

2.10: Observing the Sky - The Birth of Astronomy (Exercise)

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.

Brahe and Kepler

Christianson, G. "The Celestial Palace of Tycho Brahe." *Scientific American* (February 1961): 118.

Gingerich, O. "Johannes Kepler and the Rudolphine Tables." *Sky & Telescope* (December 1971): 328. Brief article on Kepler's work.

Wilson, C. "How Did Kepler Discover His First Two Laws?" *Scientific American* (March 1972): 92.

Newton

Christianson, G. "Newton's *Principia*: A Retrospective." *Sky & Telescope* (July 1987): 18.

Cohen, I. "Newton's Discovery of Gravity." *Scientific American* (March 1981): 166.

Gingerich, O. "Newton, Halley, and the Comet." *Sky & Telescope* (March 1986): 230.

Sullivant, R. "When the Apple Falls." *Astronomy* (April 1998): 55. Brief overview.

The Discovery of Neptune

Sheehan, W., et al. "The Case of the Pilfered Planet: Did the British Steal Neptune?" *Scientific American* (December 2004): 92.

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. An interesting biography.

Hipparchus of Rhodes: 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/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. A biography including links to photos about his life.

Brahe and Kepler

Johannes Kepler: His Life, His Laws, and Time: kepler.nasa.gov/Mission/JohannesKepler/. From NASA's Kepler mission.

Johannes Kepler: <http://www.britannica.com/biography/Johannes-Kepler>. Encyclopedia Britannica article.

Johannes Kepler: www-history.mcs.st-andrews.ac.uk/Kepler.html. MacTutor article with additional links.

Noble Dane: Images of Tycho Brahe: <http://www.mhs.ox.ac.uk/tycho/index.htm>. A virtual museum exhibit from Oxford.

Newton

Sir Isaac Newton: www-groups.dcs.st-and.ac.uk/~...es/Newton.html. MacTutor article with additional links.

Sir Isaac Newton: <http://www.luminarium.org/sevenlit/n.../newtonbio.htm>. Newton Biography at the Luminarium.

The Discovery of Neptune

Adams, Airy, and the Discovery of Neptune: <http://www.mikeoates.org/lassell/adams-airy.htm>. A defense of Airy's role by historian Alan Chapman.

Mathematical Discovery of Planets: www-groups.dcs.st-and.ac.uk/~...and_Pluto.html. MacTutor article.

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).

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

Brahe and Kepler

"Harmony of the Worlds." This third episode of Carl Sagan's TV series *Cosmos* focuses on Kepler and his life and work.

Newton

Beyond the Big Bang: Sir Isaac Newton's Law of Gravity: <http://www.history.com/topics/enligh...law-of-gravity>. From the History Channel (4:35).

Sir Isaac Newton versus Bill Nye: Epic Rap Battles of History: <https://www.youtube.com/watch?v=8yis7GzIXNM>. (2:47).

The Discovery of Neptune

Richard Feynman: On the Discovery of Neptune: <https://www.youtube.com/watch?v=FgXQffVgZRs>. A brief black-and-white Caltech lecture (4:33).

Review Questions

1. Explain, according to both geocentric and heliocentric cosmologies, why we see retrograde motion of the planets.
2. In what ways did the work of Copernicus and Galileo differ from the views of the ancient Greeks and of their contemporaries?
3. What were four of Galileo's discoveries that were important to astronomy?
4. The Sun was once thought to be a planet. Explain why.
5. Why did Pythagoras believe that Earth should be spherical?
6. How did Aristotle deduce that the Sun is farther away from Earth than the Moon?

7. What are two ways in which Aristotle deduced that Earth is spherical?
8. How did Hipparchus discover the wobble of Earth's axis, known as *precession*?
9. 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?
10. Why did Copernicus want to develop a completely new system for predicting planetary positions? Provide two reasons.
11. What two factors made it difficult, at first, for astronomers to choose between the Copernican heliocentric model and the Ptolemaic geocentric model?
12. What phases would Venus show if the geocentric model were correct?
13. State Kepler's three laws in your own words.
14. Why did Kepler need Tycho Brahe's data to formulate his laws?
15. Which has more mass: an armful of feathers or an armful of lead? Which has more volume: a kilogram of feathers or a kilogram of lead? Which has higher density: a kilogram of feathers or a kilogram of lead?
16. Explain how Kepler was able to find a relationship (his third law) between the orbital periods and distances of the planets that did not depend on the masses of the planets or the Sun.
17. Which major planet has the largest . . .
 1. semimajor axis?
 2. average orbital speed around the Sun?
 3. orbital period around the Sun?
 4. eccentricity?
18. Why do we say that Neptune was the first planet to be discovered through the use of mathematics?
19. Why was Brahe reluctant to provide Kepler with all his data at one time?
20. According to Kepler's second law, where in a planet's orbit would it be moving fastest? Where would it be moving slowest?
21. Write out Newton's three laws of motion in terms of what happens with the momentum of objects.
22. The gas pedal, the brakes, and the steering wheel all have the ability to accelerate a car—how?
23. Explain how a rocket can propel itself using Newton's third law.
24. To calculate the momentum of an object, which properties of an object do you need to know?
25. To calculate the angular momentum of an object, which properties of an object do you need to know?
26. What was the great insight Newton had regarding Earth's gravity that allowed him to develop the universal law of gravitation?
27. Which of these properties of an object best quantifies its inertia: velocity, acceleration, volume, mass, or temperature?
28. Pluto's orbit is more eccentric than any of the major planets. What does that mean?
29. Why is Tycho Brahe often called "the greatest naked-eye astronomer" of all time?

Thought Questions

1. 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?
2. 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.)
3. Parallaxes of stars were not observed by ancient astronomers. How can this fact be reconciled with the heliocentric hypothesis?
4. 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?
5. 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.
6. What were two arguments or lines of evidence in support of the geocentric model?
7. 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.
8. 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.
9. 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.

10. Hipparchus could have warned us that the dates associated with each of the natal astrology sun signs would eventually be wrong. Explain why.
11. Explain three lines of evidence that argue against the validity of astrology.
12. What did Galileo discover about the planet Jupiter that cast doubt on exclusive geocentrism?
13. What did Galileo discover about Venus that cast doubt on geocentrism?
14. Is it possible to escape the force of gravity by going into orbit around Earth? How does the force of gravity in the International Space Station (orbiting an average of 400 km above Earth's surface) compare with that on the ground?
15. What is the momentum of an object whose velocity is zero? How does Newton's first law of motion include the case of an object at rest?
16. Evil space aliens drop you and your fellow astronomy student 1 km apart out in space, very far from any star or planet. Discuss the effects of gravity on each of you.
17. A body moves in a perfectly circular path at constant speed. Are there forces acting in such a system? How do you know?
18. As friction with our atmosphere causes a satellite to spiral inward, closer to Earth, its orbital speed increases. Why?
19. Two asteroids begin to gravitationally attract one another. If one asteroid has twice the mass of the other, which one experiences the greater force? Which one experiences the greater acceleration?
20. How does the mass of an astronaut change when she travels from Earth to the Moon? How does her weight change?
21. If there is gravity where the International Space Station (ISS) is located above Earth, why doesn't the space station get pulled back down to Earth?
22. If identical spacecraft were orbiting Mars and Earth at identical radii (distances), which spacecraft would be moving faster? Why?

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