AST 120 Activity 2
The Dome of the Sky

Name	Full	Partial	None

In this activity we will begin observing the night sky, with the goal of constructing a scientific model that fits what we see. But since it is 9:30 AM we will need to use a computer simulation to do this observing. It turns out that using a computer simulation has all kinds of advantages. If only Ptolemy had a copy of Stellarium (and a computer to run it on, and electricity to power the computer, and . . .)!

1. Go to a computer and launch Stellarium[1] (there should be a desktop icon for this program).
2. Move the cursor to the left side of the screen. A toolbar should pop up. Click on the compass-rose (Location window). In the window that appears there is a magnifying glass. Next to this, type Rome. Select Rome (Georgia), United States from the list. Click the box to set this location as your default. Click the X at the top right to close this window.
3. Look through the list of keyboard commands you have been given. Use keyboard commands to stop the flow of time (set time rate to zero) and to set time to now.
4. Take a moment to enjoy the pleasant view. Does it remind you of the cow and horse pastures out by the Normandy Dairy (now the Winshape Retreat)?
5. Although the scene is pretty, it's not very conducive to observing the night sky since it is bright and sunny. Let's get rid of the atmosphere. Find the correct keyboard command on your handout and turn off the atmosphere.
6. Use the up and down arrows to tilt your view up and down (you can also click and drag to do this). Play around with this for just a bit.
7. Use the left and right arrows to turn your view left and right (you can click and drag to do this too).
8. Notice that the sky seems like a big dome. The base of the dome has a circular edge which we call the *horizon*. The top of the dome is the point directly above your head. We call this the *zenith*.
9. Suppose you wanted to point out something interesting in the sky to a friend. You would need some way to specify where the interesting feature is located on the dome of the sky (unless they are standing right next to you - then you could just point). We're going to take a shot at building a *coordinate system* that we can use to locate different points in the sky. We will start by facing due North. Move around until you are facing North (look for the N - if is not there, turn on the Cardinal points). Make sure you are looking right at the horizon.

[1]Stellarium is a free, open-source program that you can download for your own computer (Windows, Mac, or Linux) from `http://www.stellarium.org/`. I've put a link to this page in the Bookmarks on the VikingWeb page for AST 120. I encourage you to install Stellarium on your own computer.

10. We will define two coordinate as follows:
    - The *altitude* of a point is how far you must tilt your head *above the horizon* to look at the point.
    - The *azimuth* of a point is how far you must turn your head *to the right* to look at the point.
11. If you are staring at the horizon while facing due North, what are the coordinates of the point at which you are staring? Note that you can click on a star or other object that is near the horizon and due North. The coordinates of this object (Az/Alt) should be displayed in the top left. But this object is probably not exactly on the horizon, or exactly due North. I want you to give me the coordinates of the point that is *exactly* on the horizon and due North.

    az = ______________ alt = ______________

12. Now face due East and look at the horizon. What are the coordinates of the point at which you are looking?

    az = ______________ alt = ______________

13. Now face due South and look at the horizon. What are the coordinates of the point at which you are looking?

    az = ______________ alt = ______________

14. Now face due West and look at the horizon. What are the coordinates of the point at which you are looking?

    az = ______________ alt = ______________

15. Now look straight up. What are the coordinates of the point at which you are looking?

    az = ______________ alt = ______________

    Hopefully this gives you a sense of how the alt/az coordinate system is set up. To get a better sense, use the keyboard commands to turn on the Azimuthal grid. You should now see a grid showing coordinates in the alt-az system. Take a look at the various parts of this grid (especially near the horizon and the zenith) in order to become familiar with how it is laid out. One particular grid line runs from due North (az=0°) up to the zenith and then down to due South (az=180°). This line is called the *Meridian*. The meridian dives the dome of the sky into two equal halves.

16. Now face South and look up until you can barely see the horizon at the bottom of the screen. Use keyboard commands to increase time speed until you can easily discern the pattern of the stars' motion. (Note: there is another keyboard command to decrease time speed if you get it going too fast.) Do the stars appear to move relative to each other, or do they all move together as a whole?

17. Sketch the general motion of the stars you see while facing South. Draw a line to represent the horizon and a few curves to indicate the paths taken by the stars. Use arrows to indicate the direction of the stars' motion.

18. Now face East and repeat. Sketch the apparent motion of the stars.

19. Do the same thing for facing West.

20. Now face North and repeat.

21. When you are facing North you should see one moderately bright star that moves very little. Stop the simulation (with the keyboard command to set time rate to zero) and click on this star to find out its name. Record the name below.

22. Give the coordinates of this star in the alt-az system (try to read this from the grid, then check your answer against the information displayed at the top left):

    az = ______________ alt = ______________

23. Does this star actually move a little bit, or is it completely stationary?

24. Now face East. We want to find a star that rises (appears at the horizon) due East of us. One such star is named Mintaka. It is one of a short line of three relatively bright stars which form the "belt" of the constellation Orion. When these stars rise in the East Mintaka is the topmost of the three. Try to find this star and click on it to label it (ask Dr. T if you need help). Then run the simulation and watch how this star moves across the sky. Try to determine exactly where this star crosses the meridian (when a star crosses the meridian it is said to *transit*). At what point in the sky does Mintaka transit? To make fine-scale adjustments in the time you may want to open the Date/time window. Move the cursor to the left of the screen. In the toolbar that appears click on the Clock icon. This opens a window showing the date and time. You can adjust the time forward or backward by seconds, minutes, hours, days, months, or years.

    az = ______________ alt = ______________

25. Continue following Mintaka. Where does this star set (drop below the horizon)? Note that the trees, etc may block your view of Mintaka crossing the horizon. If you want to get rid of the pesky Earth, just use the keyboard command to turn off Ground and Fog.

    az = ______________ alt = ______________

26. Do the Alt and Az coordinates for a star remain constant, or do they change over time? Explain the reasons for your answer.

27. Which star has Alt and Az coordinates that change the *least*? Give reasons for your answer.

28. Go ahead and quit the Stellarium program. Open a web browser and Google "latitude Rome, GA". Record the latitude of Rome, GA below.

29. Do you see any connection between the latitude of Rome, GA and the alt/az coordinates of Polaris as seen from Rome, GA? Explain.

30. Now let's take a different look at this Alt/Az coordinate system. Quit Stellarium and run the EJS Local Coordinates program. Move the Altitude and Azimuth sliders around to see what effect this has. You should also click and drag in the window to change your viewing angle. Set the arrow to alt=30° and az=135° (you can type this in, but make sure to hit Return after typing). Describe the location by giving the general compass direction of this point (ie North, Southwest, etc) and also indicating how far above the horizon the point is.

31. Use the Display Options menu to Show Test Stars. Determine the coordinates of the red star *without* adjusting the alt/az values in the simulation. Use the grid (which is marked in 10 degree increments) to estimate the alt and az of this star. Record your answer below. Once you have recorded your answer you can check your work by adjusting the sliders to match your answer and see if the arrow points to the red star.

    az = ______________ alt = ______________

32. Now repeat this procedure to find the local coordinates for the yellow star. Again, estimate using the grid first, then check your answer using the slider.

    az = ______________ alt = ______________

33. Do the coordinates you found make sense given the location of the stars on the sky? In other words, do you understand *why* these test stars have these particular values for their coordinates? (Note: ask

Dr. T for help if you are having any trouble seeing the connection between the coordinates and where the stars are located in the sky.)

Local coordinates (alt/az) are convenient because they tell us exactly where to look in the sky to find a particular star or other object. But they are inconvenient because the local coordinates for a given star are constantly changing as the star moves around in the sky. If we know a star's local coordinates at one time, we do not know what its coordinates will be at a later time. But we have seen that the stars all move together in a common pattern. We can exploit this common pattern to define new coordinates that will remain fixed even as a star moves around the sky.

The basic idea is to think of the stars as being fixed to the inner surface of a great sphere. This "Celestial Sphere" surrounds the Earth and turns daily, carrying the stars with it. The Celestial Sphere is so large that the Earth is just a tiny speck at the center of it.

34. Run the EJS Equatorial Coordinates program to get an idea of how the Celestial Sphere works. This simulation shows the horizon plane (in green) for an observer on Earth. Use the Display Options menu to Show Stars. Note that the stars are displayed as though they are all on the surface of a big sphere, and this sphere is cut in half by the horizon plane. Hit the Play button to see what happens as time passes. What does the Celestial Sphere do?

35. Use the Display Options menu to Show Celestial Axis. This shows a line representing the axis about which the Celestial Sphere appears to turn. Locate the North tip of this axis, where it intersect the Celestial Sphere itself. You should find a relatively bright star located near the North tip of the axis. What is the name of this star?

36. The axis runs through the poles of the Celestial Sphere, which can be thought of as extensions of the poles of Earth's rotation axis.[2] Likewise, we can extend the equator of Earth onto the Celestial Sphere. Use the Display Options menu to Show Celestial Equator. At what two directions does the Celestial Equator intersect the (green) horizon circle?

[2]But you should be aware that the celestial poles were identified long before anyone thought of a rotating Earth.

37. The idea of celestial poles and equator can be used to help define a new set of coordinates, called *Equatorial Coordinates* (or *Celestial Coordinates*) which are fixed to the Celestial Sphere. Since the stars seem to behave as though they are fixed to the Celestial Sphere, the coordinates of a star in this new system will remain constant even as the star moves around in the sky. The first of these coordinates is called *Declination* (Dec). Dec is very similar to latitude on Earth. It measures the degrees North (positive) or South (negative) of the Celestial Equator. What is the Declination for Polaris?

38. What is the Declination for Mintaka? (Hint: we looked at this star in Stellarium. It is located on the Celestial Equator. See if you can find it in the Equatorial Coordinates program.)

39. Use the Celestial Sphere model, and Mintaka's location on the Sphere, to explain why Mintaka always rises due East and sets due West.

40. The other equatorial coordinate is called *Right Ascension* (RA). RA is somewhat like longitude on Earth, but it's a bit trickier. For one thing, the line of zero RA runs through a special point called the Vernal Equinox (more on this later).[3] RA increases in the counterclockwise direction if you view it from outside the celestial sphere above the north celestial pole. Another tricky thing about RA is that it is measured in units of TIME not units of ANGLE. Going all the way around the celestial equator the RA changes by 24 hours. So each hour of RA corresponds to 15° of angle. Why do we use time units for RA? To understand this, consider about how long it takes for the sky to make one complete rotation about us (or, in modern terms, for the Earth to complete one full rotation). How many degrees does the sky (or Earth) rotate in one hour of time?

41. Hopefully this illustrates why we might want to measure RA in time units. Now, let's use the sliders in the program to try to determine the RA and Dec of a particular star. Use the Display Options menu to Show Celestial Grid. This displays a grid of RA and Dec lines (like longitude and latitude lines on a globe of Earth). The grid is marked in increments of 10° (for Dec) and 1^h (for RA). Now use Display Options to Highlight Sirius and Arcturus (two bright stars). Use the sliders to try to determine the coordinates for Sirius (the cyan star).

    RA = ______________ Dec = ______________

42. Now do the same for Arcturus (the yellow star).

    RA = ______________ Dec = ______________

[3]Longitude on Earth is measured in degrees west from the meridian that passes through Greenwich in the U.K.

43. Play around with the sliders a bit more to make sure you see how RA and Dec are related to location on the celestial sphere. Then try changing the latitude. If you increase the latitude, what happens to the location of the north celestial pole?

44. If you set the latitude to 90°, where is Polaris located (not on the celestial sphere, but in your sky)? (Use the technical term for this location please.) Do you understand why this happens? (If not, ask Dr. T.)

45. Where in your sky would the north celestial pole be found if you set the latitude to zero? Try to answer this without using the simulation, then check your answer with the simulation.

46. What is the general relationship between the latitude of an observer on Earth and the altitude of the North Celestial Pole for that observer?

47. Suppose you are told the alt, az, RA, and Dec of a star at a given time. Which of these coordinates will still have the same values at some later time? Which coordinates will change over time?