

## 2.E: Observing the Sky - The Birth of Astronomy (Exercise)

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### For Further Exploration

#### Articles

##### Ancient Astronomy

Gingerich, O. "From Aristarchus to Copernicus." *Sky & Telescope* (November 1983): 410.

Gingerich, O. "Islamic Astronomy." *Scientific American* (April 1986): 74.

##### Astronomy and Astrology

Fraknoi, A. "Your Astrology Defense Kit." *Sky & Telescope* (August 1989): 146.

##### Copernicus and Galileo

Gingerich, O. "Galileo and the Phases of Venus." *Sky & Telescope* (December 1984): 520.

Gingerich, O. "How Galileo Changed the Rules of Science." *Sky & Telescope* (March 1993): 32.

Maran, S., and Marschall, L. "The Moon, the Telescope, and the Birth of the Modern World." *Sky & Telescope* (February 2009): 28.

Sobel, D. "The Heretic's Daughter: A Startling Correspondence Reveals a New Portrait of Galileo." *The New Yorker* (September 13, 1999): 52.

#### Websites

##### Ancient Astronomy

Aristarchos of Samos: <http://adsabs.harvard.edu/full/seri...00029.000.html>. By Dr. Alan Batten.

Claudius Ptolemy: [www-history.mcs.st-and.ac.uk/...s/Ptolemy.html](http://www-history.mcs.st-and.ac.uk/...s/Ptolemy.html). An interesting biography.

Hipparchus of Rhodes: [www-history.mcs.st-andrews.ac.uk/...ipparchus.html](http://www-history.mcs.st-andrews.ac.uk/...ipparchus.html). An interesting biography.

##### Astronomy and Astrology

Astrology and Science: <http://www.astrology-and-science.com/hpage.htm>. The best site for a serious examination of the issues with astrology and the research on whether it works.

Real Romance in the Stars: <http://www.independent.co.uk/voices/...s-1527970.html>. 1995 newspaper commentary attacking astrology.

##### Copernicus and Galileo

Galileo Galilei: [www-history.mcs.st-andrews.ac.uk/...s/Galileo.html](http://www-history.mcs.st-andrews.ac.uk/...s/Galileo.html). A good biography with additional links.

Galileo Project: <http://galileo.rice.edu/>. Rice University's repository of information on Galileo.

Nicolaus Copernicus: [www-groups.dcs.st-and.ac.uk/~...opernicus.html](http://www-groups.dcs.st-and.ac.uk/~...opernicus.html). A biography including links to photos about his life.

#### Videos

##### Astronomy and Astrology

Astrology Debunked: <https://www.youtube.com/watch?v=y84HX2pMo5U>. A compilation of scientists and magicians commenting skeptically on astrology (9:09).

##### Copernicus and Galileo

Galileo: <http://www.biography.com/people/galileo-9305220>. A brief biography (2:51).

Galileo's Battle for the Heavens: <https://www.youtube.com/watch?v=VnEH9rbrlkk>. A NOVA episode on PBS (1:48:55)

Nicolaus Copernicus: <http://www.biography.com/people/nico...rnicus-9256984>. An overview of his life and work (2:41).

## Collaborative Group Activities

1. With your group, consider the question with which we began this chapter. How many ways can you think of to prove to a member of the “Flat Earth Society” that our planet is, indeed, round?
2. Make a list of ways in which a belief in astrology (the notion that your life path or personality is controlled by the position of the Sun, Moon, and planets at the time of your birth) might be harmful to an individual or to society at large.
3. Have members of the group compare their experiences with the night sky. Did you see the Milky Way? Can you identify any constellations? Make a list of reasons why you think so many fewer people know the night sky today than at the time of the ancient Greeks. Discuss reasons for why a person, today, may want to be acquainted with the night sky.
4. Constellations commemorate great heroes, dangers, or events in the legends of the people who name them. Suppose we had to start from scratch today, naming the patterns of stars in the sky. Whom or what would you choose to commemorate by naming a constellation after it, him, or her and why (begin with people from history; then if you have time, include living people as well)? Can the members of your group agree on any choices?
5. Although astronomical mythology no longer holds a powerful sway over the modern imagination, we still find proof of the power of astronomical images in the number of products in the marketplace that have astronomical names. How many can your group come up with? (Think of things like Milky Way candy bars, Eclipse and Orbit gum, or Comet cleanser.)

## Review Questions

1. From where on Earth could you observe all of the stars during the course of a year? What fraction of the sky can be seen from the North Pole?
2. Give four ways to demonstrate that Earth is spherical.
3. Explain, according to both geocentric and heliocentric cosmologies, why we see retrograde motion of the planets.
4. In what ways did the work of Copernicus and Galileo differ from the views of the ancient Greeks and of their contemporaries?
5. What were four of Galileo’s discoveries that were important to astronomy?
6. Explain the origin of the magnitude designation for determining the brightness of stars. Why does it seem to go backward, with smaller numbers indicating brighter stars?
7. Ursa Minor contains the pole star, Polaris, and the asterism known as the Little Dipper. From most locations in the Northern Hemisphere, all of the stars in Ursa Minor are circumpolar. Does that mean these stars are also above the horizon during the day? Explain.
8. How many degrees does the Sun move per day relative to the fixed stars? How many days does it take for the Sun to return to its original location relative to the fixed stars?
9. How many degrees does the Moon move per day relative to the fixed stars? How many days does it take for the Moon to return to its original location relative to the fixed stars?
10. Explain how the zodiacal constellations are different from the other constellations.
11. The Sun was once thought to be a planet. Explain why.
12. Is the ecliptic the same thing as the celestial equator? Explain.
13. What is an asterism? Can you name an example?
14. Why did Pythagoras believe that Earth should be spherical?
15. How did Aristotle deduce that the Sun is farther away from Earth than the Moon?
16. What are two ways in which Aristotle deduced that Earth is spherical?
17. How did Hipparchus discover the wobble of Earth’s axis, known as *precession*?
18. Why did Ptolemy have to introduce multiple circles of motion for the planets instead of a single, simple circle to represent the planet’s motion around the Earth?
19. Why did Copernicus want to develop a completely new system for predicting planetary positions? Provide two reasons.
20. What two factors made it difficult, at first, for astronomers to choose between the Copernican heliocentric model and the Ptolemaic geocentric model?
21. What phases would Venus show if the geocentric model were correct?

## Thought Questions

1. Describe a practical way to determine in which constellation the Sun is found at any time of the year.
2. What is a constellation as astronomers define it today? What does it mean when an astronomer says, “I saw a comet in Orion last night”?

3. Draw a picture that explains why Venus goes through phases the way the Moon does, according to the heliocentric cosmology. Does Jupiter also go through phases as seen from Earth? Why?
4. Show with a simple diagram how the lower parts of a ship disappear first as it sails away from you on a spherical Earth. Use the same diagram to show why lookouts on old sailing ships could see farther from the masthead than from the deck. Would there be any advantage to posting lookouts on the mast if Earth were flat? (Note that these nautical arguments for a spherical Earth were quite familiar to Columbus and other mariners of his time.)
5. Parallax of stars were not observed by ancient astronomers. How can this fact be reconciled with the heliocentric hypothesis?
6. Why do you think so many people still believe in astrology and spend money on it? What psychological needs does such a belief system satisfy?
7. Consider three cosmological perspectives—the geocentric perspective, the heliocentric perspective, and the modern perspective—in which the Sun is a minor star on the outskirts of one galaxy among billions. Discuss some of the cultural and philosophical implications of each point of view.
8. The north celestial pole appears at an altitude above the horizon that is equal to the observer's latitude. Identify Polaris, the North Star, which lies very close to the north celestial pole. Measure its altitude. (This can be done with a protractor. Alternatively, your fist, extended at arm's length, spans a distance approximately equal to  $10^\circ$ .) Compare this estimate with your latitude. (Note that this experiment cannot be performed easily in the Southern Hemisphere because Polaris itself is not visible in the south and no bright star is located near the south celestial pole.)
9. What were two arguments or lines of evidence in support of the geocentric model?
10. Although the Copernican system was largely correct to place the Sun at the center of all planetary motion, the model still gave inaccurate predictions for planetary positions. Explain the flaw in the Copernican model that hindered its accuracy.
11. During a retrograde loop of Mars, would you expect Mars to be brighter than usual in the sky, about average in brightness, or fainter than usual in the sky? Explain.
12. The Great Pyramid of Giza was constructed nearly 5000 years ago. Within the pyramid, archaeologists discovered a shaft leading from the central chamber out of the pyramid, oriented for favorable viewing of the bright star Thuban at that time. Thinking about Earth's precession, explain why Thuban might have been an important star to the ancient Egyptians.
13. Explain why more stars are circumpolar for observers at higher latitudes.
14. What is the altitude of the north celestial pole in the sky from your latitude? If you do not know your latitude, look it up. If you are in the Southern Hemisphere, answer this question for the south celestial pole, since the north celestial pole is not visible from your location.
15. If you were to drive to some city south of your current location, how would the altitude of the celestial pole in the sky change?
16. Hipparchus could have warned us that the dates associated with each of the natal astrology sun signs would eventually be wrong. Explain why.
17. Explain three lines of evidence that argue against the validity of astrology.
18. What did Galileo discover about the planet Jupiter that cast doubt on exclusive geocentrism?
19. What did Galileo discover about Venus that cast doubt on geocentrism?

### Figuring for Yourself

1. Suppose Eratosthenes had found that, in Alexandria, at noon on the first day of summer, the line to the Sun makes an angle  $30^\circ$  with the vertical. What, then, would he have found for Earth's circumference?
2. Suppose Eratosthenes' results for Earth's circumference were quite accurate. If the diameter of Earth is 12,740 km, what is the length of his stadium in kilometers?
3. Suppose you are on a strange planet and observe, at night, that the stars do not rise and set, but circle parallel to the horizon. Next, you walk in a constant direction for 8000 miles, and at your new location on the planet, you find that all stars rise straight up in the east and set straight down in the west, perpendicular to the horizon. How could you determine the circumference of the planet without any further observations? What is the circumference, in miles, of the planet?

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