Lab $6\frac{1}{2}$
Phases of Venus

One of the most important things Galileo observed with his telescope is that Venus has phases like the Moon. This was the "smoking gun" that showed that the earth-centered (pre-Copernicus) system couldn't possibly be right, so it went a long way toward convincing people that the Earth really did go around the Sun. We're going to examine the phases of Venus to see what Galileo saw and why it mattered.

Start up *Starry Night*, and configure it as follows:

- Set the time to noon today. Set the time step to "days."
- Turn off daylight, so that it's possible to see the stars and planets when the Sun is up. (Remember that you can do this by clicking on the "View Options" tab on the left and unchecking the "Daylight" option under "Local View.").
- Turn on labels for the planets by checking the "Labels" box next to "Planets-Moons" in the "View Options" menu.
- Set the view to be centered on the Sun (right-click on the Sun and choose "centre").

Let time run forwards and backwards for a year or two and observe the motion of Venus. Note that it swings back and forth past the Sun, never getting more than a certain angular separation from the Sun in the sky. Once you've done this, reset the date to today.

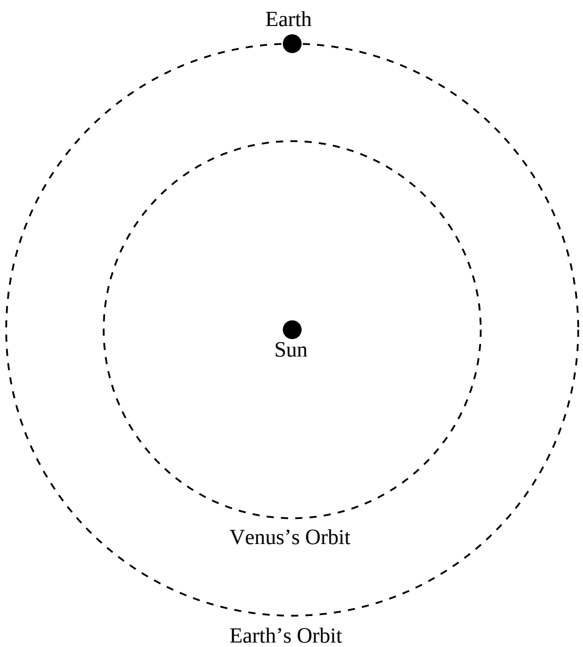
Here's one preliminary question before we look at the phases of Venus. If you wanted to observe Venus today, at what time of night should you observe? Specifically, find a rough time when Venus is above the horizon but the Sun is below the horizon. The easiest way to do this is to set the time step to hours and step forward or backward one hour at a time.

Best time to observe Venus these days:

Note that you've got a fairly narrow window of time when the Sun is down but Venus is up, so it'd be pretty hard to observe Venus right now. The easiest time to observe Venus is when its as far away from the Sun in the sky as possible. This is called the time of "maximum elongation." Set the time back to noon, set the time step to days, and run time backwards until you find the most recent time of maximum elongation. (Hint: it's some time in March 2006.) Measure the angular separation between Venus and the Sun at that time. (Remember that you can do that by dragging the mouse from one object to the other, but be sure the pointer looks like an arrow, not a hand, when you start.)

Maximum angular separation between Sun and Venus:

Here's a diagram showing the Earth's and Venus's orbits around the Sun. Suppose that the Earth is at the uppermost point in its orbit as shown, and suppose that Venus is at maximum elongation from the Sun (so that it appears as far from the Sun as possible in the sky). Draw a circle to mark the position of Venus in its orbit. (There are actually two possibilities. One corresponds to the case where Venus is to the East of the Sun and one to the case where it's to the West. If you assume everything orbits counterclockwise, you can figure out which which, although it's a bit tricky. For the moment, it doesn't matter which one you choose.)



Venus, like the Moon, shines by reflected sunlight. That means that the only part of Venus we'll see is the part that's illuminated by the Sun. In the diagram above, shade in the half of Venus that's lit up by the Sun, and then use the diagram to predict the phase of Venus at this time. (That is, will Venus appear like a crescent, like a "full" Venus, or what?)

After you've made your prediction, use *Starry Night* to test it. Center the view on Venus and zoom in to enlarge the image of Venus. Does it have the phase you predicted?

Now set the date back to today, and zoom in on Venus to observe its phase. What is the phase of Venus today?

Based on your observation, is Venus in front of the Sun or behind the Sun today?

Zoom back out again, and center the field of view on the Sun. Let time run forward until Venus has gone through about half of one orbit. You should see it pass by the Sun, go out to maximum elongation, and then come back until it approaches near the Sun again. At this point, when Venus's path is about to cross past the Sun again, is Venus in front of the Sun or behind the Sun? (Don't use *Starry Night* to answer this; use what you know about the orbits.)

Based on your answer to the previous question, what do you expect the phase of Venus to be?

What do you expect about the angular size of Venus: should it be bigger or smaller than the last time you looked at it?

Center the view on Venus and zoom in to test these two predictions. Did they come out right?

Keep the field of view centerd on Venus and zoomed all the way in. Let time run forward fast for a year or two. The main things to note are that Venus goes through a full set of phases (from crescent to full and back), and that its angular size changes along with its phase.

Earlier, I said that this observation provided strong proof that the old Earth-centered theory was wrong. Let's see why. Remember that in the old theory the Earth was at the center, the Sun went around the Earth, and Venus moved on an epicycle between the Earth and the Sun like this:

At each of the points A,B,C,D in the diagram, what would the phase of Venus be, according to this model?

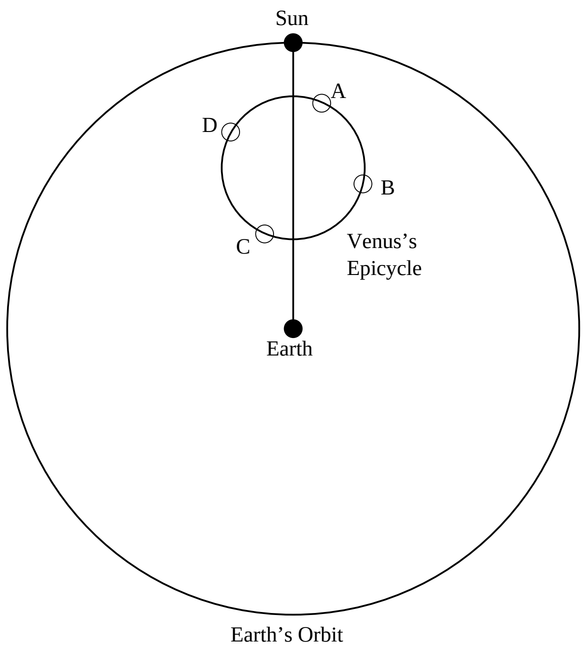
A:

B:

C:

D:

What phases of Venus would *never* occur in the earth-centered model?



The fact that Venus is observed to have those phases is the "smoking gun" I referred to.

One more thing. Now that you've measured the maximum elongation of Venus, you can use it to figure out the radius of Venus's orbit. Sketch a picture showing Earth, Sun, and Venus at the moment of maximum elongation (this will look the same as the diagram on the second page).

Connect these three bodies with straight lines to form a triangle. When Venus is at maximum elongation, this triangle will have a right angle at Venus. The angle at the Earth is the angular separation between Venus and Sun (that is, the angle you determined on the second page). Indicate both of those angles on the diagram.

We also know the length of one side of the triange: the distance from the Earth to the Sun is 1 AU. Mark this on your triangle as well.

Now you have a right triangle, and you know one angle (other than the right angle) and one side. That means you can use trigonometry to find the lengths of the other sides. Determine the radius of Venus's orbit trigonometrically. (If you don't remember how to do this, ask me.)