AST101: Our Corner of the Universe
Lab 5: Solar System Models

Name:

Partners:

NetID:

Lab section number:

1 Introduction

Objectives

The Solar System Models Lab introduces the universe as envisioned by early thinkers culminating in a detailed look at the Copernican model.

Materials

Links to the animations required for this lab are available at

`https://walterfreeman.github.io/ast101/lab5.html`

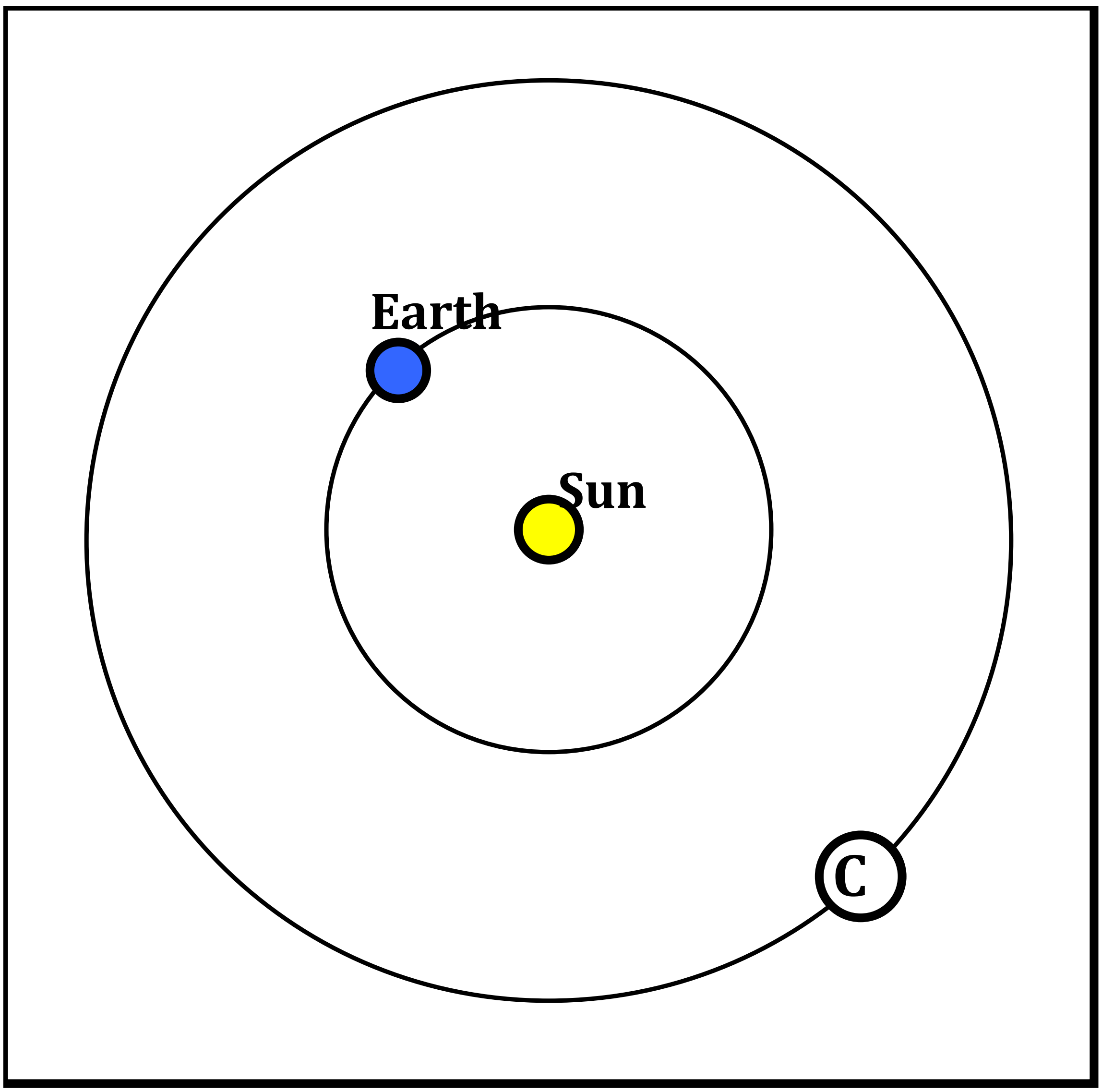
2 Background Material

Review the Geocentric Model background material. The simulation of Ptolemy's model demonstrates the dominant model when Copernicus presented his heliocentric model. Thoroughly review the Heliocentric Model background material. Terms like "Western quadrature", "elongation angle", and the like are defined there.

Question 1. Look at the animation of the Copernican Solar System on the "Heliocentricism" page. What relationship do you notice between how fast a planet moves in its orbit and its distance from the Sun?

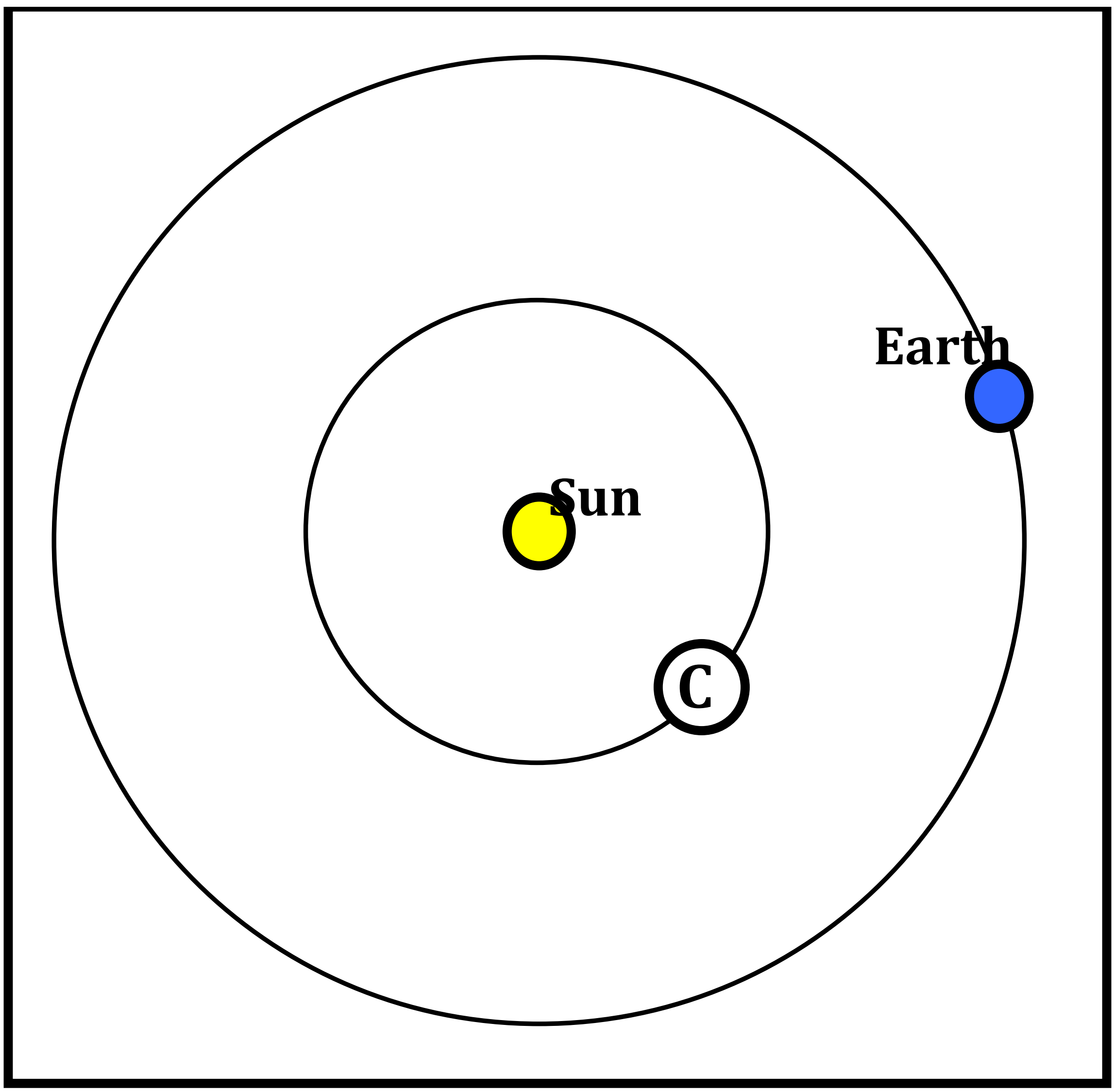
Question 2. The table below concerns various elongation configurations for a hypothetical superior planet. Complete the diagram by adding the locations for the superior planet at locations A, B, and D from the table. Add any missing elongation angles and the name for that angle to the table for locations A, B, C, and D.

Location	Elongation Angle	Name for this Elongation Angle
A	180°	
B		Western Quadrature
C		
D	East 120°	N/A



Question 3. The table below concerns various elongation configurations for a hypothetical inferior planet. Complete the diagram by adding the locations for the superior planet at locations A, B, and D from the table. Add any missing elongation angles and the name for that angle to the table for locations A, B, C, and D.

Location	Elongation Angle	Name for this Elongation Angle
A		Superior Conjunction
B		Inferior Conjunction
C		
D	West 20°	N/A



3 Simulator Exercises

Open up the Planetary Configurations Simulator and complete the following exercises.

Question 4. In this exercise we will measure the synodic period of Mercury. Set the observer's planet to Earth and the target planet to Mercury. The synodic period of a planet is the time it takes to go from one elongation configuration to the next occurrence of that same configuration. However, it makes sense to use an easily recognized configuration like superior conjunction. Drag a planet (or the timeline) until Mercury is at superior conjunction. Now zero the counter, click "start animation", and observe the counter. A synodic period is the time from the start until Mercury is once again at superior conjunction.

What is the synodic period of Mercury?

Question 5. In the previous exercise superior conjunction was used as the reference configuration, but in practice it is not the best elongation configuration to use. Explain why.

What is the best elongation configuration to use? (Hint: when is an inferior planet easiest to observe in the sky?)

Do you get the same result for the synodic period you got in Question 4?

Question 6. Use greatest elongation as the reference configuration to calculate the synodic period of Venus. (Be careful. There are two different occurrences of greatest elongation for an inferior planet: eastern and western.) Also, record the value of the greatest elongation of Venus.

Synodic period of Venus:

Greatest Elongation of Venus:

What general trend do you notice between an inferior planet's distance from the Earth and its synodic period?

Question 7. Now use the simulator to find the value of Mercury's greatest elongation.

Greatest Elongation of Mercury:

Compare the values of greatest elongation for Mercury and Venus. What relationship do you notice between the value of greatest elongation of a planet and its distance from the Sun? Can you create a hypothetical third inferior planet in the simulator to check your reasoning?

Question 8. Now we will measure the synodic period of Mars. As before, set Mars up in a particular elongation configuration, zero the counter, and then animate the simulator again to see how long it takes Mars to return to the same configuration.

Synodic period of Mars:

Question 9. Just as with superior conjunction in Question 2, conjunction is not the best configuration to observe a superior planet in the sky. Explain why this is and explain which configuration is best for observing a superior planet.

Measure the synodic periods of Jupiter and Saturn.

Synodic period of Jupiter:

Synodic period of Saturn:

Question 10. Look over the synodic periods of the superior planets. Is there a trend? What value does the synodic period of a superior planet approach as we consider planets farther and farther away from Earth? Explain this trend.

Question 11. Compare your answer above and your answer to the last part of Question 5, and then state a relationship between a planet's synodic period and its distance from Earth that is valid for both inferior and superior planets.

Question 12. So far we have only considered elongations of planets as viewed from Earth. Suppose you were standing on Mars, watching the planets go through their motions. Could you use the same terminology as before to explain the configurations of other planets? Yes, you could—the only difference would be that there is an additional inferior planet: the Earth. As an observer on Mars, you would see the Earth go through the same configurations as any other inferior planet. For example, when the Earth appears on the opposite side of the Sun as viewed from Mars, it is at superior conjunction. When the Earth appears at superior conjunction from Mars, at what configuration does Mars have as seen from Earth?

Set up the simulator so that the Earth appears at superior conjunction from Mars and time how long it takes the Earth to return to this same elongation configuration—that is, the synodic period of Earth as observed from Mars. Record the synodic period of Earth as viewed from Mars:

How does this answer compare with the synodic period of Mars as found in Question 8? Explain why they are related.

Question 13. Copernicus was interested in measuring the synodic periods of the planets so that he could calculate their sidereal periods. Note that in a heliocentric model (i.e. reality) the synodic period takes into account both the Earth's motion and the other planet's, while the sidereal planet relates only to the orbit of the other planet. Since we know the Earth's sidereal period, we can use the knowledge of the synodic period (which we can measure) to calculate the sidereal period (orbital period) of any other planet.

In this exercise we will calculate the sidereal periods of the planets using the data you have already collected. You may use a handheld calculator or make use the "Synodic Period Caclulator" on the Elongations and Configurations background page.

Recall that the sidereal and synodic periods of a planet are related by

$$\frac{1}{S} = \frac{1}{P} - \frac{1}{E} \quad \text{for inferior planets,}$$

$$\frac{1}{S} = \frac{1}{E} - \frac{1}{P} \quad \text{for superior planets,}$$

where P stands for the planet's sidereal period, S stands for the planet's synodic period, and E stands for the Earth's sidereal period.

We will now work an example to see how these formulas are used to find a planet's sidereal period. The synodic period of Jupiter is 1.09 years. Since E is 1 year, we have

$$\frac{1}{1.09 \text{ years}} = \frac{1}{1 \text{ year}} - \frac{1}{P}$$

so

$$\frac{1}{P} = 0.0826 \frac{1}{\text{year}}$$

and so $P = 12$ years.

Now calculate the sidereal periods of the rest of the planets to complete the table below, using your answers for synodic period from the previous questions. (Be sure to use the same units of time for each of the variables. If you measured S in days then you should convert it to years by dividing by 365.25 days/year.)

Planet	Synodic Period of Planet	Sidereal Period of Planet
Mercury		
Venus		
Earth	N/A	1 year
Mars		
Jupiter	1.09 years	12 years
Saturn		

Is there a relationship between the sidereal period of a planet and its distance from the Sun? How does this relate to your observations in Question 1?

Question 14. Put yourself on the planet Mars and carefully note the location of the sun on the Zodiac Strip. Now zero the counter, animate, and time how long it takes for the apparent position of the sun relative to the background to return to the same position. How does this value for the Sidereal Period of Mars agree with your value in the table from the previous question?

Question 15. Let's use the simulator to observe the retrograde loops of a superior planet. Set up the simulator so that the observer is on the Earth and is viewing Mars at conjunction. Zero the counter and start the animation. How long after conjunction does retrograde motion start and how long does it last?

Question 16. Make Earth the observer's planet and Mars the target planet. Zero the Counter and note the location of Mars in the Zodiac Strip. Animate the planets until Mars (the target planet) comes back to the same place in the Zodiac Strip. How long did it take? Try this two more times with different starting constellations and note the time. Do you get the same number each time? Do you think that observing a planet pass through the constellations of the zodiac is a good way to measure its period? What causes it to take different amounts of time?
