ASTR 380 History of the Cosmos

1 Objectives of the Course

This course will introduce the major ideas which have been invented to account for astronomical phenomena and it will trace how the history of astronomy interacts with and reacts to the larger history of ideas in Western civilization. Emphasis will be given to evolution of the conceptions of space, time, and motion from ca. the second millennium BCE, to Einstein and beyond, to current multi-dimensional ideas arising from string theory, both driven by, and impacting, astronomical observation and discovery. Though largely non-technical, the course will examine the logic of scientific discovery and the relation of the ways of knowing in science to ways of knowing in other aspects of human experience.

This is proposed as an upper division 300-level course, with a prerequisite of ASTR 110 (the general education Survey of Astronomy), or by permission of the instructor. Since it will emphasize the historical context of astronomical discovery and the evolution of scientific theory, as well as the feedback of new physical ideas on the areas of philosophy, religion and politics, the course is likely to be of interest to students whose primary interest is in western history, philosophy of science, and the history of ideas, as well to those specializing in the physical sciences.

Reading and discussion of primary source material from some of the books in Section 3b will be emphasized.

2 Organization & Syllabus

The course will cover the twelve major topics listed below. We are still undecided whether to take a straightforward historical approach or to cover these topics with a thematic organization. In either case, the major themes are: i) ideas of space and time, ii) ideas of terrestrial and celestial motion, iii) astronomy as an example of a scientific theory, and iv) interaction between scientific ideas and the larger culture. In a thematic approach one would still trace the historical evolution of these ideas and re-visit the primary source material with each new theme.

Introduction to the course
A historical overview will be followed by a brief discussion of the themes of the course.

1 Mesopotamian celestial forecasting
After a quick review of the ancient near-Eastern historical context in the first and second millenia BCE, the motivations of the Babylonian observational program will be discussed: astrology and maintenance of a common calendar for administering a large empire. We will show that the Babylonians developed accurate celestial forecasting for solar and lunar events, based on extrapolation of patterns in their centuries-long cunei-
form records, but they failed to develop an underlying conceptual model for why the heavens behave as they do.

2 Hellenistic astronomy and the emergence of scientific theory
It is the Ionian natural philosophers who invented the idea of a scientific theory, and we will examine the context out of which this idea arose. The Pythagoreans played a seminal role and there will be special emphasis on their ideas. Plato’s geocentric cosmology and his theory of matter and theory of science will be reviewed. Substantial attention will be given to Aristotle’s dynamics and his notions of proper place and natural motion, and how these lead to his mechanization of the cosmos. Finally, there will be a review of later Greek developments, with discussion of the fine-tuning of Aristotle’s model of the solar system by Hipparchus and Ptolemy, and ending with Ptolemy’s great synthesis of Greek cosmology.

3 Arabic continuation and development of the Greek tradition
This section opens with a review of historical developments in the first six centuries of the common era, and then the Islamic expansion. We will discuss the importance of the Arabic translation program and trace the diffusion of Greek astronomy throughout the Islamic world. Following a review of the achievements of Islamic astronomy we will try to understand the decline of Arabic science.

4 The Greek tradition re-emerges in medieval Europe
This section will begin with a review of the historical context in the European middle ages. We will discuss the recovery of Greek and Islamic astronomy, the rise of the universities, and the synthesis of theology and Aristotle in Scholasticism. We will describe the medieval cosmos and the Great Chain of Being and show how the geocentric cosmology was central to the medieval world-picture. Examples from art and literature will illustrate how widely-held this world view was.

5 Copernicus proposes a heliocentric cosmology
A brief biography of Copernicus will be followed by a discussion of his introduction of a helio-centric cosmology, why he did so, and how he might logically have gone further in revision of the Ptolemaic system. Finally we will discuss the implications and problems of a moving Earth.

6 Galileo supports the heliocentric cosmology
A brief review of Galileo’s life will be followed by discussion of his telescopic observations and their implications for the demise of the Ptolemaic model, and indeed, for the entire medieval world-picture. We will show how Galileo provided both observational and rhetorical support for the heliocentric model, and discuss his trial and punishment by the Inquisition. Finally we will describe his achievements in understanding inertia and Galilean relativity.

7 Kepler and his three laws of planetary motion
These lectures will begin with a review of the work of Tycho Brahe and the importance of observational accuracy, which played a critical role in Kepler’s great achievements.
We will discuss Kepler’s attraction to Pythagorean thought and his cosmology based on the five Platonic solids, and why he had to give this idea up. We will then discuss Kepler’s three laws of planetary motion, and his introduction of the ideas of orbits and motion in space. Kepler was aware of the problem he introduced, viz. what force moves planets in their orbits and we will discuss his ideas about this. Finally we will review the implications of the demise of Ptolemaic cosmology and the medieval world-picture.

8 Newton’s laws of motion and universal gravitation
A brief review of Newton’s life will be followed by his introduction of the law of universal gravitation and his unified dynamics, presented in his great Mathematical Principles of Natural Philosophy. We will give emphasis to this work, including his “Rules of Reasoning in Philosophy.” We will also discuss his invention of absolute space and time and the problems these concepts raised. Finally we will discuss the Newtonian Universe, with its key feature of perfect predictability.

9 The 17th Century Scientific Revolution
In these lectures we will investigate the larger cultural and philosophical legacy of Newton’s achievements: the realizations that there are natural laws, and that they may be comprehended by human reason. We will discuss readings from several authors who sought natural laws in economics, politics, and biology, and argue that this legacy continues to the present day.

10 The 20th Century Revolution
In this section we will discuss the work of Planck, Schroedinger, Heisenberg, and Bohr and the Quantum Revolution, demonstrating how it brought to an end the perfect predictability of Newton. We will then discuss Mach and Einstein, and the demise of absolute space and time in the General Theory of Relativity. Finally we will discuss Hubble’s discovery that the Universe is expanding, and the Big-Bang cosmological model.

11 Grand Unified Theories and Multi-Dimensional Universes
We will show how observations interpreted with Newtonian gravity lead to the idea that about 30% of the matter in the Universe is in some “dark” form that does not emit light. Even more bizarre, we will show that a variety of different observations show that the expansion of the Universe is accelerating, and there must be some form of “dark energy” whose equivalent mass is about 70% of the total mass in the Universe. We will show how speculative theories of high-energy particle physics can account for these phenomena, but they also raise a number of new questions: how many dimensions are there; are there any astronomical tests which might in principle confirm such theories?

12 Epilogue: How Science Works
This historical review of the development of physical ideas central to astronomy provides a key opportunity to examine the evolution of scientific methodology. While understanding that science is a human enterprise that is certainly in part an art form, we will try to identify some key aspects of the scientific method, its strengths, and its limitations.
3 Reading

3a Text

Science and Technology in World History by James E. McClellan III and Harold Dorn (Johns Hopkins University Press, 1999) [paperback].

3b Reading List

The first five books cover much of the primary source material, and the remaining books are background reading and reference--not all required reading.

- The Realm of the Nebulae, Edwin Hubble, (Yale University Press, 1982). [paperback]
- The Origins of Modern Science by Herbert Butterfield (The Free Press, 1965) [paperback].
- Early Greek Science: Thales to Aristotle by G. E. R. Lloyd (W. W. Norton & Company, 1970) [paperback].
- The Elizabethan World-Picture by E. M. W. Tillyard (Vintage, 1959). [paperback]
- The Discarded Image, C.S. Lewis (Cambridge University Press, 1994). [paperback]
4 Relation of Proposal to Current and Future Curriculum Plans

This course will be a second addition to the undergraduate curriculum which looks at astronomical ideas in a cultural context. The first such course, introduced about three years ago, was ASTR 130, Introduction to Archæoastronomy, and this has been well-received by the students.

We propose that this course be at the upper-division level, since this is appropriate for the depth and rigor at which the course will be presented. Current undergraduate course offerings in astronomy are all at the lower division level, with the exception of ASTR 427, Cosmology, and 430, The Solar System, which are graduate courses which may be taken by undergraduates with reduced achievement standards. Some knowledge of basic astronomy will be assumed and hence ASTR 110 or equivalent is a prerequisite, or permission of the instructor.

5 Possible Overlap with Existing UH Courses

The closest overlap would be with HIST 394 & 395, History of Science. However these courses have not been offered since the death of Prof. Fritz Rehbock in 2002. The History Department has not been able to replace Prof. Rehbock with another historian of science, so the proposed new course goes some way to solve this problem for the History Department. It could be asked whether the astronomers proposing the new course could simply give the existing HIST 394 & 395, but since they are by training physicists and astronomers they do not feel they have the knowledge of the history of the biological sciences needed to credibly offer the existing courses. We hope that this course can be cross-listed with history.

There is no doubt some overlap between the proposed course and HIST 337 & 338, European Intellectual History, but the latter is given as a seminar course rather than a lecture course, and the time period seems to begin with the 17th Century. More significantly, the focus of the proposed course is on astronomical and physical ideas and their interaction with the larger culture, whereas the intellectual history courses would survey the broader range of intellectual history.

6 Instructor Resources

Dr. Antoinette Cowie and Dr. Bob Joseph propose to team-teach this course the first few times it is offered. However in the course of informal discussions other IfA colleagues have expressed interest in also taking a turn at presenting this course. We believe this course will become a regular feature of the astronomy curriculum and be presented every year.

The IfA Graduate Chair, Dr. Joshua Barnes, confirms that this course will not impact our ability to give other astronomy courses already listed in the catalogue; no other course will need to be sacrificed for us to offer this course.
7 Credit Level

This is offered as a 3-credit course.

8 Evaluation of Performance

We propose to assess achievement in this course from a mid-term exam, a final exam, one research paper, and homework discussion sheets, and in-class discussion. Approximately one class session every fortnight will be devoted entirely to discussion and analysis of a reading from the primary source material.