Galileo and Venus, Background

Astronomy 101, Prof. Kendall. Stellarium and the Celestial Sphere.
Self-Study Lab Tutorial

Using the software Stellarium on the Lab PCs or on your own Laptop, answer the following questions. Set up your Location to Wayne, NJ. Use Latitude: 40° 55' 31" North, Longitude: 74° 16' 36" West. Unless otherwise indicated, always use the current year. Also, to help you, you can turn off the atmospheric effects by clicking "a", turn off the fog with "f", and turn off the ground with "g". You'll want to use the Altitude/Azimuth grid to help you. Rise and set are, of course, 0 altitude. Stellarium is installed on the PCs at the Science Enrichment Center in Science Hall East. www.stellarium.org

The goal of this exercise is to duplicate how Galileo proved that Venus orbited the Sun, rather than the Earth, using only the tools available to him at the time.

"Since changes evidently occur not only in the position of the stars but also in that of the whole heaven, there are three possibilities. Either both are at rest, or both are in motion, or the one is at rest and the other in motion. That both should be at rest is impossible; for, if the earth is at rest, the hypothesis does not account for the observations; and *we take it as granted that the earth is at rest*. It remains either that both are moved, or that the one is moved and the other at rest." – Aristotle, On the Heavens, Book 8, 350 B.C.

Aristotle's ideas held sway for over 2000 years until it was shown that the Earth must in fact move. In order to see how Galileo overthrew Aristotle, you'll need to note your responses on a separate sheet or paper and upload them. You'll also need to print out this Tutorial, and have a protractor at the ready.

Galileo only had a clock, a calendar, a small telescope, familiarity with the Moon's phases, and the knowledge that Venus stays close to the Sun in the sky. To prove what Galileo found, that Venus orbited the Sun, we need to see how the two competing models at the time stacked up against each other. The first was Ptolemy's Geocentric Model, and the second was Copernicus' Heliocentric model.

Galileo and Venus, Part 1: The Moon

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1) First, make a sketch of the orbital arrangement required for the various phases of the Moon, as seen from "above" the Solar system. You may also grab a diagram from the web, so long as you provide the source web page for the image you submit. In any event, this image or sketch must show and name all aspects of the Moon's phases, as well as the orbital positions. That the Moon orbited the Earth was not a matter of debate in Galileo's time.

2) Now, we'll use Stellarium to look at the Moon.
   - Focus on and zoom in on the Moon so that it fills half the screen.
   - Turn off the ground, atmospheric effects and fog.
   - Turn on the Equatorial Mount.
   - Speed up time so that a day goes by every second.
   - Notice the progression of the phases.
   - Notice the apparent size of the Moon as it goes through those phases.
   - Take three representative screenshots to turn in with your submission.

3) The Moon will appear to get a little bit bigger or a little bit smaller as you look at the exercise. What are two possible explanations for this appearance change?

4) Which is more likely and what are your reasons?

5) Based on the task above, do you agree or disagree that the Moon varies by a huge amount in distance from Earth as it goes through its various phases? (*Note, you are pretending that you do not have distances to any objects in the sky, so ignore that distance indicator in Stellarium.*)

6) Justify your answer above. *(Your answer needs to be only in terms of what you found by looking at Stellarium. It is poor form to use Google or Wikipaedia. Again, ignore the distance indicator in Stellarium. Galileo didn't have that.)*

7) Discuss why it is impossible to see a crescent phase of the Moon high in the sky at midnight.

8) Discuss why it is impossible to see a gibbous phase of the Moon when it's near the Sun.

Galileo and Venus, Part 2: Venus in the Sky

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Next we want to show what Galileo saw that overturned the Geocentric Model. So, all answers will be in terms of the observations we will make using Stellarium. Furthermore, we'll assume that it's 1609 and that we're looking at Venus through a telescope for the fist time in the history of humanity.

1) First, find Venus in the sky. It will be close to the Sun. Click on the Sun to center on it and stay focused on the Sun.
   - Zoom out so that the Field of View is about 60 degrees.
   - Do NOT zoom in on the Sun or on Venus.
   - Turn off the ground, atmospheric effects and fog.
   - Turn on the Equatorial Mount.
   - Speed up time so that a day goes by every second.
   - Notice how Venus moves across the sky over a long period of time, at least 3 Earth years.
   - Take three representative screenshots to attach to your submission.

2) Don't zoom in on Venus yet. For a minute, think about the Moon's phases, and assume that Ptolemy is correct and WITHOUT zooming in on Venus, what phases might you guess would correspond to when Venus is close to the Sun in the sky? (*Think only in terms of how the Moon goes through its phases as it goes around the Earth.)*

3) Define "Elongation Angle" with respect to the planet Venus.

4) What is the greatest elongation angle that you can determine from Venus? *(You need to click on Venus to get that measurement. It'll be in Venus' data that pops up. You might need to play with the Settings on Stellarium for it to show up.)*

5) WITHOUT zooming in on Venus, what phase might you guess would correspond to this greatest elongation angle of Venus? (*Think only in terms of how the Moon goes through its phases as it goes around the Earth.)*

6) Just by looking at it in the sky, and how it moves, and only thinking about how phases work with the Moon, and assuming Ptolemy's model, would you ever be able to guess that Venus could have a gibbous phase?

   1. If so, on what basis do you make your guess? Remember, all you have is a clock and your eyes, and no telescope or measuring device for distance. Imagine you only get to see what you see in the sky on a clear night standing outside.
   2. If not, what are the only available phases you would predict if you had NO telescope, and no way to zoom in?

Galileo and Venus, Part 3: Data

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To follow Galileo, let's pretend that the telescope has just been invented. Starting in the Fall of 1610, one of the first things he did was to study Venus. He wanted to know exactly what the phases were, assuming it was not just a point-like star, but spherical like the Moon and Sun and Earth.

1) Now we're going to do the same thing with Venus we did with the Moon.
    - Focus on and center in on Venus.
    - Zoom in on Venus.
    - Turn off the ground, atmospheric effects and fog.
    - Turn on the Equatorial Mount.
    - Speed up time so that a day goes by every second.
    - Notice the progression of Venus' phases.
    - Notice the size of Venus as it goes through those phases.

2) Galileo has asked you to observe that data for Venus on a series of dates. Luckily, it will be clear every day Signior Galileo will ask you to take out the telescope. Fill in the data sheet below using the dates provided. Notice that we are rounding numbers off. Galileo's telescope wasn't THAT good. Fill in the table at the bottom of this activity list.

3) Take a series of 15 screenshots on the dates given in the table below. Alternately, you can record a movie of your screen. You'll need to speed up time to do so. For these screenshots, keep the field of view the same. So long as you don't zoom in and out, the field of view will stay the same. For each of these 15 screenshots, note the distance to Venus in A.U. The distance can be seen if you look in the configuration window, and the “Information” tab, and check off “distance.” Include these screenshots in your submission.

4) How exactly does the elongation angle vary over the observations?

5) How exactly does the phase vary over the observations?

6) How exactly does the angular diameter vary over the observations?

Galileo and Venus, Part 4: Comparing the Two World Orders

Now it's time to compare the two models of the Solar System.

1) There are two drawings to fill in. The first is for Ptolemy's model. In this drawing, we keep the Earth and Sun fixed, with a line between them, remembering that Ptolemy thought that the Sun orbited the Earth with Venus in between. Assuming that the circles upon epicycles are correct, plot all the data in the table below, in order, on the model sheet. Then take a photo of your plot to upload. Venus will need to lie somewhere on its circular epicycle, determined by the elongation angle. You'll need a protractor. You can print one out from Google Image Search. Draw the phase of Venus next to a few of the dots just so you can see the progression of the phases. The first data point is plotted.

2) How did you decide which of the two intercepts was the one you were going to use?

3) Finally, plot the Earth and Venus on the Copernican model drawing, using all of the data in the table below. Notice that on the drawing the days and months are listed out. You'll need to use a protractor to plot the position of Venus on the plots. You'll need to make a line between the Earth and Venus for each measurement, just to keep things straight. Draw a point for the Earth and for Venus. Draw a line-of-sight marker between the two points just to keep things straight. The angle between your line-of-sight from Earth to Venus and the line-of-sight to the Sun is the elongation angle you found on that day. Draw the phase of Venus next to a few of the dots just so you can see the progression of the phases. I've plotted the first data point for you to compare. Notice I put the blue dot for Earth near where August 24 is on the chart.

4) For the first data point on both plots, how did you choose which of the two dots must be Venus?

5) Galileo did these exact observations with a telescope, and said that the Ptolemaic system was in error. Justify Galileo's assertion.

6) How does this whole exercise help to show that the Earth goes around the Sun, and not the other way around?

Galileo and Venus: Data Table

You will now observe Venus on EXACTLY the same days that Galileo did and take exactly the same measurements. Use the first three to help you. You'll need to see the most information you can in Stellarium. Go to the "Configuration" window, then the "Information" tab, and check off "All Available". This only appears in the most recent versions of Stellarium.

Date in YYYY.MM/DD	Elongation angle	Phase	Angular diameter in arcseconds	Is Venus to the left or the right of the Sun as seen from Earth?
1610.08/24	28 degrees	Waning gibbous	11 arcseconds	Venus is to the left of the Sun
1610.09/07		Waning gibbous	12 arcseconds	
1610.09/21	34 degrees	Waning gibbous		
1610.10/05				
1610.10/19				
1610.11/01				
1610.11/15				
1610.11/29				
1610.12/13				
1610.12/27				
1611.01/04				
1611.01/11				
1611.01/18				
1611.01/25				
1611.02/01				

"To His Holiness, Pope Paul III. I can readily imagine, Holy Father, that as soon as some people hear that in this volume, which I have written about the revolutions of the spheres of the universe, I ascribe certain motions to the terrestrial globe, they will shout that I must be immediately repudiated together with this belief. For I am not so enamored of my own opinions that I disregard what others may think of them. I am aware that a philosopher's ideas are not subject to the judgement of ordinary persons, because it is his endeavor to seek the truth in all things, to the extent permitted to human reason by God. Yet I hold that completely erroneous views should be shunned."

--- Nicholas Copernicus, On the Revolutions, 1543.