TEACHER'S GUIDE
PRIMARY SOURCE SET

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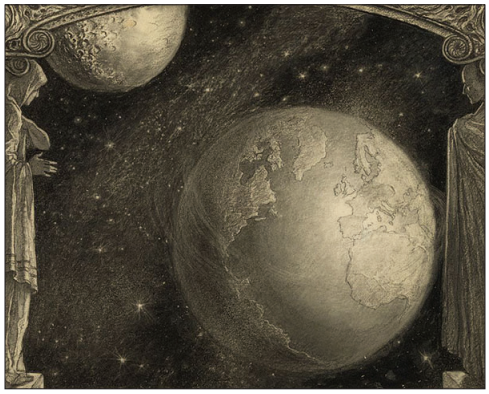
TEACHING with PRIMARY SOURCES

Understanding the Cosmos: Changing Models of the Solar System and the Universe

For millennia, humans have gazed at the sky and tried to make sense of what they saw there. Many of the men and women who puzzled over the dazzling displays and movements of the stars recorded their explanations in systematic ways—that is, they created models of the cosmos.



The Earth with the Milky Way and moon
http://www.loc.gov/item/2010715099/

Historical Background

These models were small versions of large systems that astronomers could hold in their minds, and that they could then set down on paper to share with their fellow stargazers. The astronomers who created them came from many different cultures and eras, and they often used very different approaches.

However, they shared many of the same methods and practices that are used by scientists and engineers today. They made observations and identified patterns. They evaluated evidence to determine the merits of arguments, and they used their models to test theories and make predictions about other cosmic phenomena.

The models in this primary source set were found in a variety of items in the collections of the Library of Congress, and span more than five centuries--from the pages of rare 15th-century books, to educational charts, to 20th-century magazine illustrations. Today, these models can tell us not only about the ways in which their creators understood the cosmos, but also about the times in which they lived, and the nature of discovery across centuries. Teachers and students exploring science, world history, the theory of knowledge, or even philosophy can find much to discover in these age-old illustrations.

Models as Arguments about the Natural World

These models were created by many different individuals, and their creators had a wide range of perspectives on the natural world. When each model first appeared, it offered an argument--a set of claims about the universe. For example, Copernicus'

diagram of a cosmos centered on the sun served as a powerful representation of a core part of the argument of his book. Today, a student can analyze Copernicus' images to articulate and evaluate the claims he made, just as his fellow mathematicians and astronomers did.

When Thomas Wright published his *Synopsis of the Universe* in 1742, he included a diagram of the theory of tides showing the moon, the Earth, and the shifting of the tides. Wright sought to show how Newton's universal theory of gravitation explained the relationship between the movement of the moon and the tides. Close observation and analysis of this diagram can help students today understand both Newton's theory and how to interpret these kinds of diagrams and models.

Changing Models, Changing Ideas

Scientific knowledge is always open to revision. The changing models of the cosmos show how scientists reassess and revise scientific knowledge. Studying select primary sources in chronological order can illuminate how ideas of the structure of the universe have developed over time.

A comparison of models from different eras can reveal the gradual shift from an Earth-centered universe to a sun-centered solar system, the discovery of new planets and moons orbiting other planets, and eventually the understanding that our solar system is just one of many in our galaxy.

These sources clearly show that ideas change gradually--even once new discoveries are made. Older models of the universe persisted for centuries even after new evidence contradicted them. Seemingly contradictory ideas about the cosmos still exist today.

Models and Evidence

The argument made by each model's creator depended on evidence. A close look at a particular model can reveal a great deal about the evidence that its creator used to support his or her perspective.

Many major breakthroughs were triggered by new technologies for gathering evidence--from the first telescopes, to improvements in lenses, to the rise of photography and radio telescopes. For example, for many centuries astronomers largely accepted Aristotle's notion that the moon was a perfect sphere. However, when Galileo saw the moon through a telescope and discovered that it was actually cratered and mountainous, he argued against Aristotle's interpretation. Galileo included drawings of the moon in his treatise *Sedarius Nuncius* as evidence to support his argument about the nature of the cosmos.

These models may have been intended primarily for their creators' peers and contemporaries. Today they might seem alien in their language and their assumptions. But they speak to us across the centuries about the endless drive to discover what lies beyond the Earth and about the ways in which scientific practices have shaped our understanding of the cosmos.

Suggestions for Teachers

Invite students to select and study one model from the primary source set. Ask them to speculate on what information was available to the person who created the model and consider the following questions: What assumptions about the natural world are evident in the item? How might the item have shaped the worldview of those who encountered it? You can use this activity in world history, Earth science, or astronomy classes to enrich student understanding of the era represented.

Ask students to select and study one item from the set. If this model were the only portrayal you knew, what else would you believe to be true about the universe and Earth's place in it? What would you need to know or do to challenge this model? Include this activity in a world history or astronomy class studying historical understandings of the cosmos.

Select or ask students to choose a few items featured in the primary source set from different eras that explain the same phenomenon, such as eclipses or the movement of celestial objects. Lead a class discussion with the following questions: Which elements are consistent across time? Which elements change over time? How does current scientific thinking explain that phenomenon? This exercise would be valuable in an Earth science or astronomy class studying the origins and evolution of the universe, a physics class studying planetary motion, or world history/world cultures courses.

Each model and depiction of the universe grapples with communicating the relative size and scale of the immense universe. Present students with an array of items and ask them to identify various ways that they communicate size and scale. Ask them to consider the difficulty of communicating the vastness of space. Select one item and ask students to identify decisions that the astronomer made about where to skew the scale. What evidence do they find to indicate whether the scale is skewed intentionally or from a lack of information? These activities meet standards for Earth science studies of scale and map-reading.

Additional Resources

Finding our Place in the Cosmos: From Galileo to Sagan and Beyond

http://www.loc.gov/collection/finding-our-place-in-the-cosmos-with-carl-sagan/

World Treasures of the Library of Congress

http://www.loc.gov/exhibits/world/heavens.html

Primary Sources with Citations

Bartholomaeus, Anglicus. *Le proprietaire en francoys*. Image 57. Lyon: Mathieu Husz, 1491. From the Library of Congress, Rare Book and Special Collections Division.

Christ standing amid the four elements
http://www.loc.gov/item/00522095/

Sufi, ʻAbd al-Rahman ibn ʻUmar. *Suwar al-kawākib*. Image 155. February 18, 1417. From Library of Congress, African and Middle Eastern Division.

Constellation Andromeda as recorded by al-Sufi around 946 AD.
http://www.loc.gov/resource/amed.200149120/#seq-155

Sacro Bosco, Joannes de. *Sphaera Mundi*. Diagram, image 38. Venice: July 6, 1482. From Library of Congress, Rare Book and Special Collections Division.

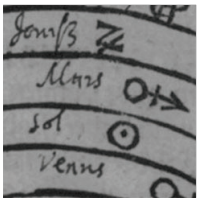
Illustration of a solar and lunar eclipse from a popular pre-Copernican astronomy textbook.
http://www.loc.gov/item/90172781

Von Megenberg, Konrad. *Buch der Natur*. Image 67. Augsburg: Johann Bämler, August 20, 1481. From Library of Congress, Rare Book and Special Collections Division.

Representation of the universe with heaven above, bands containing stars, planets, and Earth, below.
http://www.loc.gov/item/48035378

Ptolemy. Almagest. Illustration, image 20. Venice: Johannes Hamman, August 31, 1496. From Library of Congress, Rare Book and Special Collections Division.

Greek astronomer Ptolemy and his Renaissance translator Regiomontanus, seated beneath an armillary sphere.
http://www.loc.gov/item/48040724



Glogowczyk, Jan. An illustration of the Ptolemaic concept of the universe showing the Earth in the center. Print. Cracow: 1513. From Library of Congress, Prints and Photographs Division.

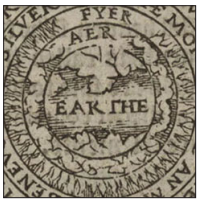
Illustration of the Ptolemaic concept of the universe showing the Earth in the center.
http://www.loc.gov/pictures/item/2007681147/

Copernicus, Nicolaus. *Nicolai Copernici Torinensis De revolvtionibvs orbium cœlestium*. Diagram, image 36. 1543. From Library of Congress, Rare Book and Special Collections Division.

Copernicus' Sun-centered model of the cosmos.
http://www.loc.gov/item/46031925

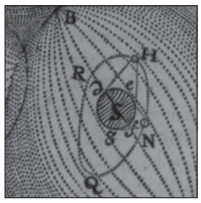
Galilei, Galileo. *Sidereus Nuncius*. Illustration, image 23. 1610. From Library of Congress, Rare Book and Special Collections Division.

Galileo's detailed depiction of the moon (made possible by using his telescope).
http://www.loc.gov/item/2010667904m



Blundeuile, M. *M. Blundeuile his exercises: containing eight treatises...* Illustration, image 301. London: William Stansby, 1613. From the Library of Congress, *The Kraus Collection of Sir Francis Drake*.

Illustration of the heavenly spheres showing Earth at the center surrounded by the four elements and eleven heavens.
http://www.loc.gov/item/64058795



Descartes, Rene. Illustration showing Descartes' mechanical view of a universe as a system of vortexes that carries planets around the sun. Print. In *Principia Philosophiae*. Amsterdam: Apud L. Elzevirium, 1644. From Library of Congress, Prints and Photographs Division.

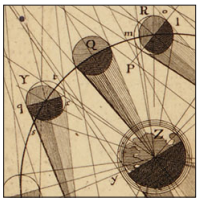
Illustration of Descartes' mechanical view of the universe.
http://www.loc.gov/pictures/item/92518505/

Allegorical Scene of Three People with Astronomy Equipment. Illustration, 1651. From Library of Congress, Prints and Photographs Division.

Presentation of the state of the astronomy in 1651, featuring the Copernican sun-centered model and the geocentric models of Tycho Brahe and Ptolemy.
http://www.loc.gov/pictures/item/96517795/

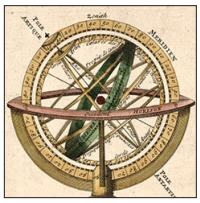
Cellarius, Andreas. *Harmonia Macrocosmica*. Map. Amsterdam: 1708. From Library of Congress, Geography and Map Division.

Includes an elaborate presentation of Ptolemy's model of the universe showing each planet's deity riding a chariot through the heavens.
http://www.loc.gov/item/2011589506



Wright, Thomas. *A Synopsis of the Universe, or, the Visible World Epitomiz'd*. Map. London: 1742. From Library of Congress, Geography and Map Division.

Includes text, illustrations of armillary spheres, diagrams of Pythagorean, Platonic, Egyptian, Chaldean, and other systems.
http://www.loc.gov/item/2008621668

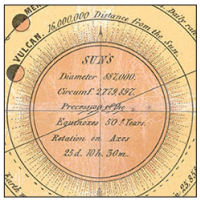


Collection of Nine Images Including Astronomical Instruments, Celestial Charts, and a World Map. Map. 1769. From Library of Congress, Geography and Map Division.

Nine printed images and two panels of printed text including a presentation of the universe according to Brahe, Copernicus, and Descartes, as well as Ferguson's method of constructing sundials.
http://www.loc.gov/item/2013593153

Allard, Carel. *Planisphaerii coelestis hemisphaerium meridionale: calculatum ad finem anni MDCC, pro aevo SVIII praesente*. Map. Amsterdam, 1700. From Library of Congress, Geography and Map Division.

Hemispheric view with signs of the zodiac and the constellations, including model of an eclipse.
http://www.loc.gov/item/2012590167



Colby, Hall. *A plan or map of the Solar System projected for schools & academies*. Map. Rochester, New York: Jones & Newman, 1846. From Library of Congress, Geography and Map Division.

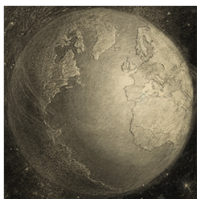
Diagram of the solar system includes the planet Vulcan as well as the asteroids Vesta, Juno, Ceres, and Pallas.
http://www.loc.gov/item/2013593145

Smith, Asa. *Eclipse of the Sun*, 1846: April 25. Map, 1846. From Library of Congress, Geography and Map Division.

Hand-colored illustration of "magnificent eclipse" of the sun on April 25, 1846.
http://www.loc.gov/item/2013593158

Mattison, Hiram. *Atlas Designed to Illustrate Burritt's Geography of the Heavens*. Map. New York: Sheldon, 1856. From Library of Congress, Geography and Map Division.

Illustrations of stars, nebulae, and a proposed structure for the universe in 1856.
http://www.loc.gov/item/77370907



Benda, Wladyslaw T., artist. " The Earth with the Milky Way and moon." Charcoal drawing. In Maeterlinck, Maurice. "The Future of the Earth, " *Cosmopolitan* 64, no. 41 (March 1918). From Library of Congress, Prints and Photographs Division.

Illustration of Earth with the Milky Way and moon.
http://www.loc.gov/pictures/item/2010715099/