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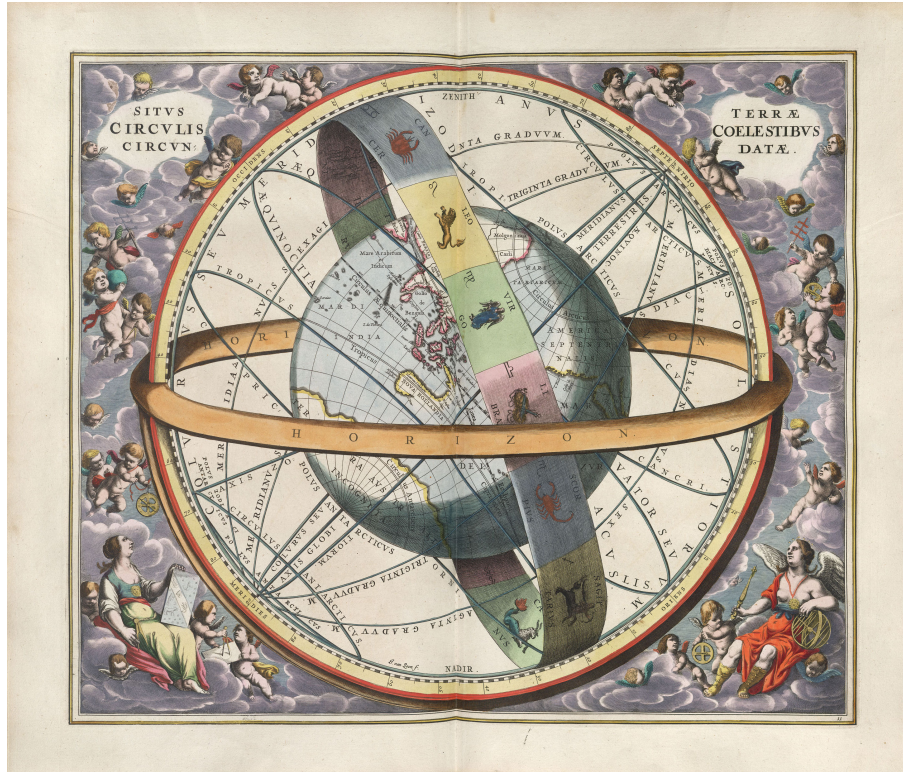


Figure 1: The Celestial Sphere as illustrated in the *Harmonia Macrocosmica* of Andreas Cellarius, published in 1660.

Introduction: Imagine the sky to be a giant sphere with the stars painted on it all the while rotating around the Earth. This model is known as the **Celestial Sphere**. Although clearly incorrect, it is nevertheless a useful model for it allows a simple and clear way to observe and analyze the motions of the stars and other celestial objects. Pragmatically, the Celestial Sphere was also crucial for our ancestors who navigated without the use of modern instruments. In this lab, we will explore the celestial sphere and understand why it is the foundation for further studies in astronomy.

Learning Objectives:

- *Science Process Skills: Observing* – evaluate the results of an observation and how it applies to the problems at hand.
- Define the main features of the celestial sphere.
- Describe the apparent motions of the stars and planets.
- Understand the coordinate systems.

Materials: In your lab station you will find the following: Model of the celestial sphere (Farquhar globe) and computers that we will use – you may also use your personal phone, tablet, or computer if you prefer.

Pre-Lab Exercises

1) Take a look at globe on your table. It is known as a **Farquhar Globe**. This geocentric model is incorrect, but extremely useful. The basic components are:

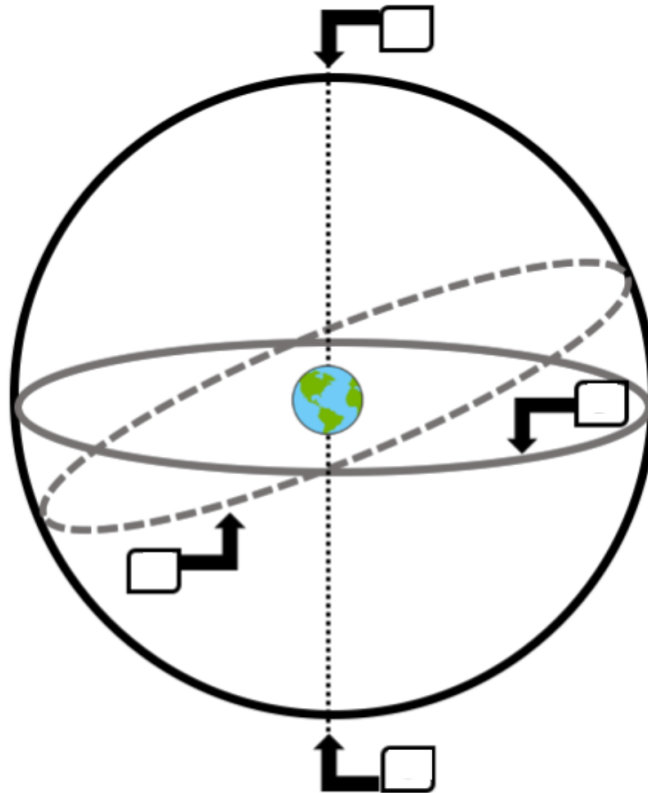
A) **Ecliptic** – path the Sun appears to follow through the stars over the course of a year.

B) **Celestial Equator** – projection of Earth's equator across the celestial sphere.

C) **North Celestial Pole (NCP)** – point directly above Earth's rotation.

D) **South Celestial Pole (SCP)** – same as NCP for the Southern Hemisphere.

Match the letters to the corresponding location in the celestial sphere.



2) Examine the Farquhar Globe. What star is nearest to the NCP and SCP?

3) You should have noticed that the celestial equator and ecliptic are offset from each other by a certain amount of degrees. Why are they offset from each other and what is this amount?

Getting Started With Stellarium

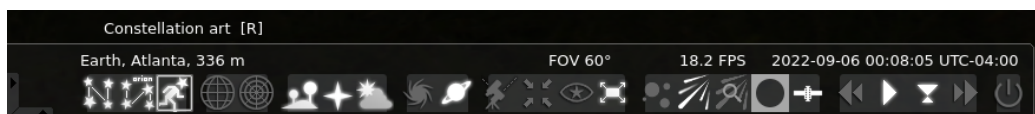
For this section we will be using **Stellarium** which is software that allows you to explore the sky and track the movement of objects including our Sun, stars, and planets. The software should be downloaded on your computer, and you can easily install it on your own device. Stellarium is free, and available here: <http://stellarium.org/>

Launch Stellarium. When you do, you should first see a green meadow under a sky. Stellarium typically knows your location and time of day, therefore the scene might be night or day depending on when you access it. Regardless, you should see something similar to the picture below –



Towards the bottom left of the window you will find a vertical toolbar with configuration options. Most of that you will not need to use. That said, press **F6** which should open up the location window. Type in “Atlanta” and then hit enter, and poof, like magic we are now viewing Atlanta! Press **F5** and it will open the Date & Time window. Most likely the date and time will automatically be filled. If not, enter the current time and date.

At the bottom is also a horizontal toolbar. Make sure you click on the leftmost tabs: “Constellation lines”, “Constellation labels”, and “Constellation art”. You can also press the shortcuts which are *c*, *v*, *r*. Hold the **right mouse button** and you can change your viewing angle.



4) What time is it and how many constellations are on the sky? Are any planets visible? Hint: If it is daylight and you do not see any stars/planets, press *a*.

5) Find a “bright star” – basically any star that appears to be decently bright. Click on it. Doing so should provide you with lots of information.

A) What is the name of the star?

You will see something called “RA/Dec (J2000.0)” that is the coordinate of the star given in units of **right ascension** (RA) and **declination** (Dec).

B) Write down the RA and Dec.

C) You will notice that most of the parameters of the star you clicked on do not change. However, some values such as “Mean Sidereal Time” constantly change. Why?

D) Can you spot this star on the Farquhar Globe? How is it using the Farquhar Globe in comparison to Stellarium?

6) **Altitude** is the angle measured from the horizon to the zenith (directly overhead).

Azimuth is the angle measured in a horizontal circle around the horizon. If you are facing due north, the azimuthal angle is 0° . Facing west is 270° . You can toggle the azimuthal grid by clicking on the appropriate icon in the horizontal tab or pressing *z*.

A) If you are facing due east, what is your azimuthal angle?

B) If the altitude at the horizon is 0° , what is the altitude at the zenith?

C) Toggle the azimuthal grid. Each grid is how many degrees?

D) Go back to your star from Q5. Cycle through different days. Does the RA/Dec change? What about altitude and azimuth? Explain.

7) We can also pause the passage of time by pressing *k*. There are different ways to speed up and reverse time. If you want a specific point in time, the easiest thing to do is simply to enter that time after pressing F5. Halloween is coming up! This Halloween, at about what time (to the hour) will the Moon first be visible after the Sun has set?

Stellarium Sun

8A) Take your best guess – how many times a day is the Sun directly overhead?

My guess is _____ times.

B) Now, count how many times the Sun is directly overhead in the next five days.

The Sun crossed the zenith _____ times.

C) There is a special place on Earth called the **Tropic of Cancer**. It is located $23^{\circ}26'10.8''$ north of the Equator. Plug that value into Stellarium. Go there on June 21, 2023 at 1:00 pm. Now increase the minutes. At what time is the Sun directly overhead?

The Sun is directly overhead at _____.

D) Will the Sun ever be directly overhead here in Atlanta? Explain.

9) Go to noon on Thanksgiving day in Atlanta. Start increasing the days but *do not change the time*. Cycle through a whole year. What does the Sun appear to do and why?

10) Now go back to Thanksgiving this year in Atlanta. Start cycling through the years until you get to the year 2100. Explain the movement of the Sun.

Stellarium Planets

11) Enter Jan 1, 2101, at 6:00 am. Locate and click on Mars – it will be the faint dot near the horizon around the SE. You will also notice that at a higher altitude lie Saturn and Jupiter. Keeping the time constant, start cycling through the days. Is Mars behaving in a similar fashion to Saturn, Jupiter, the constellations? Explain.

12) Go back to Thanksgiving of this year. Find Mars once it is visible in the sky. Click on Mars, and then press CONTROL + G. Note that although your landscape picture has not changed (you can do so by pressing F4 if you wish), Stellarium has now moved us to Mars! We are viewing what we would see if we were on Mars.

A) How does the night sky compare to Earth?

B) Does Mars follow a 24-hour day/night cycle like the Earth?

13) Find Jupiter and go there.

A) How does the night sky compare to Earth?

B) Does Jupiter follow a 24-hour day/night cycle like the Earth?

C) Would our coordinate systems – altitude, azimuth, RA, and Dec work properly on Mars or Jupiter?

Putting Things Together

14) The celestial sphere is a geocentric model. However, there were a number of phenomena we observed in this lab that are unusual if the Earth were truly the center of the Universe. What are they?

15) What did you find most surprising in this lab? What did you find most exciting? What did you find most challenging? What if any questions do you still have regarding the celestial sphere?

Questions, suggestions? – Dr. Idan Ginsburg – iginsburg@gsu.edu
