

## Lab 6: Solar & Lunar Observations and Models for the Solar System

### Essentials of Physics: PHYS 101

In this lab we will use observations of the Sun's position in the sky during a day to explore physical models for the Earth's and Sun's position in the solar system. We will also consider a model for the Earth-moon system that matches our observations.

**NOTE: PLEASE BRING IN ALL YOUR SOLAR (plastic dome) OBSERVATIONS TO LAB!**

**Introduction:** This lab is about “models” for reality and what they predict. We would like to compare the predictions for various models to our observations made over the past few weeks. For our solar observations, we used a transparent half-dome to mark the location of the sun in the sky for several times during the day. Imagine that we were a very tiny person standing at the center of the half-dome (“X” on the paper) and looking up at the Sun (don't do this!) several times during the day. To make our observation, we somehow mark where a line connecting us and the sun intersects the dome.

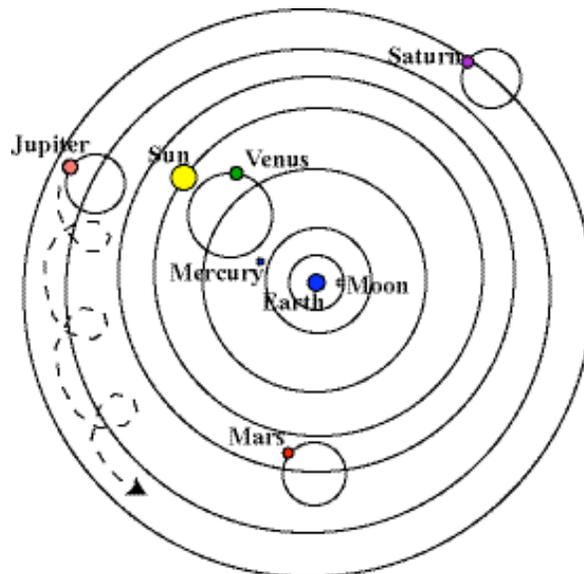
We will work up a joint set of solar observations for one day and for a different day to refer to below. Ditto for the lunar observations.

Then we will construct “physical analog models” for the Earth/Sun and Earth/moon system using simple equipment (globe, laser pointer, another clear half-dome, etc.). We can use a particular physical model (e.g., Ptolemaic model, below) to predict what the Sun's position in the sky would be during the day, and compare it to our observations. In this manner, we can reject, accept or refine particular physical models until we have one that works!

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#### Solar Observations:

Until the 1500's the common perception was that the sun revolved around the earth. One of the better *geocentric* models for the Earth and Sun was constructed by the Greek astronomer Ptolemy (see Figure 1). We will first concentrate on this “**Ptolemaic**” model.

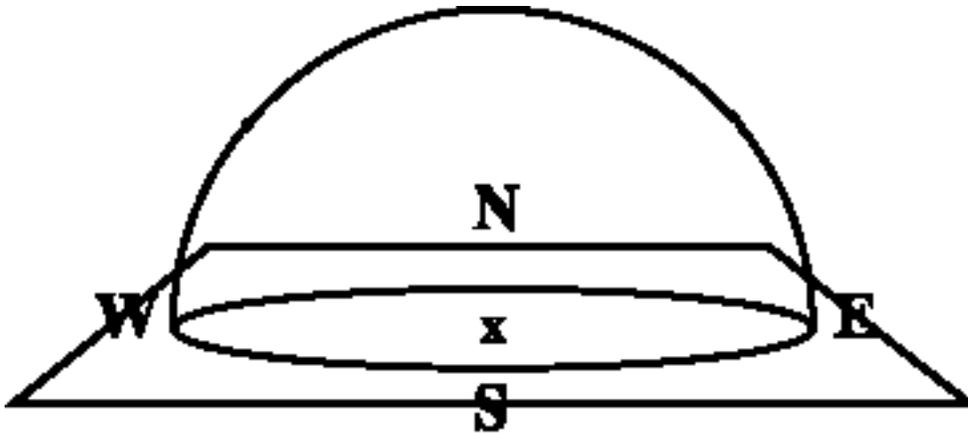


**Figure 1:** The Ptolemaic model giving the circular orbits of the Sun, moon and other planets around the Earth.

**NOTE: The Ptolemaic model doesn't assume that the Earth is spinning.**

**Question 1:** We wish to construct a "physical model" for the Earth/Sun system using a globe, a laser pointer and another clear half-dome. Draw in the space below how we decided to do this using these items. Label your drawing.

**Ptolemaic model prediction 1:** You are standing in Oregon (about half way between the equator and the north pole), observing the Sun's path during the day. Given the Ptolemaic model, in which direction would the Sun rise (be precise, for example, northeast, or even east northeast). Where would the Sun be at noon? Where would it set? Mark on the representation of your dome, below, where the sun would rise, etc., for the Ptolemaic model



**Figure 2:** A clear hemispherical dome covers a sheet of paper. You are in Oregon, observing the Sun "move" across the sky by standing at the "X" mark and peering through the dome at different times of the day. "S" marks the direction of south.

**Question 2:** Is the position of the Sun in the sky predicted by the Ptolemaic model consistent or inconsistent with the single day's observation we have generated? Explain.

**Question 3:** Would the predictions for the Sun's position in the sky taken from our simple Ptolemaic model change from day to day? Would it account for seasons? Explain.

**Question 4:** Is the prediction for daily “solar motion” from the Ptolemaic model consistent or inconsistent with our solar observations taken from different days? Explain your choice.

To better understand models for the solar system, it is important to understand the notion of a *plane*. In the standard Ptolemaic model, above, all the planets and the Sun and moon are in the same plane as that described by the Earth’s center and its equator (called the *celestial plane*).

**Question 5:** We’ve all heard the term “equator” in reference to a part of the Earth’s geography that goes through certain countries, etc. Given an unmarked sphere, how would you establish the sphere’s equator? Describe your procedure for doing this below:

**Question 6:** Given the Ptolemaic model, is it necessary that the Earth spin on an axis? Explain.

**Question 7:** Would either having the Earth spin or tilting the celestial plane relative to the ecliptic plane improve the Ptolemaic model? If so, how. If not, why not?

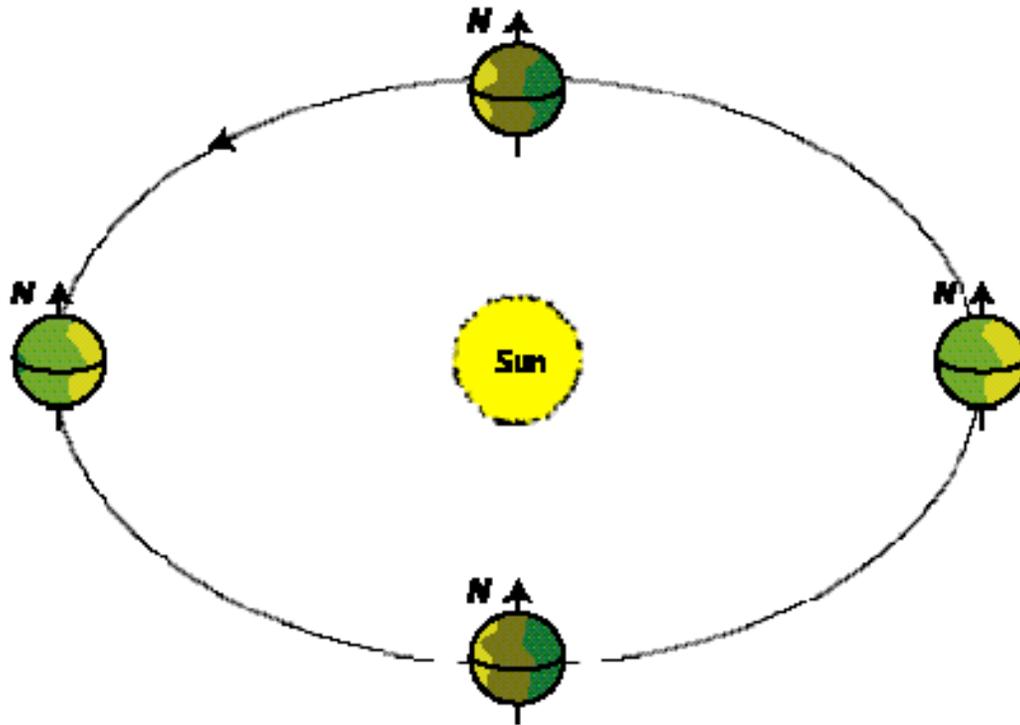
**Question 8:** Given what we generally observe about things that orbit other things, and *inertia*, and *Newton’s Universal Law of Gravitation*, which is bigger in the Ptolemaic model, the Earth or the Sun? Explain.

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## A Heliocentric Model

(Note: Earth starts spinning for below)

Nicholas Copernicus gave us a different model of the solar system. In his model the Sun was in the middle and all the planets orbited around it (see Figure 3, below). Later Johannes Kepler, using Tycho Brahe's painstakingly acquired data, showed that observations of the positions of the planets were entirely consistent with this sun-centered (heliocentric) model.

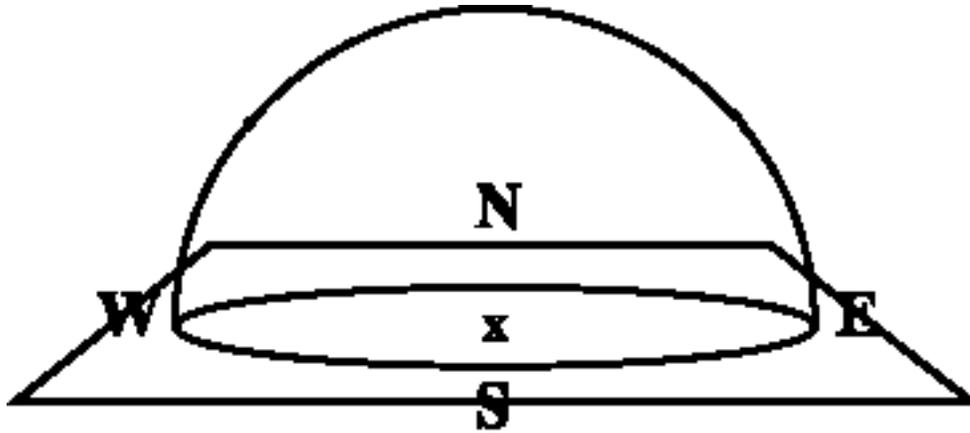


**Figure 3:** The Heliocentric model giving the circular orbits of the planets around the Sun.

**Note that in this first heliocentric model we consider, the Earth's celestial (equatorial) plane is not tilted relative to the ecliptic (the plane with the planets and Sun in it).**

**Heliocentric model prediction 1:** You are standing in Oregon (about half way between the equator and the north pole), observing the Sun's path during the day. Given the heliocentric model, in which direction would the Sun rise (be precise, for example, northeast, or even east northeast). Where would the Sun be at noon? Where would it set?

Mark on the representation of your dome (Figure 4, next page) where the sun would rise, etc., for the heliocentric model



**Figure 4:** You are in Oregon, observing the Sun “move” across the sky by standing at the “X” mark and peering through the dome at different times of the day. “S” marks the direction of south.

**Question 9:** Is the position of the Sun in the sky predicted by the heliocentric model consistent or inconsistent with the single day’s solar observations that we have generated? What must we say about the Earth’s motion to account for the change in the Sun’s “position” during the day? Explain.

**Question 10:** Would the predictions for the Sun’s position in the sky taken from our simple heliocentric model change from day to day? Would it account for seasons?

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*Hmm, what can be done to fix our initial heliocentric model?*

**Question 11:** Well, what can be done to fix or heliocentric model? Explain. (Hint: what happens if we tilt the axis of the Earth (and the equator) relative to the ecliptic?)

**Question 12:** How, specifically, does the modified heliocentric model account for variations in the Sun’s path from day to day or month to month? Explain.

**Question 13:** According to the modified heliocentric model, how many days does it take for the Sun's path through the sky to repeat itself exactly. Explain.

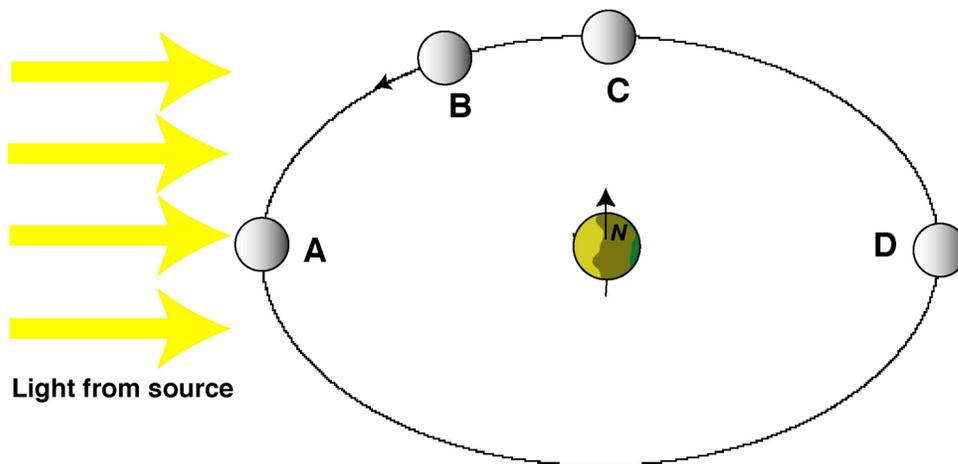
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**Lunar-Earth Model:**

**Question 1:** Does the moon orbit the Sun or the Earth? How do we know this?

Figure 5 gives a simple model for the orbit of the moon about the Earth. We want to test this model and see if it explains lunar observations.



**Figure 5:** A simple model showing the moon at various positions as it orbits around the Earth.

**Question 2:** Where does the light come from that illuminates the moon? How do you know this?

**Question 3:** Using the observations you are given, about how many days does it take the moon to orbit the Earth? Show your work.

The *phases of the moon* tell us what the moon looks like from one night to the next. For example, a *full moon* is when we see the entire disk of the moon, and a *half moon* is when we see only half of the disk.

**Question 4:** Which of the positions in Figure 5 (A, B, C, or D) corresponds with the position of the moon when it is full? Where are we standing on the Earth relative to the Sun when we observe the full moon? Explain.

**Question 5:** How does our simple model for the moon's motion about the Earth account for phases of the moon?

**Question 6:** The observations of the moon you were given being about 3 days after the full moon. Mark on Figure 5 where the moon was when we began these observations. Referring to Figure 5, explain why we could see the moon in the morning and why it was in the west.

**Question 7:** The arrow in Figure 5 shows the direction the moon travels as it orbits the Earth. Explain how and why the distance between the moon and the Sun (distance across the sky) will change after the full moon.