AST 120 Activity 21
The Message of the Stars

Name	Full	Partial	None

Although Galileo did not invent the telescope (it was probably invented by Dutch lens-maker Hans Lipperhey in about 1608), and he may not have been the first person to use a telescope for astronomical observations (that was probably the Englishman Thomas Harriot in 1609), he most certainly produced telescopes that were far superior to anything else available at the time and used these telescopes (in late 1609) to see things in the heavens that no one else had ever seen. His report of his observations, which he published in a pamphlet entitled *Siderius Nuncius* (The Sidereal Messenger) in 1610, was enormously influential in gaining support for the Copernican system. This activity focuses on two of Galileo's telescopic observations: the mountains on the Moon and the phases of Venus. We will talk about some of his other observations later in the course.

1 The Mountains of the Moon

Galileo studied the Moon extensively through his telescope. He noticed right away that the Moon had a rough appearance, as though it had mountains and valleys like those of Earth. He became convinced that there were mountains on the Moon when he noticed an odd occurrence: a tiny bright spot on part of the Moon that was otherwise dark. He watched this bright spot over time and saw it move closer to the *terminator* (the line separating the bright and dark parts of the Moon).[1] As it approached the terminator the spot seemed to stretch toward the bright part of the Moon. Eventually it merged into the bright part and was no longer clearly visible. Galileo interpreted this bright spot as a mountain peak that rose up so high that it caught the sunlight even when the land around it was shrouded in darkness. From his observations he was even able to determine the height of the mountain. Let's see how he did it.

Run the `GalileoMoonMountain` program. The window on the left shows a view of the Moon as seen from above the Moon's north pole. A mountain (in white) is shown at the very bottom edge of the Moon. The bright and dark parts of the Moon are indicated, as is the direction to Earth. A ray of sunlight passes just across the side of the Moon, touching the Moon at the top of the terminator. A slider adjusts the angle between the sun and the moon, thereby changing the angle between the terminator and the line from the center of the moon to the mountain. The window on the right shows the view from Earth, in which the mountain would be in the center of a full Moon.

[1] Also the name of a fine film written and directed by the guy who did *Titanic* and starring the former Governor of California as a cyborg assassin from the future. I can't believe I didn't have to make any of that up!

1. Adjust the slider and watch both windows carefully. The bright spot becomes visible in the right window when _____ in the left window.

   (a) the top of the mountain touches the ray of sunlight

   (b) the right side of the mountain crosses the terminator

   (c) the center of the mountain crosses the terminator

   (d) the left side of the mountain crosses the terminator

2. Explain why the bright spot is not visible until this point.

3. Adjust the slider until the bright spot is just visible (so that if you went any farther it would no longer be visible). What is the angle between the line which connects the center of the Moon to the top of the mountain and the terminator line? Note: this angle is given in the left window, so you only need to record the value.

4. In the space below, draw a triangle showing the following lines from the left window: the terminator, the line from the center to the mountain, and the sun ray from the terminator to the top of the mountain. Indicate the degree measurements of all angles in the triangle. [Note: if you are having trouble with this, deselect Show Moon and Mountain from the Display Options menu.]

5. Use trigonometry (see pp. 187-188 in your text) to determine the distance from the center of the Moon to the top of the mountain. The radius of the Moon is approximately 1000 miles. Show all of your work.

6. What is the height of the mountain? Note that the height of the mountain has been greatly exaggerated here so that you can see how this works. Mountains on the Moon aren't really that high.

7. Now Galileo didn't have the view seen in the left window, he only had the view in the right window. But he could still do essentially the same calculation. He could determine how far (relative to the size of the whole Moon) the spot was from the terminator. Note that this is just the short side of the triangle you drew above. How far is the spot from the terminator when it first appears? Note that the distance of the spot from the terminator is given in the right window (in units of the Moon's radius). Give your answer in miles.

8. Referring to the triangle you drew above, use trigonometry to determine the distance from the center of the Moon to the top of the mountain. Don't use any angles, just use the Moon's radius and the distance you found in the previous question. Show all of your work.

9. What height do you get for the mountain using this method? Does it agree with your previous height?

10. What Galileo actually found was that a bright spot appeared about 1/20 of the Moon's diameter (or 1/10 of its radius) from the terminator. Use this information to determine the height of the mountain that Galileo saw. Show all of your work.

2 The Phases of Venus

1. Both the Ptolemaic and Copernican theories predict that Venus will have phases, just like the Moon.[2] However, the two systems give very different predictions for what the phases will look like. First let's look at the Ptolemaic system. Run the `VenusPhases` program and make sure it is set to Ptolemaic in the Select System menu. The left window shows a view from above the ecliptic plane. Earth is in blue, the Sun is orange, and Venus is yellow (on its bright side) and black (on its dark side). The deferent and epicycle of Venus are shown in green and magenta. A slider controls the location of Venus on its orbit (with the Earth and Sun held fixed) or you can just hit play and let Venus move through its orbit. The right window shows the Ptolemaic prediction for what Venus would look like through a telescope on Earth. In the space below, sketch the phases of Venus (as seen through the telescope) for at least 6 different positions on its orbit. Try to get a complete picture of the phases of Venus. In your sketches, indicate the shape and relative size of Venus as seen in the right window. Make sure to arrange the sketches in a proper sequence. Pay attention to how the phases relate to Venus' position relative to the Sun and to the Earth. Try to understand why Venus would appear as it does in the right window.

[2] Assuming that Venus shines because it reflects light from the Sun. If it is itself luminous then it should always be "full."

2. Now let's look at the Copernican system. Select Copernican in the Select System menu. The setup is the same as in the previous simulation, except now Venus is orbiting the Sun as in the Copernican system. In the space below, sketch the phases of Venus for at least 6 different positions on its orbit. Spread the positions out along the entire orbit so that you get a complete picture of the phases of Venus. In your sketches, indicate the shape and relative size of Venus as seen in the right window. Make sure to arrange the sketches in a proper sequence. Pay attention to how the phases relate to Venus' position relative to the Sun and to the Earth. Try to understand why Venus would appear as it does in the right window.

3. Now take a look at Galileo's own sketches of Venus, as shown in the bottom part of Figure 6.9 on page 135 of your text. [Note: for convenience you can also display these sketches by selecting Show Galileo's Drawings of Venus from the General Options menu.] Which system's predictions (if any) agree with the phases observed by Galileo? Explain your answer.

4. Do Galileo's observations of Venus disprove the Ptolemaic theory? Is there any way the Ptolemaic theory can be made to fit with what Galileo saw?

5. Do Galileo's observations of Venus disprove the Tychonic theory? Explain why or why not.

6. Given what you now know about the phases of Venus, explain why Venus does not vary in brightness as much as Mars does even though it relative variation in distance is about the same as that of Mars. (Think about this: does Mars have phases? What phase would it be in when it is in opposition and thus closest to Earth? What phase would it be in when it is in conjunction and thus farthest from Earth?)