

Inventing Reality: The Human Search for Truth

California Institute of Technology

Spring, 2005

Lecture Times and Locations: Tuesday 4:00 – 5:30 PM, Rm. 023 Robinson
Thursday 8:00 – 9:30 PM, Rm. 106 Robinson

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Office Hours: Tuesday 5:30 – 6:30 PM

Thursday 9:30 – 10:30 PM

and by appointment

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Course Description

Ay 40. Inventing Reality: The Human Search for Truth. 9 units (3-0-6); third term.

Creating order out of our universe has been a perennial human pastime. Accepted truths have had a history of transience, with the models of each age yielding to the paradigm shifts of the next. Here we examine this continuing human dialogue, tracing a crooked line from ancient Babylonia to the present, accompanied along the way by such powerful thinkers as Aristotle, Lucretius, Newton, and Einstein. We will explore the physical world on all scales, from the fundamental constituents of matter to the origin, evolution, and fate of the universe. Though the focus will be on astronomy (and cosmology in particular), related topics in classical physics, quantum mechanics, and philosophy will not be avoided.

No prior background beyond high school physics is required, and the course may be profitably taken by students at all levels, from first-years desiring a broad overview of human inquiry into the physical world to seasoned astrophysics majors seeking a “big picture” view of what they have been studying. We shall directly confront the original writings of the philosophers, scientists, and theologians studied, and there will be frequent short writing assignments in addition to one longer paper.

General Notes on the Course Reader

The course Reader consists of five parts. The first, *Reading Assignments*, contains the weekly reading assignments that will accompany you through the Reader. The second, *Primary Writings*, contains the original (sometimes translated) writings of many of the scientists/philosophers that we will study. By reading their original words, I hope you’ll gain a better feel for the minds, personalities, and ideas of the people we’ll be discussing. At the risk of lacking continuity (but with the desire for brevity), I have included only those selections that are crucial to the lines of thought we’ll be following in this course. The third part of this Reader contains *Contemporary Writings* from a variety of sources, including popular books as well as texts. The fourth section contains copies of many of the *Class Overheads* that will be shown in class; this way, you don’t have to scribble things down during class, but can instead *focus on what is being said*, and just annotate the notes. Finally, there is a small *Appendix*, containing some maps and star-charts for your nighttime viewing pleasure.

A note on notation: whenever you see a set of 3 dots (in the second part of the Reader)

this means that some of the original text has been skipped.

Course References

Recommended Books (On Reserve at Millikan Library)

Kuhn, T. 1957, *The Copernican Revolution: Planetary Astronomy in the Development of Western Thought* (Harvard University Press: Cambridge).

A classic work on the history of science, with a very good account of the ancient celestial models that were replaced in the Renaissance. The first four chapters are especially relevant, and well worth reading.

Lindberg, D. 1992, *The Beginnings of Western Science: The European Scientific Tradition in Philosophical, Religious, and Institutional Context, 600 B.C. to A.D. 1450* (The University of Chicago Press: Chicago).

A unique work that will closely parallel the first part of this course. Though it looks dangerously like a dry textbook, don't be fooled: Lindberg writes with a broad perspective and a passionate vision. For a nice, coherent read, I highly recommend paging through this book.

Munitz, M. K. 1957, *Theories of the Universe: From Babylonian Myth to Modern Science* (Macmillan: New York).

Provides additional primary source material and commentary.

Toulmin, S. & Goodfield, J. 1961, *The Fabric of the Heavens: The Development of Astronomy and Dynamics* (Harper & Brothers: New York).

Exhaustive account, from the ancients through Newton, addressing implications for the modern era of the early thinkers. Unlike most works of its kind, this one allows the original thinkers to do much of the talking.

Wolf, F. 1989, *Taking the Quantum Leap: The New Physics for Non-Scientists* (Harper & Row: New York).

The story of how we struggled, resisted, and ultimately accepted the modern view of physical reality is beautifully told in this readable account of 20th century physics. This book is especially relevant in the last half of the course.

Morrison, D., Wolff, S., & Fraknoi, A. *Abell's Exploration of the Universe* (Saunders: Philadelphia).

The 7th edition of the classic, comprehensive astronomy text by George Abell. Contains a thorough treatment of the history of astronomy in addition to the latest discoveries.

Ferris, T. 1988, *Coming of Age in the Milky Way* (Doubleday: New York).

A nice, easygoing work, the first two chapters on the Greeks being especially good. Though the later chapters delve a bit further into modern physics than we will, the first dozen chapters provide a good overview of topics up to the twentieth century.

Koestler, A. 1989, *The Sleepwalkers: A history of Man's Changing Vision of the Universe* (Penguin: New York).

A thorough, irreverent work, with especially good descriptions of Copernicus, Brahe, Kepler, Galileo, and Newton. Very amusing and filled with Koestler's opinions.

Course Syllabus

Week 1 (March 28 → April 1): *A Beginning*

Topics covered – Inventing Nature’s Language. The study of *ideas*. Prehistoric attitudes towards nature, and the Children of Woot. Beginnings of science in Egypt and Mesopotamia; ancient Greece, and the development of writing – the world of Homer, Hesiod, and the rise of philosophy; the Ionian School and the question of ultimate reality; the validity of the senses. The 2-sphere cosmology.

Readings and Activities – Pick a Universe: Hesiod, Plato or Lucretius. Hesiod: Theogony. Lucretius: The Nature of the Universe. Nighttime star-gazing: Polaris – a special star.

Week 2 (April 4 → April 8): *A Question of Freedom*

Topics covered – Lucretius and free will. The discovery of the invisible: Empedocles and the “water thief”. Harmony in music: An introduction to Pythagoras and the Pythagorean Brotherhood. Unity behind diversity – numbers or atoms. Retrograde motion and the problem of the planets.

Readings and Activities – Empedocles: Love and Strife. Socrates. Ferris: “The Dome of Heaven.”

Week 3 (April 11 → April 15): *A Leap of Faith and Understanding Everything*

Topics covered – Different perspectives: Plato and Aristotle. The beauty of a sphere. The power of pure thought. Euclid’s axiomatic method. Aristotle explains it all: Violent motion and an idealized cosmos. The entrenchment of Aristotelian thought.

Readings and Activities – Plato: The Simile of the Caves; Theory of Art. Euclid: Elements. Aristotle: Physics and On the Heavens.

Week 4 (April 18 → April 22): *Having Eyes but Refusing to See*

Topics covered – The invisible supernova of 1054. Copernicus, the last gasp of Plato, and Tycho’s island. The marriage of Kepler and Pythagoras, and the struggle to smash the sphere. Kepler’s 3rd law. Galileo’s telescope.

Readings and Activities – Abell: Copernicus and the Heliocentric Hypothesis; Kepler; Galileo. Copernicus: On the Revolutions of the Heavenly Spheres. Kepler: The moment of his conception, and the Harmonies of the World. Telescopic viewing of sunspots.

Week 5 (April 25 → April 29): *Newton’s New Language I – The End of Explanation*

Topics covered – The Newtonian synthesis and a glimpse into the world of genius: Newton’s laws, gravity, the *Principia*, the secret life of an alchemist, and his fundamental reality, theory of light, the immutable nature of time, theology and spiritualism. Momentum. Newton’s version of Kepler’s 3rd law.

Readings and Activities – Newton: Certain Philosophical Questions, Principia, Letters to Richard Bentley, and his alchemical notebooks. Wolf on Galileo and Newton. Serway & Faughn: Motion, inertia, force and acceleration; universal gravitation.

Week 6 (May 2 → May 6): *Newton's New Language II – The Nightmare*

Topics covered – Newton's legacy: The nightmare of determinism. How does energy get from here to there? The union of physics and astronomy, and the study of particles and waves. It sure looks like a wave: Young's experiment and Maxwell's discovery. Fuzzy patches hold the key – The question of the nebulae: Island universes or solar systems forming?

Readings and Activities – Laplace: On Probability. Wolf: The Nightmare of Determinism. Hewitt: Vibrations and Waves; Diffraction and Interference. Gribbon: Light.

→Midterm project due: In-class oral presentations on Tuesday, May 3, paper due Thursday, May 5.

Week 7 (May 9 → May 13): *Finding Our Place in the Universe*

Topics covered – The science of spectroscopy – Kirchoff's Laws and the fingerprints of the elements. The Doppler effect and discovering black holes. The controversy rages, and the mystery is solved. Hubble discovers a law; the expanding universe; looking back to the Big Bang, shadows of creation; the unity of physics and cosmology. The fate of the universe. An invisible universe: Dark matter.

Readings and Activities – Ferris: Island Universes. Hubble: The Realm of the Nebulae. Pasachoff: The Dark Side of Matter. Lab: The Expansion of the Universe.

Week 8 (May 16 → May 20): *Smashing Certainty and Inventing a New Language*

Topics covered – Einstein draws a picture: The photon is born. A new look at Young's double-slit experiment. Einstein's "biggest blunder": The Cosmological Constant. Inside the atom. Bohr takes a quantum leap; a Prince imagines a wave; the end of pictures: Schrodinger's unimaginable world; God's dice and uncertainty; Einstein's hidden orders.

Readings and Activities – Gribbon: The Atom. Wolf: The End of the Mechanical Age; Einstein and Bohr. Feynman: Quantum Behavior. Griffiths: The Wave Function.

Week 9 (May 23 → May 27): *A Paradoxical World*

Topics covered – Einstein's challenge – The EPR paradox and Bell's stunning discovery. Parallels: Western and non-Western thinking.

Readings and Activities – Gribbon: The EPR Paradox. Griffiths: What is a measurement? Capra: The Unity of All Things.

Week 10 (May 30 → June 3): *An Ending*

Topics covered – Supernovae and dark energy; Sisyphean nightmares and happiness.

Readings and Activities – Riess, Perlmutter: Recent cosmological results; Albert Camus: The Myth of Sisyphus.

Week 11 (June 6 → June 10)

→Final exam. Final paper (book review) due by 5:00 PM Friday, June 10.