Physics 10293 Online Lab #2:
<u>Motions of the Planets</u>

Due Date: Thu Apr 9, 11:59pm CDT

<u>Online Lab Instructions</u>

Although we will not be doing these labs together in the classroom, please remember as you work through this that you are not alone. Your lab instructor will be happy to help answer any questions you have about the lab, either via email or in the discussion forum on your D2L course shell.

Ideally, you should print out this lab, answer the questions, and then scan it or take pictures of each page, and send that completed work to your TA by the deadline. If you are unable to print out the lab, please just answer each question on your own paper and submit that work to your TA by the deadline.

<u>Introduction</u>

Today we will explore the motions in the sky of the outer planets that are easily visible to the naked eye: Mars, Jupiter and Saturn. And we will discuss how planetary motions played a role in shaping our understanding of our place in the Universe.

You may already be familiar with some of the history surrounding the Copernican revolution. If not, the first of two articles I am asking you to read will provide some introduction, and I will also explain some basic terminology.

One of the first to author a detailed model of the cosmos that was widely disseminated throughout the world was Ptolemy. Ptolemy proposed an Earth-centered (geocentric) model around the year 150 AD. In this model, everything we see in the sky that moves (Sun, Moon, planets) orbits around the Earth in a circular way against a distant backdrop of fixed, unmoving stars (the celestial sphere).

The primary purpose of this mathematical model of the sky was to try to successfully predict the future motions of the Sun, moon and planets for the purpose of casting horoscopes or observing certain events on the calendar. The geocentric model did a poor job of such predictions. Astronomers using Ptolemy's prediction tables often found huge errors in the predicted position of a planet in the sky when compared to its actual position at a certain time.

These tables were updated regularly in an attempt to be more accurate, and model was tinkered with as well, adding layers of more complex motion on top of the initial circles. Despite this, the predictions were still very poor, so Astronomers were constantly looking for a simpler, more accurate model.

Copernicus published his Sun-centered (heliocentric) model in the 1543 AD, proposing that the Sun is at the center of planetary motion and that the planets orbit the Sun in perfect circles. This model is much simpler than the geocentric model, as you can see from this simulation showing how the planets moved in each model:

http://www.malinc.se/math/trigonometry/geocentrismen.php

We know today that Copernicus' model is closer to the truth than Ptolemy's model, but it is interesting to review the historical record to see why Copernicus' model wasn't more broadly accepted when it was first proposed. Instead, it was disputed for over 300 years!

For starters, when it was initially proposed, the heliocentric model was just as poor at predicting planetary motions as the original geocentric model. That's because Copernicus assumed circular motion for the planets (wrong) instead of elliptical orbits with varying speeds (right).

Tycho Brahe painstakingly compiled a detailed table of observations for planetary positions over more than a 20 year interval, hoping to use this data to settle the dispute or develop his own model. Tycho's model was no more successful than that of Copernicus, but eventually Johannes Kepler was able to use Tycho's great set of observations to develop and test Kepler's own model.

Kepler was eventually able to reconcile the seemingly chaotic motions of the planets with a model that resembled the heliocentric model but had a couple of significant differences. The accuracy and simplicity of his model eventually convinced everyone it had to be correct, but it still took another couple of hundred years to fully disprove all of the arguments against the heliocentric theory.

One of biggest problems the geocentric theory had was its inability to easily explain the retrograde motion of the planets. For a helpful demonstration of what retrograde motion is and how the heliocentric model best explains it, please watch the video: https://www.youtube.com/watch?v=1nVSzzYCAYk

After watching the video, please answer the following:

Q1. How did Ptolemy's original Earth-centered (geocentric) model explain the backwards "retrograde" motion of the planets?

Q2. Briefly explain what causes retrograde motion in the sky in the heliocentric model (a diagram will make it easier to explain but both diagram and explanation are required to answer this one).

The first article I would like you to read on this subject is called "The Case Against Copernicus," in which the scientific arguments in opposition to Copernicus' theory are explored in some detail.

http://personal.tcu.edu/dingram/Case_Against_Copernicus.pdf

As you read through this article, please answer the questions below. They are asked in the same order that they are covered by the article.

Q3. Describe how Tycho's model differed from the standard geocentric model and Copernicus' heliocentric model.

Q4. Explain why Tycho felt it was unreasonable for the Earth to move quickly around the Sun but perfectly reasonable for the other planets to move quickly around the Sun or the Earth.

Q5. Based on the boxed explanation "The Problem with Star Sizes" and the article's discussion below the box, briefly explain why Tycho deduced that distant stars must be impossibly large, thousands or millions of times larger than our Sun.

Q6. Explain how Tycho's model of planetary motion avoided the problem of "impossibly large stars".

We will explore the geocentric vs heliocentric debate a little further by reading a Scientific American article with a more detailed history of the issue. Read the article "Astronomy in the Age of Columbus" at the link:

http://personal.tcu.edu/dingram/Astronomy_Columbus.pdf

Answer the questions below, which are asked in the same order as they are covered in the article.

Q7. Describe two arguments used by Aristotle that indicate the ancient Greeks understood that the Earth must be spherical and not flat.

Q8. The author asserts that most scientists of Columbus' era (late 15th century) agreed that the Earth is round. Why did many people abandon this belief in the United States after the American Revolution? Explain.

<u>Q9</u>. Columbus himself agreed that the world is round. Explain two "errors" he made in order to justify his voyage to the king and queen of Spain, to make them believe it was possible (the maps on page 103 of the article may help you visualize this).

<u>Q10</u>. Although Columbus wasn't much of an astronomer, he did make use of "Ephemerides," a reference book for timing astronomical phenomena such as lunar phases and eclipses. Explain how.

Q11. Explain two reasons why Ptolemy's original geocentric model of the solar system was doubted by scholars of Columbus' era such as Peuerbach and Regiomontanus.

Q12. Explain why Copernicus' original heliocentric model of the solar system was no more accurate that Ptolemy's geocentric model.

Q13. Describe two historical changes that occurred around the time of the publication of Copernicus' heliocentric theory that helped ensure the theory got a serious hearing in the scientific community, unlike times in the past when it had been suggested and quickly dismissed.

There is no essay with this week's lab.