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Unit 4: The Constellations

This Unit illustrates the classical constellations and helps you learn your way around the sky. Astronomers treat constellations like regions of space. Constellations are used to refer to galaxy clusters, bright star names, meteor showers and more. In ancient times people used the rising and setting of constellations to keep track of the seasons and planting and harvesting times. Also in this unit you will construct your own planetarium and use it to learn the names of the constellations. This is a major project which requires group effort and cooperation. Good luck!

Every constellation has a three-letter abbreviation, such as UMa for Ursa Major, and Sag for Sagittarius. Within each constellation, the brightest star is usually called Alpha (α). Thus, αCen is Alpha Centaurus, the brightest star in the constellation Centaurus. It is also the closest star to us aside from the sun.

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CA1 4.0: The Constellations Objectives

At the end of this unit, students will …

1. Distinguish between asterisms and official constellations.
2. Be able to state the origin and interpretation of several constellation stories.
3. Use the Bayer system of star nomenclature.
4. Use official abbreviations for constellations.
5. Identify various constellations depending on the season.
6. Use a planisphere to predict what stars are visible given two of the three following things: date, time, event in the sky (such as a particular constellation crossing the meridian.)
7. Construct a 1 or 2 frequency geodesic dome.
8. Explain the relationship between the alt-azimuth and equatorial system of coordinates.
9. Locate stars and objects on star maps.
10. Use Right Ascension and declination to find objects on star maps.
11. Define coordinates in the sky and origin points such as the first point of Aries.
12. Make organized observations of constellations in an observing notebook.
13. Explain the relationship between the altitude of the North Star and the observer's latitude.
14. Estimate visual magnitudes.
15. Explain the effects of light pollution on nighttime sky observing.
16. Perform factor-label conversions in general, and specifically about angles and time.
17. Predict the rising and setting time of various astronomical objects.
18. Convert degrees, minutes, and seconds of arc into decimal degrees.

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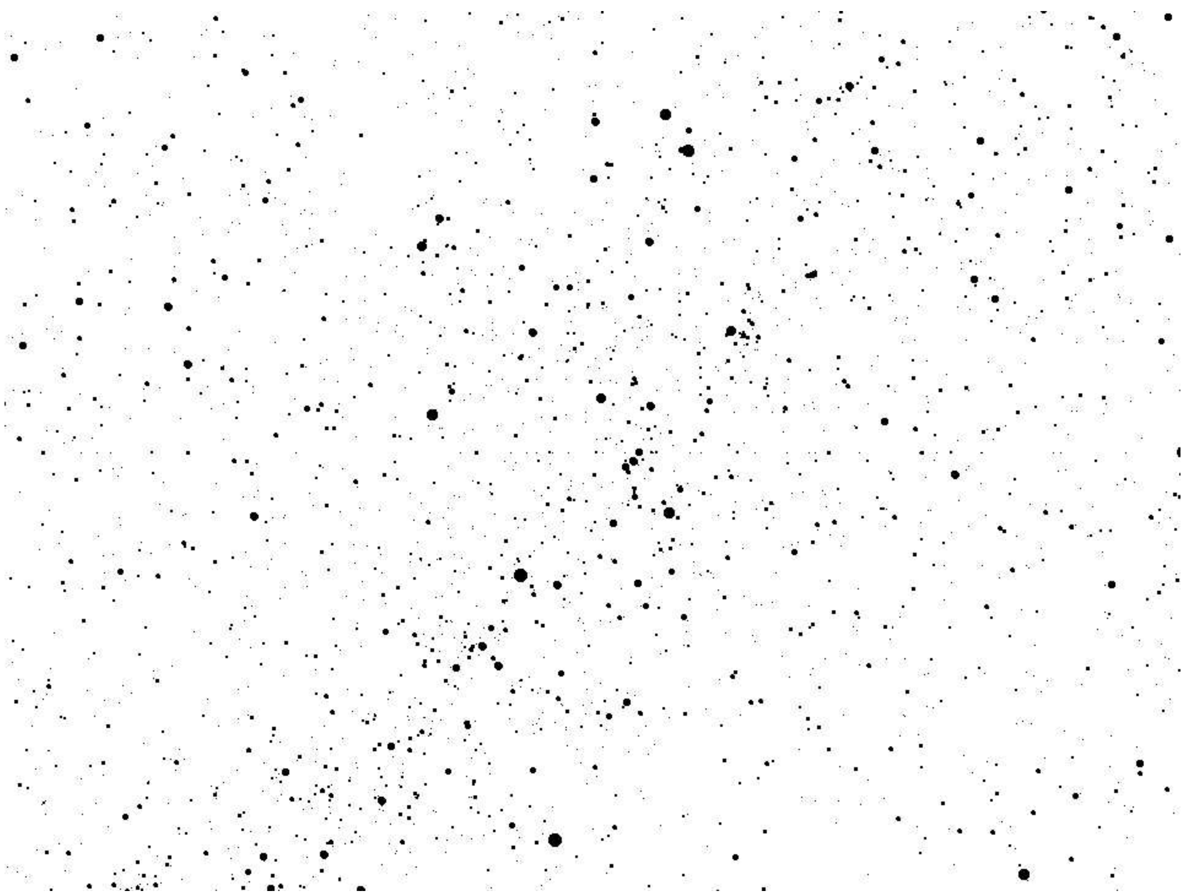
CA1 4.1: My Constellation Activity

Purpose: The point of the activity is to reinforce the concept that constellation stories are cultural in nature and do not represent actual pictures of thinks in the sky. Rather, they remind us of things on the earth, and serve as a primitive sort of writing to help us remember stories and events.

Procedure: In this activity, you will take a blank star map and invent your own constellations. A segment of an unlabeled star chart appears below for you to draw on. Design at least three new constellations. When you have finished drawing, write three short paragraphs on the back of the handout to explain what story or inspiration caused you to draw these pictures. For inspiration see H.A. Rey's book "Find the Constellations."



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CA1 4.1: My Constellation Activity

Three Short Paragraphs

Directions: Write 3 paragraphs describing the three made-up constellations you drew on the other side of this page.

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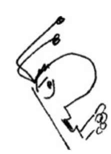
CA1 4.2: Constellation Reports Activity

Purpose: To research and learn some basic information about constellations.

Procedure: Using library books and internet sites (see http://www.Astronomyteacher.com for links leading to constellation sites) look up one of the 88 constellations assigned by your teacher and list the following information about it in a report. Cite references.

- Name of the constellation (Official)
- Three-letter IAU abbreviation
- English name or translation
- Story or legend involving constellation
- Genitive form (Latin possessive)
- Name the brightest stars in the constellation. Use the name of the star and the Bayer designation*.
- List the maximum and minimum *right ascension* and *declination* of stars in the constellation.
- List interesting objects in the constellation (Messier or NGC objects). Give coordinates.
- State whether or not the constellation is visible from your school, and during what seasons. Some constellations are *never visible* and some are always visible or *circumpolar*.
- If the constellation is a member of the zodiac, mention this. The zodiacal constellations are the ones the ecliptic passes over and are used in newspapers for horoscopes.

Draw a picture of the constellation, including a stick figure of the picture it is supposed to represent. Or take a photograph yourself to make an official **observation**.



*Bayer Designations**

John Bayer invented a system in the 17th century for designating stars in rank order of brightness, or importance, within a constellation. Generally (with some exceptions) the system assigns the Greek letter alpha (α) to the brightest star in the constellation, the letter beta (β) to the second-brightest, and so on. The naming system then adds the genitive (possessive) form of the constellation name. Therefore the brightest star in the constellation Centaurus would be referred to as Alpha Centauri, or α Cen, using the IAU's 3-letter constellation abbreviation for Centaurus, the constellation.

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CA1 4.3: Using a Planisphere Lab

Greek Alphabet

Here is the Greek alphabet, which you may encounter when looking up information about particular stars.

α	β	γ	δ	ε	ζ	η	ι	κ	λ	μ	
Al-pha	Beta	Gamma	Delta	Epsilon	Zeta	Eta	Iota	Kappa	Lambda	Mu	
ν	ξ	ο	π	ρ	σ	τ	υ	φ	χ	ψ	ω
Nu	Xi	Omicron	Pi	Rho	Sigma	Tau	Upsilon	Phi	Chi	Psi	Omega

Constellation Names

Constellation Names and the genitive form of them used in astronomy can be found from a number of online resources such as www.sizes.com/natural/constellations.html and others.

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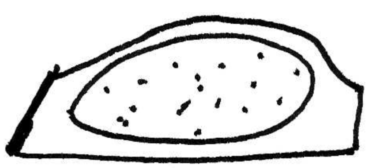
CA1 4.3: Using a Planisphere Lab

Purpose: To learn how to use a planisphere to identify constellations.

Background: A planisphere is a flat circular map of the sky that can be used to determine what stars and constellations are visible on a given day. Imagine taking a traditional star ball and shining a light on it from above. The projected image would be the star map used in a planisphere.

Materials:
Planispheres are available from a variety of sources. Links to commercial vendors are posted at the links page at www.AstronomyTeacher.com. There are also online plans to make your own, such as Uncle Al's Sky Wheel from the Lawrence Hall of Science.

Procedure:



Assemble your planisphere. All planisphere have the same operating instructions.
1. Set the current date to be aligned with the current time.
2. What appears in the hole is what is currently visible in the sky.

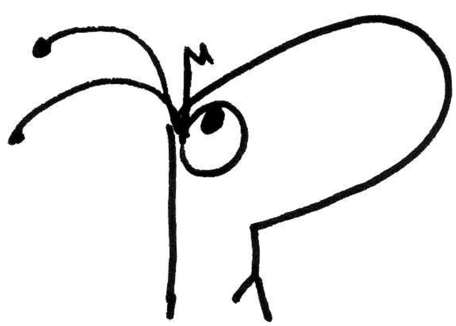


Figure 1. The planisphere is supposed to represent the entire visible sky.

Understanding what a planisphere does is perhaps a bit more complex. The edge of the hole represents the horizon—in all directions. The center of the hole is the zenith (straight up). The North Star, on the other hand, is usually a pivot or grommet located in the center of the star wheel (*not* the center of the hole.)

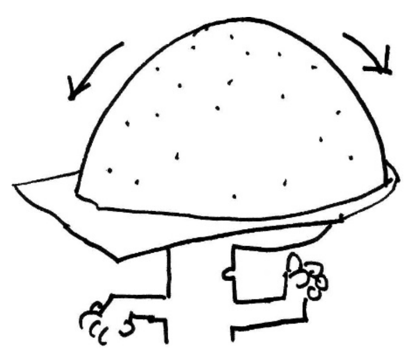


Figure 2. Imagine wearing a planisphere like a cap. Note the "bill" is backwards on Cosmo's head. Isn't that cool, kids?

To visualize what the planisphere is doing, imagine the map is printed on a rubber sheet. Hold the sheet over your head and stretch it down in all directions. This shows that the entire visible sky is contained in the portion of the map in the hole. The meridian runs from the North edge through the center to the South edge.

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CA1 4.3: Using a Planisphere Lab

3. Set the planisphere for September 15 at 9 PM. List two or three constellations visible near the zenith.

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4. Set the planisphere for December 21 at midnight. What constellations are visible near the meridian?

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5. During the month of March, what time will the constellation of Cygnus be closest to straight overhead?

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6. Observe the handle of the Big Dipper (Ursa Major) shown at right. During what month at 10 PM is the handle nearly vertical as shown in this picture?

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7. You are observing and waiting for the constellation Pegasus to rise on the night of October 15. Approximately what time will this occur?

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Figure 3. The Big Dipper.

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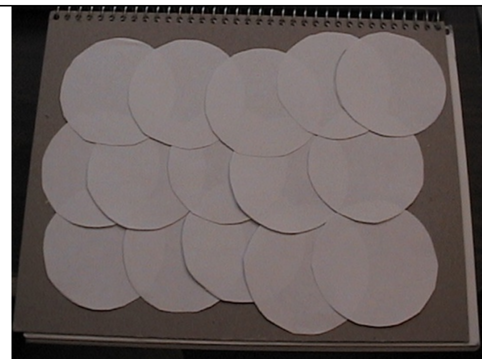
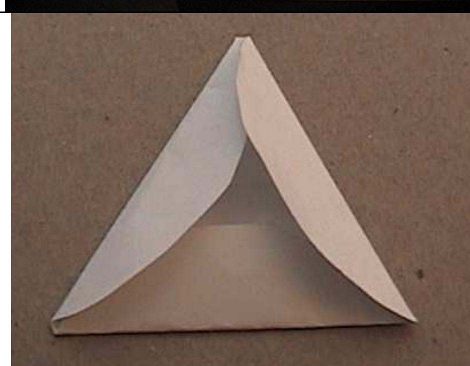
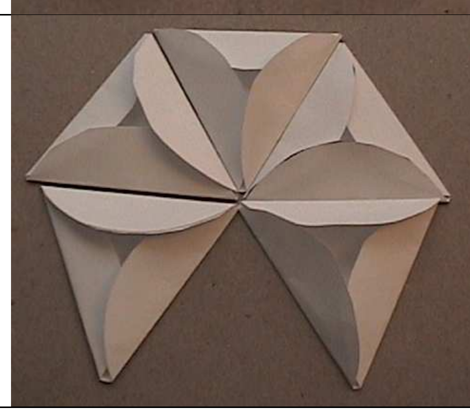
CA1 4.4: A Small 1-F Dome Activity

Purpose: Build a simple desktop dome or sphere using circles formed into triangles.

Materials: compass, scissors, glue, thick paper, ruler, pencil or marker, glue

In technical terms, this is a one-frequency geodesic dome, or a dodecahedron (if fully assembled). One-frequency (1-f) refers to the fact only one type of triangle is needed.

1. Draw 15 identical circles. You can make the circles out of paper, construction paper, or cardboard. You can draw the circles by using a compass, or tracing a can, or whatever method suits you. Cut each out carefully. If you want to make a dodecahedron make 20 circles.	
2. Fold each circle into the shape of an equilateral triangle as shown in Figure 2. Fold by trial and error to make an equilateral triangle that appears to be the same length on all three sides. It doesn't have to be perfect.	
3. Arrange five triangles into a pattern as shown below.	

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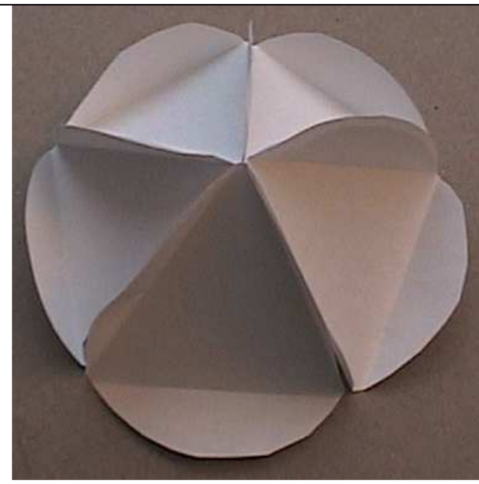
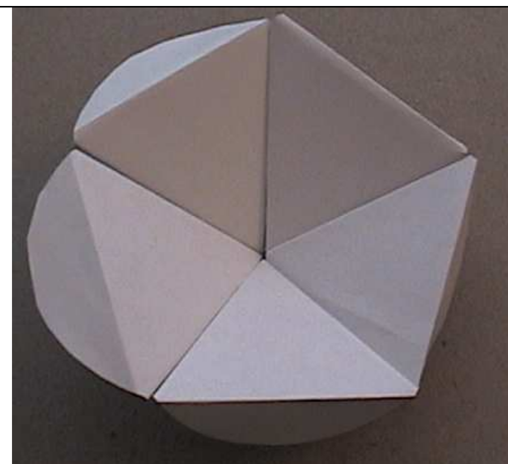
CA1 4.4 A Small 1-F Dome Activity

4. Unfold the adjacent flaps and glue them together. When the glue is dry enough to take the stress, glue the final two flaps together by lifting the center of the construction together to form a little cap. Then the two remaining flaps can be brought together to be permanently attached. This is what the finished cap should look like.	
5. If you want a dodecahedron (complete "sphere") make another cap with five more triangles.	
6. Arrange the remaining 10 triangles into an alternating pattern like this, gluing adjacent flaps.	

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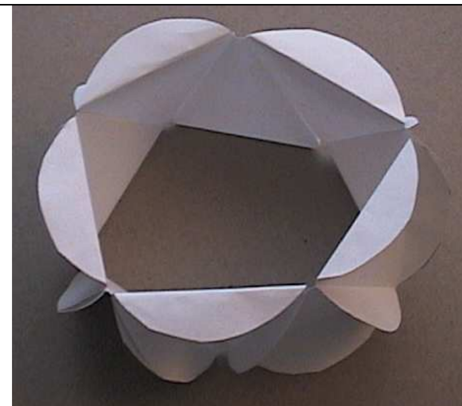
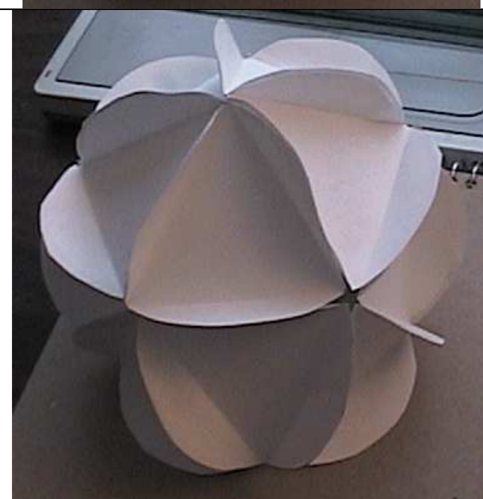
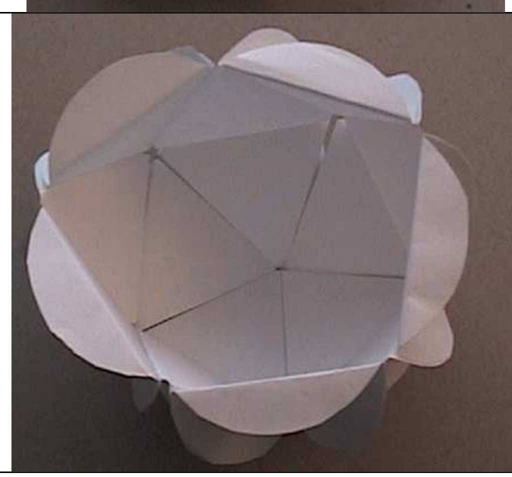
CA1 4.4 A Small 1-F Dome Activity

<table>
<tr><td>7. Form this strip of 10 triangles into a ring, with flaps out to match the caps you made earlier.</td><td></td></tr>
<tr><td>8. You will notice that on the top of the ring has 5 flaps, and so does the bottom of the cap. Match them up and glue them together and you have a little 1-f planetarium dome model made of one type of triangle!</td><td></td></tr>
<tr><td>9. Turn over the dome to see the inside surface.</td><td></td></tr>
<tr><td colspan="2">If you want a dodecahedron, attach the second cap to the bottom to close the interior. (Don't do this if you are doing CA1 4.5 Lines in the Sky.) Design adapted from a diagram at www.desertdomes.com. Used with permission.</td></tr>
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CA1 4.5: Lines in the Sky Activity

Purpose: The purpose of this activity is to build a simple hemisphere and use it to understand how coordinate systems are arranged in the sky.

This activity is adapted from the "Build your own planetarium" project posted at http://www.cccoe.net/stars/.

Equipment needed: Marker, clear plastic dome OR 1-f dome materials from the previous activity.

Procedure:

This activity is based on the idea that the sky looks like a giant inverted bowl. Defining the position of an object in the sky, then, becomes a matter of drawing it on the underside of a bowl. The problem is: there is more than one bowl, and one of them is moving!

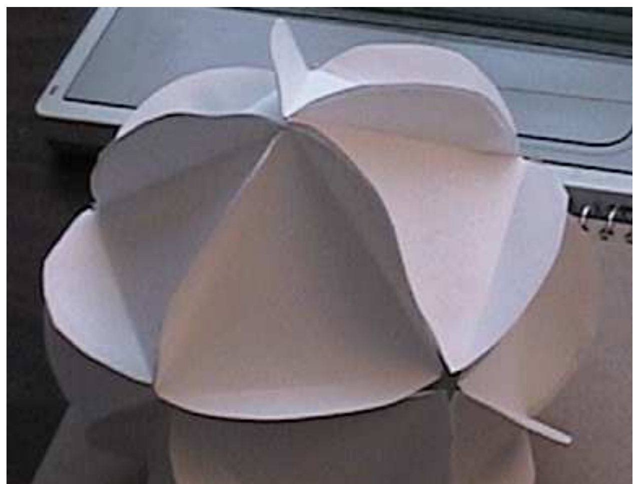

Figure 1. A 1-frequency dome. Make two of these, using 3 inch circles for one and 4 inch circles for the other.

1. Start by following the directions at the end of this activity for making a "Small 1-frequency Dome." Use 3-inch circles for making this dome, with flaps out (you'll understand when you read the directions.) Then make *another* dome using 4-inch circles.

2. (Optional) Fold the flaps of the smaller dome against its outer surface and tape them flat. This may make the dome easier to visualize as a smooth dome in the sky.

The Alt-Az coordinate system

Altitude and Azimuth have been used previously in this course (during the sun and moon units) but this will show you another way to look at them and serve as a review.

3. The small bowl represents the local sky around you. Hold it over your head and imagine you are looking straight up. Where would straight up appear in the dome?

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CA1 4.5: Lines in the Sky Activity

4. Draw a large dot in this location and label it *zenith*. (The *nadir* is in the opposite direction of zenith, but your dome has no bottom so we can't draw it.)

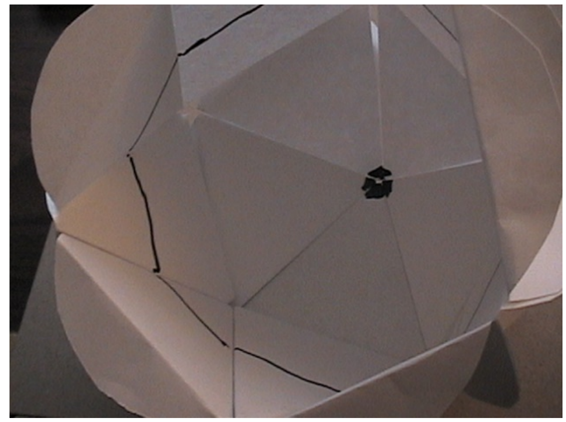

Figure 2. In your model, the horizon runs through the middle of the ring of 10 triangles.

5. Located 90 degrees from the zenith is the *horizon*. It is equivalent to where the earth meets the sky on the surface of a flat ocean. In your model, the horizon runs halfway up the first row of triangles, all the way around. Draw the horizon on your dome and label it.

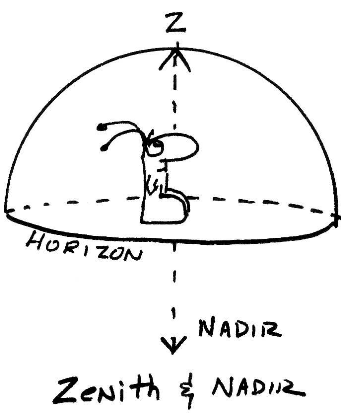

Figure 3. A line connecting zenith and nadir is perpendicular to the plane of the horizon.

Here is another illustration of the zenith, nadir, and horizon to help you understand the arrangement. In the illustration, the "dome of the sky" is drawn as a smooth circle instead of with triangles for clarity.

5. Altitude angles are measured from the horizon (at zero degrees) to the zenith (at 90 degrees.) What is the vertex of the angle we are discussing?

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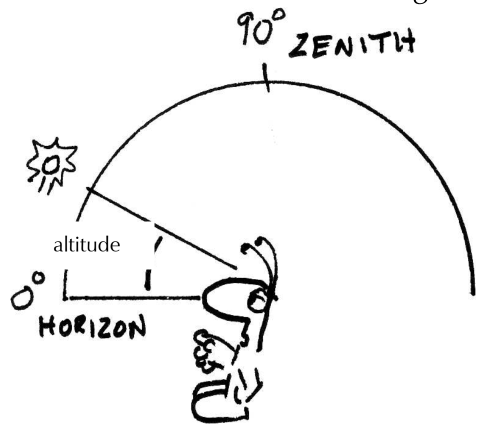

Figure 4. Altitude is measured from the horizon up towards the zenith.

6. Azimuth angles start due north on the horizon and proceed towards east on the horizon. Mark North, South, East, and West on your horizon line inside your dome. Since there are 360 degrees in a circle, what degree measure is the azimuth of West?

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CA1 4.5: Lines in the Sky Activity

7. Here are two diagrams to help you understand Azimuth. Sketch the azimuth angle shown in the first illustration onto the second one.
Note the second picture is the view seen from above. The azimuth angle starts at North and increases in a clockwise direction towards east.

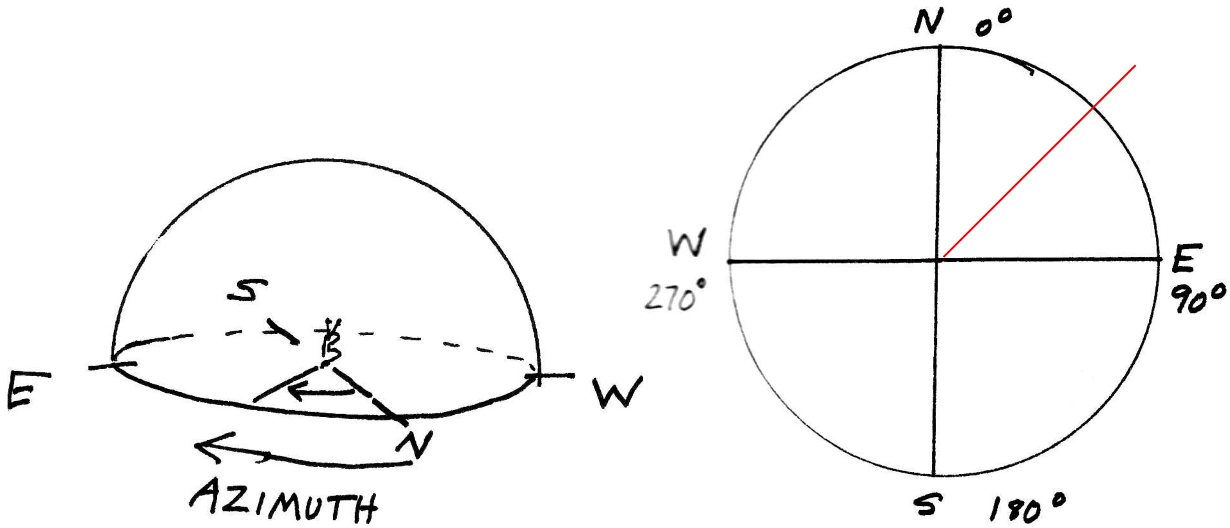

Figure 5. Azimuth angles are measured horizontally, with North as zero.

> Pilots need azimuth skills to know which direction they are flying a plane. Also, when you hear a pilot refer to "Runway 22," that means the runway is lined up with an azimuth of 22 degrees. Spacecraft pilots need to know about azimuth as well (trust me on this one.)

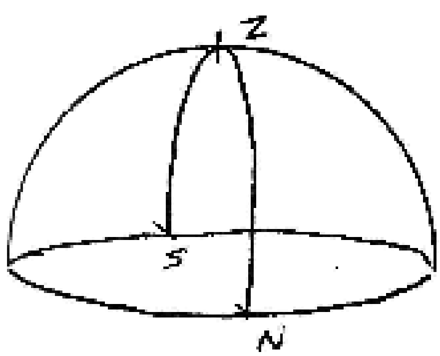

Figure 6. The meridian is a line going from North to South, through the zenith.

One last (important) component of the Alt-Az coordinate system is called the *meridian*. The meridian is an imaginary line which starts from due North on the horizon, goes through the zenith, and ends due South on the horizon. The meridian is important because objects reach their highest point of the day when they cross the meridian. This event is called *culmination* for most objects. It is called *local solar noon* for the sun. Draw the meridian in your dome and label one intersection with the equator N (for north) and the other S (for south).

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CA1 4.5: Lines in the Sky Activity

Alt-Az coordinates are fine, as far as they go, but the problem is the sky *moves*. As the earth turns, the sun, moon and stars appear to spin around you. If you gave the coordinates of a particular star, two hours later it would have moved to a new place. Three weeks later at the same time it would be in a different position. So we need another set of coordinates—ones that move with the stars so that the coordinates don't change. In other words, another coordinate system.

Keep your dome for the next portion of the activity.

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CA1 4.5: Lines in the Sky Activity

Right Ascension and Declination

These steps use your *second dome*, made from the 4 inch circles. Right Ascension and Declination are equivalent to longitude and latitude on earth, respectively. There are some differences, however. We'll get to that presently.

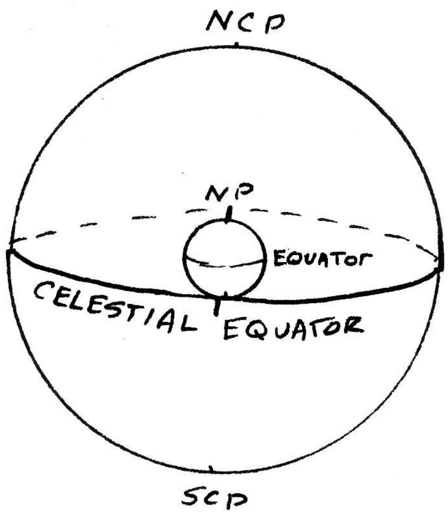

Figure 7. The North Celestial Pole (NCP) is directly above the North Pole of the Earth. The Celestial Equator is directly above the Earth's equator.

1. First, like zenith in the Alt-Az system, the RA-Dec system is based on the location of a single point called the *North Celestial Pole*, located directly above the earth's rotation axis. The star Polaris is very close to this direction from the earth. Put a dot in the center of the top of your larger dome's cap and label it NCP (for North Celestial Pole).

2. Just like latitude on the earth, *declination* refers to a North-South coordinate. You can't get any farther north than the NCP, so the declination of the NCP is 90 degrees. Zero degrees declination is called the *celestial equator* and is located (again) in the center of the base row of triangles that make up your dome.

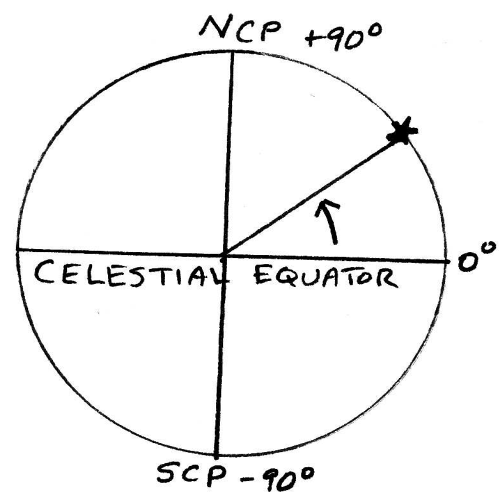

Figure 8. The arrow shows the declination of the star.

Negative declinations are below the equator.

3. What is located at the vertex of the declination angle we are dealing here?

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CA1 4.5: Lines in the Sky Activity

4. What do declination values which are negative supposed to represent? What is the declination of the South Celestial Pole?

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5. If there is "sky latitude" there must be "sky longitude." This is known as *Right Ascension*, and it is somewhat more complex than any of the coordinates discussed so far.

This next part may take a couple of readings before you get it, but make sure you don't skip it!

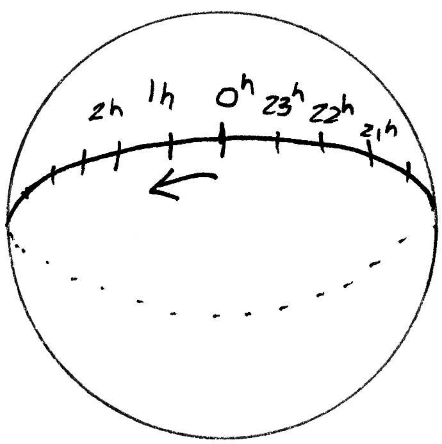

Figure 9. RA increases to the left in the sky. In this view, the observer in the center of the sphere facing south.

The first problem is that if you want the "sky longitude" coordinate to stay with the stars—so they always have the same map coordinate for plotting—then the coordinate system must move with the stars because the stars *move*.

The stars move because the earth turns; the earth turns once in 24 hours; therefore isn't it *logical* that the "sky longitude coordinate" is based on a system of 24 *hours* instead of degrees?

6. If *that* makes sense, then it should make sense that when you look up into the sky, the Right Ascension coordinates increase to the *left* while you face south. Why is that?

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CA1 4.5: Lines in the Sky Activity

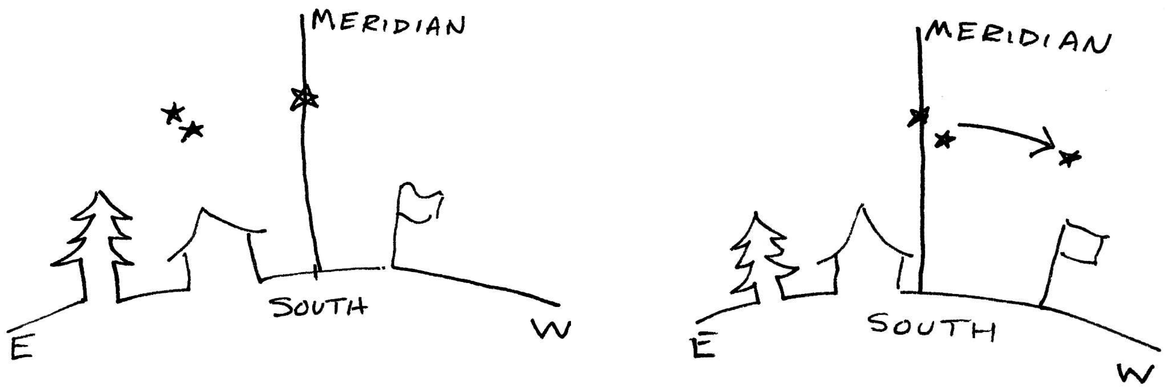

Figure 9. A star on the meridian moves towards the west as an hour passes; new stars are now on the meridian. If the star on the meridian at the top is at 0 hour RA, the star on the meridian in the right illustration is at 1 h RA.

The reason is because as the earth turns from west to east, it makes things *appear* to rise from east to west. Consider an object on the meridian with Right Ascension zero hours.

One hour later, this object has moved $1/24^{th}$ of a circle to the West (everything in the southern sky moves towards west when you live in the northern hemisphere). Now *new* objects are on the meridian. They are exactly *one hour (or $1/24^{th}$ of a circle)* to the left of the object designated *zero*, therefore they are located at *one* hour of Right Ascension.

This is why RA increases to the *left* as you face south.

When you write Right Ascension (R.A.) coordinates, then, they aren't the same as degrees, minutes or seconds.

7. Given that 24 hours of RA is the same as 360 degrees on a standard protractor, how many degrees are in one hour of RA? Explain.

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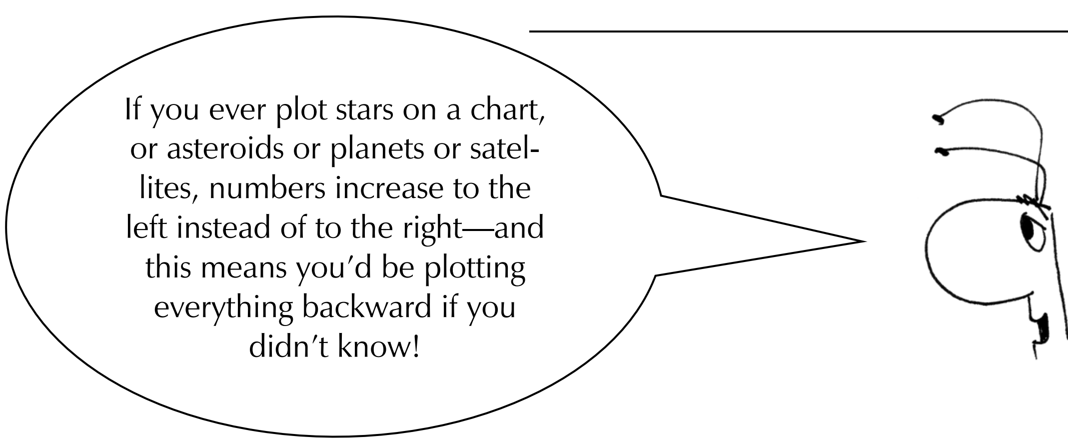

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CA1 4.5: Lines in the Sky Activity

8. Inside your large dome, label the following RA coordinates: 0 hours, 6 hours, 12 hours, and 18 hours. It doesn't matter where you put zero, but the hour marks should be 90 degrees or 2 1/2 triangles apart.

Zero Hours RA

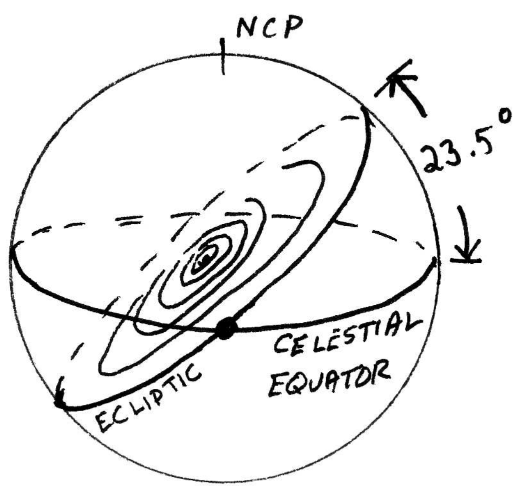

Figure 9. Zero hours RA (The first point of Aries) is defined as where the ecliptic crosses the celestial equator with the sun heading north.

That brings up a final point about Right Ascension: where does zero start? Zero could have been defined to be a particular star, or a certain galaxy or some other object. Astronomers instead chose an imaginary point not corresponding to a real object. This point is called the *First Point of Aries*. The first point of Aries has this symbol: ♈ (for Aries the Ram).

What is this imaginary point? Recall the ecliptic is the plane of the earth's orbit in space. The earth's axis (and the RA/dec system with it) is tilted 23.5 degrees with respect to its orbit.

Cut out another circle roughly the size of the bottom of your large dome. Draw concentric circles on it to represent the solar system. The circle represents the plane of the solar system and it is aligned with the ecliptic (some of the planets are tilted a bit, but we'll let that slide for now.)

If you put your solar system inside your dome and tilt it 23.5 degrees, this would represent how the ecliptic and the RA/dec system are related. Notice the edge of the solar system disk intersects the RA circle in just two places. One of those is marked with a large dot in the illustration.

A better definition of the *ecliptic* is the apparent path of the sun through the sky caused by the earth orbiting the sun.

To emphasize this point, flip the solar system circle over and draw just one circle representing the earth's orbit. If this were inside the dome, tilted at 23.5 degrees, you can see that as the earth goes around the sun, the sun appears to move around the ecliptic.

We could pick either intersection as a zero place. Astronomers picked the one that defines the first day of Spring: when the sun rises due east and is crossing the celestial equator, heading towards the summer solstice.

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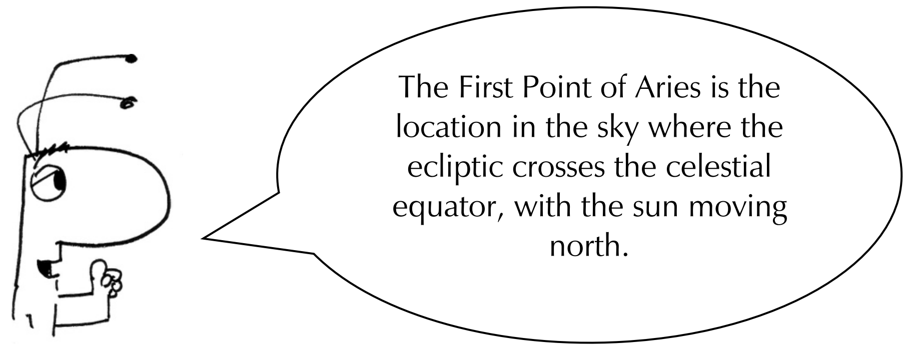
CA1 4.5: Lines in the Sky Activity

The First Point of Aries ♈ therefore represents *all* of the following:

Zero Hours Right Ascension
Location of the Sun on the first day of Spring
One of the days when the sun rises due East*



9. Mark 0h Right Ascension with this symbol ♈ in your dome.

One last point: Unfortunately, it turns out that the First Point of Aries *moves*. (Kind of negates the whole point, doesn't it?). It moves because the earth's axis wobbles a bit as it spins—an effect called precession. This means that when astronomers make star charts, they have to specify the *year* the coordinates were measured, because as the wobble continues, a star's Right Ascension and Declination *change!*

Figure 10. A dreidel is a kind of top. It is used to play a game which requires the top to precess when it spins.

Precession

If you spin a top, the top will wobble as it spins. The rotation axis will *precess*, or describe a circle. The Earth's axis precesses. This has the effect that the Earth's rotation axis is not always pointing at the North Star; sometimes it points at other stars, sometimes it doesn't point to anything in particular. (This is the case today with the South Celestial Pole. There is no South Star *per se*.)

The precession has about a 27,000 year period. That means it has not even completed one cycle during recorded history. However, it has precessed enough that records show that thousands of years ago, the star Thuban in the constellation Draco the Dragon was once considered to be the North Star!

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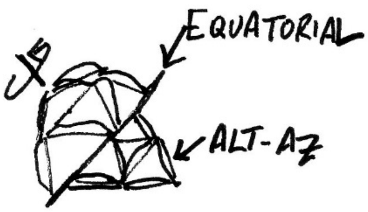
CA1 4.5: Lines in the Sky Activity

On star maps you'll see a label like this: 1950 Epoch, 2000 Epoch, etc. This refers to the coordinates as set up for that year. Most astronomers use 2000 Epoch coordinates as of this writing, but as this book goes on into the immortal future and is used by future generations that may not be true. (Forgive my wishful thinking.)

Why did we build two domes?

Well, there had to be a reason, right? If the smaller dome has its flaps flattened, the bigger one fits on top of it. Set the large dome on top of the small one. If that is the way the sky was arranged, the earth's axis wouldn't be tilted. Since the earth's axis is tilted, you would have to hold the domes like this to make it simulate the earth.



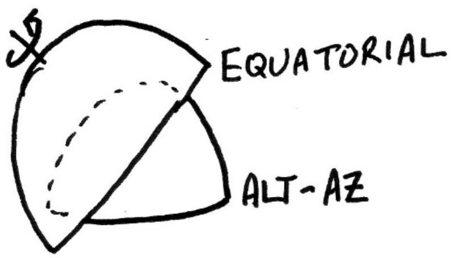


Figure 11. The equatorial dome is tilted with respect to the alt-az dome. The amount of the tilt is 23.5 degrees.

Keep in mind that not only are the domes tilted with respect to each other, the larger one is also *spinning*. No wonder celestial coordinates are complicated!

*Note: I have to add this for the astronomers who may be reading this: The sun does not rise due east exactly on the Spring Equinox. One reason is that the Spring Equinox is a moment in time, whereas the sun could rise up to nearly 24 hours later during the day that the equinox occurs. Another reason is that the analemma is not perfectly vertical; it has width due to the elliptical nature of the earth's orbit. This offset will put the sun slightly off of due east during sunrise on the day of the Spring Equinox. But it's *close*, so we're going to let this little technicality slide for the sake of the concept. But interestingly, this helps explain the significance of the fact that the analemma is not a perfect figure 8 but has a top smaller than the bottom.

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CA1 4.5: Lines in the Sky Activity

Questions:

1. If the earth's axis were not tilted, how is the definition of the First Point of Aries affected?

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2. Does 2 hours of RA always represent the same angular size as seen by the observer? Hint: consider 2 hours of RA near the pole as opposed to near the equator. Think orange slices.

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3. Explain in as simple terms as you can manage why Right Ascension numbers increase to the left as you look south in the sky.

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CA1 4.5: Lines in the Sky Activity

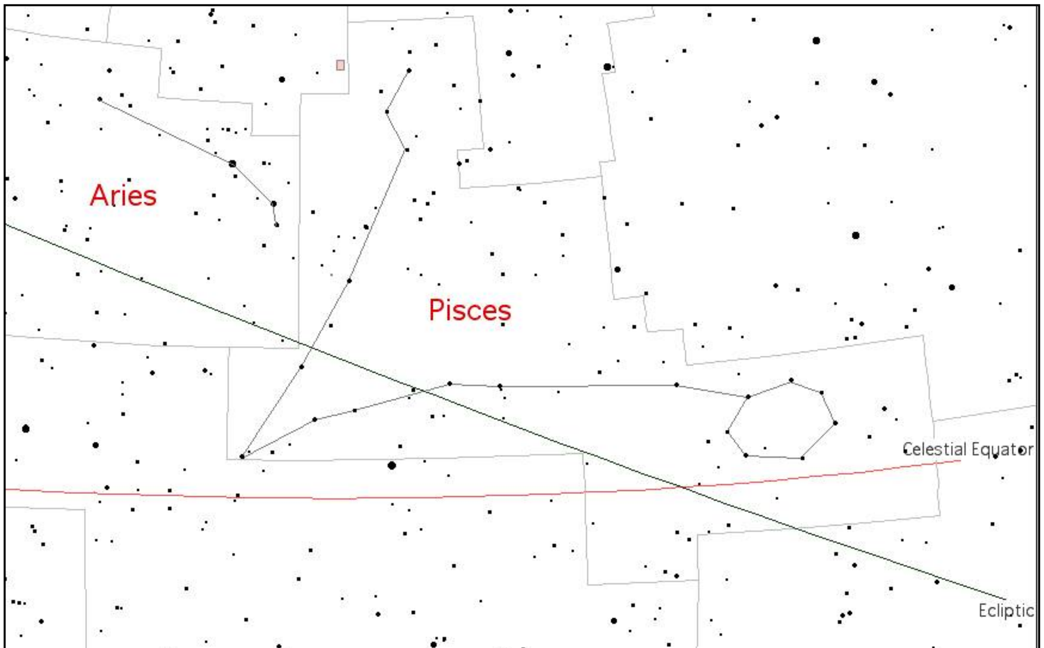

Figure 12. Star Map generated by Starry Night software showing the area near the First Point of Aries.

4. Look on a star map above and mark where 0h RA is located. Is the First Point of Aries actually in the constellation Aries? Given that the definition of the First Point of Aries is very ancient, what is the significance of this answer?

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5. What implications does this have for the pseudoscience of astrology?

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CA1 4.6: Basic Constellation Observations Lab

Purpose: To learn several constellations, asterisms, and stars by sight.

Background: Constellations are like a roadmap to the sky. There are many different constellations identified by traditional Western culture and codified by professional astronomers, who mapped the sky with some precision hundreds of years ago. The International Astronomical Union (IAU) recognizes 88 official constellations. Some of these constellations are easy to see; others are not. Some look a lot like their namesakes (for example, Scorpius) and others do not (Cancer the Crab, for example). Using a planisphere, you can learn a few of the major constellations and use those to "star-hop" to the remainder of constellations on your planisphere.

Equipment needed: Planisphere, Sky, Eyes.

Figure 1. Constellations as pictures are a human invention. Different cultures recognize different constellations. In some ways constellations can be seen as an impetus that led our earliest ancestors to draw pictures.

Procedure: The constellations visible depend on the season of the year. Most students will be observing during the Fall or Spring. Only a few constellations are presented here. The idea is these basic constellations will serve as landmarks in the sky for you to find more obscure constellations. The emphasis is on constellations visible from a relatively light-polluted environment. The introduction to the observation recording pages gives you some idea of which constellations are visible when.

The key idea is this: once you find one or two bright constellations, see what is between them or near them on the planisphere. Then use these as "landmarks" to find other things in the sky.

The following diagrams show some easy to find constellations and asterisms visible at various times of the year.

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CA1 4.6: Basic Constellation Observations Lab

Circumpolar Constellations

We'll begin with the autumn sky in the Northern Hemisphere. Even if this isn't when you are observing, read through this section for tips on how to observe when it is some other season. If you go outside on a clear night around August 30, 9:30 PM local time, in a dark country sky, you might see this.

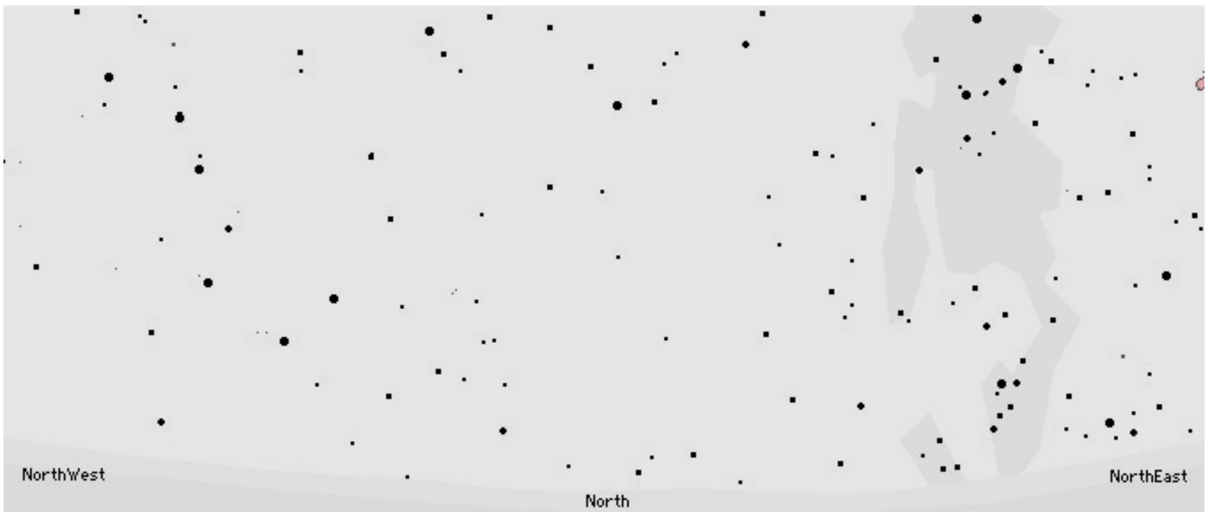

Figure 2. Facing North August 30, 9:30 PM from mid-northern latitude. Image generated by Starry Night.

Now, you might not even know which way is north when you go outside; there might be trees in front of some of this stuff (which is close to the horizon at the bottom of the picture) and unless you're out in the country you'll almost certainly not see so many stars due to the local shopping mall's light pollution. And as you'll notice, there are no lines on the stars in the sky. Here we've shown the brighter ones as darker dots (which isn't exactly accurate but the best you can do with ink.)

To begin trying to make sense of what you see, try connecting the dots (especially the dark ones; ignore the dim ones) to make diagrams in the picture above. Look for rectangles, triangles, line segments, arcs...you don't have to use every star. Odds are you'll only see the bright ones anyway.

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CA1 4.6: Basic Constellation Observations Lab

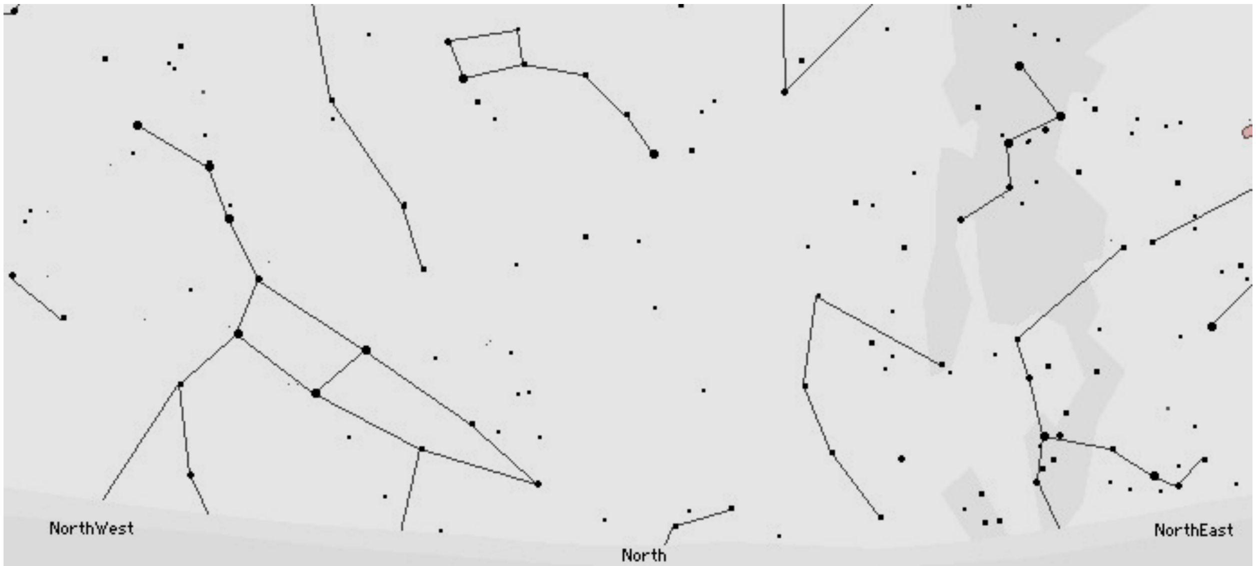

Figure 3. The same sky labeled with constellation stick-figures.

This diagram shows some constellations and asterisms visible according to official maps. Don't worry if your diagrams don't look like these; the constellations drawings are somewhat arbitrary and differ from author to author and especially from culture to culture. We are going to concentrate on the "official" constellations from the International Astronomical Union's definitions—these are the ones based on Greek mythology, Arabic definitions from the Middle Ages and Western European definitions in the past few hundred years—and some common "unofficial" constellations called "asterisms." Let's start with the most famous asterism—the Big Dipper.

Figure 4. A drinking gourd. Photo courtesy Geoffery Holt.

Dippers are not as well known as they used to be, so let's first take a look at a Dipper. A dipper is a small cup on a handle used for drinking. A picture of a dipper made from a gourd is shown at left.

Facing north, we find the Big Dipper tilted as shown.

The asterism consists of the *handle* (three stars on the left) and the *bowl* (four stars lower to the right). This is an important constellation because it leads you to at least two other ones nearby.

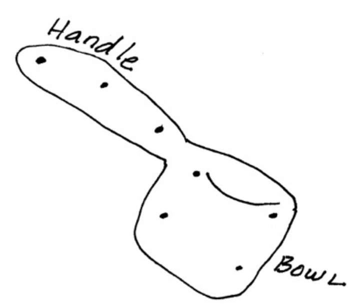

Figure 5.The handle and bowl.

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CA1 4.6: Basic Constellation Observations Lab

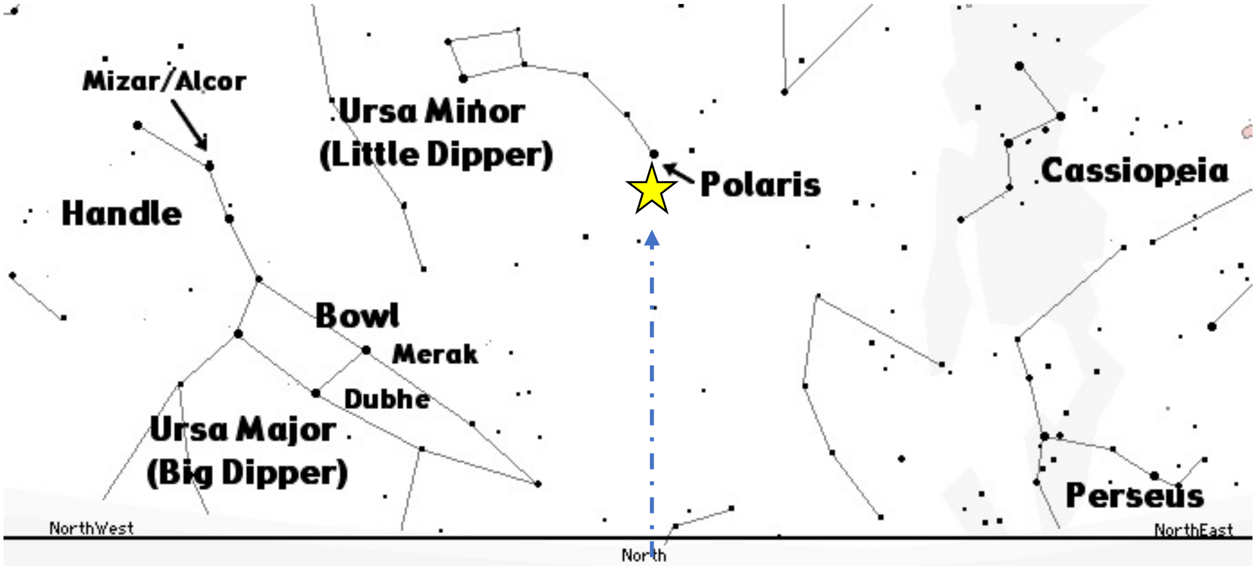
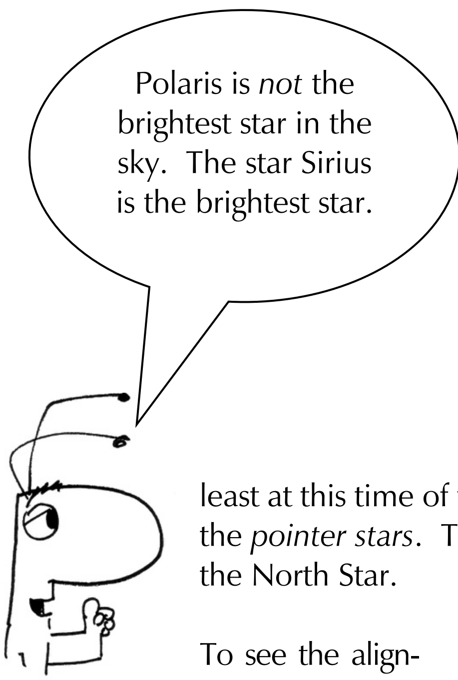


Figure 6. Facing North in the early evening, September, Northern Hemisphere.



Here we see the same star field labeled with some common star names and constellations. If you look at the middle star in the handle, you may be able to see two separate stars. The bright one is called *Mizar* and the smaller one *Alcor*. This is called a *double star* and it can be easily *split* or separated with your eyes or binoculars if you can't quite make it out. Certain Native Americans used this star as an eye test: if you can see the smaller star, you pass.

Attached to the handle we see the bowl which consists of four stars. The rightmost stars in the bowl (at least at this time of year) are called *Dubhe* and *Merak* and are referred to as the *pointer stars*. These stars align pretty well with the star called "Polaris", the North Star.

To see the alignment, extend your arm, sketch a line from Dubhe, through Merak, and keep going in the same direction. You'll go right by Polaris, which is the next bright-ish star along the path.

Figure 7. Polaris is the North Star because it is nearly directly above the rotation axis of the earth. Everyone on earth who points at Polaris points in the same direction because it is so far away.

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CA1 4.6: Basic Constellation Observations Lab

What makes Polaris unique is that by a happy coincidence, it sits almost directly above the earth's North Pole (Figure 7). As the earth rotates, all other stars in the sky appear to move around Polaris as shown in a long-exposure photograph.

Opposite the Big Dipper we find the constellation Cassiopeia, or as I call it sometimes, 3MEW. This is because depending on the season and time of night, the zigzag constellation can appear as a 3 (as it does in the illustration) an M, an E, or a W. If you see either the Dipper or Cassiopeia high in the sky, odds are the other one is low; depending on your latitude, all or part of the lower one is obscured.

Whatever constellations are always visible from your location regardless of the time of night or day of the year are called *circumpolar* constellations as they seem to simply spin around the North Star without ever setting.

Finally, attached to the star Polaris we find another Dipper-shaped asterism called (appropriately) the *Little Dipper*. (It is a subset of a larger official constellation known as Ursa Minor, or the little Bear.) Notice that in the configuration shown, the Little Dipper appears to be "pouring into" the Big Dipper.

In the space below and on the next page if necessary, sketch the configuration of the Big Dipper, Polaris, the Little Dipper, and Cassiopeia for 9:30 PM on December the 1st, March the 1st, and June the 1st. (These dates are arbitrary and have no particular significance other than they are separated by several months.) You can either use a planisphere or you can use Stellarium to complete this activity.

Next sketch the appearance of the Big Dipper every 3 hours on the night of June 21 starting at sunset. Be sure to label dates and times for each sketch.

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CA1 4.6: Basic Constellation Observations Lab

Record your sketches of the Big Dipper here.

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CA1 4.7: Common Asterisms Handout

Common Asterisms and Constellations

If this were a book about constellations (and there are several available) we would now proceed to show you all the stars you can see in the Autumn, followed by another section with all the stars you can see in the Spring, followed by all the stars you can see in the Winter. Being an astronomy text, we have to leave some work for you to do and there are some other points to be made besides which constellation is which.

Therefore, we're going to show you some common star-hopping asterisms not usually shown on typical star-maps, then ask you to use your planisphere to find other constellations as observations for your observing notebook. See the observing guide at the end of this workbook for suggestions about large constellations you can see from most locations for each season.

Arc to Arcturus and Spike to Spica

The handle of the Big Dipper forms a sort of circular section or arc. If you follow the arc away from the dipper in a sweeping circular motion, the first bright star you encounter is known as Arcturus. Arcturus is the brightest star in the constellation Bootes (pronounced Boh-oh-tees), which resembles a kite or an ice-cream cone.

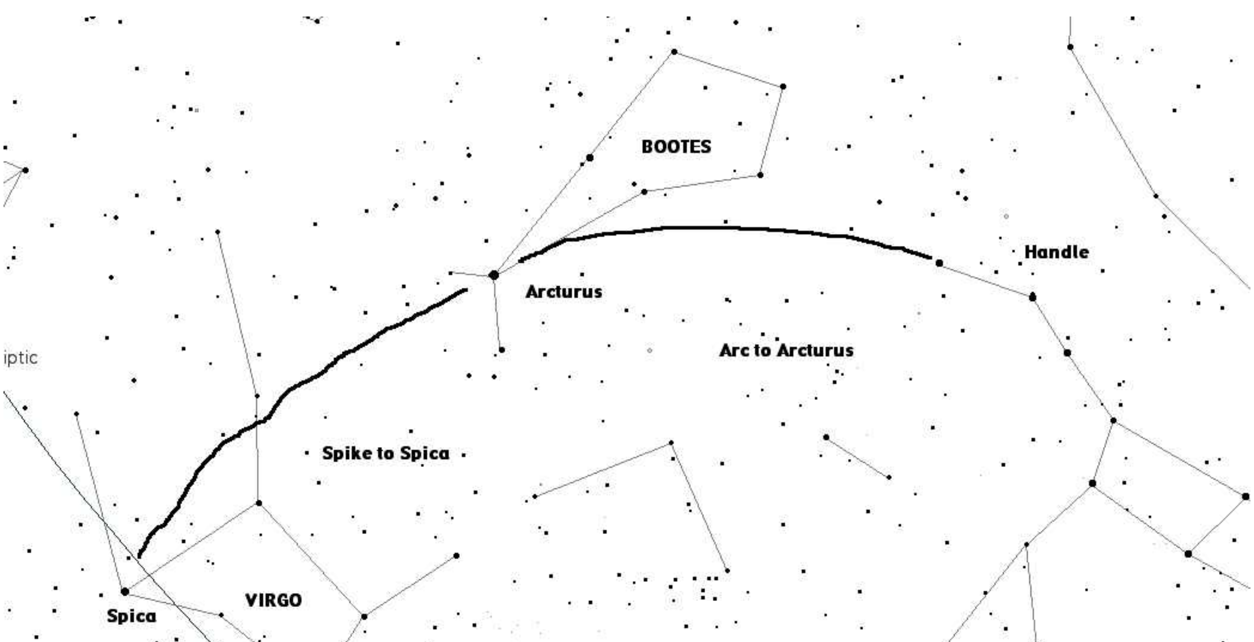

Figure 1. Arc to Arcturus and Spike to Spica.

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CA1 4.7: Common Asterisms Handout

Continuing the arc of started with the Dipper we pass by Arcturus and, as if playing volleyball, smash a spike down to Spica. Spica is the brightest star in the constellation Virgo (the Virgin) and is very near to the ecliptic in the sky.

Summer Triangle

In this asterism we see three bright stars forming a near-perfect isosceles triangle. Each star is the brightest star in a constellation; together they make the asterism known as the *Summer Triangle*. The triangle is visible from summer through autumn in the early evening sky.

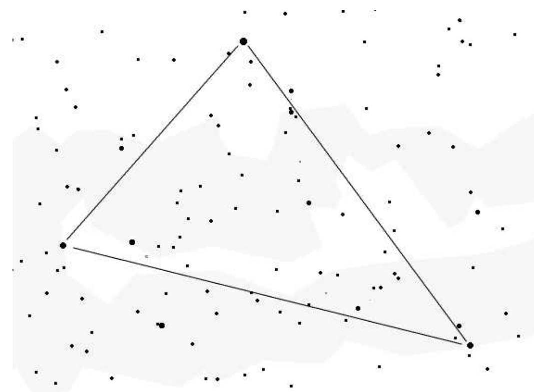

Figure 2. The summer triangle, facing east just after dark in July. Cygnus and Deneb are on the left, Vega at top, and Altair to the right.

The brightest star in the asterism (at the top here) is *Vega*, also the brightest star in the sky during the summer. (Sirius is the brightest star in the entire sky as seen from Earth.) Vega is associated with the constellation Lyra (the Lyre), which is represented by the parallelogram nearby.

The next brightest star (on the bottom of the picture as shown) is called Deneb, and it is part of the constellation Cygnus (the Swan). As has been mentioned, every culture has its own tradition concerning the constellations, and the "official" interpretation is no more important than any other because the constellations are merely reminders of stories or pictures relevant to our culture. Other cultures refer to this constellation as the *Northern Cross,* because of its resemblance to a crucifix. The longest "bar" of the cross points generally Northward. Coincidentally the Milky Way goes through Cygnus, so if Cygnus is high in the sky this is a good test to see if you are in a truly dark-sky location.

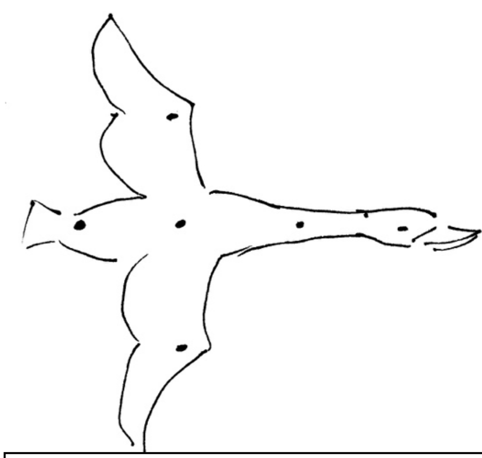

Figure 3. Cygnus the Swan. Deneb is the tail.

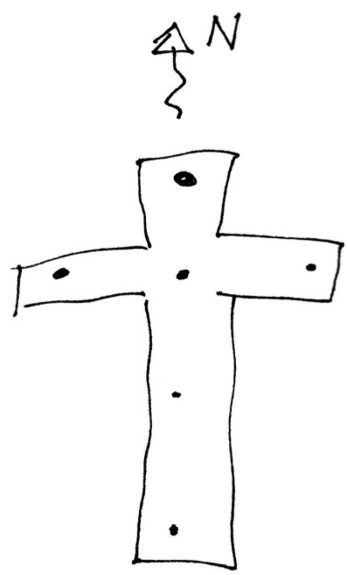

Figure 4. The Northern Cross.

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CA1 4.7: Common Asterisms Handout

Most suburban and urban sites cannot see the Milky Way at all. In very dark neighborhoods far from car dealerships, you might have a chance.

The third star in the triangle is called *Altair*, which is associated with the constellation *Aquila* the Eagle. The constellation has a remarkable resemblance to the symbol worn by crew members on certain starship (except it is backwards). My college astronomy professor said that was because they were out in space, viewing the constellation from the other side.

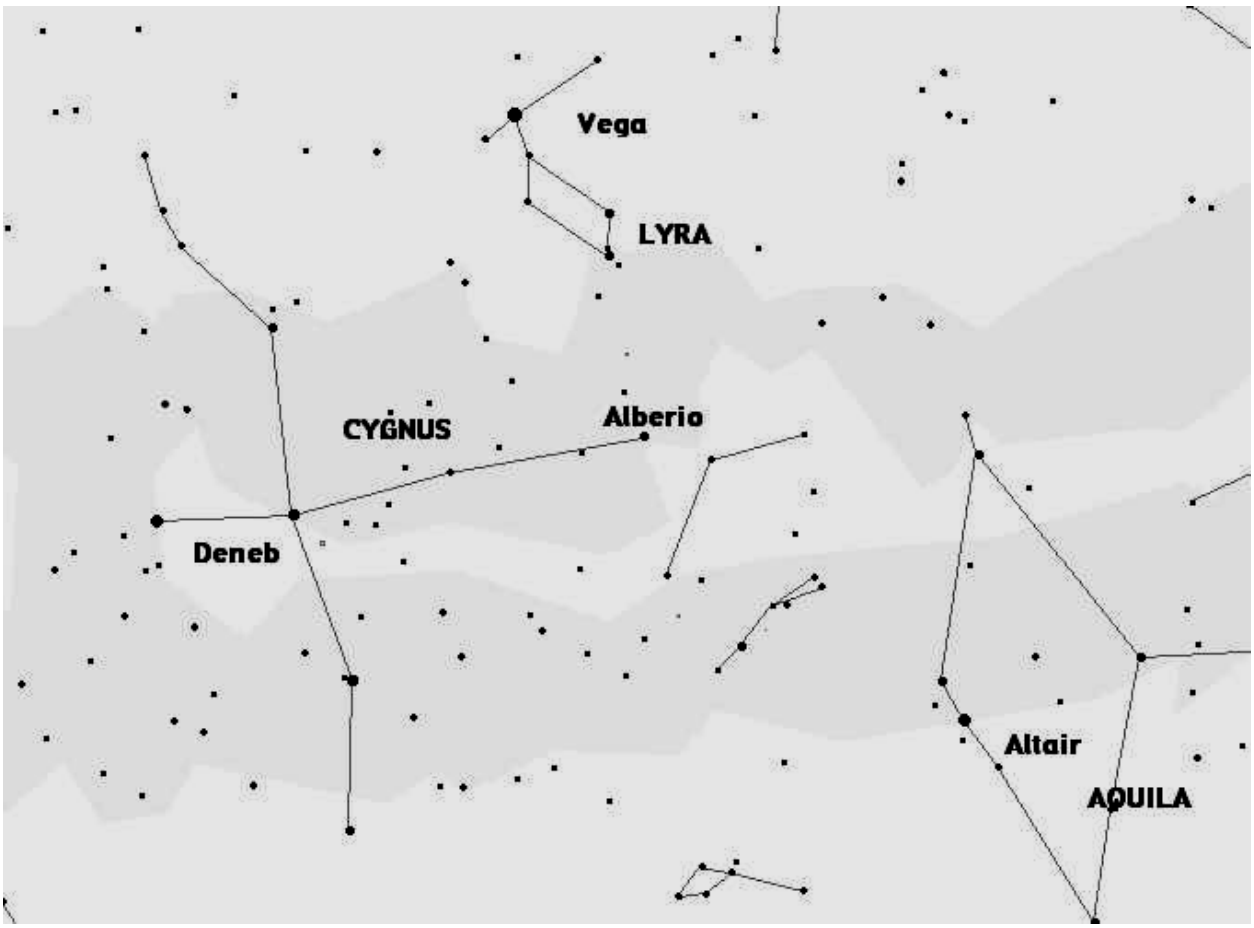

Figure 5. Stars and constellations of the Summer Triangle.

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CA1 4.7: Common Asterisms Handout

Scorpius the Scorpion and Sagittarius the Teapot

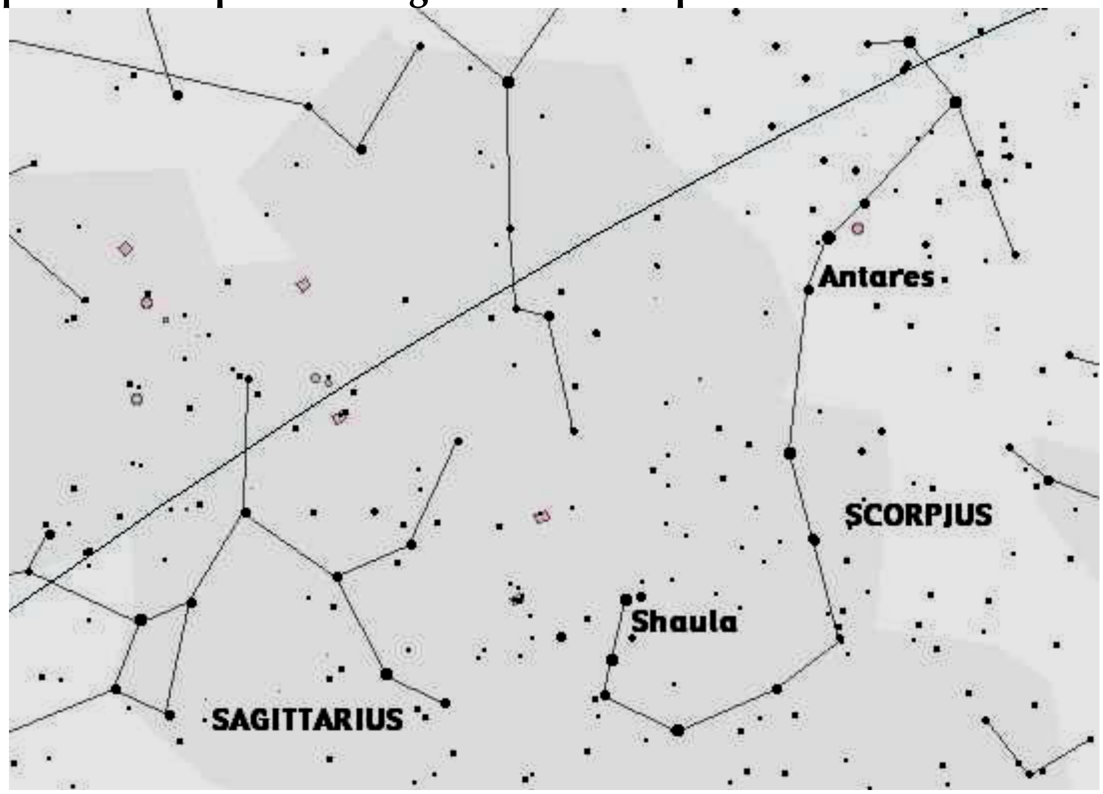

Figure 6. Scorpius and Sagittarius.

In the summer sky in the early evening, we find *Scorpius* and *Sagittarius* in the southern sky. These bright and distinctive constellations are easily recognizable. Scorpius (note: Scorpio is the astrological sign; Scorpius is the constellation) is one of the few constellations strongly resembling the thing it is named after. We can easily see the curl of the tail and the stinger (a star called *Shaula*) as well as the bright red star representing the heart of the Scorpion, known as *Antares*. This brings up an important point: The stars do appear to have colors. This is best observed in extremely dark skies.

Sagittarius is another constellation easily observed, although to see the Archer it is supposed to represent, dark skies are needed. Casual observers from suburban settings can easily make out the asterism called the Teapot, which is perhaps a bit easier to see and remember.

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CA1 4.7: Common Asterisms Handout

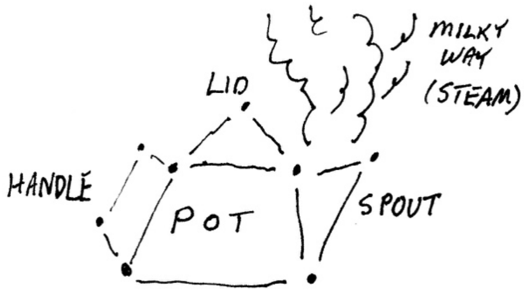

Figure 7. The teapot.

In dark skies, the Milky Way can be seen rising from the spout of the teapot like steam from a kettle. There are also a number of deep sky objects in this region including globular clusters and nebulae, easily visible with a small telescope. In the diagram on the previous page they are marked with small triangles and circles.

The Winter Football and Orion

These constellations are visible in the late fall, winter, and early spring and make a remarkable asterism known (in the United States) as the *Winter Football*. This isn't as well known as some other asterisms—possibly because people are more reluctant to observe in the wintertime—but it is remarkable because it contains some of the brightest stars in the sky, as well as the most famous open cluster and emission nebula known.

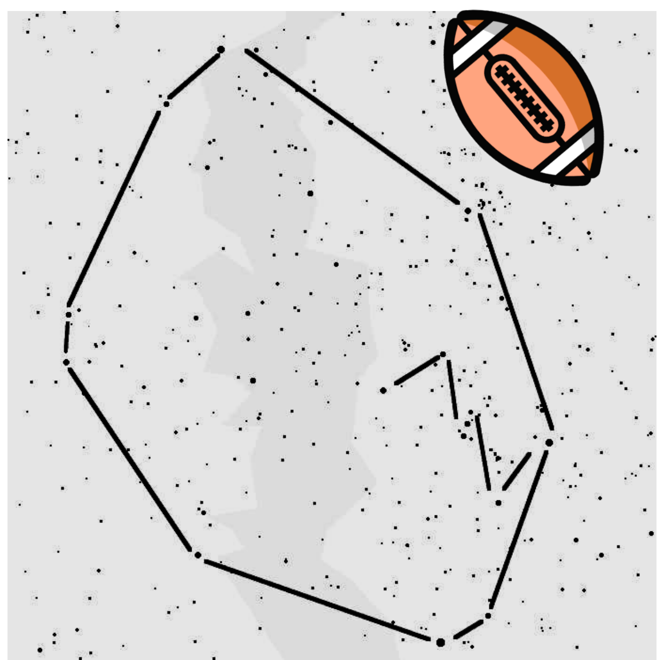

Figure 8. The Winter Football. The constellation Orion represents the stitching.

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CA1 4.7: Common Asterisms Handout

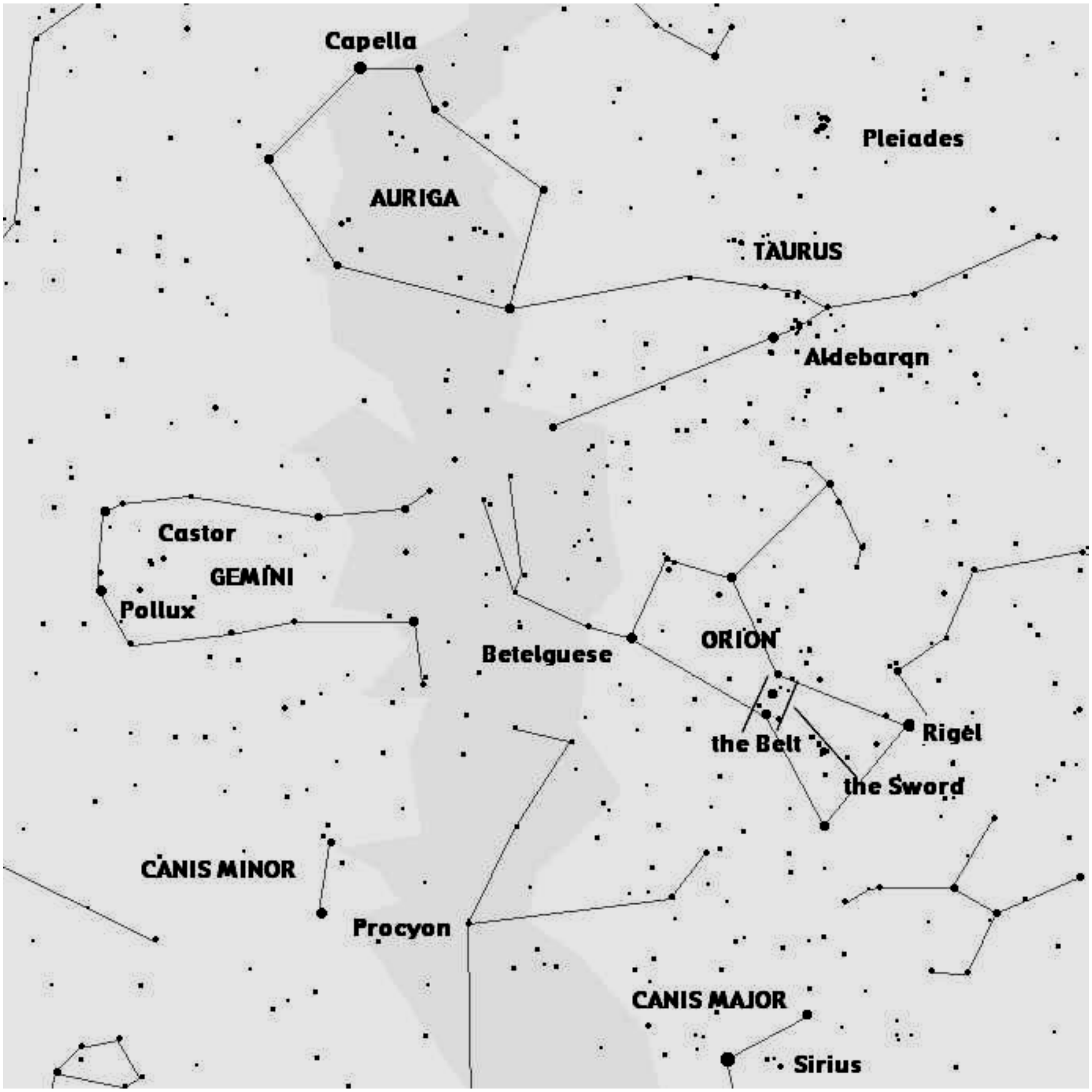

Figure 9. Important constellations and stars in the Winter Football.

By far the most easily recognizable constellation in this area of the sky is Orion the hunter. Orion's figure is notable for the number of bright stars it has, making it visible even in light-polluted skies.

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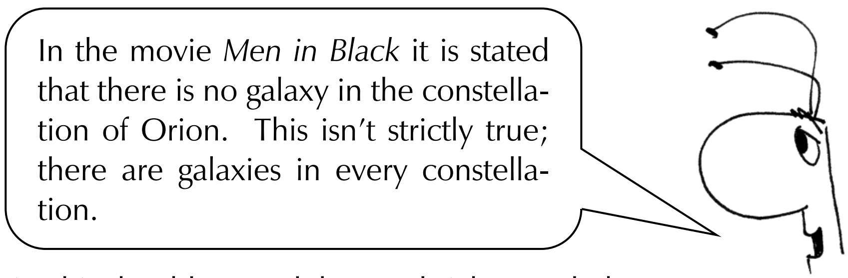
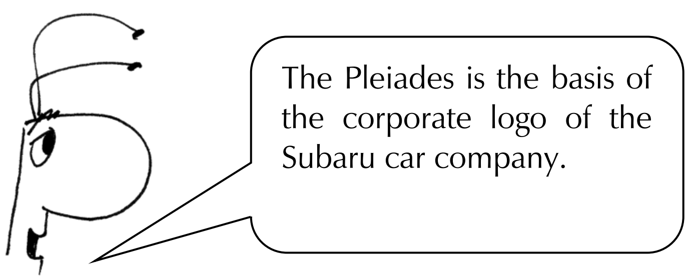
CA1 4.7: Common Asterisms Handout



Within this constellation we see three bright stars in a row, called the *belt of Orion*. Orion's figure is drawn starting with the belt. The usual interpretation has the two bright stars above the belt representing his shoulders, and the two bright stars below representing his knees. Most people find this one fairly easy to visualize. The bright star representing his right shoulder (on the left side of the constellation) is called Betelgeuse (pronounced Beetle-juice, like the movie, or Bay-tel-gice). This is a red giant star which shows color easily, especially in contrast to blue-white *Rigel*, located where Orion's right knee would be. Under the belt there is a fuzzy patch, visible in reasonably dark skies, which represents his sword or scabbard. This fuzzy patch is actually a bright emission nebula, called the *Great Nebula in Orion*, and can be shown to be a gas cloud even with binoculars.

Continuing around the football, we find above Orion the constellation Taurus the bull, with its great red eye Aldebaran. Two horns can be seen pointing in Orion's general direction. The usual interpretation is Orion is fighting the bull.



Above Taurus (and not usually included in the football asterism) is a small cluster of stars known as the Pleiades, or the seven sisters. It is an open cluster, sometimes mistaken for the Little Dipper because it looks sort of like a small dipper.

At the peak of the football high in the sky is the constellation Auriga, containing the bright star *Capella*. Continuing down the left side we see the *Gemini* twins, *Castor* and *Pollux*. You might think of these stars as fraternal twins because even casual observers can see they aren't exactly alike.

Completing the football figure we have *Procyon* in the constellation *Canis Minor*, and at the bottom point of the football lays the star *Sirius* in the constellation *Canis Major*.

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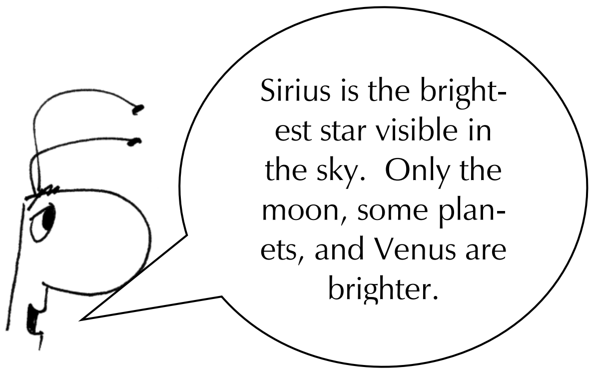
CA1 4.7: Common Asterisms Handout



You've read through a tremendous amount of material in this section with no specific instructions on what to do with the information. Your assignment is simple: observe as many of these constellations, stars, and asterisms as you can, and record what you see in your observing notebook. Careful observations can be used to document limiting magnitudes caused by light pollution, so draw carefully.

Then use a star map or planisphere, and observe the things we haven't mentioned!

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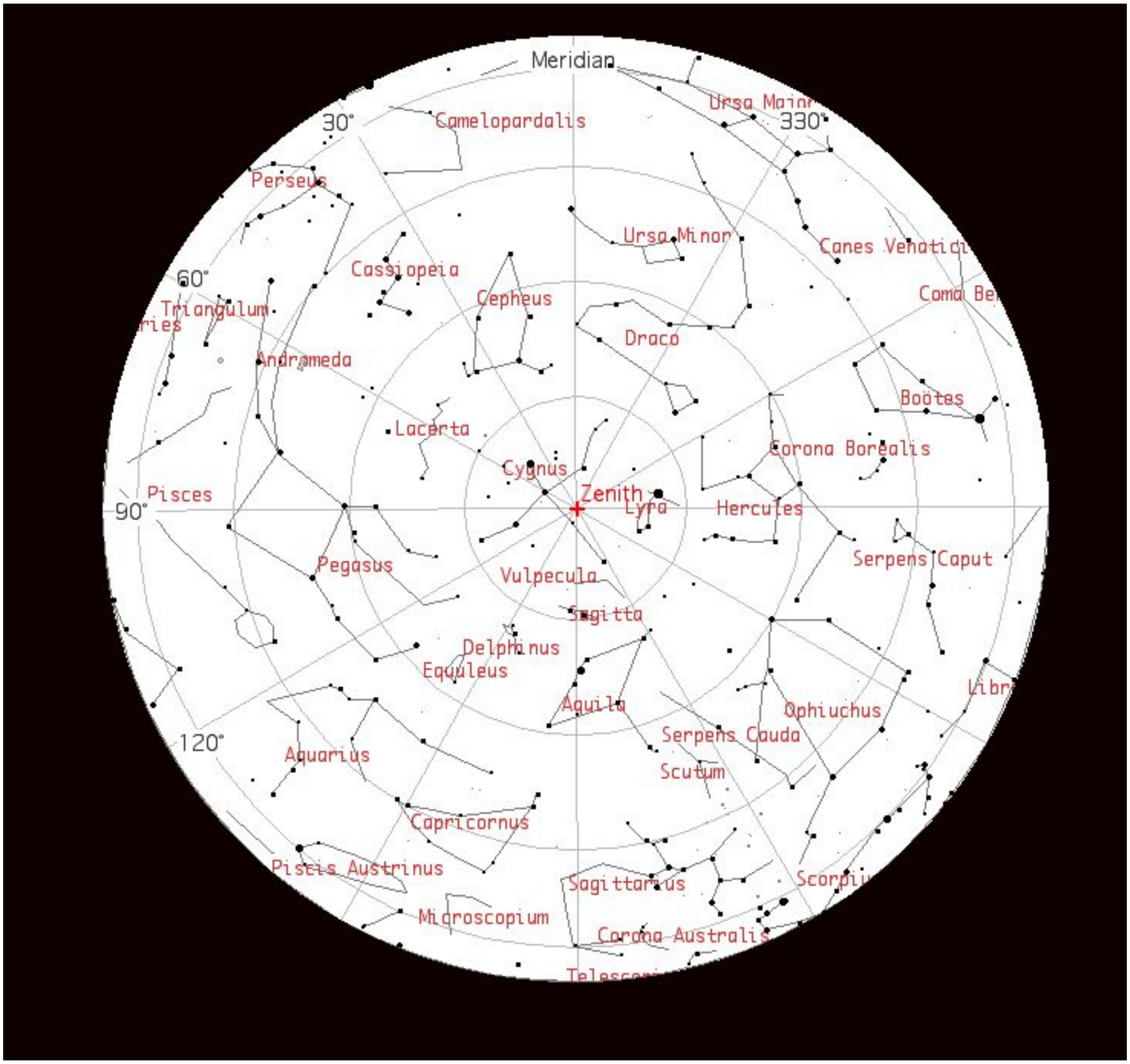
CA1 4.8.1: September Constellations Handout



This chart shows the night sky at 9 PM in September for mid-northern latitudes. The center of the chart is at the Zenith (straight up.)

The bottom of the chart represents the southern horizon. Facing south, east is to your right, west to your left, and north is behind you.

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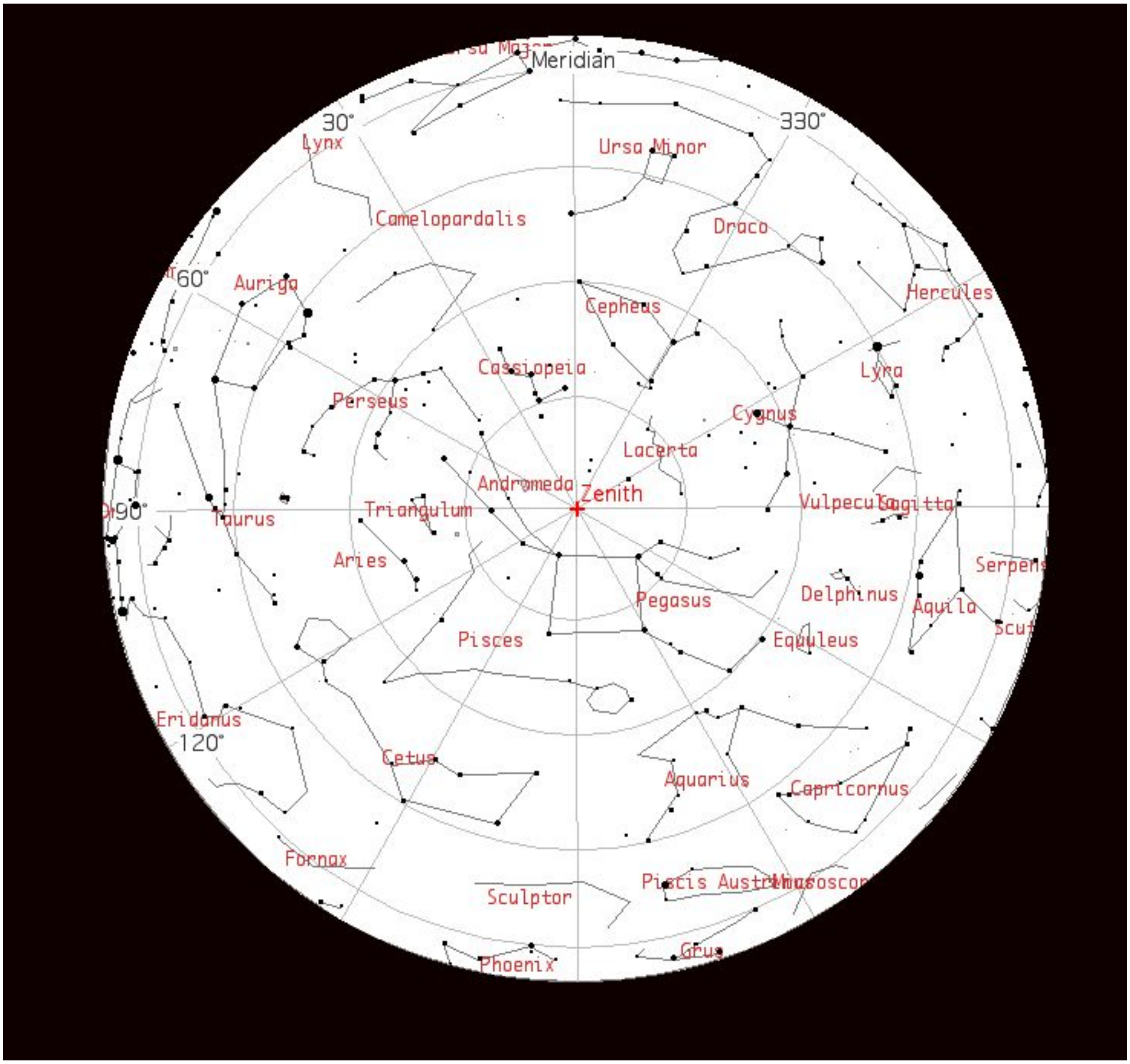
CA1 4.8.2: November Constellations Handout



This chart shows the night sky at 9 PM in November for mid-northern latitudes. The center of the chart is at the Zenith (straight up.)

The bottom of the chart represents the southern horizon. Facing south, east is to your right, west to your left, and north is behind you.

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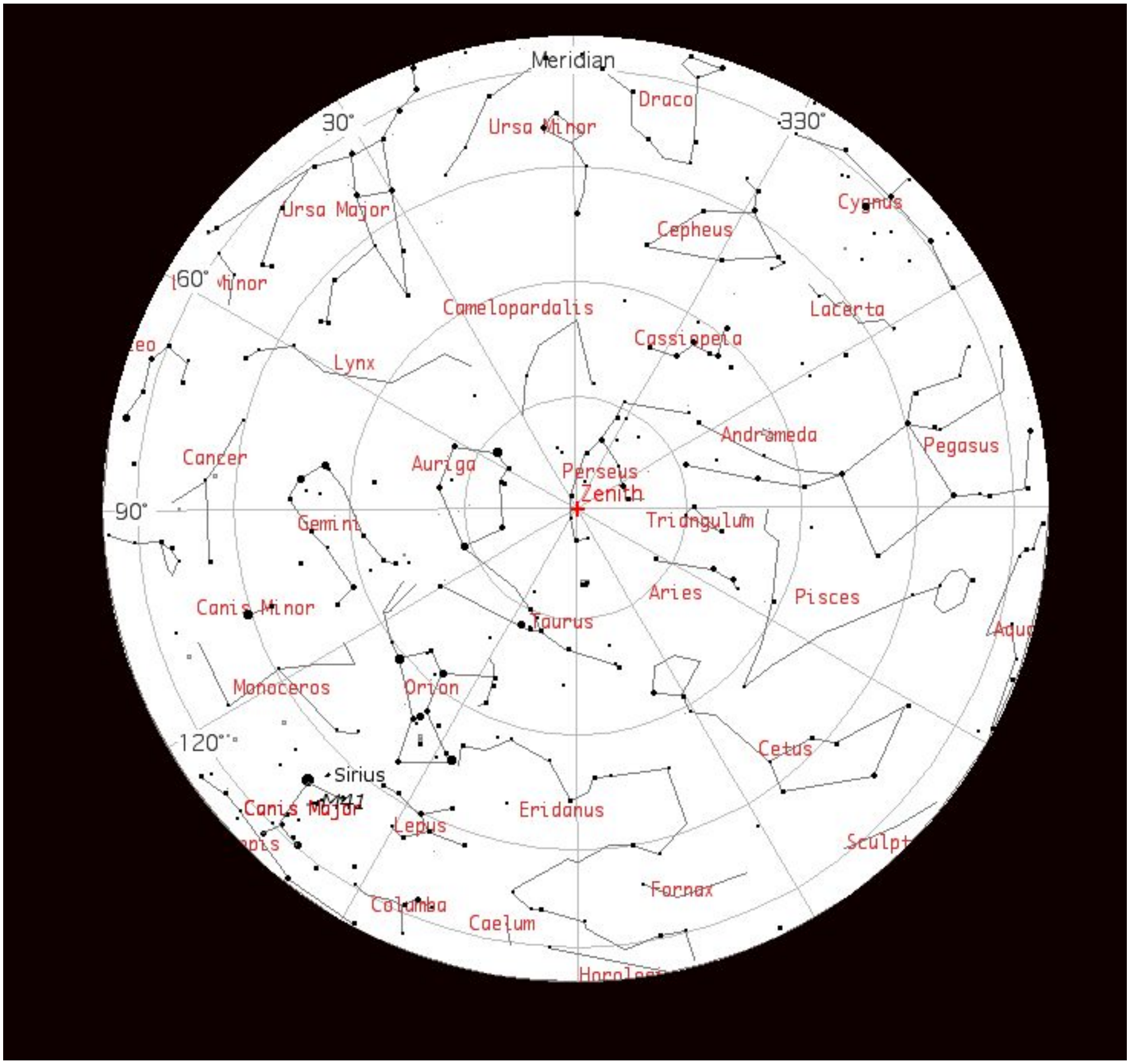
CA1 4.8.3: January Constellations Handout



This chart shows the night sky at 9 PM in January for mid-northern latitudes. The center of the chart is at the Zenith (straight up.)

The bottom of the chart represents the southern horizon. Facing south, east is to your right, west to your left, and north is behind you.

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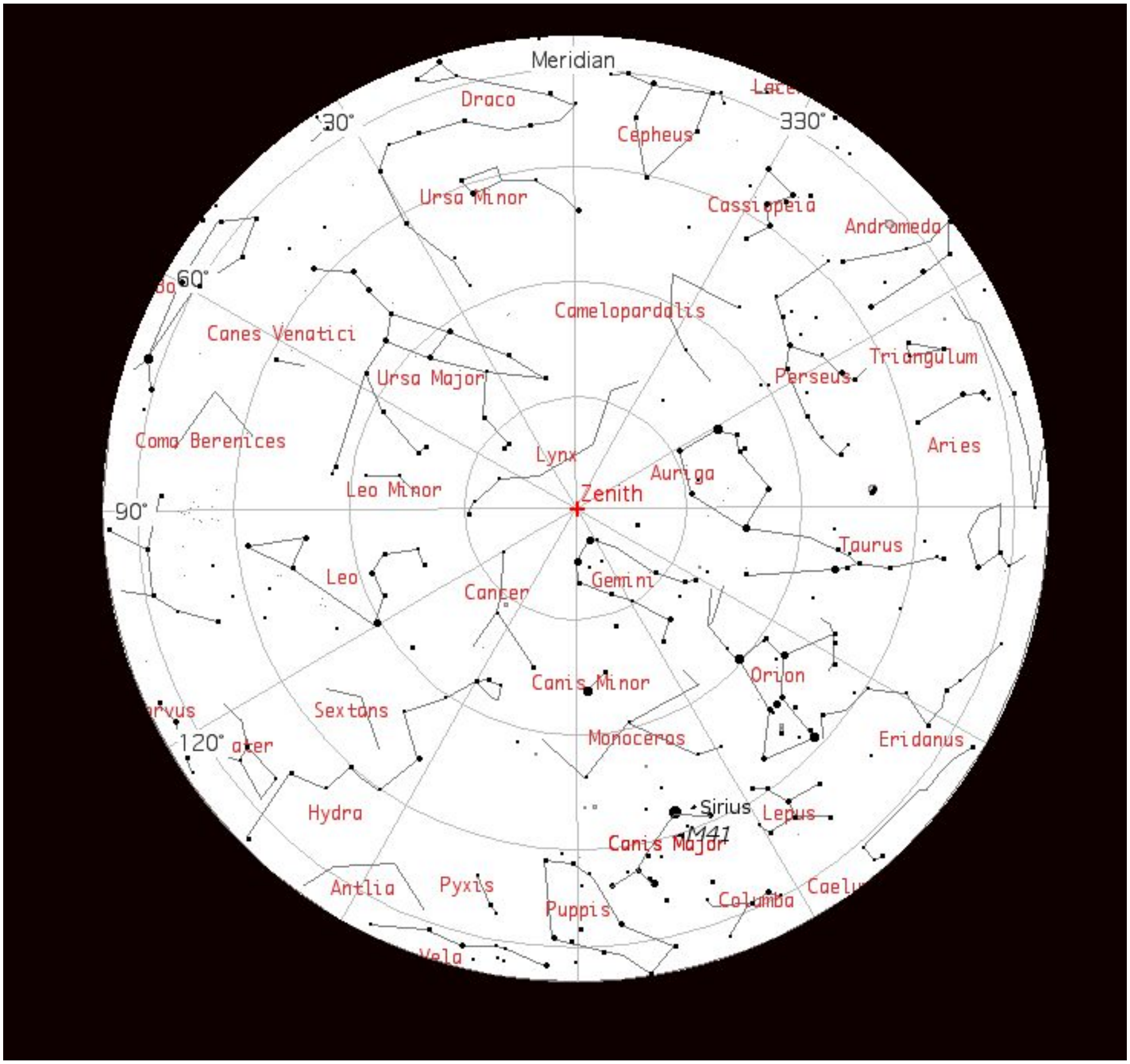
CA1 4.8.4: March Constellations Handout



This chart shows the night sky at 9 PM in March for mid-northern latitudes. The center of the chart is at the Zenith (straight up.)

The bottom of the chart represents the southern horizon. Facing south, east is to your right, west to your left, and north is behind you.

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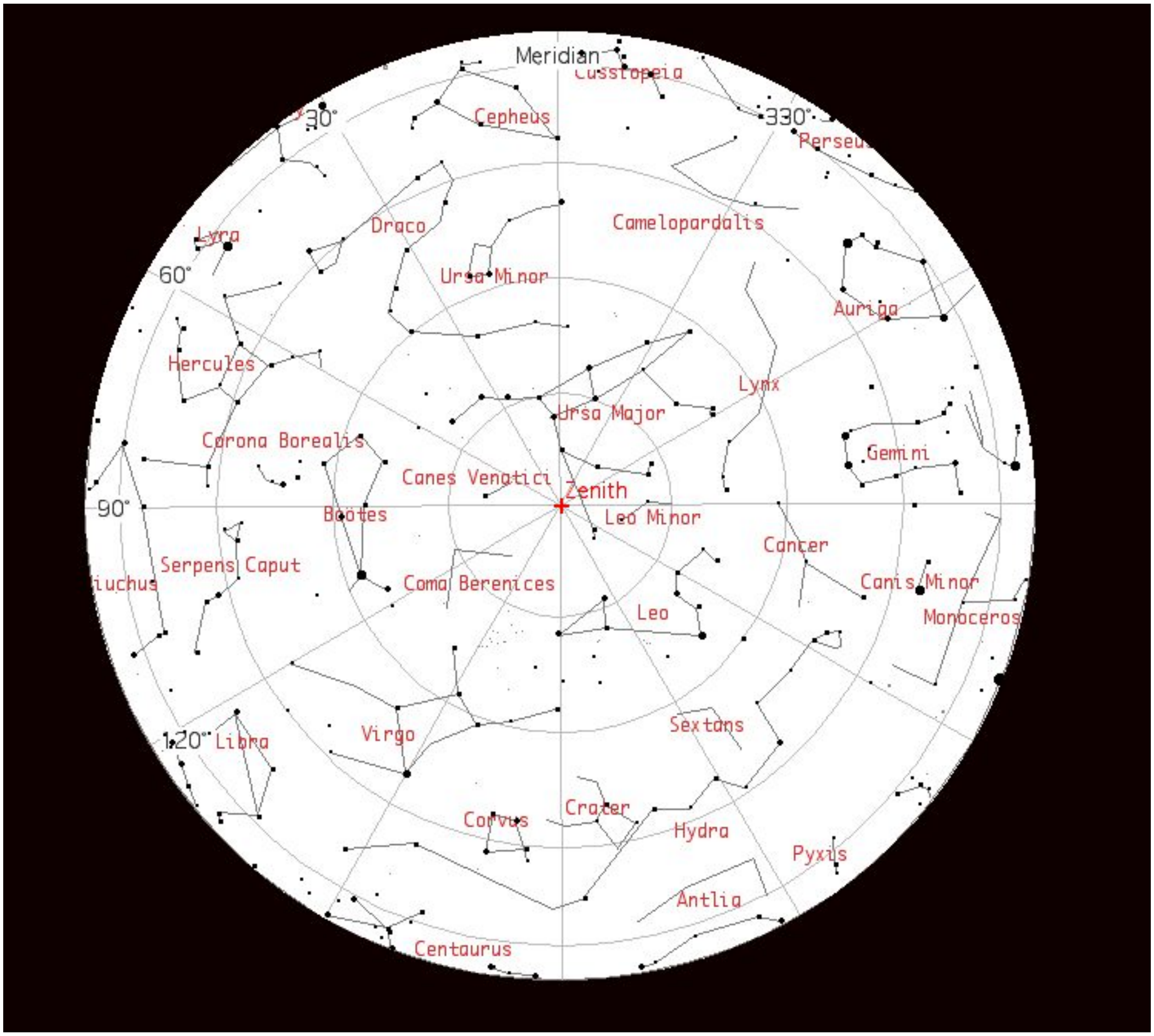
CA1 4.8.5: May Constellations Handout



This chart shows the night sky at 9 PM in May for mid-northern latitudes. The center of the chart is at the Zenith (straight up.)

The bottom of the chart represents the southern horizon. Facing south, east is to your right, west to your left, and north is behind you.

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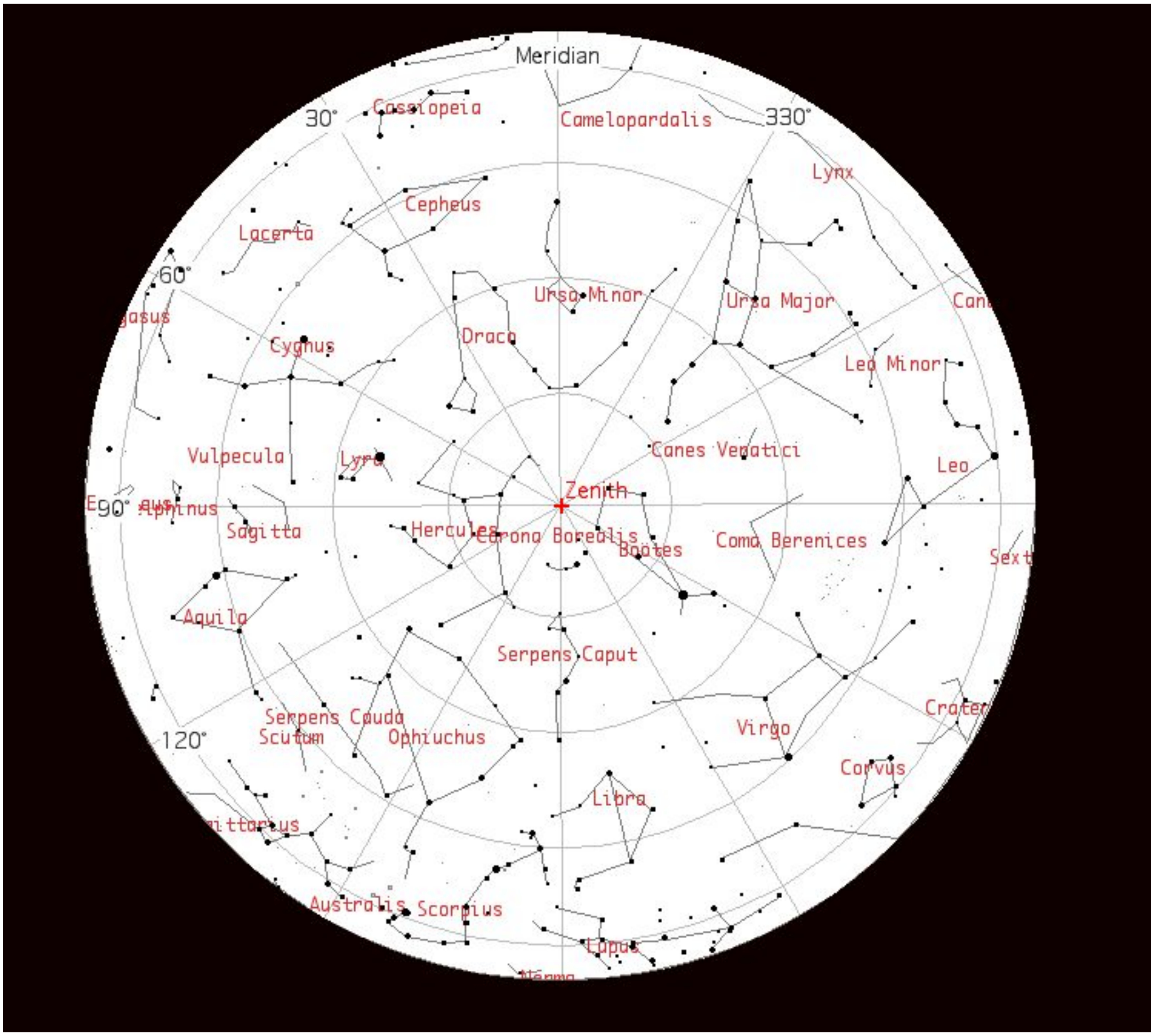
CA1 4.8.6: July Constellations Handout



This chart shows the night sky at 9 PM in July for mid-northern latitudes. The center of the chart is at the Zenith (straight up.)

The bottom of the chart represents the southern horizon. Facing south, east is to your right, west to your left, and north is behind you.

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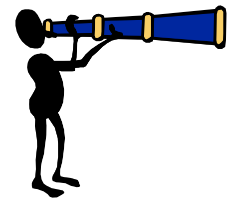
CA1 4.9: Estimating Magnitudes Lab



Purpose: To teach students how to visually estimate the magnitude of stars.

Background: The magnitude scale was originally invented as a scale representing the *importance* of stars. Thus, a magnitude 1 star was more important than a magnitude 2 star. Early star catalogs sorted stars into magnitudes 1 – 6, and when the system was made into a systematic physical measurement some magnitudes were re-defined to be zero or negative 1. Magnitude 6 is the dimmest thing humans can see in a dark sky with no light pollution with fully dark-adapted eyes.

Procedure:
Make an observation of the Big Dipper and Little Dipper. Draw only the stars you can see. Use the chart below to determine the dimmest magnitude you can see from your observing location. This is the *limiting magnitude* for your observing site and should be noted when you are doing a series of observations. The limiting magnitude is in itself an observation.

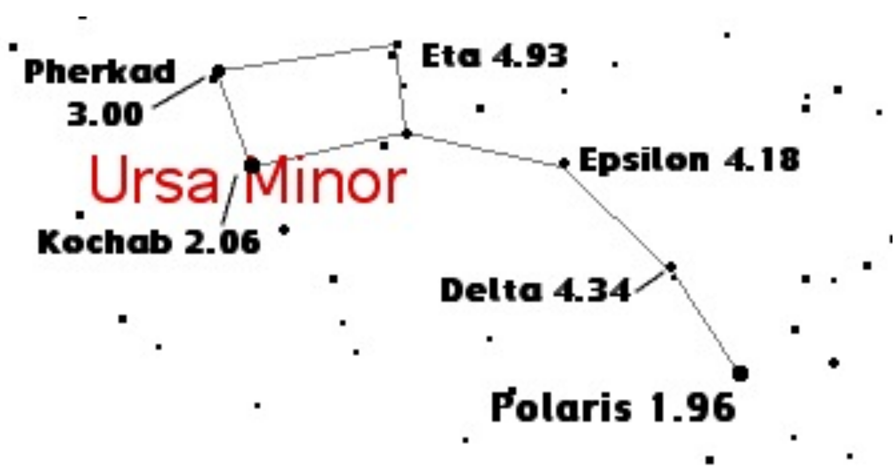


Figure 1: Magnitudes of stars in Ursa Minor.

What is the limiting magnitude for your observation? Include the date and time.

On the next page, sketch exactly what you see when you look at Ursa Minor.

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CA1 4.9: Estimating Magnitudes

Record your observations of the little dipper here.

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CA1 4.10: Light Pollution Map Lab

Purpose: To map light pollution in your community.

Background:
Light pollution is caused by poorly designed lighting which sends light up into the sky. The sky gets brighter, the stars less visible, and the ground the light is intended to illuminate is not lit. This wastes electricity and money. For more information about light pollution visit the International Dark Sky Association's web site (http://www.darksky.org).

Materials:
Planisphere, map of community.
Design:
Hypothesis: Light pollution in your community is greater near commercial zones.
Independent variable:

Dependent variable:

Interfering variables:

Be sure to review interfering variables before beginning the experiment.

Procedure:
1. Using the method of measuring limiting magnitude (Lab 4-3) make measurements of light pollution in your neighborhoods. On a map of the community, mark the limiting magnitudes you measured.

2. Use a highlighter to identify shopping centers, especially movie theatres, car dealerships, and similarly brightly lit businesses.

3. Is there a pattern to the light pollution in your community?

____

____

____

____

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CA1 4.10: Light Pollution Map

4. Where is the best place to observe the night sky?

____

____

____

5. "Full cut off" lighting is outdoor lighting which uses shields or hoods to direct light downward so it cannot be seen from the side or above. "Partial cut off" lighting is visible from the side, but not from above. Some decorative lighting shines straight up in the air for no apparent good purpose other than to light up the sky. What kind of lighting exists at your school?

____

____

____

____

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CA1 4.11: Factor-Label Conversions Handout

Purpose: To learn how to convert measurements from one unit to another efficiently.

Background: Units of measurement are simply comparisons against an agreed-upon measurement standard. Often, many different units can be used to measure the same thing. Feet and meters both measure length, while seconds and years both measure time. It is often necessary to convert units so that comparisons can be made.

To convert units, use the *factor label method*. This is a reliable method that, if applied properly, can allow you to make complex conversions in the shortest number of steps possible.

First you must gather information that will help you decide. These are the *conversion factors*. Conversion factors of interest to astronomers are listed in Appendix A-5.

Example: Consider this question. How many seconds are in a year?

You might not know how many seconds are in a year, but you probably know that there are:

- 60 seconds in a minute
- 60 minutes in an hour
- 24 hours in a day
- 354.24 days in a year.

But what do you do with these numbers? Add, subtract, multiply or divide? and in what order? Consider the following calculation:

$$\frac{1 year}{1} x \frac{365.24 days}{1 year}$$

Note that the quantity we wish to convert (1 year) is written as a fraction over 1. Then the conversion factor (365.24 days = 1 year) is also written as a fraction, but arranged so that the units of *years* will cancel.

Now consider a string of conversions taking the 1 year all the way to seconds in a series of calculations. Cancel out units everywhere you can in the calculation shown here.

$$\frac{1 year}{1} x \frac{365.24 days}{1 year} x \frac{24 hours}{1 day} x \frac{60 \min}{1 hour} x \frac{60 \sec}{1 \min} =$$

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CA1 4.11: Factor-Label Conversions

What does this calculation tell us to do? Multiply everything in the numerator, and divide by everything in the denominator. (The denominator is not always 1.)

1. Do the arithmetic and show the numerical answer above. Now, using conversion factors from Appendix A-5, perform the following conversions. Use this generic format:

$$\frac{\text{Original value and unit}}{1} x \left\{\frac{\text{New unit}}{\text{old unit}}\right\} x \left\{\frac{\text{New unit}}{\text{old unit}}\right\} x \left\{\frac{\text{New unit}}{\text{old unit}}\right\} \ldots$$

2. How many inches are in a 100-yard football field?

3. Light travels 186,282 miles in one second. How far will it travel in a year?

4. One parsec of distance equals 3.26 light years. How many miles are in a parsec?

5. How many pennies are equivalent to a 20 dollar bill?

6. How many arcseconds are there in a 0.5° declination angle?

7. How many minutes of right ascension are there in 3 hours of RA?

8. How many radians are there in a 3 degree 22 minute angle?

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CA1 4.12: Constellation Homework Handout

Purpose: To practice using a planisphere or sky simulation software.

Answer the questions below using planisphere or sky simulator software such as Stellarium.

1. Approximately what time does Orion rise on January 15?

____

2. What constellations are straight up at 10:00 PM on June 10?

____

____

____

____

3. You plan to observe the Ring Nebula, which is located in the constellation Lyra. The best time is when the Ring Nebula is close to straight overhead. What time of night would this be on September 14?

____

____

4. Describe or sketch the orientation of the Big Dipper on October 20 at 3 AM.

____

____

5. If observing at midnight, during which months does the constellation Cassiopeia look like a:

“3”:

M:

E:

W:

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CA1 4.13: A Large Geodesic Dome Activity

Purpose: This activity takes several days, but at the end of it you will have a working planetarium! This set of plans tells you how to build a 5-meter dome suitable for a small high school class or a large elementary class. This activity is focused on building the dome and obtaining a projector; the next set of instructions tells what to do with the dome once you build it.

These instructions are adapted from a web page by the Contra Costa County (CA) Office of Education and the Dean and Margaret Lesher Foundation's CTAG project "A Planetarium for Every School." Other versions are posted at the web site. http://www.cccoe.net/stars/

Materials needed: corrugated cardboard—ten to twenty 4x8 foot sheets, giant binder clips (2 inch or larger), cutting tools (scissors and x-acto knives), rulers and meter sticks, string, paint (flat white, grey, or black, depending on design), brushes, clear plastic bowl or cylinder, 3-6 V light bulb plus battery and wires to make it glow, commercial star projector toy (optional); thin strips of plywood, nuts and bolts (optional).

Getting materials

This dome is a 2v, or two-frequency geodesic dome based on plans posted at www.desertdomes.com (plans used with permission). Plans are not presented here to make this into a sphere, although you could easily do so by adding additional triangles and continuing the pattern (but where would you put it?). Two different triangle sizes are used. An optional base ring lifts the dome off the floor, and even makes it possible to add a door and ventilation system to the dome.

Unlike smaller domes, only corrugated cardboard is strong enough to support the weight of the dome. Even though each individual panel is lightweight, in combination all the cardboard used would be difficult to lift at best. Cutting corrugated cardboard isn't easy and scissors are probably not the best tool to use.

In some cases, if you use box cutters or an X-Acto knife to cut one side of the cardboard following a straightedge, you can fold the cardboard along the cut and just snap it apart. Otherwise, turn the cardboard over and fold it into a V-shape, then cut in the narrow channel that results.

If you have access to a paper manufacturing facility, sometimes cardboard can be purchased with one side already made white for producing white cardboard boxes. Such cardboard typically comes in 4 x 8 foot sheets, and you should take care not to bend it until absolutely necessary in order to retain its strength. It is entirely possible to build the dome

CA1 4.13: A Large Geodesic Dome

out of scrap cardboard from a variety of boxes, and a grocer or warehouse store probably has lots of boxes they would be willing to donate to your project.

If you don't have white cardboard, you should paint one side of the cardboard white with any white flat paint. It is best to note that painting is probably best done before the cardboard is assembled into a dome. The connecting flaps do not need to be painted.

The optional thin strips of plywood and nuts and bolts probably should not be used unless you intend to leave the dome assembled permanently. You will need to cut two strips for each joint, and use 3-4 nuts and bolt sets to create reinforcing strips that hold the cardboard tabs together. Used alone, the nuts and bolts will eventually pull through the cardboard.

Procedure:
This dome uses two different size triangles. To create a dome with a radius of 2.5 meters, construct the following templates for use in tracing triangles on other pieces of cardboard.

One way to make the template accurately for these triangles is to use an old geometry technique. First, draw the base the triangle with a pencil and ruler. Next, measure a length of string equal to one of the remaining sides, and draw an arc centered on one end of the line you drew. Repeat on the other side, and where the arcs cross must be where the top of the triangle is located.

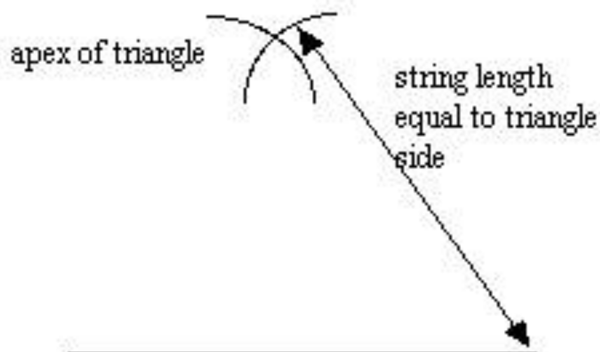

Figure 1. Use string to make a near-perfect isosceles triangle.

1. The first triangle, called an "A" type in these instructions, is an equilateral triangle with each side equal to 1.545 meters, or 154.5 centimeters. No gap between triangle sides is needed as you lay out this triangle and the next one on the cardboard, because these will be your templates for tracing.

This will be called triangle A. Make one of these. The measurements of the triangles were determined using an online dome calculator at Desert Domes.

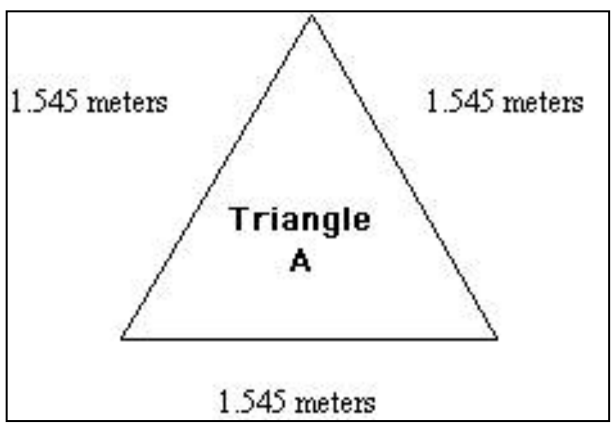

Figure 2. Triangle A.

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CA1 4.13: A Large Geodesic Dome

If you want to make a triangle using some other size, simply multiply these dimensions by the factor you would like to make the dome larger or smaller, or visit www.desertdomes.com and enter the new radius you would like to use. The reference to Desertdomes.com is used with permission.

2. The second triangle template is an isosceles triangle, which means two sides are the same length and the third side is different. In this case, the two identical sides are 1.365 meters long, and the third side is 1.545 meters long (the same as triangle A.) This is called triangle B. Make one of these. Again, leave at least a 4 inch gap between this triangle and the next.

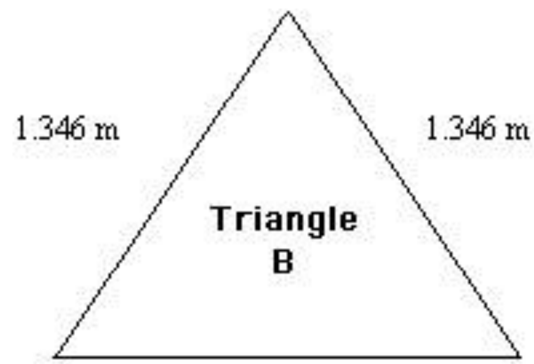

Figure 3. Triangle B.

3. Once you have the templates made, assemble enough cardboard to make the remaining triangles. You will need to make 10 A-type triangles and 30 B-type triangles. Don't put them right next to each other, however; you'll need to leave a 4-inch gap between them (keep reading).

Your teacher may assign you the task of determining how much cardboard is needed prior to the assembly.

Each time you make a triangle, trace the shape from the template so that all the triangles are identical. This will work better than measuring from scratch each time. You need to leave about a 5-cm (2 inch) flap along each edge to use when connecting the triangles together. A single completed triangle will look like this. The flap should not be substantially larger or smaller than the giant triangular binder clips you will use to connect the panels.

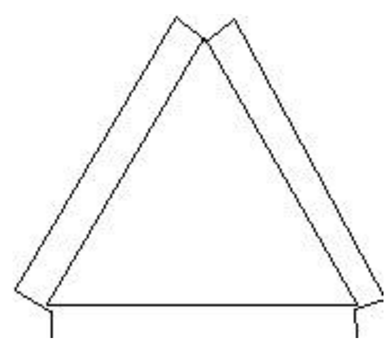

Figure 4. Each triangle edge needs a flap.

The connecting flaps for this dome will need to be folded carefully so they bend straight. In this case score the cardboard by drawing a heavy line with a ball-point pen (not a felt-tip) which will weaken the bending joint.

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CA1 4.13: A Large Geodesic Dome

Then bend the cardboard along the line you drew to make a flap or other junction. Don't be afraid to practice on some scrap before committing yourself to a more permanent part.

Another good idea is to label the outside of the triangle with the type, A or B; when you have a stack of triangles it can be difficult to tell which is which. The outside of the triangle is the side the flaps bend toward.

4. At this point you need to obtain binder clips, the large black triangular kind you get from office supply stores. Four per tab should be sufficient, and including the base ring and having some spares, 400 clips will be required. One student who built a larger dome with clips proclaimed, "Rule number one: You can never have too many clips," so consider buying extra for loss and breakage and reinforcing weak spots. The advantages of clips are ease and speed of construction. Their primary disadvantage is they do not take a lot of force to pop loose and slip. This is your best choice if you wish to assemble a temporary dome. When disassembled, the parts fit nicely in a large box or behind a cabinet.

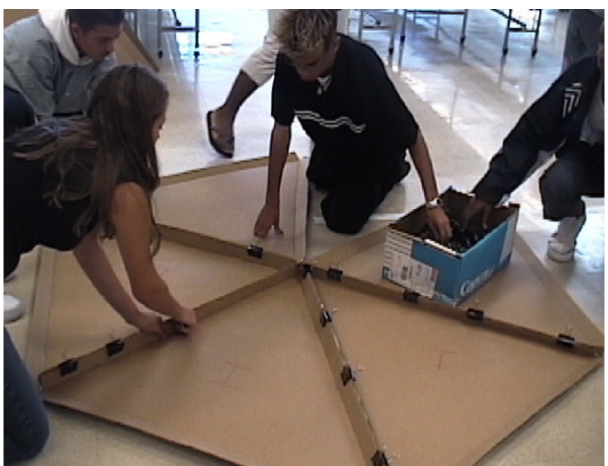
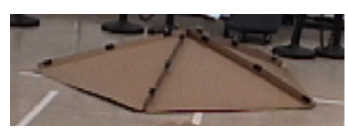


Figure 6. Assemble 5 triangles on the floor.

5. To assemble the dome using your chosen method of attachment, begin by building a pentagon of 5 "B" triangles, with the long sides all on the outside. Leave the last joint unconnected until all the others are done to make the assembly easier.

Connect the last two interior sides together to make a little "cap" or inverted bowl shape. The cap will pucker up and make a little peak.

6. Make 5 more of these pentagon shapes. Set one of the pentagons aside.



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CA1 4.13: A Large Geodesic Dome

7. Set 5 pentagons into a circular pattern on the floor as shown in Figure 7.

Next insert an "A" triangle between them. In the diagram, the "A" triangles are black. The view is looking down from above.

If you are working alone, having lots of chairs around to brace things is helpful. Helpful tip: Don't try this alone.

Stand the pentagons up on one edge and attach the "A" triangles. It's easier if you do two pentagons at a time.

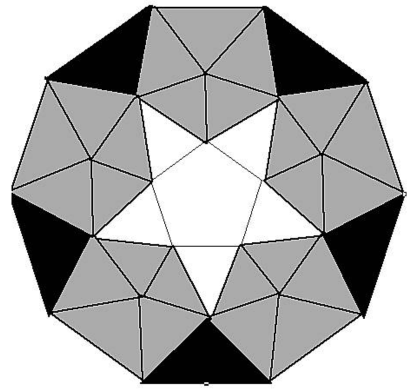

Figure 7. Arrange five pentagon-caps as shown.

Figure 8. Stand the pentagons up on their sides and connect the adjacent "A" triangles with clips.

8. Insert another "A" triangle into the gaps at the tops of the pentagons, this time with the point of the "A" pointing downward. This will make a "ring" of pentagons leaving a hole in the top.

9. Set the remaining "B" triangle pentagon into the remaining hole and attach with clips. Again, two people working at once is much easier, especially on the larger domes.

9. You should next construct a base ring. Make ten panels 1.545 meters wide, and as tall as you would like the dome to be off the floor (probably not more than a meter would be best.) Don't forget to leave extra flaps on the edges and top to attach the panels to each other and the dome. Before you put the dome on the base ring, however, you need to add the lid to the top of the dome.

Figure 9. Build a base ring to support the dome.

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CA1 4.13: A Large Geodesic Dome

Figure 10. A completed dome with base ring.

This is what the finished dome will look like.

10. Ventilation.
Would you like to be closed into a cardboard box with 30 people for half an hour with no ventilation? Neither would we. You can easily build a simple ventilator with a floor fan and a large cardboard box. Simply put the fan at one end of the box, add two or three interior baffles (painted black if possible) to help stop the light leaks, and set the other end of the box in a hole in a base ring panel.

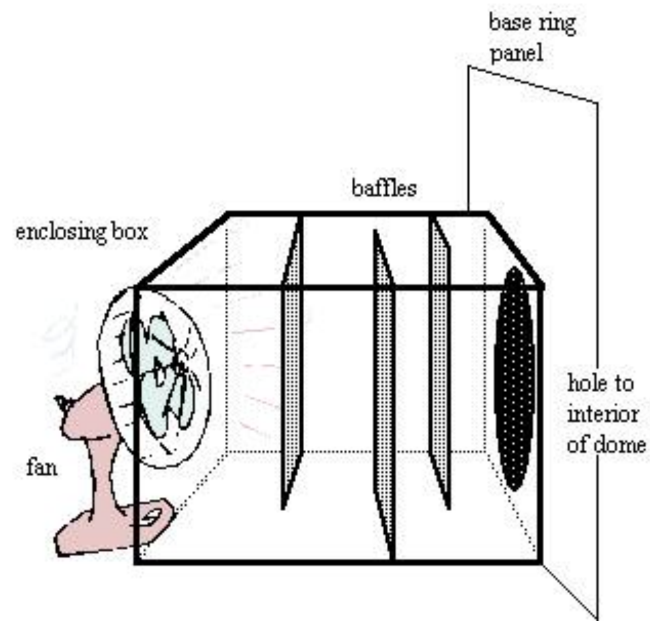
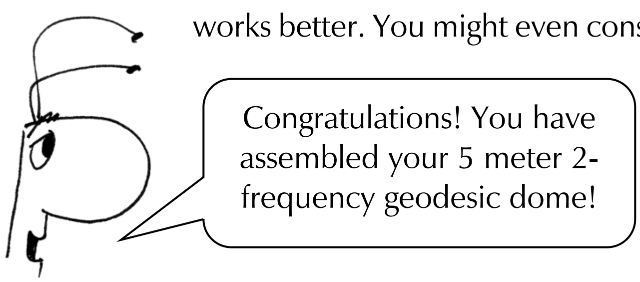


Figure 11. A ventilation system for your dome.

11. Add a Door.
Make a light-tight door by cutting a "clubhouse" door in a base ring panel (probably not adjacent to the ventilation system for strength). If you glue a piece of cardboard on the door slightly larger than the size of the door, the extra cardboard will serve as a light-blocking seal. A loop of string or a wooden knob can serve as a doorknob.

12. Plugging light leaks
If the room you are using cannot be completely darkened, light may leak at the joints where the triangle corners meet.

If you discover this is a problem, you can either drape sheets over the entire assembly or use poster board or aluminum foil to cover each individual junction to prevent light leaks. Darker works better. You might even consider taping the interior joints with white tape if you intend to leave the dome assembled for a while.



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CA1 4.14: The Night Sky Puzzle

Complete the puzzle below. When you finish, a message will be displayed.

1 N	2 N		3 N	4 E	5 V	6 E	7 B		8 A	9 A	10 O	11 G	12 D	13 E		14 H	15 H	16 G		17 O	18 C	19 E	20 I	,
	21 C	22 U	23 D		24 K	25 E	26 I	27 E		28 L	29 G	30 E	31 L		32 F	33 I	34 X	35 E	36 O		37 A	38 A		39 T
40 F	41 E		42 P	43 F	44 E	45 F	46 D	47 D	48 J	,		49 M	50 E		51 I	52 B	53 T	54 E		55 D	56 E	57 T	58 T	59 G
60 G	61 L		62 B	63 O	64 O	65 T	66 G	67 F	,		68 C	69 H	70 H		71 H	72 L		73 N	74 H	75 E		76 N	77 E	78 E
79 C	-	-	80 W	81 H	82 A	83 G	84 H		85 K	86 E	87 F		88 H	89 A	90 A	91 I		92 C	93 K	94 H	95 L		96 A	97 H
98 H		99 W	100 I	101 E	102 M	,		103 K	104 N	105 D		106 W	107 H	108 L	109 H	110 H		111 A	112 K	113 F	114 N	115 J		116 G
117 M	118 L	119 N	120 D		121 A	122 N	123 D		124 I	125 O	126 U	127 N	128 D		129 W	130 H	131 A	132 J	133 B		134 B	135 B		136 G
137 B	,		138 F	139 E	140 C	141 J	142 D	143 N		144 O	145 K	146 M	147 O	148 N	,		149 F	150 A	151 E		152 L	153 L	154 G	155 N
156 C		157 N	158 D	159 V	160 E	161 K		162 D	163 D	164 F	165 F	166 H	167 G	168 G		169 J	170 N	171 H	172 O		173 E	174 H	175 F	
176 B	177 G	178 D	179 L	180 A	181 B		182 A	183 F		184 O	185 C	186 L	187 G	188 H	189 J	190 D		-	-	191 H	192 K	193 E	194 F	195 L

A. ___(8) ___(182) ___(150) ___(90) ___(96) ___(131) ___(9) ___(89) ___(180) ___(111) ___(82) ___(37) ___(38)
A collection of stars representing a region of the sky, a story, and a picture

B. ___(52) ___(137) ___(135) ___(133) ___(7) ___(134) ___(176) ___(181)
An "unofficial" constellation

C. ___(21) ___(68) ___(18) ___(156) ___(79)
Method of labeling stars using Greek letters

D. ___(178) ___(163) ___(55) ___(12)   ___(46) ___(142) ___(47)   ___(190) ___(158) ___(23)
The sun and the stars both do this. (3 words)

E. ___(151) ___(78) ___(173) ___(54)   ___(139) ___(50) ___(13)   ___(27) ___(101) ___(193) ___(160)
Which constellation you see at a particular night depends on the ...

F. ___(164) ___(43) ___(149) ___(87) ___(45) ___(67) ___(165) ___(40) ___(175) ___(113) ___(194)
A circular star map used to show which stars are up for a given date and time.

G. ___(116) ___(136) ___(168) ___(29) ___(177)   ___(187) ___(11) ___(83) ___(66) ___(167) ___(16) ___(59) ___(154) ___(60)
Sky longitude

H. ___(70) ___(98) ___(109) ___(94) ___(15) ___(69) ___(88) ___(171) ___(166) ___(71) ___(188)
Sky latitude

I. ___(26) ___(91) ___(51) ___(100) ___(124) ___(33) ___(20)
This star never rises or sets and is very nearly above the earth's north pole

J. ___(48) ___(141) ___(132) ___(169) ___(189) ___(115)
Brightest star in the night sky

K. ___(112) ___(145) S ___(93)   ___(85) ___(103) J ___(192) ___(161)
Constellation commonly known as the Big Dipper is officially a part of...

L. S ___(118) ___(31) M ___(179) ___(195)   ___(28) R ___(108) ___(152) ___(72) ___(61) ___(95) ___(186)
Big. Triangular.

M. ___(117) R ___(146) ___(49) ___(102)
This constellation includes the star Betelguese.

N. ___(76) R I ___(143) ___(1) ___(73) ___(104) ___(2) S S
Magnitudes are measurements of a star's

O. ___(36) I M M ___(17) R
Larger magnitude numbers represent _____ stars

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CA1 4.14: The Night Sky Puzzle Solution

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CA1 4.15: Lessons in a Planetarium Activity

Purpose: To present a list of demonstrations and observations you can do in your small planetarium or you can ask for in a large planetarium. Of course, you can observe all of these things in the real sky as well!

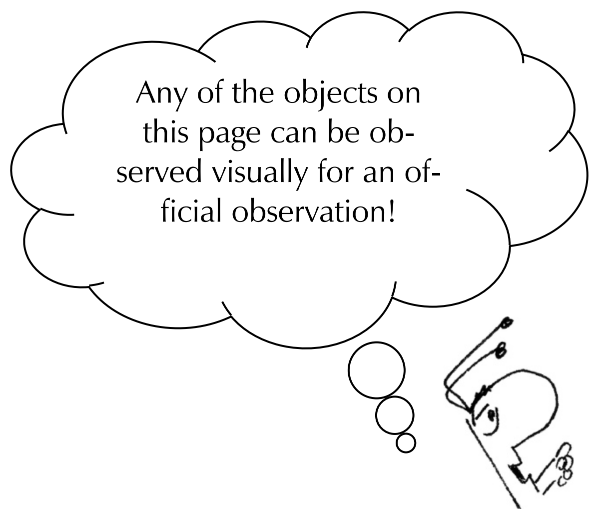
The list shows many kinds of specific observations of things you should see when you are in a planetarium if you are not seeing a “canned” show.

You can also use Stellarium to virtually observe everything in this list. Just use the program’s “Find” function to locate the constellations and other objects quickly.

Observations (No Deep Sky objects included)

Constellations, Stars and Asterisms

- Circumpolar (visible all year)
    - Ursa Major (Big Dipper)
    - Ursa Minor (Little Dipper)
    - Polaris
    - Dubhe, Merak, Mizar, Alcor
    - Cassiopeia
- Fall
    - Cygnus, Lyra, Aquila
    - Pegasus, Hercules
    - Sagittarius, Scorpius
    - Deneb, Vega, Altair, Antares
- Winter
    - Orion, Gemini, Taurus, Perseus
    - Betelguese, Rigel, Capella, Castor, Pollux, Procyon, Sirius, Aldebaran
- Spring
    - Leo, Libra, Bootes, Hercules, Corona Borealis, Gemini
    - Regulus, Arcturus, Spica, Denebola



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CA1 4.15: Lessons in a Planetarium Activity

"Landmarks in the sky"

- Summer Triangle
- Pointer Stars on the Big Dipper
- Arc to Arcturus
- Spike to Spica
- Winter Football

Planetarium Demonstrations

Coordinate Systems

- Zenith and Nadir and meridian
- Altitude and Azimuth angles
- Right Ascension and Declination
- Ecliptic Coordinates
- Galactic coordinates

The Effects of Latitude

- Position of the North Star
- Motion of stars through the heavens
- Definition of the arctic circle/polar days and nights

The Annual Motion of the Sun

- Definition of the zodiac
- Daily vs. annual motion
- The analemma

The Shifting Position of the Sun at Sunrise and Sunset

The Moon's Phases

Eclipses

- Solar and Lunar
- Partial and Total

Inferior/Superior Planets

- Maximum Elongation
- Inferior/Superior Conjunction

Retrograde Motion of Superior Planets

- The Retrograde Loop

The Phases of Venus

Meteor Showers

- Determining a radiant

Precession

Print Name ______________________________ Period _________ Date ________________

CA1 4.16: Dec- Degrees, Minutes, Seconds Handout

Purpose: to learn to convert degrees, minutes, and seconds of arc to decimal degrees.

Background: Altitude, azimuth, and declination are all measured in traditional degrees with 90 degrees representing a right angle. Degrees are further subdivided into 60 slices each called *minutes of arc,* and each minute of arc is composed of 60 seconds of arc, or arc seconds.

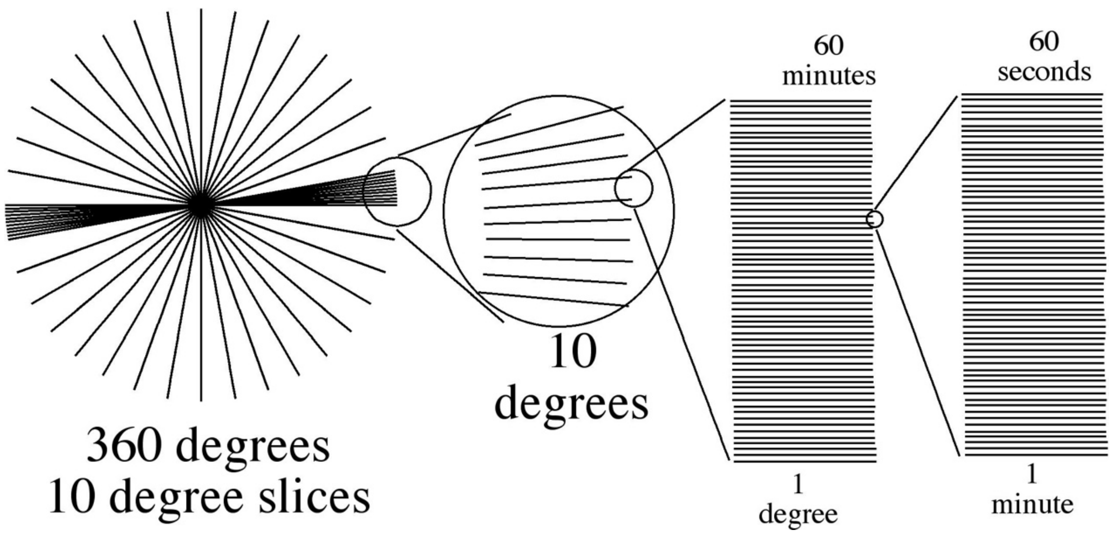

Figure 1. There are: 360 degrees in a circle, 60 minutes in a degree, and 60 seconds in a minute.

1. Can you figure out how many arc seconds are in a degree? Show your reasoning.

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The traditional symbol for degrees, minutes and seconds measured in this way is as follows: degrees are represented by ° (which you probably already knew from math class); minutes are indicated by the symbol ‘; and seconds are represented by “.

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2. Write the following angle measurements in ° ‘ “ form.

a. 15 degrees 32 minutes 16 seconds _____________________________

b. 89 degrees 89 minutes 4 seconds ______________________________

c. 36 degrees 12 minutes 0 seconds_______________________________

3. If you measured an angle sometimes you will need to convert this angle into “decimal degrees” which are written like this: 15.33 degrees (which is the same as 15 degrees 20 minutes or 15°20’).

The general procedure for converting degrees from degrees, minutes, and seconds to decimal degrees is this:

- Take the number of arcseconds and divide it by 60.
- Add the answer to the number of arcminutes. Divide this answer by 60.
- Add the answer to the number of degrees.
- Done!

Convert the following degree measurements into decimal degrees. Use the method above or the *factor-label* method, but show your work.

34 degrees 30 minutes _____________________________

28 degrees 48 minutes _____________________________

89 degrees 20 minutes 12 seconds _______________________________

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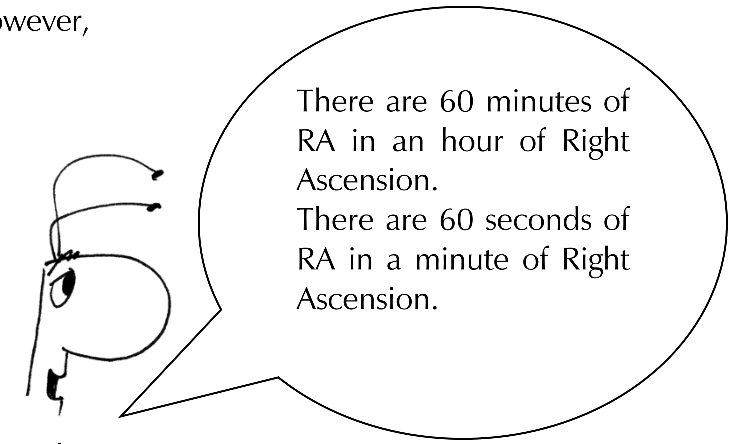
CA1 4.17: RA- Hours, Minutes, Seconds Handout

Purpose: To learn how Right Ascension is defined and used.

Background: Right Ascension is made of hours, which are further subdivided into subsections called, confusingly, *minutes of Right Ascension* and *seconds of Right Ascension*. These minutes and seconds are entirely *different in size* than the minutes and seconds used in protractors (and declination, altitude, and azimuth). However, they work the same way.



Because one hour of RA is 15 degrees of declination, minutes and seconds of RA are *fifteen times larger* than minutes and seconds of Right Ascension at the celestial equator.

Once again, it is easier to do this with the factor-label method, but just in case you haven't studied that yet, here is the procedure for converting minutes and seconds of Right Ascension to decimal hours of Right Ascension.

- Take the number of seconds of Right Ascension and divide by 60.
- Add this to the number of minutes of Right Ascension.
- Take the answer you got and divide by 60 again.
- Add this answer to the hours of Right Ascension.

If you need to further convert the hours of Right Ascension into degrees, add one more step:

- Divide the Hours of RA by 15.

To keep the RA numbers distinct and separate from the Declination numbers (because they're different sizes even though they use the same words) we use different symbols.

Degrees, minutes, and seconds are denoted by ° ' ", respectively.
Hours, minutes, and seconds of RA are denoted by h m s, respectively.
Both sets of symbols are written as superscripts, like this:

-14 degrees 32 minutes 12 seconds of declination are written as dec = -14° 32' 12".
9 hours 44 minutes 3 seconds of RA are written as RA = $9^h44^m12^s$.

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CA1 4.17: RA—Hours, Minutes, Seconds

Write the following using h m s notation and convert the following Right Ascension measurements into decimal hours.

2 hours 3 minutes 55 seconds

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4 hours 19 minutes 2 seconds

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12 hours 0 minutes 14 seconds

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CA1 4.18: Practice RA and Dec Handout

Purpose: To practice plotting stars on standard star charts

Procedure: Plot the stars whose coordinates are given below. Use a scale appropriate to standard star charts which makes all the points fit on the grid in as large a picture as possible. A familiar constellation will be formed. Name the constellation here.

Hints:
Recall that RA runs right to left unlike most graphs which run left to right. Hours and minutes decrease as you move left on the graph.

Remember there are 60 minutes (m) of right ascension in an hour (h) and 60 minutes (‘) of declination in a degree (°)—the two kinds of minutes have different symbols because they are not the same size! RA minutes at the celestial equator are 15 times larger than declination minutes. Keep that in mine as you set up your scales.

Negative declinations include minutes which are also negative. -1° 56′ does not mean “go down 1 degree and up 56 minutes.” It means “go down 1 degree and down 56/60 of another minute.”

RA	dec
5h 55 m	7° 25′
5h 25 m	6° 21′
5h 41 m	-1° 56′
5h 36 m	-1° 12′
5h 32 m	-0° 18′
5h 48 m	-9° 40′
5h 14 m	-8° 12′

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