AST101: Our Corner of the Universe
Lab 1: The Celestial Sphere

Name:

Student number (SUID):

Lab section number:

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1 Introduction

Materials

Links to the animations required for this lab are available at

`https://walterfreeman.github.io/ast101/labs/`

2 Background Information

Work through the explanatory material on *The Observer, Two Systems: Celestial*, *Horizon*, and *Seasons and the Zodiac*. All of the concepts that are covered in these pages are used in the Rotating Sky Explorer and will be explored more fully there. These animation will help you understand the definition of the *azimuth* and *altitude* angles that will be used in this lab.

In short, *azimuth* and *altitude* work rather like latitude and longitude. Both of them are angles, and by specifying both of them, you describe a position in the celestial sphere and thus describe the location of a star in the sky, much like latitude and longitude together tell you where somewhere is on the surface of the Earth.

A star's altitude describes its elevation over the horizon. An altitude of 0° is right along the horizon, while an altitude of 90° is at the zenith.

A star's azimuth describes whether it appears in the northern, eastern, southern, or western sky. These angles are measured from north.

3 Introduction to the Rotating Sky Explorer

The Rotating Sky Explorer consists of a flat map of the Earth, Celestial Sphere, and a Horizon Diagram that are linked together. The explanations below will help you fully explore the capabilities of the simulator.

- You may click and drag either the celestial sphere or the horizon diagram to change your perspective.
- A flat map of the earth is found in the lower left which allows one to control the location of the observer on the Earth. You may either drag the map cursor to specify a location, type in values for the latitude and longitude directly, or use the arrow keys to make adjustments in 5° increments. You should practice dragging the observer to a few locations (North Pole, intersection of the Prime Meridian and the Tropic of Capricorn, etc.).
- Note how the Earth Map, Celestial Sphere, and Horizon Diagram are linked together. Grab the map cursor and slowly drag it back and forth vertically changing the observer's latitude. Note how the observer's location is reflected on the Earth at the center of the Celestial Sphere (this may occur on the back side of the earth out of view).
- Continue changing the observer's latitude and note how this is reflected on the horizon diagram. When the observer is in the northern hemisphere the North Celestial Pole (NCP) is seen above the north point on the horizon at an altitude equal to the observer's latitude. When the observer is in the southern hemisphere the South Celestial Pole (SCP) is seen above the south point at an altitude equal to the observer's latitude.
- The Celestial Sphere and Horizon Diagram are also linked in that any stars are added to the simulation are shown on both. There are many features related to stars.
  - A star will be randomly created by clicking the **add star randomly button.**
  - A star may be created at a specific location on either sphere by shift-clicking at that location. (Hold down the shift key on the keyboard while clicking at that spot.)
  - You may move a star to any location by clicking on it and dragging it. Note that it moves on both spheres as you do this.
  - Note that the celestial equatorial and horizon coordinates are provided for the "active" star. Only one star (or none) may be active at a given time. Simply click on a star to make it the active star. Click on any other location to make no star active.
  - If you wish to delete a star, you should delete-click on it. (Hold down the delete key on the keyboard while clicking on the star.)
  - You may remove all stars by clicking the **remove all stars** button.
  - **Note that stars are the vehicle by which you make coordinate measurements. If you want to make a measurement in either diagram—you place the active star at that location.**
- There are several modes of animation as well as a slider to control speed.
  - You may turn on animate continuously or for preset time intervals: 1 hour, 3 hours, 6 hours, and 12 hours.
  - If you click-drag a sphere to change its perspective while the simulator is animating, the animation will cease. Once you release the mouse button the present animation mode will continue.
- This simulator has the power to create star trails on the horizon diagram.

- A series of check boxes set the star trails option. **No star trails** is self-explanatory. **Short star trails** creates a trail behind a star illustrating its position for the past 3 hours. **Long trails** will trace out a the path of a star over an entire day.
- Stars are created without trails regardless of the trail option checked. If either short or long trails is checked, the trail will be drawn once the simulator is animated.
- Existing star trails will be redrawn in response to changes—the star being dragged on either sphere or changing the observer's location.
- What's not in this simulation? The revolution of the Earth around the sun. This simulator animates in *sidereal time.* One sidereal day (one 360° rotation of the earth) is 23 hours and 56 minutes long. You should think of this simulator as showing the Earth isolated in space as opposed to revolving around the sun.

4 Daily Motion of the Stars

Question 1. Set the Observer's location to close to Syracuse by typing latitude 43° N and longitude 76° W into the location boxes in the lower left. Look at the horizon view diagram in the explorer. Locate the North and South Celestial Poles.

Is the North Celestial Pole (NCP) above or below the horizon?

Is the South Celestial Pole (SCP) above or below the horizon?

Question 2. Complete the following table involving the horizon coordinate system. You should predict the answers and then use the simulator to check them. **You can measure coordinates by shift-clicking to create a star and dragging the active star to a location on the diagram.**

Description	**Latitude**	**Azimuth**	**Altitude**
West point of the horizon	Any		
Zenith	Any	Any	
NCP	30° N		
NCP	71° N		
SCP	52° S		
SCP	Tropic of Capricorn (23.5° S)		

Question 3. Set the simulator so that you are at the latitude of Syracuse (43° N.) You will be asked to create stars at specified azimuths and altitudes. You will then be asked to make predictions about the locations and motions of the stars as time advances.

1. Shift-click to create in star A at an azimuth of 0° and an altitude of 10°. (It is easiest to shift-click anywhere on the horizon view and then type in the azimuth and altitude in the boxes that appear.) Assume that it is midnight at this time. We'll also assume that we can see the stars during the day. In what direction would you look to see star A at midnight (use the words horizon, low, high, zenith, north, south, east, and/or west to describe the position)?

   In what direction would you look to see star A in 6 hours time (at 6am)?

   In what direction would you look to see star A in 12 hours time?

   In what direction would you look to see star A in 24 hours time?

   Does star A ever set below the horizon?

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2. Click **remove all stars** to remove star A. Now create a new star B at an azimuth of 90° and an altitude of 0°. Assume that it is midnight at this time. In what direction would you look to see star B at midnight?

   In what direction would you look to see star B in 6 hours time (at 6am)?

   In what direction would you look to see star B in 12 hours time?

   In what direction would you look to see star B in 24 hours time?

   Does star B ever set below the horizon?

Question 4. Click **remove all stars** to remove star B. Think about the characteristics of a star that passes through your zenith point in Syracuse, NY. Call this star C. Use the simulator to determine the characteristics of this star. Is star C circumpolar?

In what direction would you look to see star C when it is rising?

In what direction would you look to see star C when it is setting?

Question 5. Click **remove all stars** to remove star C. The two end stars of the Big Dipper are known as the "pointer stars" since a line drawn through them points toward Polaris (a very important marker in the sky since it is located very near the NCP). Use the constellations control to add the Big Dipper to the celestial sphere. It may help to turn on **long star trails** for these questions. From Syracuse, NY, are the stars of the big dipper circumpolar?

Now add the constellation Orion to the celestial sphere. From Syracuse, NY, are the stars of Orion circumpolar?

Now add the Southern Cross to the celestial sphere. From Syracuse, NY, can you ever see the Southern Cross?

Think about how far south you would need to travel to see the stars of the southern cross. Adjust the Observer's location until the stars of the Southern Cross are just visible above the horizon at one point during a 24 hour day. What latitude are you at?

Question 6. In this question we will explore star trails as seen by the stick figure in the diagram. Create about 20 stars randomly in the sky, turn on long star trails, and click animate continuously. Remember that when you are viewing the Sky Explorer you are outside the celestial sphere looking in. You need to imagine what the stars look like from the stick figure's perspective. Set the observer's latitude to 40° N. Which direction (clockwise or counterclockwise) do stars appear to rotate around the NCP?

You should have answered *counterclockwise* around the NCP. If you did not, make sure that you are looking from the perspective of the stick figure in the local sky (i.e. inside the celestial sphere looking out, not outside looking in). Check with your instructor if you are not sure about this.

Next sketch the star trails from the observer's perspective for each of the following observer latitudes and observer directions. You should indicate the position of the NCP or SCP when looking North or South. Indicate the direction the stars are moving with arrow heads on your star trails.

Observer's latitude	**Direction observer is looking**	**Star trail sketch**
40° N	North	
40° N	South	
40° N	East	

Observer's latitude	Direction observer is looking	Star trail sketch
90° N	Any	
40° S	South	
40° S	West	

5 Seasonal Motion and the Zodiac

In the previous question, we considered the daily motion of the stars due to the Earth's daily (24 hour) rotation about its axis. We did not consider the fact that the Earth also orbits the sun once per year (365 days).

Question 7. Use the Zodiac Explorer on the page "Seasons and the Zodiac" to answer the following questions. Remember that you can't see the stars during the day.

On May 25th the Sun is in the constellation of

During which month is the Sun in the constellation Libra?

On July 4th at 12am, midnight, the Sun will be in the constellation of

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On July 4th at 12pm, noon, the Sun will be in the constellation of

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On July 6th at 12pm, noon, the Sun will be in the constellation of

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What would be a good time of year to observe the constellation Aries?

What cause the Sun to appear in different constellations of the Zodiac at different times of the year?

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6 Path of the Sun through the Sky

The final section of this lab uses the Motions of the Sun Simulator to explore how the Sun's path through the sky changes over the course of the year. This simulator allows you to simulate the path of the sun for any date during the year for any latitude on the Earth. Spend some time familiarizing yourself with the simulator—most of the controls are fairly intuitive and similar to those in the preceding modules.

- Practice using the yearly slider to move to different dates during the year.
- Practice using the map to move to different latitudes during the year.
- Note that there are three different animation modes.
  - If you select continuous, time will move forward in a natural fashion. You may adjust the rate at which time passes using the animation speed slider. You may modify this mode with the loop day check box which will cause the sun's motion for the current day to continually repeat.
  - If you select step by day, time will leap forward in 24 hour increments and the time of day will not change.
- Special care should be taken to make sure that you understand what is being simulated at all times. This is especially true in regard to discriminating between the yearly and daily motion of the sun.
  - Move to a middle United States Latitude like 35N. Click show ecliptic and show month labels. This is the sun's yearly path on the celestial sphere and is denoted by a white circle in the simulator. Note that it crosses the blue celestial equator on the equinoxes.
  - Stop the simulation near the summer solstice. The simulator readout should state "The horizon diagram is shown for an observer at latitude 35° on 21 June at 12:00 (12:00 pm)". Think about what the sun's path should look like in the sky on that day.

Question 8. Set up the Motions of the Sun Simulator for Syracuse, NY at at latitude of 43° N and set the day of the year to July 1. Note that you may want to click *loop day* while looking at the Sun rise and set position on a given day. Click start animation to run the simulation and answer the following questions by exploring using the simulator.

What direction would you look to see the Sun rise on this day?

What direction would you look to see the Sun set on this day?

In what direction would you look to see the Sun when it is highest on the sky on this day?

Now set the day of the year to February 1. Click start animation to run the simulation and answer the following questions by exploring using the simulator.

What direction would you look to see the Sun rise on this day?

What direction would you look to see the Sun set on this day?

In what direction would you look to see the Sun when it is highest on the sky on this day?

Set the simulator to the day of the spring equinox (March 20).
What direction would you look to see the Sun rise on this day?

What direction would you look to see the Sun set on this day?

On what day is the Sun highest in the sky at noon?

Does the Sun ever pass through your zenith in Syracuse, NY? If so, on which day(s)?
