Chapter 2

Astronomy and Culture

Astronomy can be linked with many other topics, often in ways that especially interest students. Examples from astronomy in the history of science are perhaps most straightforward. Links of astronomy with classical mythology in art and music also interest many nonscientists. Science fiction, music, and poetry are other examples of fields with astronomical contexts. Further papers discuss how certain students can be brought to study astronomy from considerations of the northern lights and, for business students, the commercial use of space technology. A final, inspirational talk discusses the thrill of discovery and how students would benefit from understanding it.

THE USE OF HISTORY IN THE TEACHING OF ASTRONOMY

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Three good reasons for using historical materials in teaching astronomy are:

- The simplest concepts are introduced first in a natural sequence;
- For non-science students, history can build onto other interests;
- The historical perspective shows the changing and iterative nature of scientific explanatory structures.

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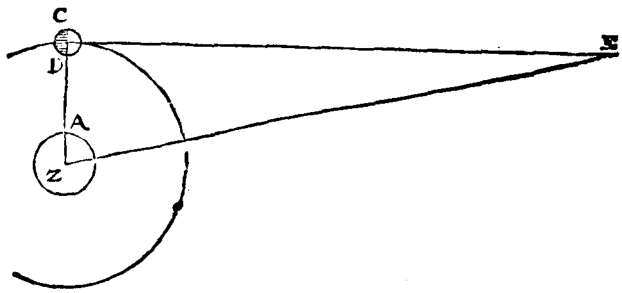

In which E is put for the Center of the Sun, Z for the Center of the Earth, D is the Moon. CZ is the common Interſection of the Plane of the Circle of the Moon's Illumination with the Plane of the Ecliptic : The Line CE, in the Plane of the Ecliptic, is the Diſtance of the Center of the Moon from that of the Sun ; and the Line ZE in the ſame Plane, is the Diſtance of the Earth from the Center of the Sun. From

Fig. 1. Whiston's Astronomical Lectures *of 1828 shows the Aristarchan method for getting the ratio of the lunar and solar distances, which came out as 1:19 for the 3rd-century B.C. Ionian cosmographer.*

Introducing Concepts in Historical Sequence

Aristarchus' method of using the lunar day-night dichotomy to get the relative distance of the sun and moon has long been used as a pedagogic tool. Our Fig. 1 is from William Whiston's *Astronomical Lectures* (London, 1728), but clear diagrams and presentations are also found in several modern textbooks. Teaching this point requires that students learn how the phases of the moon work; they can see that astronomers begin from simple principles to make deductions about the scale of the universe, they can recognize how even the ancient Greek astronomers could begin to build an understanding of the universe, and they can readily grasp the crucial role of observational error. As Whiston remarked, "Notwithstanding that great Subtilty of Wit and Reason, yet many defects are seen in [this method], which forbids us to expect an accurate Investigation of this Parallax by means [of it]." Adventuresome teachers can ask the students if Aristarchus' result, that the sun is 19 times farther than the moon, is "wrong." (If so, can we claim that our current measured distance to the Andromeda Galaxy is "right"?)

Eratosthenes' method for estimating the size of the Earth is probably even more impressive for beginning students, partly for the spurious reason overemphasized by some authors concerning the accuracy of the ancient Alexandrian's result. Here is a good opportunity to introduce the meaning of significant figures!

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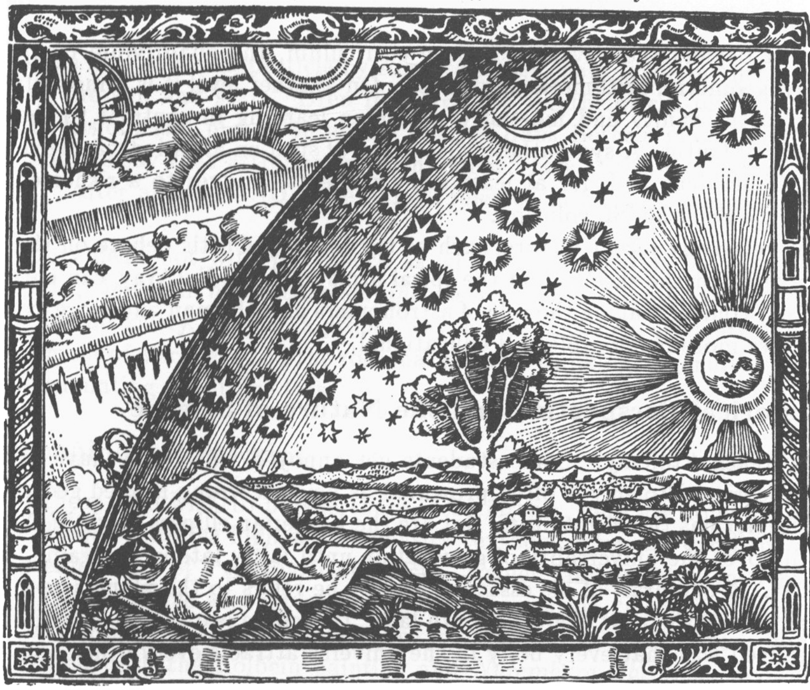

Un missionnaire du moyen âge raconte qu'il avait trouvé le point
où le ciel et la Terre se touchent...

Fig. 2. Purported medieval view of the cosmos, as conceived by Camille Flammarion and published in his L'Atmosphére: Météorologie Populaire *(Paris, 1988).*

The definitions involved with the celestial sphere (equator, ecliptic, solstice, height of the pole star, *etc.*) are most readily taught with a geocentric armillary sphere, which disconcerts some students. It is very useful to take a medieval view of a fixed Earth for the first several days of an astronomy class, to challenge students to produce a proof that the Earth moves.

Building Bridges with History

One of the most widely reproduced views of the early sixteenth-century cosmos appears in Fig. 2. It shows a medieval traveler at the end of the Earth peering beyond the dome of the sky to see the celestial machinery beyond. Unfortunately, it is pure *art nouveau*, the creation of famed French popularizer Camille Flammarion, and first published by him in 1888. The graphic is philosophically anachronistic: in that age such curiosity would have been objectionable, especially since all the iconography of the age put God and the heavenly hosts immediately outside the starry sphere, much as Dante had portrayed it with his word pictures.

Far better depictions of the cosmos around 1500 are found, for example, in the full-page illustration at the end of the creation sequence in the 1493 *Nuremburg Chronicle*, or, more subtly, in Hans Holbein's "Ambassadors." Holbein's magnificent oil hangs in the National Gallery in London, full of Renaissance symbolism. On one level, it depicts the advanced college curriculum, the quadrivium comprising astronomy, geometry, arithmetic, and music. On another level it is a morality play testifying to the vanity and mortality of human learning in contrast to the half-hidden eternal truths. A sympathetic discussion of such an artistic treasure sets the stage for Copernicus and, for at least some students, bridges to a richer cultural context of the Scientific Revolution.

Even relatively recent history, such as the Shapley-Curtis debate on the scale of the universe, or the race to find the spiral arms of the Milky Way, can enrich an introductory course, making the role of astronomers more human and more exciting, and therefore more memorable and educational.

The Historical Perspective and the Nature of Science

Why teach Ptolemy? Some students get annoyed when they have to learn "wrong" theories. Ptolemy is often presented as being a wrong-headed geocentrist, whereas Kepler has the Right Stuff. But are the Keplerian ellipses "right"? Newton did not discover the universality of gravitation until fairly late in the game, in the fall of 1684. In one draft of his essay on gravity he refers to the planets as moving in ellipses, and in the next draft, a month later, this claim is excised. What Newton finally realized was that every body in the universe attracts every other body, and because of these perturbations, no planet actually moves in a perfect elliptical orbit.

The historical material can help make the point that science is a dynamic interaction between observations and theory, or, in Einstein's words, "never completely final, always subject to question and doubt."

A year ago, *Science* magazine carried an interesting critique of introductory science courses for non-science students, under the provocative title, "Are Our Universities Rotten at the 'Core'?" (the 'Core' punning on Harvard's "Core Curriculum" of basic courses). My Harvard colleague, chemist Frank Westheimer, who is somewhat suspicious of historically oriented presentations, wrote that "Perhaps it serves a purpose to recite some of the intellectual advances in science that occurred in the last half century, long after Copernicus and Galileo and Newton ...made their contributions to the intellectual heritage of mankind. In particular, the critical discovery of atomic fission was not published until 1939; in 1937, no one knew how the sun produced its light and heat."

I frankly think it does as little good to *recite* some of the intellectual advances as to embellish a textbook with a few historical illustrations and dates. What we really want is to explain how science works in an evolving, self-correcting way, and a historical perspective often makes that clearer. Did no one know how the sun produced its light and heat in 1937? In 1920, Arthur Eddington wrote, "What is possible in the Cavendish Laboratory may not be too difficult in the sun," and "If, indeed, the sub-atomic energy in the stars is being freely used to maintain their great furnaces, it seems to bring a little nearer to fulfillment our dream of controlling this latent power for the well-being of the human race — or for its suicide." Or perhaps it was unknown until 1931, when Robert d'E. Atkinson argued that the combination of four protons into an alpha particle by some catalytic chain involving heavier nuclei could fuel the sun and stars. Even if we rewrite Westheimer a bit to say fusion instead of fission, and pick 1939 as the date of Hans Bethe's paper on the CNO cycle, could we say that astronomers then "knew" how the sun produced its light and heat? After all, the CNO cycle is now rejected in favor of the proton-proton chain.

History deals not with *facts*, such as who discovered something first or who "got it right," but with *historically significant facts*, which illuminate the process of creation and discovery. Used in a proper way, history can help students understand the excitement of discovery and the role that creative thinking, ingenuity, and genius play in formulating scientific ideas.

Bibliographical Postscript

For those who wish to pursue these ideas farther, here are come clues. Unit 2 of the *Project Physics* high-school physics textbook gives an excellent and accurate presentation of Ptolemy, Copernicus, Kepler, and Newton in a historical setting. The definitive account of the phony Flammarion "woodcut" is by Bruno Weber (in German) in *Gutenberg-Jahrbuch* for 1973, pp. 381-408. I have illustrated and discussed both the Holbein painting and *Nuremburg Chronicle* woodblock in "Copernicus: A Modern Reappraisal," pp. 27-49 in David Corson (editor), *Man's Place in the Universe: Changing Concepts* (Tucson, Arizona: University of Arizona, 1977). The most thorough discussion of the Holbein is Mary F.S. Hervey's *Holbein's "Ambassadors"* (London: G. Bell and Sons, 1900). Newton's path to *universal* gravitation is well told by I Bernard Cohen, "Newton's Discovery of Gravity," *Scientific American*, March 1981, reprinted in Owen Gingerich (editor), *Scientific Genius and Creativity* (New York: W.H. Freeman, 1986).

Excellent material on the Shapley-Curtis debate is found in Michael Hoskin's *Stellar Astronomy* (Chalfont St Giles: Science History Publications, 1982) as well as in Robert Smith's *The Expanding Universe: Astronomy's Great Debate, 1900–1931* (Cambridge, England: Cambridge University Press, 1982). My account, "The Discovery of the Spiral Arms of the Milky Way" is in H. van Woerden *et al.* (editors), *The Milky Way, IAU Symposium 106* (Dordrecht: D. Reidel Co., 1985), and a shorter version in *Sky & Telescope* **68**: 10–12, 1984. F.H. Westheimer's "policy forum" editorial appeared in *Science* **236**: 1165, 1987. The papers by Eddington, Atkinson, and Bethe are grouped together in Chapter IV, "Stellar Evolution and Nucleosynthesis" in Kenneth R. Lang and Owen Gingerich (editors), *A Source Book in Astronomy and Astrophysics, 1900–1975* (Cambridge, Mass.: Harvard University Press, 1979). Concerning the difference between *fact* and *historical facts*, see the introduction to Owen Gingerich (editor), *The General History of Astronomy*, volume 4A (Cambridge, England: Cambridge University Press, 1984).

Fig. 3. Holbein's The Ambassadors *(courtesy of the trustees, National Gallery, London).*

Discussion

M. Zeilik: *Do you have an appropriate place in your course for the history of astronomy outside of the western tradition?*

O. Gingerich: We assign a project or essay, which counts for a third of the grade, and we include as standard topics such questions as "Was Fajada Butte a solar marker?," "Would the Chinese have found a heliocentric cosmology?," and "How accurate was Mayan astronomy?" In the course itself, there just aren't enough lectures to touch on many fascinating topics.

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