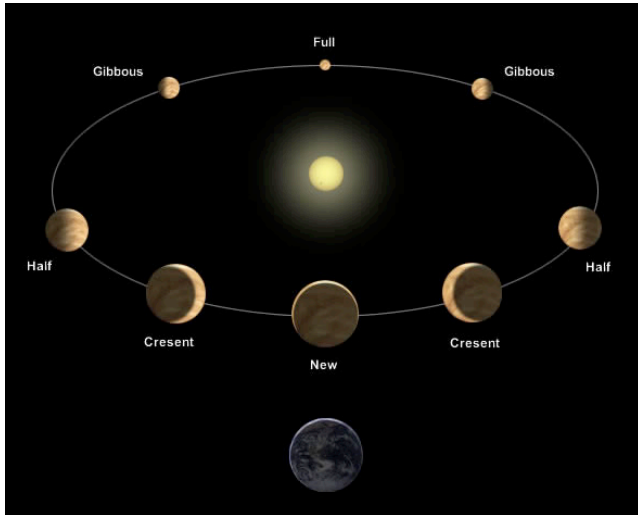




Make Up Lab: Phases of Venus

Introduction

Galileo is justifiably famous for many discoveries in both physics and astronomy. While he was fascinated by gravity and kinematics, his most valuable discovery is arguably the phases of Venus. By carefully observing and recording the progression of Venus through phases similar to our own moon, he was able to demonstrate the impossibility of the Ptolemy's increasingly complicated geocentric model.



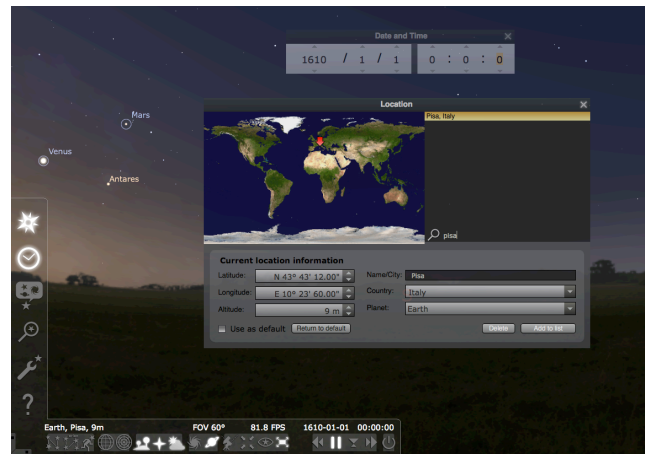
Using the Stellarium program, we can replicate his observations by placing ourselves in the same time and place as Galileo himself.

Objectives

- Distinguish the difference between sidereal and synodic measurements
- Use Stellarium to view the sky as it appeared centuries ago
- Observe and interpret the changing appearance of Venus over the course of months
- Determine the synodic and sidereal orbital periods for the planet Venus
- Discuss the reasons why Galileo did not determine the rotation rate of Venus

Procedure

1. **Launch the Stellarium program:** Your default location should be Conway, and the default time should be right now. Because the program uses the computer's clock, your time will always be local to Conway—don't be surprised when you change locations and the sun rises and sets at very odd times!
2. **Set your location:** In the search box of the location window, type in "Pisa," and select Pisa, Italy as your location. However, do not set this as your default location, since you can return to it quickly.
3. **Set your date and time:** Go back in time to **January 01, 1610**, and your time to **00:00:00**. You are now where and when Galileo was observing. Again, the actual hours on the clock still reference our Central Time zone, so be aware that it may be light when you expect it to be dark, and vice versa.



4. **Orient yourself:** Toggle on the constellation outlines and labels. Locate one or two constellations whose shapes you know. Are the constellations of 1610 recognizable to you? Face north and locate Polaris. Comment on the location of Polaris compared to its position today.

Synodic Period of Venus

The **synodic period** of an object is a measure of its motion with respect to Earth. We are most familiar with this idea as applied to the moon: to measure its synodic period, we count the time between successive full moons (or new moons, or whichever phase you like). As Galileo discovered, we can do precisely the same thing for Venus.

5. **Change the date and locate Venus:** Advance your date to **May 01, 1610**. Keep the time set to **00:00:00**. Locate Venus, and zoom in to notice its phase. Advance your day until Venus is fully illuminated (100.0%) and record the date. Use the table below as a model for recording your data.
6. **Watch the phase change:** Hit the spacebar once to keep Venus centered in your field of view, then zoom in until the phase is apparent. You should be zoomed in to a FOV of about 0.02°. Advance the time to **June 01, 1610**, and continue to advance by **two-month increments**, until Venus is at its least illuminated. Note that this will not be precisely 0.00%. Once you get close, you should advance time by days, not months. Record the date of Venus at its least, or new phase.

DATE	PHASE	PHASE SKETCH	APPARENT DIAMETER	DISTANCE
05/01/1610				
	100.0%			
06/01/1610				
08/01/1610				
10/01/1610				
12/01/1610				
02/01/1611				
	0.01%			
	100.0%			

7. **Advance rapidly back to full phase:** Once you have found "new" Venus, advance the time quickly until Venus is again full. Record the observation date on your data table.

8. **Calculate the synodic period:** The elapsed time from full phase to full is the synodic period. You may use an online unit conversion program to determine the length of time between your observations:

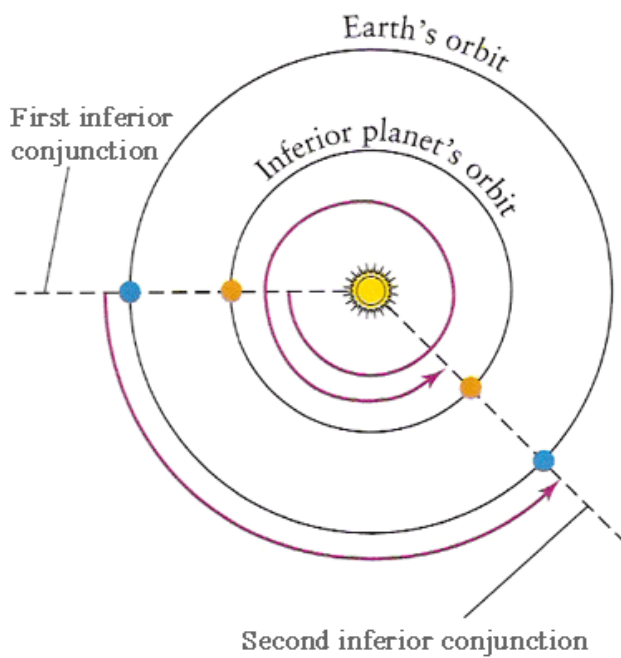
http://www.onlineconversion.com/days_between_advanced.htm

This will give you a time in days.

9. **Find your percent error:** The accepted value for Venus' synodic period is **583.9 days**. How close did you get? Calculate your percent error using:

$$\% \text{ error} = \left(\frac{\text{accepted} - \text{observation}}{\text{accepted}} \right) \times 100$$

10. **What did you (and Galileo) actually measure?** Is the synodic period a "day" on Venus? A "year"? Use the phase diagram on the previous page and the figure below to think about this, and describe in your own words what you have actually determined. You should probably also look up "inferior conjunction."



11. **Why does the size change?** Examine the data for the **Apparent Diameter** and explain why the size of Venus appears to change over the course of your observations.

Sidereal Period of Venus

When we measured the Earth's sidereal rotation, we used a distant star for reference, noting the precise elapsed time between its appearance in the same location in the sky. To measure the sidereal orbit of Venus, we will use a reference star, but we have to approach the measurement a bit differently. Let's go to the sun!

- Set your location:** In the search box of the location window, start typing "**Pontianak**". Select the location that pops up in Indonesia. We don't really want to be in Indonesia, but we do want to be on the Earth's equator. From the **Planet** pull-down menu, select **Sun**. You should be on the surface of the sun, at the solar equator!
- Set your date and find Venus:** Go to **July 11, 2016** at **00:00:00**. We do not need to be in the 17th century anymore. Locate Venus.

3. **Adjust time and align Venus:** Advance the time until Venus has a **J2000 RA = 9h00m00s**. **Adjust your time precisely**, advancing hours, minutes, and seconds of time until the J2000 RA is exact. Record your observation.

4. **Readjust and realign:** Advance the time in **one month increments** until Venus approaches the same RA = 9h00m00s again. Remember that since Venus is closer to the sun than the Earth, it won't take a full 12 months for Venus to complete its orbit. Again, fine-tune your time in hours, minutes and seconds until the J2000 RA = 9h00m00s and record the data.

DATE (MM/DD/YY)	TIME (H:M:S)

5. **Calculate the sidereal period:** The elapsed time between your observations is the sidereal period. Use the online unit conversion program to determine the length of time between your observations:

http://www.onlineconversion.com/days_between_advanced.htm

This time, because you have adjusted the time down to the second, record the period in hours, which will be a decimal value. Convert to days by dividing by 24.

6. **Find your percent error:** The accepted value for Venus' sidereal period is **224.7 days**. How close did you get? Calculate your percent error using:

$$\% \text{ error} = \left(\frac{\text{accepted} - \text{observation}}{\text{accepted}} \right) \times 100$$

7. **Is this what Galileo did?** Clearly not; he obviously was not simulating observations from the solar equator! You can use some basic kinematics to predict the sidereal period of a planet. Starting with the idea of relative velocity and skipping several steps of algebra:

$$\frac{1}{P_V} = \frac{1}{P_E} + \frac{1}{S_V}$$

where P_V is the sidereal period of Venus, P_E the sidereal period of the Earth (365.25 days), and S_V the synodic period of Venus (583.9 days). Carefully calculate Venus' sidereal period using relationship. Is this method more accurate than your observations?

The Rotational Period of Venus

Galileo was able to show, using sunspots, that the sun was rotating on its axis. But he was completely unable to measure anything about the rotation of Venus. In fact, it wasn't until the mid 20th century that its period was determined.

8. **Why wasn't Galileo able to measure Venus rotation rate?** Look up how and when Venus' rotation was finally measured, and briefly describe the method. Comment on why Galileo didn't think to do it that way.