ASTR 380 The Cosmos in Western Culture

1 Lecturers

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2 Course website

http://www.ifa.hawaii.edu/users/acowie/class07/

This site provides a variety of resources, including general course information, the course outline, recommended reading from the texts for each lecture & discussion, a supplementary reading list and collection of relevant sites for online source material, course guidelines, and course notices and announcements. It is recommended to bookmark this site for the Spring 07 term.

3 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.

4 Organization & Syllabus

The course will cover the twelve major topics listed below. 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.

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 based on extrapolation of patterns in their centuries-long cuneiform 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 Roman Church. 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 the legacy of the 17^{th} C Scientific Revolution 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?

Astronomy 380 The Cosmos in Western Culture Course Outline

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.

5 Reading

5a Required Reading

- *Science and Technology in World History*, 2^{nd} edn., by James E. McClellan III and Harold Dorn (Johns Hopkins University Press, 1999) [paperback].
- *The Fabric of the Heavens* by Stephen Toulmin & June Goodfield (University of Chicago Press, 1999). [paperback].
- *Discoveries and Opinions of Galileo,* translated by Stillman Drake (Anchor Books, 1957). [paperback].
- *The Fabric of the Cosmos: Space, Time, and the Texture of Reality*, Brian Greene, (Vintage, 2005). [paperback]

5b Supplementary Reading

Reading and discussion of primary source material will be emphasized. Part of one class session every week will be devoted entirely to discussion and analysis of reading from supplemental background and primary source material. The course web pages include a list of primary and secondary source material related to the topics under discussion. There is a particularly comprehensive source list of online materials related to the course. Background reading material will be placed on reserve in Sinclair Library.

6 Evaluation of Achievement

Grades for achievement in this course will be based on a mid-term exam, a final exam, one research paper, homework sheets, and in-class discussion. An approximate weighting for each of these will be:

Mid-term	20%
Final	30%
Research paper	25%
Homework sheets & in-class discussion	25%

7 Schedule of lecture and discussion topics

We intend to follow a general rubric of having a lecture for the first day on each topic, and lecture and discussion on the second or third day. The initials in brackets denote the lecturer with primary responsibility for each topic.

Jan 9: Introduction & Overview (BJ, AC)

Jan (9), 11, 16: Mesopotamian Celestial Forecasting (BJ)

Jan 18, 23, 25: Ionian Physics & Hellenistic Astronomy: The Emergence of Scientific Theory (AC)

Jan 30, Feb 1: Arabic Continuation & Development of The Greek Tradition (BJ)

Feb 6, 8: The Greek Tradition Re-Emerges in Medieval Europe (BJ, AC)

Feb 13, 15: Copernicus Proposes a Heliocentric Cosmology (AC)

Feb 20, 22, 27, Mar 1: Galileo Supports the Heliocentric Cosmology (BJ, AC)

Mar 6: Kepler & His Three Laws of Planetary Motion (AC)

Mar 8: Midterm Exam

Mar 13, 15, 20, 22: Newton's Laws of Motion, Universal Gravitation, and The Newtonian Cosmos (BJ, AC)

Apr 3, 5: The 17th Century Scientific Revolution & Its Implications (BJ)

Apr 10, 12: The 20th Century Scientific Revolution & The Relativistic Cosmos (AC)

Apr 17, 19: Grand Unified Theories & Multi-Dimensional Universes (AC)

Apr 24, 26: Oral presentations and discussion of research projects

May 1: Science As A Way Of Knowing (BJ, AC)

May 10: Final Exam