

Revolutionary Venus: How Observing Venus with a Telescope Changed the World



Activity C10

Grade Level: 5–12

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What’s This Activity About?

The most direct and dramatic proof of the heliocentric model of the solar system came from Galileo’s observations of the phases (different appearances of sunlit and dark areas) on the disk of the planet Venus as seen through his telescope. Here students learn about phases and then compare the motion of Venus around the Sun in two models and how it would produce phases as seen from Earth.

What Will Students Do?

Students will model phases using a central light and white balls. They will make predictions from the geocentric and heliocentric models for the phases of Venus and compare the predictions of the two models to actual photos of Venus showing the phases.

Tips and Suggestions

- It’s good to try this activity for yourself before doing it with the students, so you are oriented in using the models. It’s helpful to have another adult in the classroom to help the different student groups.
- For more on the life and work of Galileo, see the background article “Galileo: Myths Versus Facts” (3.34 in *The Universe at Your Fingertips*)
- If Venus is up in the evening and morning sky when you are doing the activity, it’s nice to get students to observe it. See *Astronomy* or *Sky & Telescope* magazines or their web sites for information on how to find Venus in the sky.

What Will Students Learn?

Concepts

- Heliocentric versus geocentric models of the solar system
- Phases of Venus

Inquiry Skills

- Modeling
- Reasoning
- Predicting
- Explaining

Big Ideas

- Patterns of change
- Models and simulations

Revolutionary Venus: How Observing Venus with a Telescope Changed the World



Vivian White

(Astronomical Society of the Pacific)

Introduction

When Copernicus suggested his model of a Sun-centered (heliocentric) solar system in the mid 1500s, it was an idea that shook the foundations of humanity's belief that the Earth must be the center of creation. It was, also, more of a mathematical simplification than a model with physical proof. That proof had to await the invention of the telescope and its use by a wonderfully clever observer named Galileo Galilei. In this activity, students discover the “set-up” of the solar system using kinesthetic activities, modeling, and coming to a conclusion based on evidence — acting like scientists, much as Galileo did 400 years ago.

Materials Needed

- One white light with no shade or reflector that can be placed about 4 feet off the ground
- Extension cord
- A room that can be darkened
- Four or more white balls (e.g. volleyballs, baseballs or softballs)
- Heliocentric model Student Worksheets (two sided) for each heliocentric group
- Geocentric model Student Worksheets (two sided) for each geocentric group
- Predictions worksheet (two-sided) for each student
- Phases of Venus photos in an envelope for each group

Historical Preface: Galileo Was a Rebel

For thousands of years, people believed the Sun and all the heavens orbited around the Earth. After all, if you observe the Sun, Moon, and stars for a while, it certainly looks like they are all going around the Earth. This is called a **geocentric system** since it is centered on the Earth.

Ask the students: Can you think of other “geo” words? (Geography, geology, geothermal energy, for example. Geo is a Greek term for Earth.)

In the sixteenth century, Nicolaus Copernicus came up with a new idea. He hypothesized that all of the planets traveled around the Sun. This is called a **heliocentric model** (Helios is Greek for Sun.) We should note that it wasn't an entirely new idea. Some ancient Greeks, such as Aristarchus of Samos, had speculated that the Sun might be the center of our solar system.

Still, it was a very controversial idea, because it seemed to contradict the Bible and the accepted traditions of the time. Copernicus' book was called *On the Revolution of the Celestial Spheres*. (The term “**revolution**” as we use it now comes from Copernicus' challenge to authority and big change in thinking.)

About 100 years later, Galileo was born in Pisa, Italy. In 1609 he heard about the invention of a telescope in Holland. It was being used to watch for ships coming into ports there. From a simple description, he made a far better telescope for himself. Galileo then pointed his new telescope to the skies. He made many discoveries by just watching the skies a lot. He was the first person to see the moons of the planet Jupiter and the “phases” of the Venus (its changing appearance over time). The latter is what this activity is about.

His job as a professor of astronomy at University of Padua in Italy required Galileo to teach the theory of that time, which said that the universe was geocentric. The idea that we are the center of the universe made people feel special and comfortable. Galileo had heard about Copernicus's heliocentric theory many years before he ever looked through the telescope. Galileo's observations with his new telescope convinced him of the truth of heliocentric theory. He had watched moons going around Jupiter and thought “Well, it appears not everything has to go around the Earth.” Once Earth lost

that special sense of being the required center, it seemed possible to consider that it might not be the center of things at all. But it was his observations of Venus that really showed Galileo the convincing evidence he needed.

The Scientific Method

Galileo is sometimes called the father of modern science for the way he went about discovering things. He used what we call today the **scientific method**.

Ask students: Does anyone know the steps in the scientific method? The scientific method involves: 1) Making observations about the world around you; 2) Inventing hypotheses for why things appear as they do; 3) Testing these hypotheses with experiments or further observations; and 4) Then drawing conclusions from the results of your tests. When a hypothesis stands up to many tests, it becomes a Theory — like the Big Bang Theory or the Theory of Evolution.

Note that the word “Theory” in science is used differently from the way we use the term in everyday language. When a detective on a television show talks about “a theory” — it usually means a reasonable idea of what happened in the commission of the crime, but it may not be backed up by any evidence. When a scientist uses the word “Theory,” it means something which has a lot of evidence behind it.

Objectives

Explain to the students that we are going to use the scientific method in class today, just like Galileo did. Here is what we will do in this experiment:

- 1) We will notice that things in the sky appear to move above us. Ask students to give an example of things that travel across the sky.
- 2) We will start with two hypotheses about our planetary system — the geocentric model (maybe everything moves around the Earth) and the heliocentric model (maybe all things move around the Sun). They can't both be right, so we will look at ways of discovering the truth.
- 3) We will make real models of the two systems and figure out a way to test the differences between the two hypotheses.
- 4) Then we will use observations of the planet Venus through a telescope and try to come to a conclusion

about our place in the Solar System.

Classroom Kinesthetic Activity: The Phases of Venus

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a. Teacher Set Up

Materials Needed for This Part:

- One white light with no shade or reflector that can be placed about 4 feet off the ground
- Four or more white balls (e.g. volleyballs, baseballs or softballs)
- Copies of the Heliocentric and Geocentric Student Worksheets (two sided)
- One for each student: Predictions Worksheet (two sided)

On the day of the activity, set up the white light in a place with enough cleared space all the way around it to fit all of the students and still give them room to turn around. Darken the room as much as possible by closing the shades, doors and turning off all lights except the bulb in the center. If you do not have shades, you may want to use dark paper to cover some of the windows. (Note that finding a room that can be darkened will be easy in some school settings and hard in others. But the activity goes best when the room is pretty dark, so you may want to see if there is an interior room, with not too many windows, that you can borrow for this day.) Also, the farther away the light is from the walls, the less reflection you will get and the easier it will be to see phases.

b. Phases of Venus In Class

This exercise is to help students understand planetary phases and where in the sky that Venus is observed. If you have already done an activity modeling the phases (the different appearances of light and dark) of the Moon, some of the ideas here may be a quick review for your students.

You can begin by asking students:

- What do you know already about Venus and its motion?
- Did you know that Venus has phases?
- What is a phase?
- Can you think of anything that shows phases? (The Moon)
- Do phases always look the same?

Tell the students: When Galileo turned his new-fangled telescope toward the night sky, starting in 1609, Venus (the brightest planet in the sky) was one of the first objects he looked at. To the unaided eye, Venus just looks like a bright point of light. But through his telescope, Galileo could see the disk of Venus and found that it did not look the same as the weeks and months went by. Sometimes Venus showed just as a thin crescent, while at other times much more of it was lit up. It showed *phases*, just like the Moon.

Galileo soon realized that these phases, when studied and understood, could help humanity decide between the geocentric (Earth in the middle) and heliocentric (Sun in the middle) models of the solar system. Let's explore phases and how they would be different in the two systems.

Now turn on the central white light, turn off or down the room lights, and close the shades. Students should come up to the front of the room, but they should stay at least a meter away from the light for the activity to work best.

Tell the students: Let's pretend that this bright white light is the Sun, the white ball is the planet Venus and your head is the Earth. People on your "Earth" live on a big mountain called Mt. Nose. Let's ask some questions to get oriented:

What time of day is it on Mt. Nose when you look directly at the Sun? (Noon)

What time of day is it when you are facing directly away from the Sun? (Midnight)

Now put your hands up on either side of your eyes, palms facing forward. These form horizons on the sides of your eyes. Have students do the same.

Tell students: Your hands form an eastern and western horizon to Mt. Nose. Now turn around and face directly away from the Sun, then start turning slowly **to**

your left. This is the way that the Earth turns. When the Sun "rises" from your eastern horizon, it's morning. You should see the Sun during your day. It is night when the Sun "sets" behind your western horizon and you are facing away from the Sun.

Ask the students:

- 1) Which hand does your Sun set behind, right or left? (Right) (For younger groups, stop and make sure students recall which hand is their right by asking them all to raise their right hands. Help any students who have trouble recalling.)
- 2) On which horizon does the sun set, the west or the east? (West)
- 3) Which of your horizon hands represents your western horizon, right or left? (Right hand)

Tell the students to turn a couple more times slowly to see the Sun rise and set, and then stop at their "noon" positions facing the Sun and rest their "horizons." They may put their hands down. Now hold Venus again about a meter to the right of the Sun (as seen by your students).

Tell the students: Now we will add Venus to our model. This ball still represents Venus. As you turn, you will see both Venus and the Sun. When the real Sun is above the horizon, it is so bright that it is difficult for you to see the real Venus. So in our model, **imagine you can only see Venus when the Sun is below the horizon** (behind your hand or behind your head). Now, put your horizons back on and start turning slowly (still to the left) to find out when you can see Venus.

Ask the students: Raise your hand if you saw Venus just before sunrise. (Most students will raise their hands.)

Tell the students: Now, stop turning and rest your horizons. You can observe Venus in the sky just before sunrise in the east or just after sunset in the western horizon. It always stays close to the Sun in the sky. It was often called the morning star and the evening star. Before the invention of telescopes, they called it a star because, although it is very bright, with your eyes alone it is too small to allow you to see that it is a planet. Without a telescope, it just appears as a point of light like the rest of the stars. Yet by following Venus for months and months and years and years, people had known that this "morning star" and the "evening star" were the same ob-

ject for many thousands of years.

Put Venus back in its original spot on the left side of the Sun (as seen by the students).

Ask students:

- 1) If you put up your horizon hands and let your Earth turn again, do you think you will be able to see Venus before sunrise or after sunset? (After sunset)
- 2) Try it. Raise your hand if you saw Venus just after sunset. (Most will raise their hands)
- 3) Was Venus a “morning star” or “evening star” for you? (Evening star)
- 4) Turn around a couple of more times to make sure you can see this “evening star” just after sunset.
- 5) Do you think there is any time when you cannot see Venus at all? (Yes)
- 6) When would you not be able to see Venus? (When Venus is either behind or in front of the Sun from the Earth’s perspective. Also when it is the middle of the night.)

We have just finished the first step of the scientific method. We made the observation that Venus is never found very far from the Sun as seen from Earth. This observation is nothing new for humans. People have known about this “star” for a very long time. What they could not see until the invention of the telescope was that Venus has phases!

Now hold the Venus ball about a meter to the left of the Sun (as seen by your students). Ask them:

1. Do you see that the Sun side of Venus is lit up and the other side is darker? If there were no light in this room except for the “Sun,” you would not be able to see the dark side of the ball at all.
2. What does Venus look like from where you are standing? (Get students to talk about what they observe. Because the students are in different places, the descriptions will be slightly different. Some may say they see phases, that it looks like the Moon’s phases. Talk about this and see if others see the same thing.)

Now move the Venus ball to different places around the Sun and ask them to report on what they see. (As you listen to their responses, make sure that they understand the concept of phases and that they see different phases as the position of Venus changes.)

Now we will make models to investigate the two ways that the movement of Venus was explained in Galileo’s time.

Geocentric Versus Heliocentric: Kinesthetic Investigation in Small Groups

At this point, you should split the class in half and then make groups of 3-4 students. Half of the groups will make a model of the heliocentric hypothesis and the other half will make a model of the geocentric hypothesis. Hand out one “Heliocentric Model” worksheet or “Geocentric Model” worksheet to each group.

Ask the students to read the first page of their worksheet together in their group. Before they start drawing, ask them to make sure everyone in the group understands this first page. Ask them to discuss it as a group if you think they are having difficulties.

When they are ready, let one group from each model come and record their predictions with a ball and the light. While they are busy with this, other groups may want to do a different astronomy activity that you have ready for them. (One suggestion is “Ancient Models of the World” (L2) from *The Universe at Your Fingertips* disk.) When each group is done, let the next group come up and do their predictions.

When all the students finish, bring the heliocentric groups together to discuss as a large group what a full cycle of Venus phases would look like. Ask all the geocentric groups to come together do the same. Make sure the groups for each model agree, and, if they don’t, that they have a chance to discuss and work out their differences.

Ask someone from each large group to present the predictions for their model. Discuss the predictions that students have made. Draw the predictions for the two different phase cycles on the board, clearly marking which prediction goes with which model.

Now ask the summary question: How would Galileo have been able to tell the difference between a Heliocentric System and a Geocentric System? (***In a heliocentric solar system, Venus through a telescope would sometimes show phases fuller than half. In a geocentric solar system, Venus’ phases would always be less than half full.***)

Comparing the Model to Actual Observations

At this point, we want to take the next step in the scientific method and compare our predictions with actual observations made through a telescope.

In the best of all possible worlds, students would observe Venus for a whole school year (or more) through their own telescopes and make their own drawings of its phases. Even if your school does not have a telescope, there are remotely controlled telescopes around the world that students can use (see Appendix 1). But in the real world, few teachers and students have the instruments, resources, and time to make their own observations, like Galileo did. So for those classes, we provide a series of Venus photographs.

For good effect, make enough copies of the photographs sheet and put them in a sealed envelope to present to each student group. Let the students take their time examining the photos and then comparing them to their predictions. The pictures have dates and times on them, which are important clues.

Ask: Which model predicted the actual observations of Venus through a telescope? (The heliocentric model.) It would be good if each student recorded the diagrams and photos in his or her own notebook and wrote an explanation for why the heliocentric model is right.

NOTE: For the teacher, we have supplied a page called “What We Observe from Earth” (an answer key). After the activity is done, you can, if you wish, give out copies of this to the students to reinforce the ideas they discussed.

Ask: Why would no one have noticed before that the phases confirm the heliocentric hypothesis and alerted the world? (We can’t see phases without a telescope.)

Extension Activity: Phases and Outer Planets

Ask students: Does a planet orbiting the Sun further out than Earth show phases? Mars or Jupiter are examples of such “outer planets”.

See if students can show why using the lamp and balls. You can do this as a class. (The answer is that outer planets do not show phases. Only planets that revolve inside the orbit of our own world show phases.)

Now ask the students: If you were living on Mars,

which planets would show phases? (Mercury, Venus and Earth — because their orbits are closer to the Sun.)

Appendix 1: Remote Telescopes that Schools Can Use

SLOOH offers three remote telescopes to use in the classroom (one on the Canary Islands, one in Australia and one in Chile.) It is user friendly and requires virtually no image processing.

<http://www.slooh.com>

Hands On Universe provides software to 6–12th grade teachers to do investigative astronomy labs, including image processing.

http://www.handsonuniverse.org/about_hou

MicroObservatory allows you to ask for a picture of a specific object and they will return the data to you from their telescopes in Cambridge, MA. They also have a great list of activities under the “Challenges” tab on their webpage.

<http://mo-www.cfa.harvard.edu/MicroObservatory/>

Global Rent A Scope Observatories have live imaging and good help. They are expanding their educational programs at the time of publication.

<http://www.global-rent-a-scope.com>

Telescopes in Education gives students access to live data from a telescope on Mt. Wilson and suggests great imaging activities.

<http://www.telescopesineducation.com>

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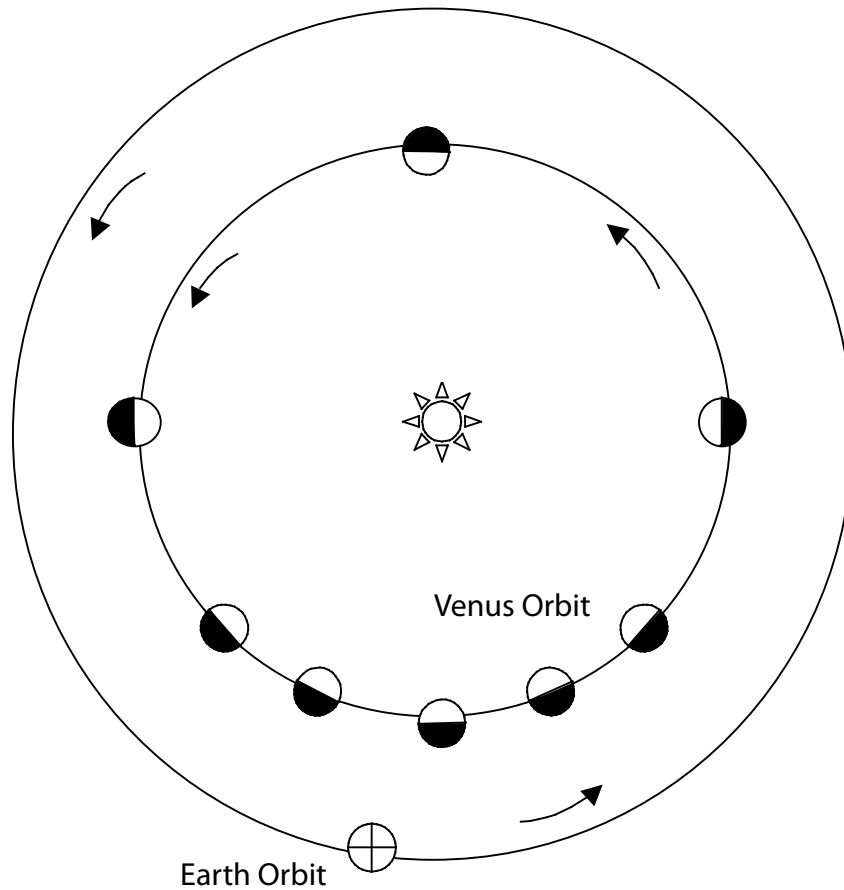
www.astro society.org

Heliocentric Model

Create a Hypothesis to Make Predictions

Group Members _____

Your group is going to examine what Venus would look like from Earth in the heliocentric model. Other groups are looking at the geocentric model and next we will compare the differences. In the Heliocentric model, Venus is about $\frac{2}{3}$ the way from the Sun to Earth.

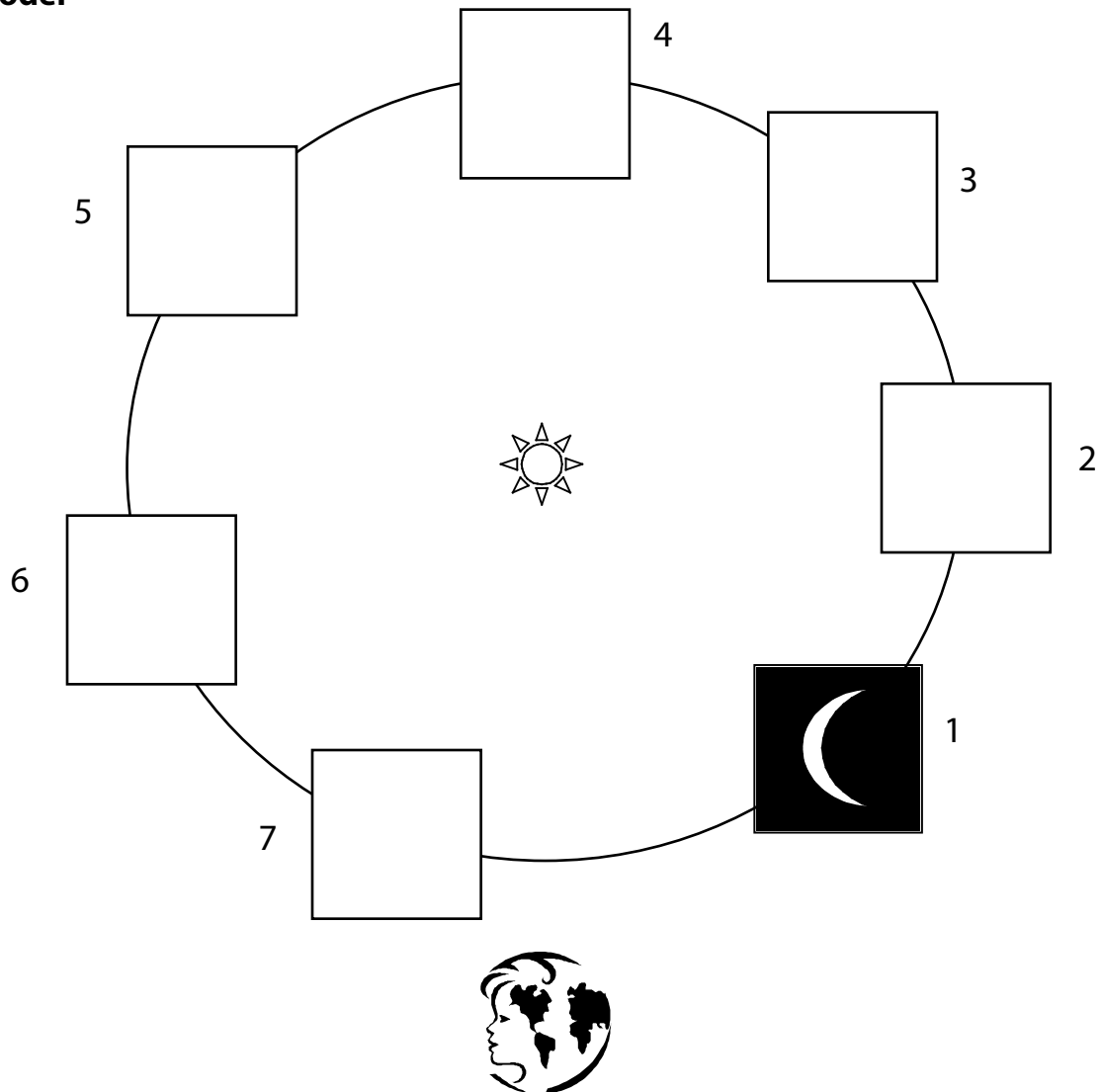


This is what the phases of Venus look like from above a heliocentric system (from the ceiling). The side of Venus that points towards the Sun is lit up. The other side is dark. Here we show what Venus looks like at different places in its orbit. Can you see why Venus never appears very far from the Sun when looking from Earth? Let's investigate further.

Scientists make models like these and then predict what they would see if the model were true. We are going to predict what Venus would look like from Earth in a heliocentric system and come up with some questions to test this hypothesis.

Heliocentric Model

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To Do in Class:

- Within your group, pick one person to be the first Venus. This person holds the ball about 1 meter away from the Sun at that height. Venus walks counterclockwise slowly around the Sun, making sure other group members can see the Venus model at all times.
- The other group members will be on Earth and stand together about a meter and a half from the Sun. When Venus passes the group, ask him/her to stop a little to your right, where position #1 is above. Does the lit up side look like that picture? Help each other.
- Let Venus walk slowly around the Sun a few times and watch the phases change. When Venus reaches position #2 ask him/her to stop. Record the phase that you see there. Then have another person be Venus. Repeat this with each person holding Venus for two drawings until all boxes are filled. Help each other fill boxes that you have missed.

Be ready to discuss the following questions with the rest of the class:

- 1) Talk about what you think a full cycle of Venus's phases would look through a telescope if we indeed lived in a heliocentric planetary system. (How full should it get? Will you always see it? Remember that the Sun is much bigger than Venus.)
- 2) What do you think a planet like Saturn or Jupiter (farther away from the Sun than the Earth is) will look like through a telescope? Will it have phases?

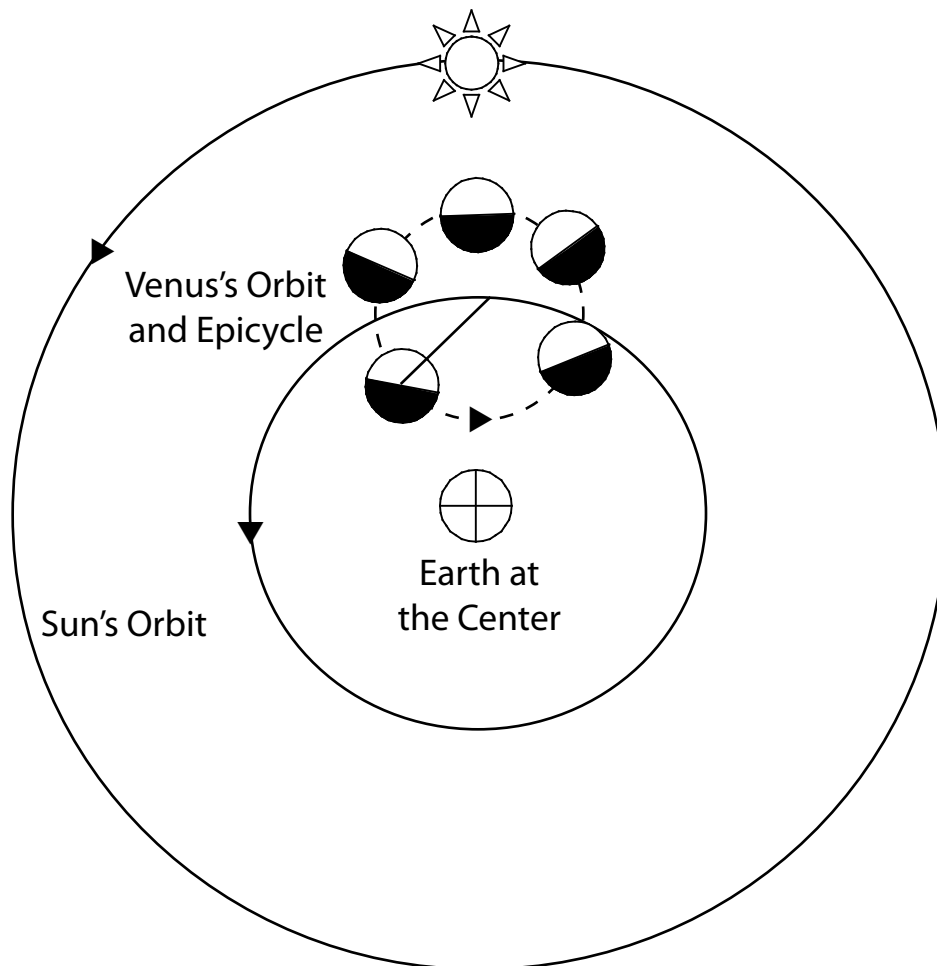
Geocentric Model

Create a Hypothesis to Make Predictions

Geocentric Members _____

Your group is going to examine what Venus should look like from Earth in the geocentric model. Other groups are looking at the heliocentric model and next we will compare the differences.

From Earth we never observe Venus very far away from the Sun. The geocentric model had to make some adjustments to keep Venus from moving to the other side of the Earth. They had to add circles on top of circles to account for this. These were called epicycles (dashed line). Venus's epicycle always stayed between the Earth and the Sun. Venus went around on the epicycle as the center of the epicycle went around the Earth. Here is what a basic geocentric model might look like from above (if you were looking down from the ceiling):

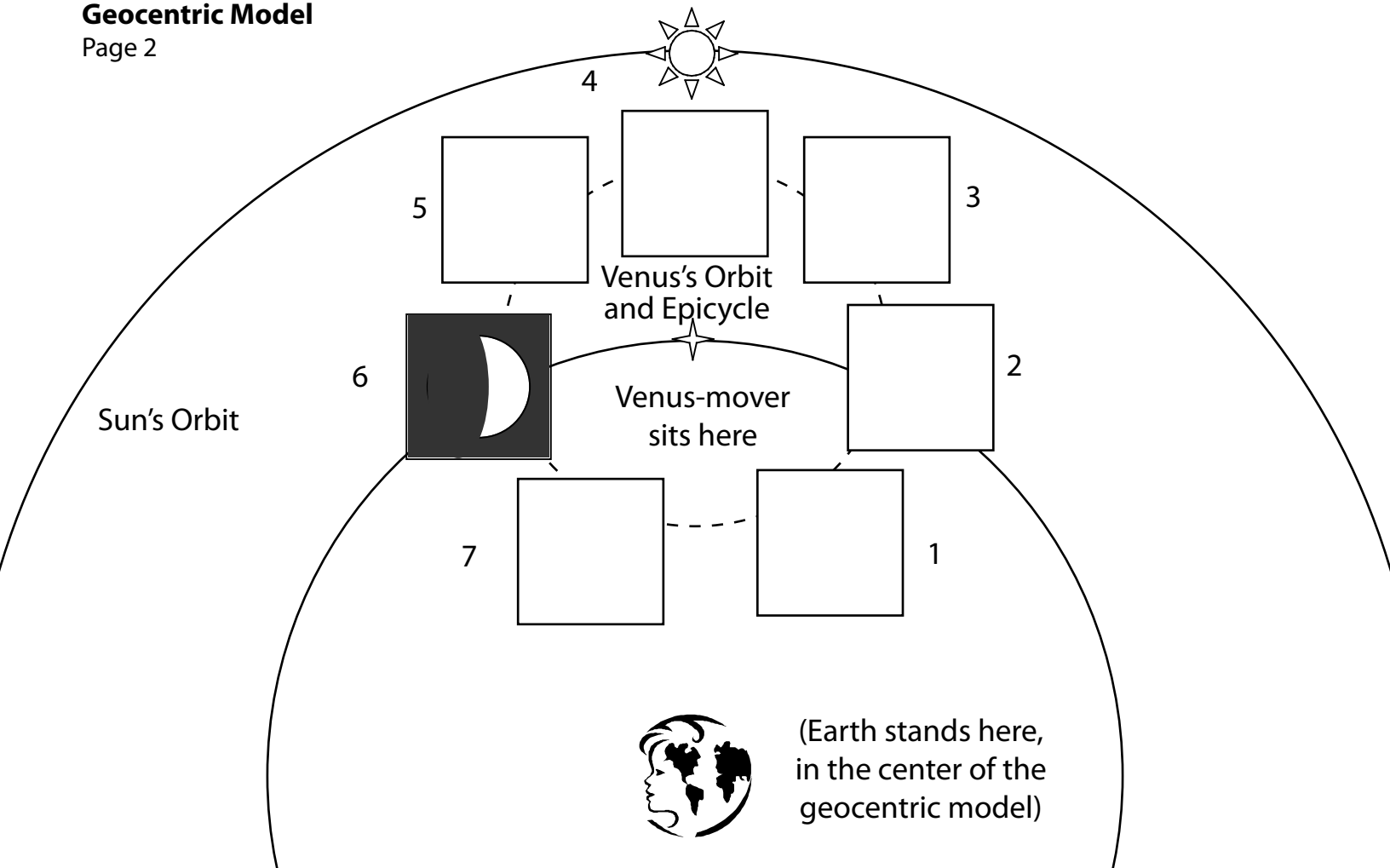


The side of Venus that points towards the Sun is lit up. The other side is dark. The Sun moves around its orbit and Venus goes around its epicycle. In this model, the epicycle stays between the Sun and the Earth.

Scientists make models like these and then predict what they would see if the model were true. We are going to predict what Venus would look like from Earth if this model were correct and come up with some questions to test this hypothesis.

Geocentric Model

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To Do in Class:

- Within your group, pick one person to be the first Venus-mover. That person will **kneel or sit about 1 meter from the Sun (light) and hold Venus above him or her at the same level as the light.**
- Another person will be the first Earth. Bring this worksheet and a pencil with you and stand about 2 meters from the Sun, in line with Venus. (see above)
- Have Venus-mover look at Earth and hold Venus in his/her right hand at arm's length at about the height of the Sun. Does Earth see the same part of Venus lit up as you see drawn above in position #6? If you do not see it, ask another group member for assistance.
- When you see the phase, ask the Venus holder to move the Venus towards Earth **in a counterclockwise circle** (as shown in the picture above) a few times. Ask the Venus mover to stop when Venus gets to position #7 and record what phase you see.
- Then the person playing Earth will become the next Venus-mover and a new person will be the Earth. Keep rotating until everyone in your group has had a chance to record the phases.

Be ready to discuss the following questions with the rest of the class:

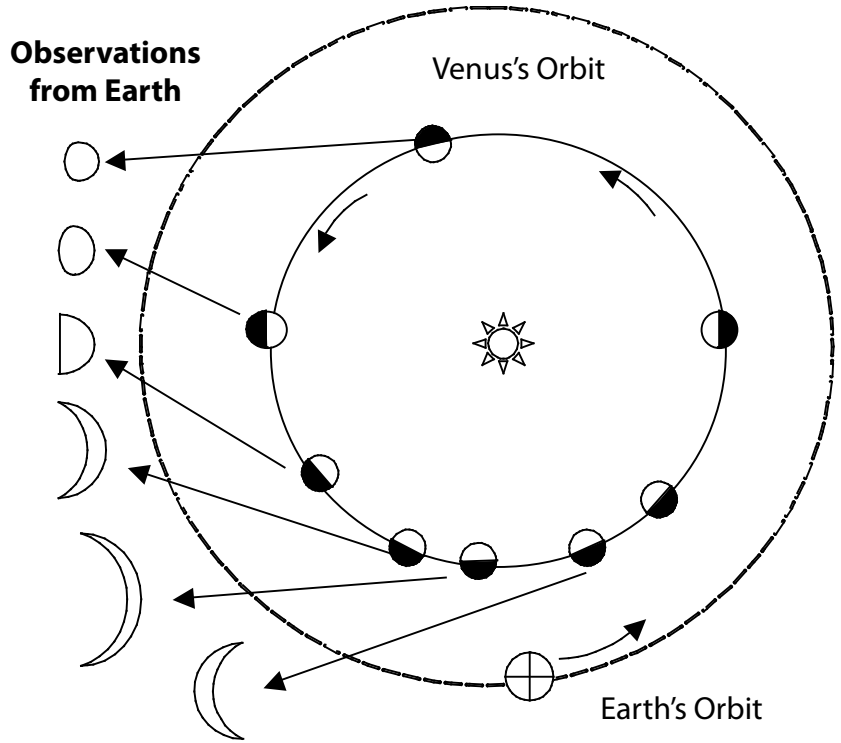
- 1) As a group, discuss what you think a full cycle of Venus's phases would look like if we lived in a geocentric planetary system. (How full should it get? Are there any times you won't see it? Remember, Venus is actually much smaller than the Sun.)
- 2) What do you think a planet that has an orbit on the other side of the Sun, like Saturn or Jupiter, will look like to us in a telescope? (If the Earth were still in the center)

What We Observe from Earth

Heliocentric vs. Geocentric Models

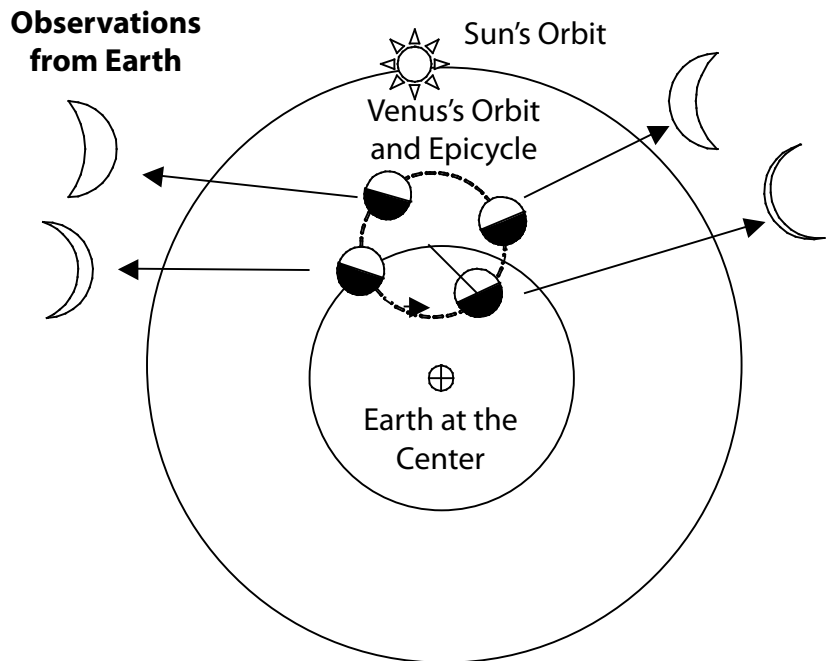
Heliocentric Model:

Here we observe Venus going from almost a circle all the way to thin “crescent” or fingernail as it orbits the Sun. When Galileo pointed his telescope into the night sky, he saw that that bright star was in fact a planet. He also saw that it had phases, including almost “full” or round.



Geocentric Model

If the Earth were in the middle, Venus would appear to stay in the area between the Earth and the Sun. It never goes very far from the Sun as viewed from Earth, so the geocentric model needs epicycles, or circles on top of circles. If this were the case, then from Earth we would only see some of the phases of Venus, not all of them. Venus would never even become half full.



VENUS



Feb 5, 2006 5:04 am



Feb 19, 2006 4:39 am



Apr 7, 2006 4:06 am



Apr 4, 2007 8:18 pm



Jun 14, 2007 9:12 pm



July 4, 2007 8:10 pm