between the two poles (see Figure 1).

To indicate your location on the surface of the Earth you must use two coordinates that are based upon the Earth's equator. The first coordinate is called *latitude*, and it indicates how far north or south of the equator that you are located (see Figure 1). Latitude is measured in degrees, where the North Pole of the Earth has a latitude of +90 degrees, and the South Pole's latitude is –90 degrees, and the Equator has a latitude of zero degrees.

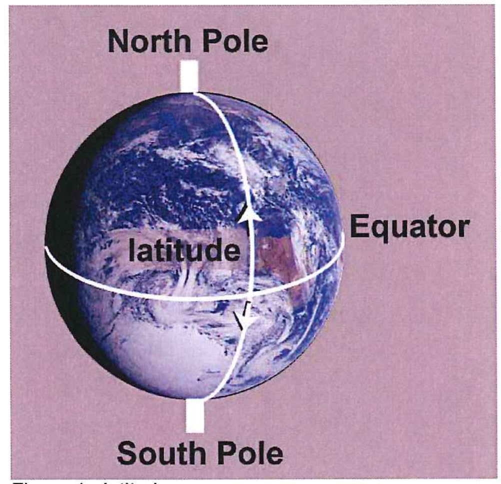

Figure 1: latitude

The second coordinate used to indicate your location on the surface of the Earth is called *longitude*, and it indicates how far along the equator you must travel to reach the point that is directly underneath your location (see Figure 2). Longitude is also measured in degrees with zero degrees longitude occurring at the longitude of Greenwich England (chosen by convention).

By combining the coordinates of latitude and longitude, any point on Earth can be indicated. Today we have very sophisticated ways of determining the precise latitude and longitude of any location on Earth using an electronic global positioning system.

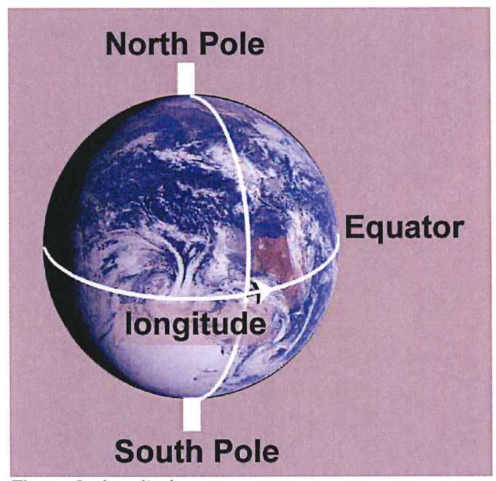

Figure 2: longitude

Largely because of the convenience of this system, astronomers adopted a similar system to use when indicating the location of celestial objects in the sky.

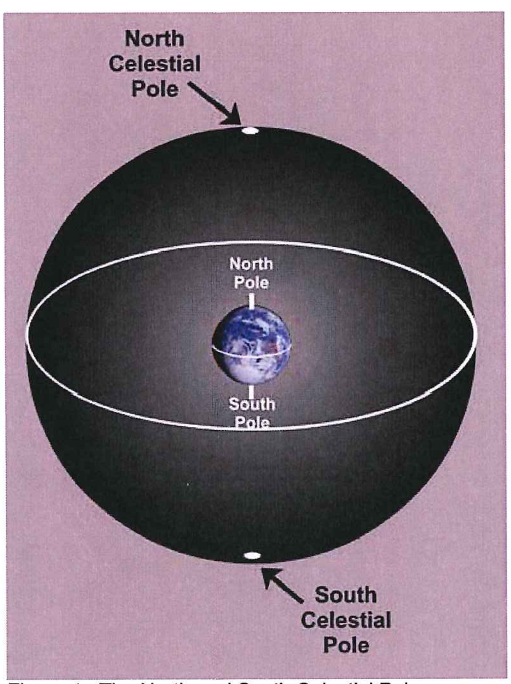

Figure 4: The North and South Celestial Poles

Imagine that the Universe is nothing more than a spherical shell that surrounds the Earth (see Figure 3). Astronomers call this imaginary sphere the ***Celestial Sphere***. The Earth is located at the center of this "shell" and the size and the distance to the Celestial Sphere are insignificant. If you imagine that the North Pole and South Pole of the Earth were projected up into the sky, you can see that they would project two points onto the Celestial Sphere. These two points would be directly over the North and South Poles of the Earth and so are called the ***North Celestial Pole*** and ***South Celestial Pole***, respectively (see Figure 4).

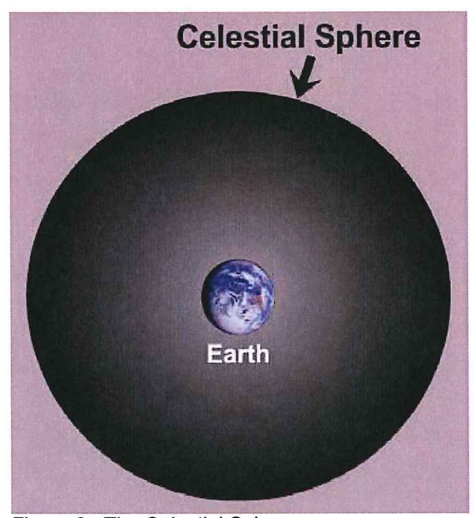

Figure 3: The Celestial Sphere

Similarly, if you imagine that the Equator of the Earth is projected up onto the Celestial Sphere, it would trace an imaginary line around the Celestial Sphere called the ***Celestial Equator*** (see Figure 5). The Celestial Equator would then be directly over every point along the Equator of the Earth.

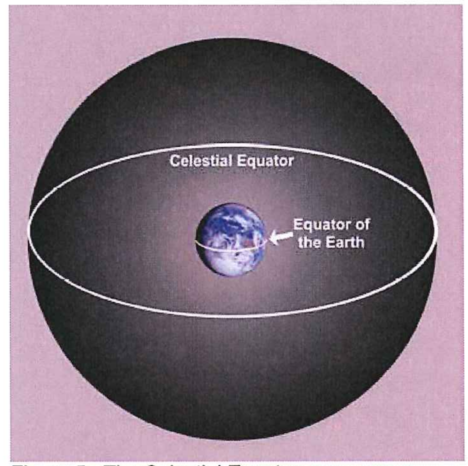

Figure 5: The Celestial Equator

With these reference points in place, astronomers created a coordinate system to use along with these three distinct locations in the Sky.

The first coordinate is called ***declination*** and is analogous to the latitude coordinate used on Earth. Declination is measured in *degrees* and represents how far north or south of the Celestial Equator an object is located in the sky (see Figure 6). The North Celestial Pole represents +90 degrees declination, and the South Celestial Pole represents –90 degrees declination (see Figure 7).

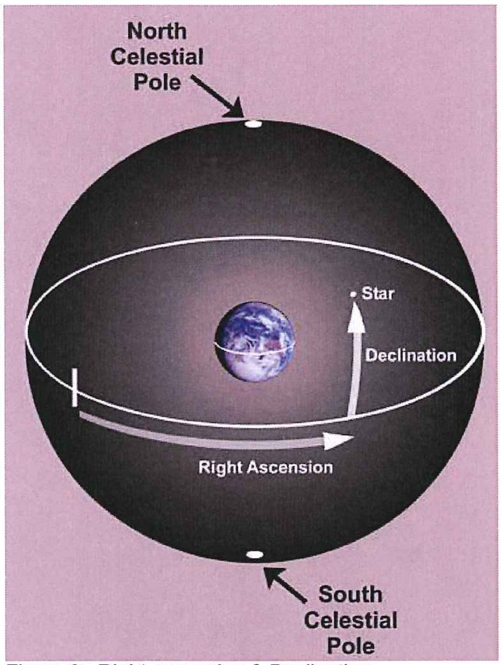

Figure 6: Right ascension & Declination

The second coordinate is called ***right ascension*** and is analogous to the longitude coordinate used on Earth. Right ascension is measured in units of *hours* and represents how far along the Celestial Equator you must go to reach a point directly beneath an object's location (see Figure 6). The zero point for right ascension is located in the constellation of *Pisces*. A complete lap around the Celestial Equator would be a total of 24 hours of right ascension (see Figure 8).

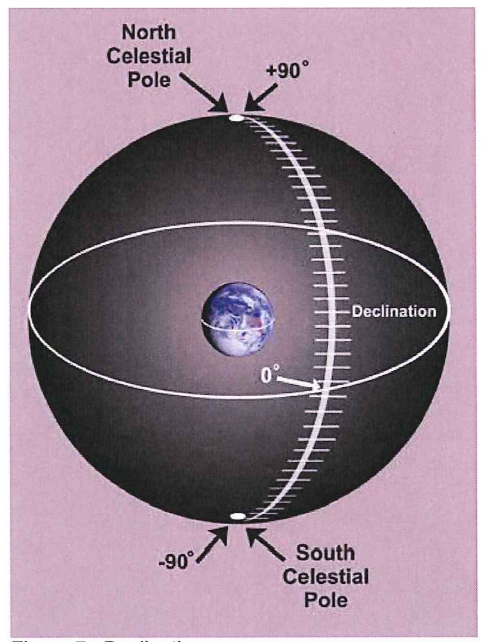

Figure 7: Declination

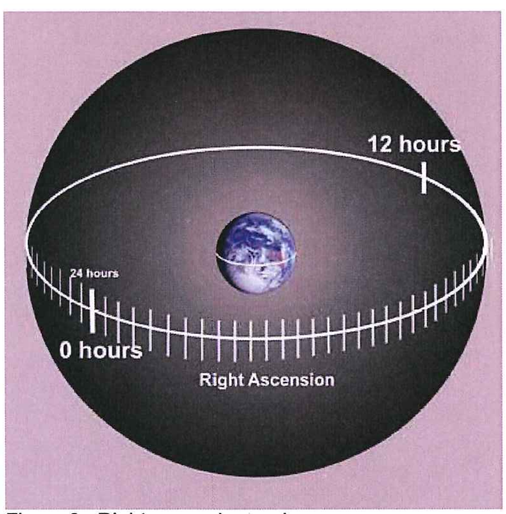

Figure 8: Right ascension scale

As with longitude and latitude on Earth, right ascension and declination can be used to determine the location of any place on the sky. It should be pointed out that not all regions of the sky are visible to all observers on Earth. Since the Earth is a sphere, each observer at any given location can see only part of the celestial sphere. If you factor in the rotation of the Earth, then some observers see all of the celestial sphere over the course of a year, whereas other observers will only see part of the celestial sphere – ever. Here in San Diego, we are only able to see part of the Celestial Sphere over the course of a year, and so we can only see a certain range of declinations in the sky.

Question 1: (Using Figures 1 – 7) What *range* of declinations would an observer at (a) the North Pole see? (b) what *range* of declinations would an observer at the South Pole see? (c) what *range* of declinations would an observer at the Equator see? *Write your answer in the space provided on the Data Sheet.*

Units of Measurement on the Sky

If the sky is imagined to be a sphere that surrounds the Earth, then spherical units must be used to measure sizes on the sphere. In geometry, spherical measurements are in ***degrees***. One trip around the entire sky would be equivalent to one lap around a circle (see Figure 9). There are a total of 360 degrees around a circle. However, many of the objects that astronomers measure are very small and the size of the degree is too large to measure objects so small. Even the Full Moon is smaller than one degree across (see Figure 10). Therefore astronomers must subdivide the degree into smaller units in order to accommodate small measurements. The degree can be divided into 60 equal parts, each part called an ***arcminute*** (abbreviated with the symbol '). As a result, there are 60 arcminutes in each degree. Although an arcminute is a small piece of a circle, it is still too large to use in measuring the smallest of celestial objects. For example, the planet Saturn is too small to be measured using an arcminute (see Figure 10). Therefore, the arcminute is itself divided into 60 equal parts, each part called an ***arcsecond*** (abbreviated with the symbol "). As a result, there are 60 arcseconds in each arcminute. In all, there are 3,600 arcseconds (60 arcseconds x 60 arcminutes) in each degree (see Figure 9 to see an illustration of how degrees, arcminutes and arcseconds are related). To get a feel for how small of a size an arcsecond is, if you were able to visualize something that was one arcsecond across, it would be the size that a U.S. dime would appear as, seen at a distance of 2 kilometers!

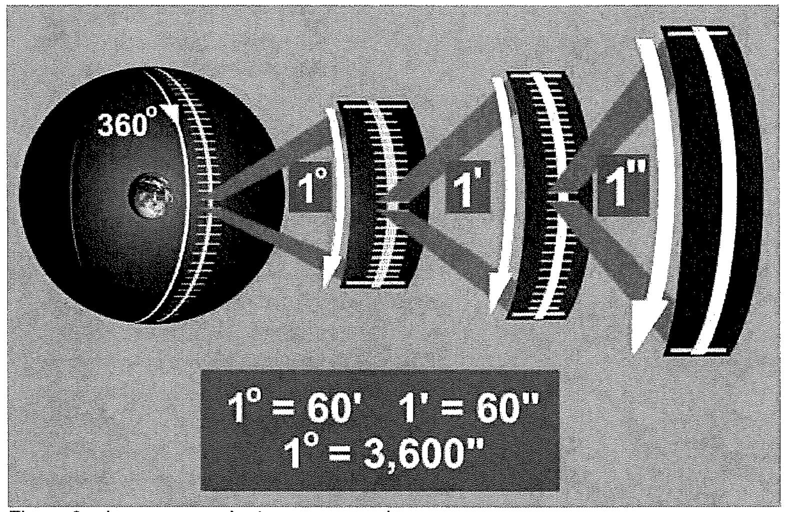

Figure 9: degrees, arcminutes, arcseconds.

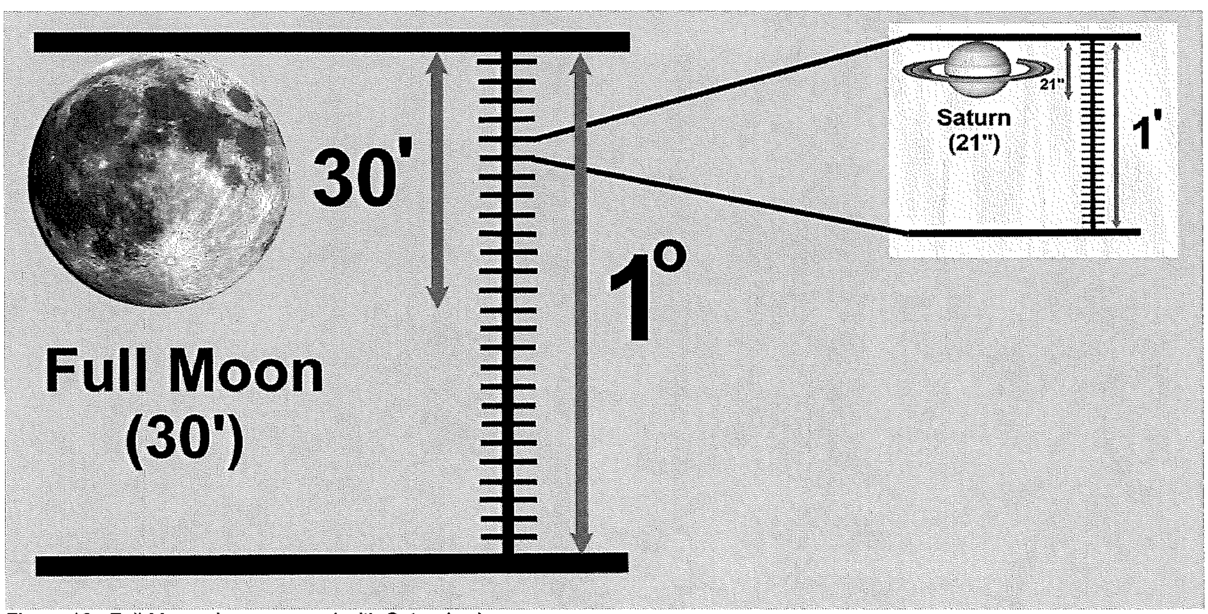

Figure 10: Full Moon size compared with Saturn's size.

The "North Star"

Many people have heard of a particular star nicknamed the "North Star". The star's real name is ***Polaris*** and it historically has had a useful significance to astronomers in the Northern Hemisphere.

4. Using your star charts, locate the constellation called *Ursa Minor*. This pattern is often referred to as the "Little Dipper" however it is actually a pattern that is named after a small bear (*Ursa* is the Latin word for *bear*).

5. Using star chart 3, locate the star that is just about at the location of the North Celestial Pole. This star is called *Polaris*. Write the name of the star next to it on your chart.

Since Polaris is *practically* at the North Celestial Pole, its location in the sky is a useful tool. Let's explore how it can be used.

Long ago, navigators in the Northern Hemisphere noticed that Polaris could be used to determine their *latitude* on Earth. First a traveler needs to find Polaris in the sky. A common myth is that the "North Star" (i.e. Polaris) is the brightest star in the sky. It is not. Therefore it can be rather tricky to locate the star in the sky. One method of locating Polaris is to look for the more obvious constellation pattern called Ursa Major. The nickname given to a group of stars in this constellation is the pattern called "The Big Dipper" (see Figure 11). "The Big Dipper" refers to a pattern of stars that resembles a spoon. The two stars that represent the end of the bowl of the spoon act as pointer stars that will point to the location of Polaris (see Figure 11). Once you have located Polaris, you have essentially found the North Celestial Pole of the sky. Since the North Celestial Pole is above the North Pole of the Earth, it can be used to locate two fundamental geographic pieces of information.

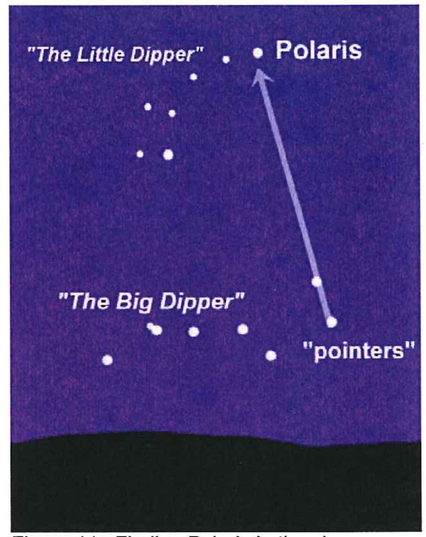

Figure 11: Finding Polaris in the sky.

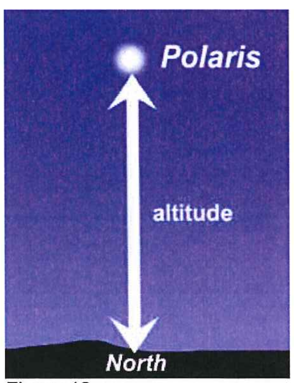

Figure 12

First, If you drop a straight line down from Polaris to the horizon, you have now found the location along the horizon of geographic north (see Figure 12). From this you can determine all the other compass points (i.e. south, east, and west). This allows you to navigate if a compass is not available.

Second, since Polaris is located at the North Celestial Pole, its location in the sky is an indicator of your *latitude* on Earth (see Figure 13). The altitude of Polaris (altitude is the number of degrees an object is above the horizon, see Figure 12) is equivalent to your latitude on Earth. Therefore to determine your latitude on Earth, all you need to do is find Polaris and measure its altitude in the sky. This fact about Polaris was one of the single most important influences in the early explorers of the Earth, up to the modern era (when electronic navigational devices became common tools).

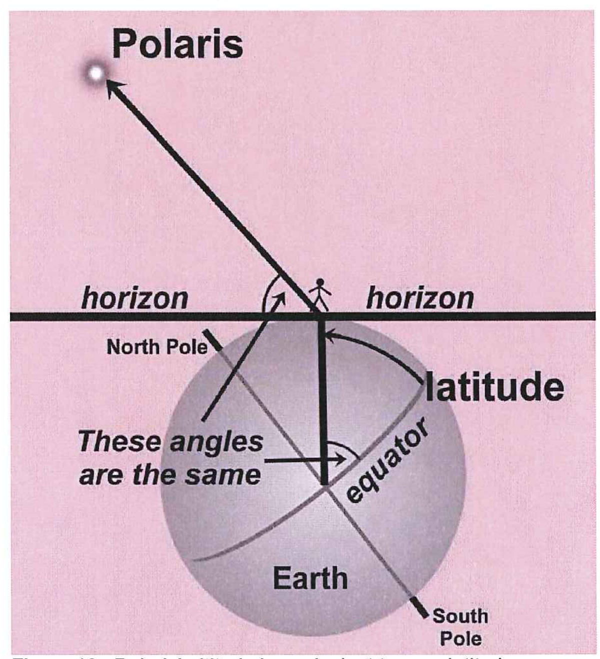

Figure 13: Polaris' altitude is equivalent to your latitude.

Question 2: If you were standing at the North Pole on Earth, what would the altitude of Polaris be in the sky? *Write your answer in the space provided on the Data Sheet.*

Question 3: If you were standing at the Equator of the Earth, what would the altitude of Polaris be in the sky? *Write your answer in the space provided on the Data Sheet.*

Question 4: What is the problem in using Polaris as a navigational tool if you are standing in Sydney Australia? *Write your answer in the space provided on the Data Sheet.*

Star Trails

The rotation of the Earth gives the illusion that the stars are slowly moving across the sky. However, the stars are not truly moving, rather it is the spin of the Earth on its axis that creates the illusion of the moving stars. Because of this, one way to demonstrate that the Earth is rotating is to create photographs called "star trails". These photographs are created by pointing a camera to any part of the sky and leaving the shutter of the camera open allowing it to expose the film for a long period of time. The photograph shows what looks like stars that have streaked, or trailed across the sky (see Figure 14 below).

Examine Figure 14 and answer questions 5 - 7. *Write your answer in the space provided on the Data Sheet.*

Question 5: Which part of the Celestial Sphere is this camera pointed at? *Write your answer in the space provided on the Data Sheet.*

Question 6: How long would you estimate that the shutter was left open on the camera to produce this image? *Write your answer in the space provided on the Data Sheet.*

6. Identify which star trail is the star Polaris.

7. Using the scale on the bottom of the photograph, determine the approximate altitude of Polaris.

Question 7: What is the latitude of the observer who took this photograph?

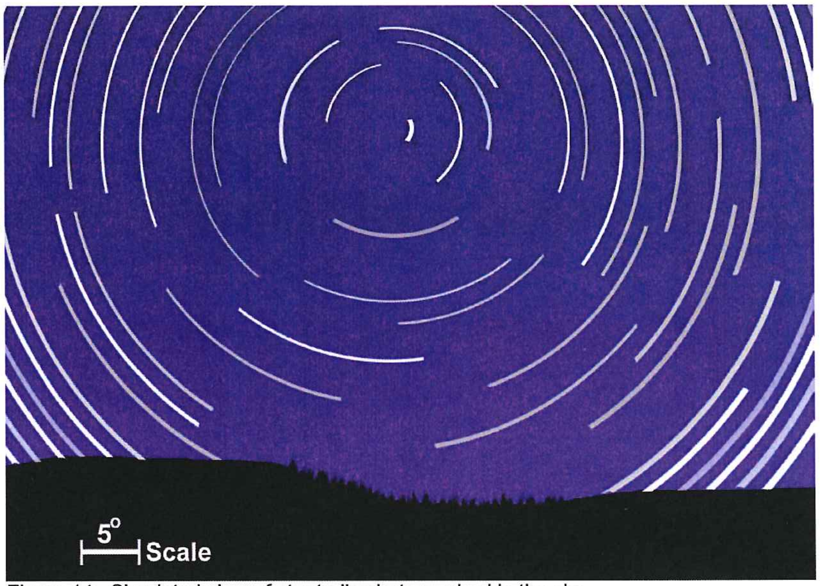

Figure 14: Simulated view of star trails photographed in the sky.

Using your Star Charts

To get a feel for how the system of right ascension and declination is used, explore your star charts and answer the following questions. Write all of your answers in the spaces provided on the Data Sheet.

Question 8: Locate the Celestial Equator on your star chart. What are the names of the 10 constellations that the Celestial Equator runs through? *Write your answer in the space provided on the Data Sheet.*

Question 9a: The brightness of the stars on your star chart is indicated by the size of the black dots. The bigger the dot, the brighter the star appears in the sky. There is one star that is the brightest star in the sky (other than the Sun). The name of this star is *Sirius*. Locate this star on your star chart. What is the constellation that Sirius belongs to? *Write your answer in the space provided on the Data Sheet.*

Question 9b: What is (estimate) the right ascension and declination of Sirius? *Write your answer in the space provided on the Data Sheet.*

Question 9c: Is the star Sirius visible from the North Pole of the Earth? Why or why not? *Write your answer in the space provided on the Data Sheet.*

The entire sky will appear to rotate due to the rotation of the Earth on its axis. Due to the rotation of the Earth, each hour of right ascension takes one hour to move across the sky (this is the reason why right ascension has 24 hour increments). At any given time, there are 12 hours of right ascension stretching across the sky from the eastern horizon to the western horizon.

Question 10: If a right ascension of *1 hour* is directly overhead right now, is the star Sirius visible in the sky? *Write your answer in the space provided on the Data Sheet.*

Question 11: If the constellation *Delphinus* is setting right now, what is the constellation *Cancer* doing? *Write your answers in the space provided on the Data Sheet.*

Question 12a: You are standing at the equator of the Earth looking directly overhead at midnight. A right ascension of 5 ½ hours is directly overhead. What constellation is directly overhead? *Write your answer in the space provided on the Data Sheet.*

Question 12b: Again the time is midnight and a right ascension of 5 ½ hours is directly overhead (as in 12a). What time will the constellation *Leo* begin to rise from your location? *Write your answer in the space provided on the Data Sheet.*

Question 13a: There is a constellation that is said to resemble a teapot (see Figure 15 to the right). Locate on your star charts a constellation pattern that resembles a teapot. What is the actual name of this constellation? *Write your answer in the space provided on the Data Sheet.*

Figure 15: a teapot

Question 13b: What is the right ascension and declination of this constellation? *Write your answer in the space provided on the Data Sheet.*

Question 14: Located at the coordinates right ascension: 3h 45min, declination: +22° is the *Pleiades*. Describe what you find at these coordinates. *Write your answer in the space provided on the Data Sheet.*

Circumpolar Constellations

It is the rotation of the Earth that gives the illusion that the stars are slowly moving across the sky. Recall that the North Celestial Pole (found by locating the star Polaris) is stationary in the sky with all of the stars rotating around this point (see Figure 14). In a previous section, you saw how the altitude of the star Polaris is an indicator of an observer's latitude.

Question 15a: If you are located in San Diego (latitude 33° north of the equator), how many degrees above the horizon would the star Polaris be located? *Write your answer in the space provided on the Data Sheet.*

Question 15b: If the sky appears to rotate around this point in the sky, there will be a region of the sky surrounding the North Celestial Pole that contains constellations that will rotate around the North Celestial Pole but never set below the horizon. These are called ***circumpolar*** constellations. Down to *what* declination will the constellations be seen to be circumpolar from San Diego? (Hint: use your answer from question 15a and recall that the North Celestial Pole is at a declination of +90°). *Write your answer in the space provided on the Data Sheet.*

Question 15c: Using your polar star chart, determine all of the constellations that are circumpolar as seen from San Diego. *Write the names of each constellation in the space provided on the Data Sheet.*

Be sure to keep your star charts with your lab manual. You will use them in future exercises.

The Organization of the Sky

Name:

Astronomy Laboratory Data Sheet

Question 1a	
Question 1b	
Question 1c	
Question 2	
Question 3	
Question 4	
Question 5	
Question 6	
Question 7	
Question 8	
Question 9a	
Question 9b	
Question 9c	
Question 10	
Question 11	
Question 12a	
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Question 14	
Question 15a	
Question 15b	
Question 15c	

Appendix: Star Charts

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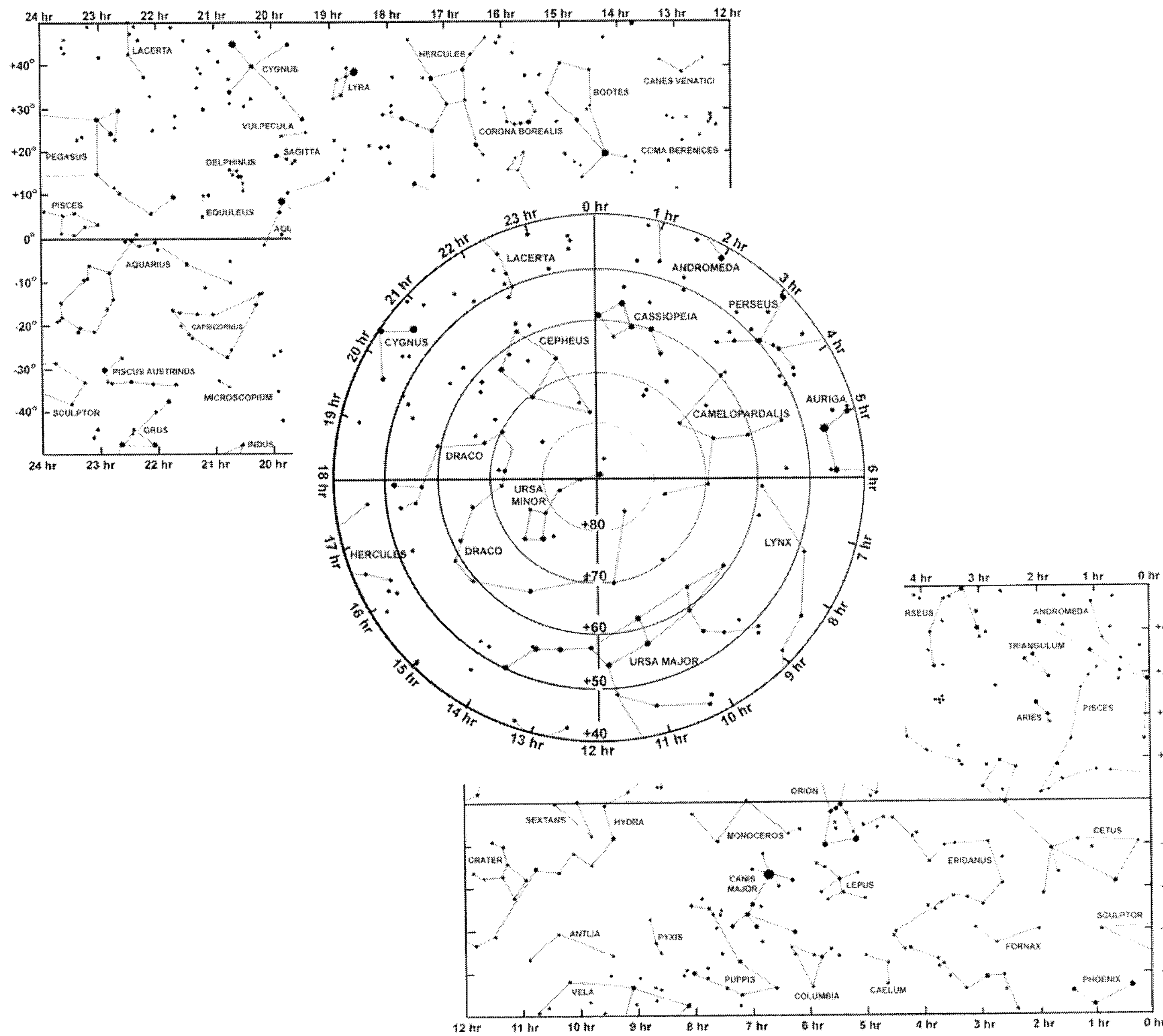

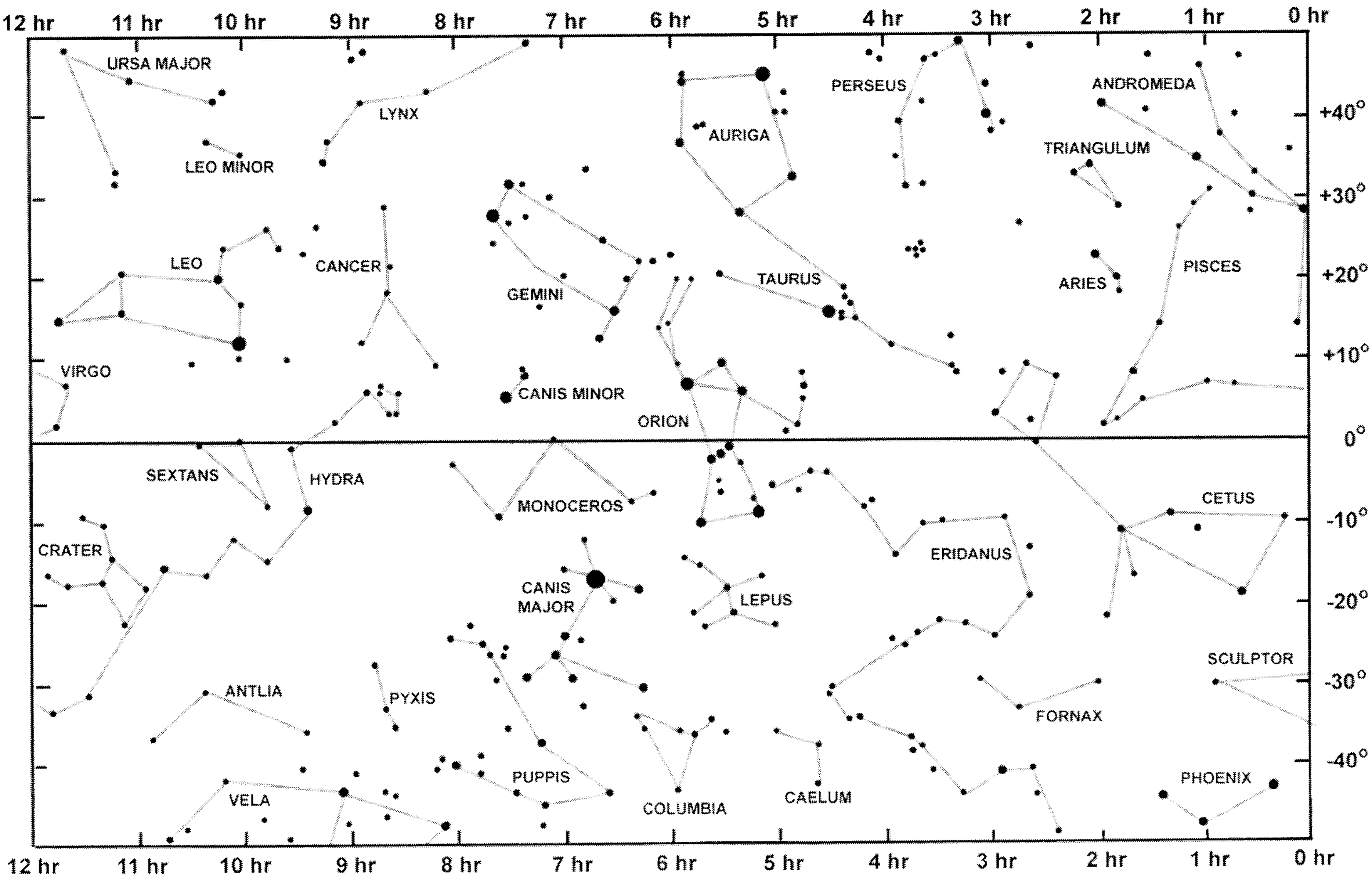

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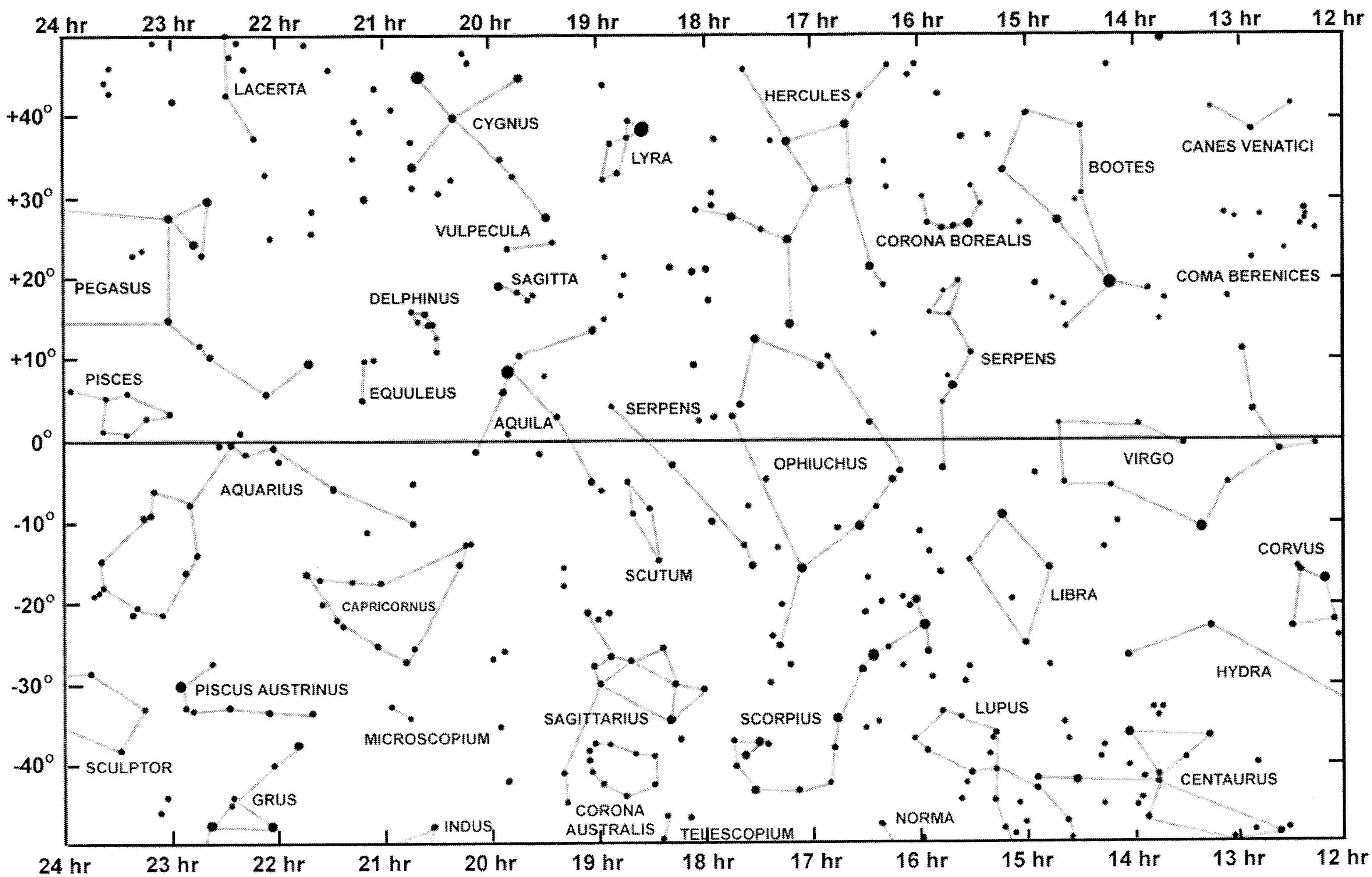
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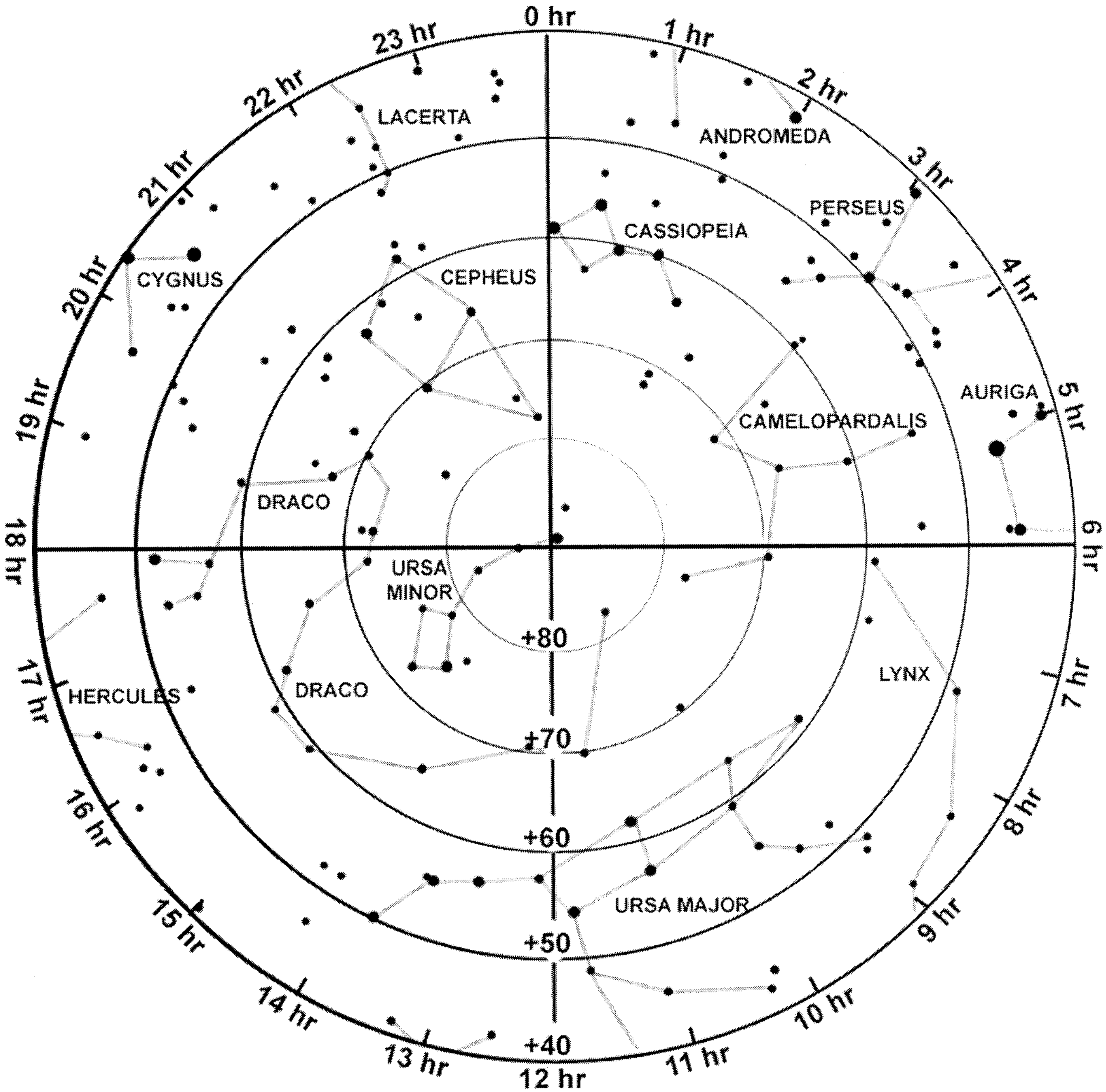
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