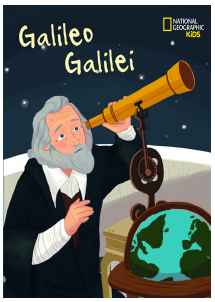
Become Galileo for a while



Studying the phases of Venus

Metadata

General Info

Title
Become Galileo for a while

Short description

Have you ever imagined to be a sky observer at the time of Galileo in Pisa? Through the observations of Venus, you could be ahead of your time and make a scientific revolution showing that the planets revolve around the Sun.

Keywords

Inferior planet, phases, Venus, sidereal and synodic period, Stellarium

Educational Context

Context from the Greek curriculum

- 6th Grade of Primary School, Science, Modern Physics-Technology-Environment-Space, Solar System
- 1st Grade of Junior High school, Physics, Measurement of time
- 2nd Grade of Junior High school, Physics, Smooth circular motion
- 1st Grade of High school, Physics, Periodic Motions, Smooth circular motion
- 2nd Grade of High school, Physics (orientation), Introduction, Types of Uncertainties
- Skills Laboratory

Age

14 – 17

Prerequisites

None

Duration
3 hrs max

Educational Objective

Cognitive Objectives

- Use of Stellarium for learning of celestial object motions
- To understand what sidereal and synodic periods are and to calculate them

Affective

- To have a taste of the scientific revolution by Galileo and his contemporaries

Subject Domain

Big Ideas of Science

How the research of the motion of an inferior planet affects our perspective about our cosmos

Subject Domain

Astronomy, Spherical Geometry, History

Orienting & Asking Questions

Orienting: Provide Contact with the content and/or provoke curiosity

What is Venus?

It's the second closest planet, after Mercury, to the Sun in our solar system.

Can you recognize any characteristics of this celestial object from the photo below?

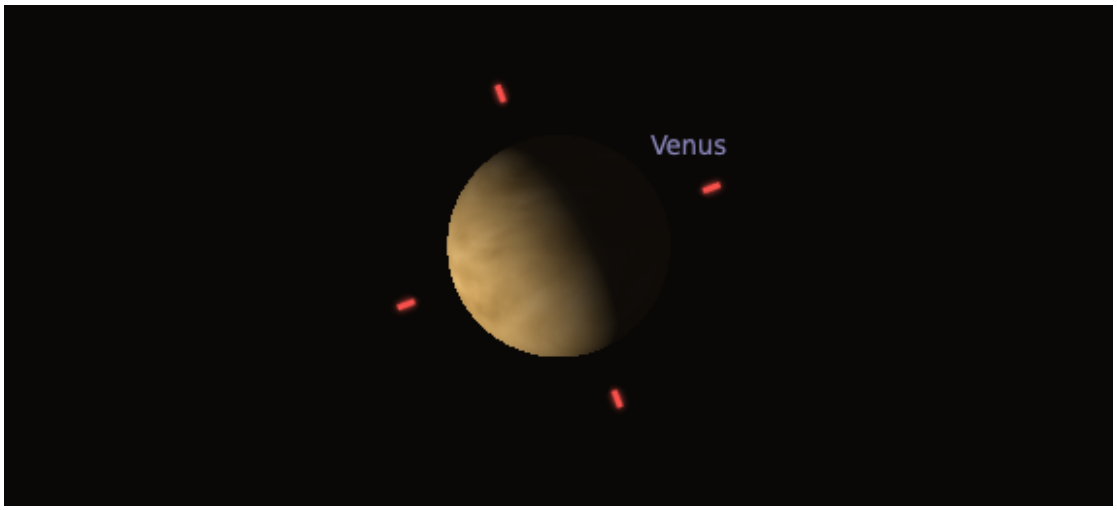
Magellan and Pioneer Venus Orbiter
Credits: NASA/JPL-Caltech

- It is the hottest planet in our solar system
- It is a terrestrial planet. It is small and rocky.
- It has an active surface, including volcanoes!
- It spins the opposite direction of Earth and most other planets

Take a look https://spaceplace.nasa.gov/all-about-venus/en/

What does it look like on the sky observing it with naked eye?

Let’s take a minor telescope or binoculars to observe the Venus or take a look from it through Stellarium which is a free open-source planetarium for your computer and any other mobile device.



Credit: Stellarium

Define Goals and/or questions from current knowledge

Does Venus emit its own light or reflects sunlight?

Is there anything similar to what we see when we observe the Moon?

Do you think that there is a periodicity on the phases of Venus? Could we calculate it?

Do you expect to observe any changes at the apparent diameter as time passes? Apparent diameter is the angular distance describing how large a sphere or circle appears from a given point of view. The night sky seems to be a dome, so we measure the distances among the celestial objects to degrees.

Hypothesis Generation and Design

Generation of Hypotheses or Preliminary Explanations

Suppose you are in Galileo's position and want to research if there are phases in the view of Venus as it is a planet with an inner orbit compared to that of the Earth, on which you are. See the chart below.

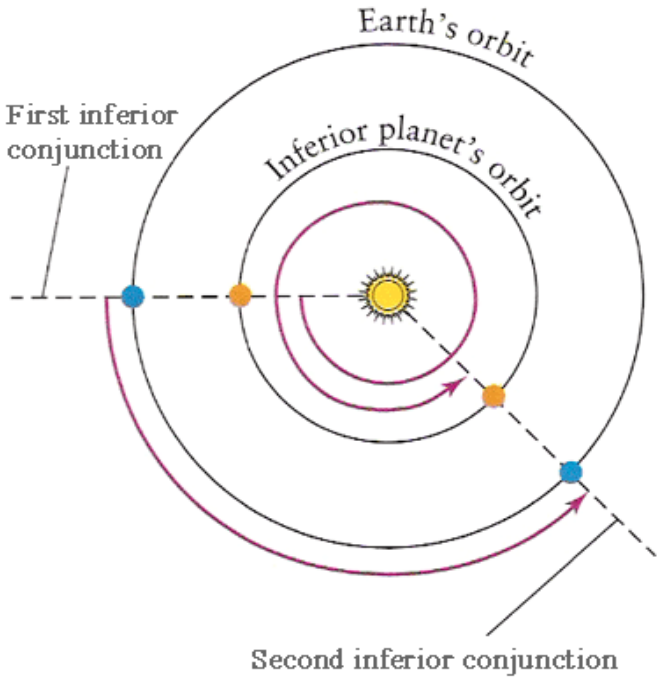


Figure not to scale and not necessarily alignment among Earth, Venus and the Sun (rare phenomenon)

If we think about what we will observe in the study of Venus, can we visualize it?
Draw the phases of Venus as a terrestrial observer and then as an observer on the surface of the Sun. Will the result be the same?
In addition, in order to represent the phases from the point of view of a terrestrial observer, also consider the relative Earth-Venus distance in terms of how much larger or smaller Venus appears each time on the sky.

Design/Model

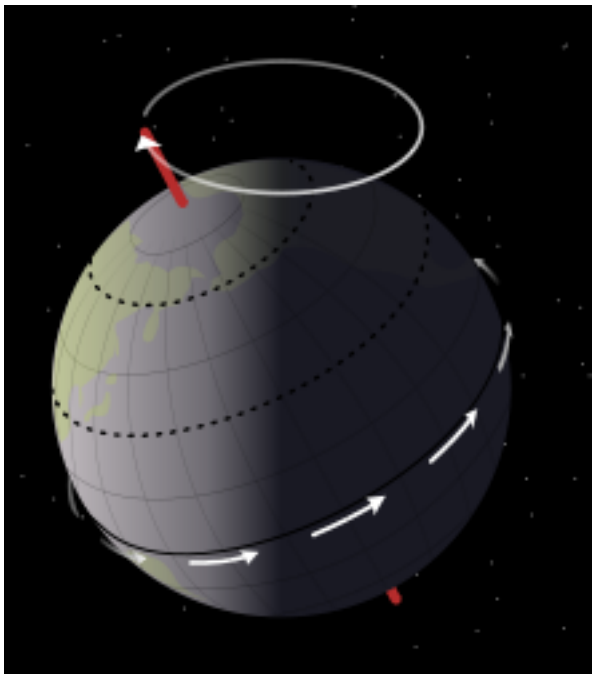
General view of Stellarium

You can simulate the past or future sky, anywhere on Earth or even in other places in our Solar System through Stellarium. You can also toggle labels on and off, increase or decrease the number of visible objects, and many more.
Stellarium's own YouTube channel contains several detailed videos showcasing the software's capabilities, including how to remotely control a telescope: https://www.youtube.com/channel/UC04hR2mrcRaM9MtMSG7uWLA.
So, using the Stellarium program, we can replicate the Galileo's observations by placing ourselves in the same place as Galileo himself and in the same time.

Planning, Investigation and Analysis

Plan Investigation

We'll launch the Stellarium and set the location as "Pisa, Italy" in order to see the sky as Galileo did in his time.
Our date and time will be January 1st 1610 at 17:00:00.
Additionally, in order to be familiar with the sky at that time, we can see that our Polaris is not so close to the north celestial pole as today, due to axial precession of the Earth.
Have a look: https://en.wikipedia.org/wiki/Axial_precession



Axial Precession of the Earth (a full rotation in approximately 26000 years)

Measuring the synodic period of Venus

The synodic period is the time between two successive same phases either for the Moon or the Venus.
So we'll observe the change at the phases of Venus. We set the date to June 1, 1610 and advance by two months increments, until Venus is at a phase

of about 0.01% illuminated. Once we get close, the increment should be days and not months.
After the minimum phase percentage, we advance quickly until the full phase and we fill the table below.

Date	Phase	Apparent diameter	Distance (AU)*
05/01/1610	99.9%	9.65''	1.73
05/05/1610	100%	9.64''	1.722
06/05/1610			
08/05/1610			
10/05/1610			
12/05/1610		22.05''	0.757
03/02/1611	1.7%		
….	….		
?	100%		

**AU is the mean distance between Earth and the Sun*

We can calculate the synodic period from full phase to the next full phase and we may use a unit conversion program such as: *http://www.onlineconversion.com/days_between_advanced.htm*

The accepted value for Venus' synodic period is 583.9 days. So how close was your calculation? Additionally, you can calculate the percentage error of your "observation" from the following formula and if it is lower than approximately 5%, your calculation is really very accurate!!

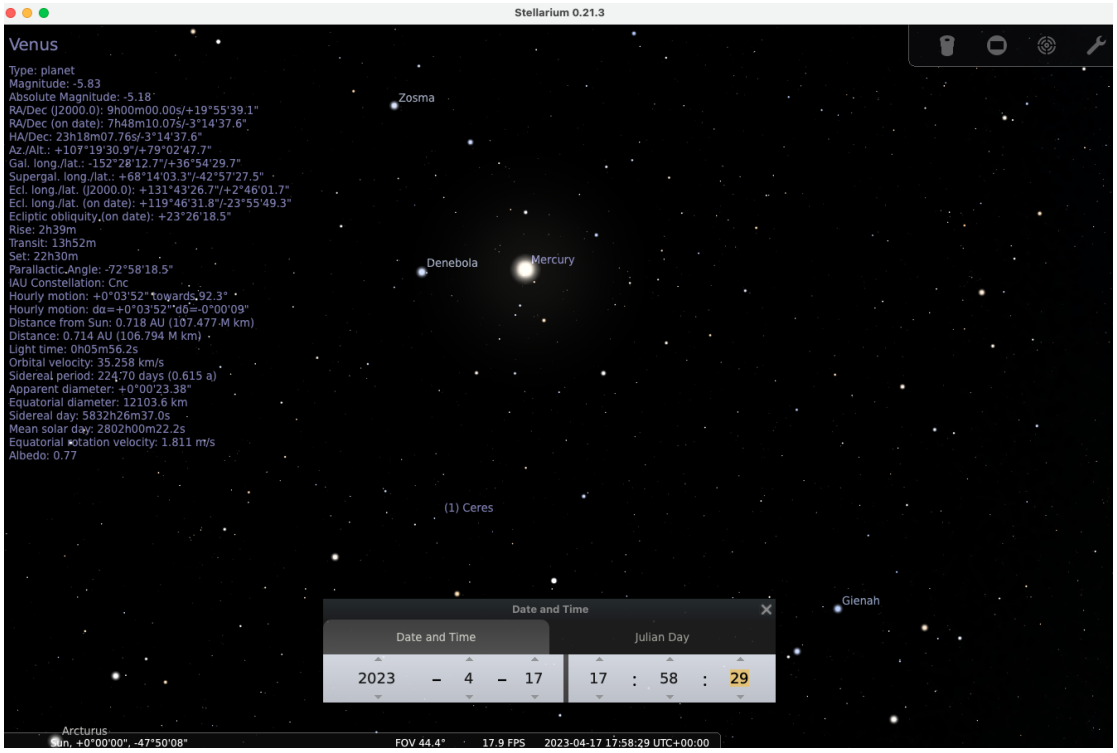
$$\% \ error = \left(\frac{accepted - observation}{accepted} \right) \times 100$$

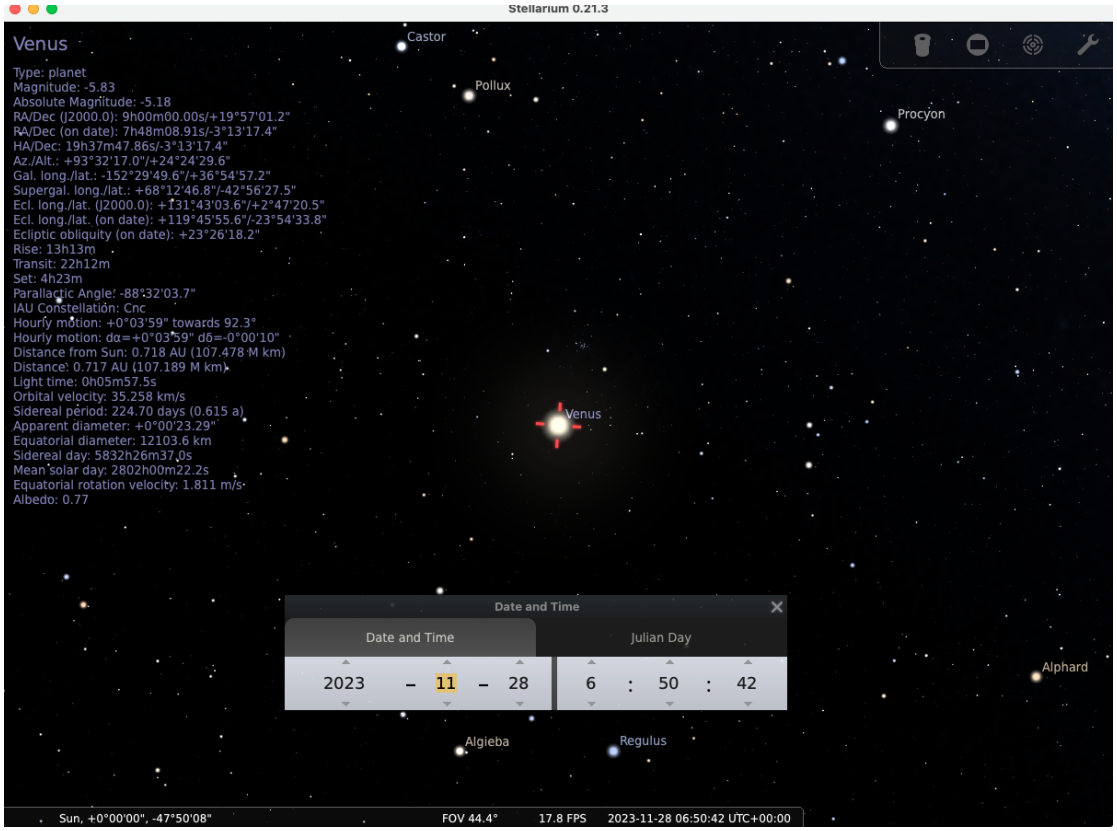
Measuring the sidereal period of Venus

Think about that we are at the solar surface, specifically at the solar equator and we want to measure the period of time that Venus needs to revolve around the Sun. Imagine also that we set the Sun at the position of the Earth at the figure below, so Venus has different celestial coordinates (Right Ascension RA and declination DEC) that show its position to the sky.
If we observe Venus at two successive moments with the same RA and calculate the elapsed time between these two moments, we'll find the sidereal period. In short, the sidereal period is the time interval between

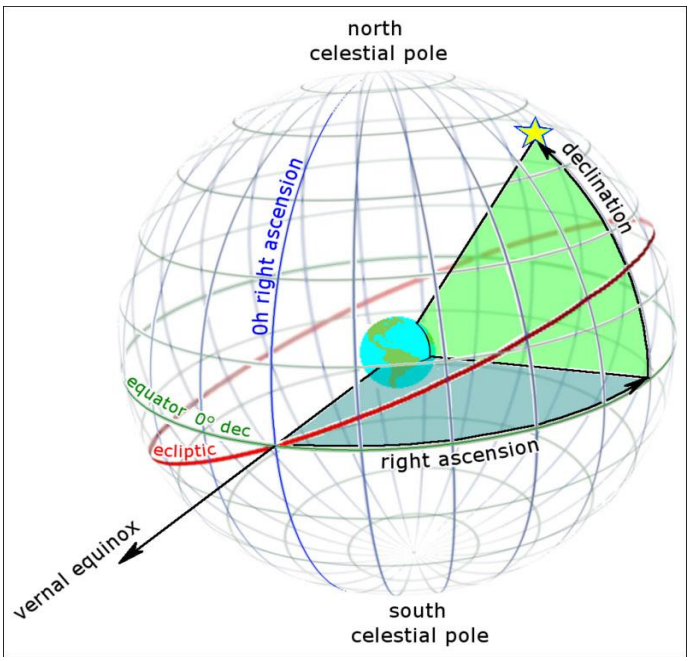
two successive transits of Venus through the same star background of the sky.

In order to do the calculation, we have to adjust the time precisely with a J2000 RA = 9h00m00s, for example. Two successive moments with the previous J2000 RA are, for example: a) 17 April 2023 17:58:29 UTC and b) 28 November 2023 06:50:42 UTC.
Try to find other date/time with the same J2000 RA for your scenario.





These snapshots above show these moments with the same J2000 RA and the figure below shows the declination (DEC) and the right ascension (RA) with the Earth at the center of the celestial sphere, in order to be more familiar with these terms.



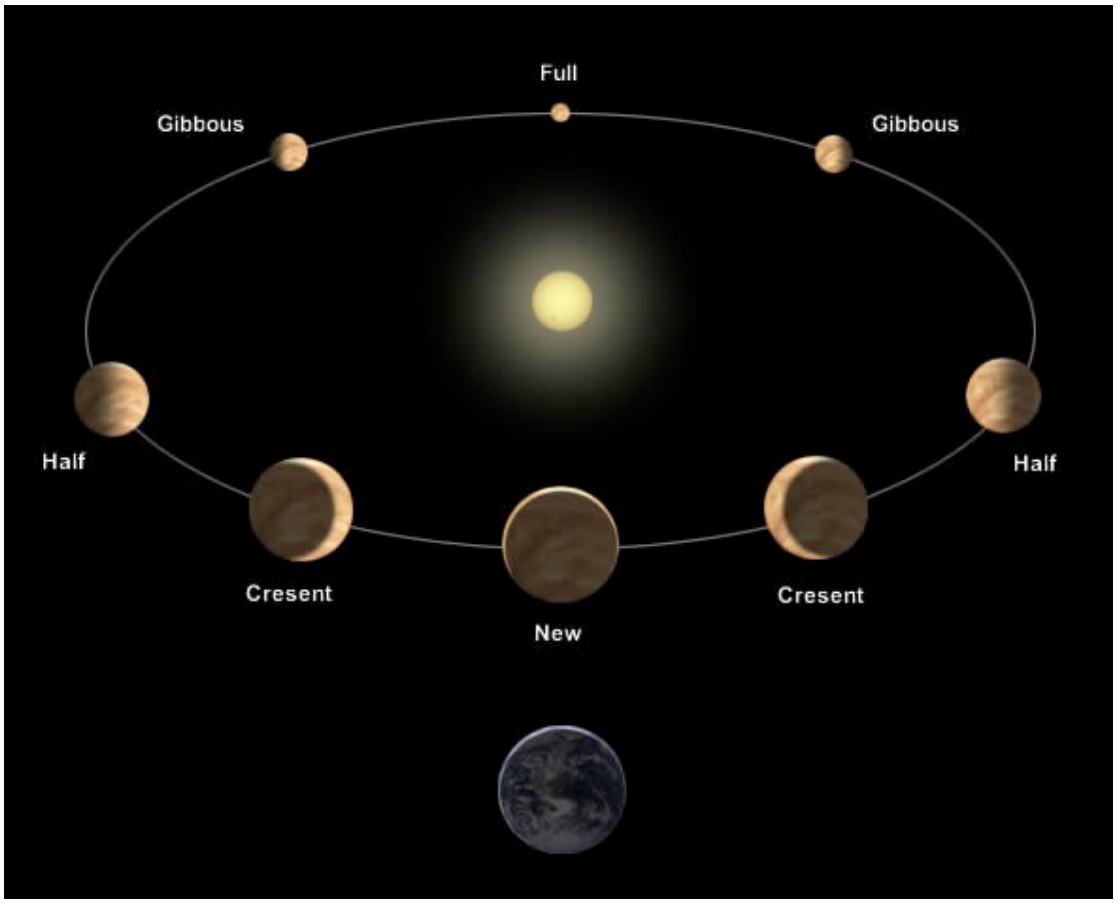
Credit: Tom Ruen / CC BY-SA 3.0

Analysis & Interpretation

Analysis and interpretation : Gather result from data

Now we have to already understand what kind of periods we've actually measured. Think about the figure in the generation of hypotheses. This figure can help us realize that the period of time between two successive inferior conjunctions is quite bigger than the period of revolution of Venus and it seems from the length of the pink arrow. The last one is the sidereal period.

Another crucial conclusion is the correlation among the apparent diameter that is recorded on the table above, the phase and the distance of Venus from the Earth. The following figure is very informative about this correlation and it lead us to have a better look at the phenomenon. So, **when the phase percentage decreases, Venus come closer to us, so the apparent diameter increases.**



Conclusion & Evaluation

Conclude and communicate result/explanation

You can divide the class into groups of two people and share the results with others.
You can also make posters and presentations on PowerPoint to share all the results and the impressions.
So, it's really important for you to learn and realise the historical background of that era and the fact that nowadays what we take for granted, it wasn't always obvious. This fact is food for thought for you and your classmates!!

Evaluation/Reflection

About the importance of this project for you, rate from 1 (lowest) to 5 (highest) each topic:

- The interest that this activity provoked to you
- The desire to talk about it to your classmates
- The knowledge acquired/reinforced
- The skills you obtained