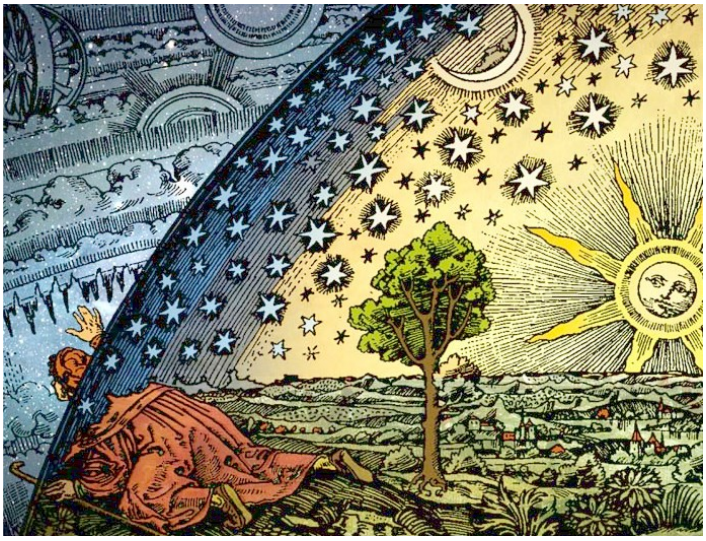
ASTRONOMY 1610 SPRING 2023

THEORIES OF THE UNIVERSE
FROM BABYLON TO THE BIG BANG

M W • 6:10 – 7:25 pm • Pupin 329

Joe Patterson • Pupin 1422
jop@astro.columbia.edu



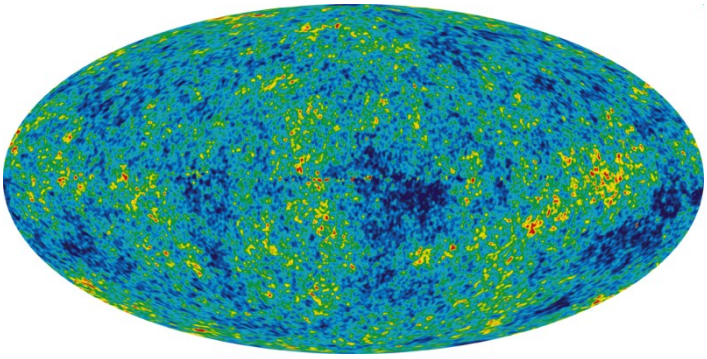
The basic ideas of cosmology (the origin and structure of the Universe) are many millennia old, and not the territory of any one academic specialty. Religion and literature have had plenty to say about them over the years, and we'll spend some time on these. In the 17th century, the view emerged that the Universe is a vast machine operating according to known or soon-to-be-known mathematical laws — not requiring any essential role of God, and in which humans are reduced to mere spectators. We'll spend a couple of weeks discussing this fascinating period of history.

Cosmology did not really become a "science" — in the sense of being based on some empirical facts and proceeding with agreed-upon rules of evidence — until around 1950. Today it is all the rage and dominates the astronomical landscape. Whether it will prove to have great staying power as a science, no one knows. But its power to excite human curiosity is clear. We'll spend the last third of the class on the most recent developments which have still not been thoroughly digested: the discovery of the primeval fireball signifying the birth of the Universe, and the tantalizing clues to dark matter and dark energy.

The phrase "agreed-upon rules of evidence" compels humility. The rules of evidence are not *entirely* agreed upon, and many scientists flavor the evidentiary aspects with aesthetic considerations, like elegance and simplicity. Does the injection of such criteria amount to a high-brow version of mere *opinion*, or even *religion* (a well-known cosmologist compared his data to "the face of God"). Maybe so! One can only hope that what looks like progress today won't seem awfully silly twenty years from now. That's the penalty for undertaking so grandiose a subject.

Despite the grandiosity, some of the big questions will, *mirabile dictu*, actually get answered: what are stars made of? how old is the Universe? Others will remain as mysterious as when they were first debated: is God a mathematician? what role does life play in the Universe? how will it all end?

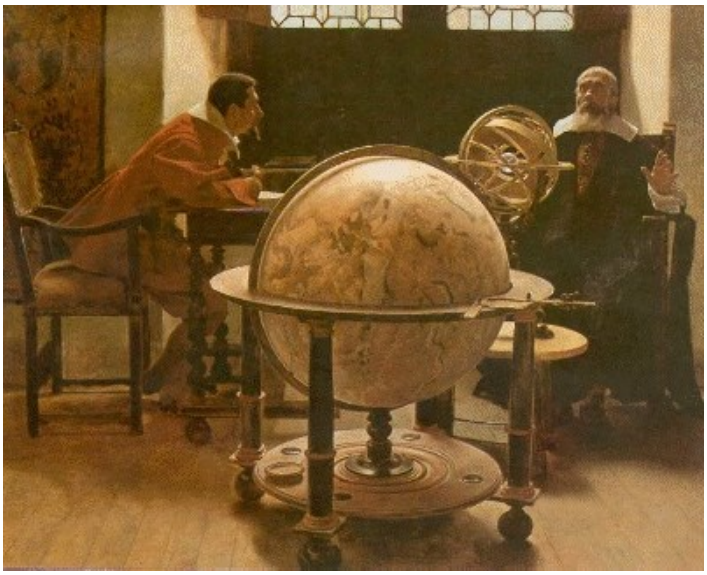
The class is designed for liberal-arts majors, but is also suitable for science (or any) students with a special interest in the history and philosophy of science. Since Pythagoras it has been recognized that some of the deepest secrets of Nature are written in the language of mathematics. For some reason which no one has yet explained, we often make great progress — and elevate the discourse beyond armchair speculation — when we use mathematics. So we'll do that. Most of the essential ideas require only high-school algebra; that's all you'll need, but it'll be woven into the fabric of every class.



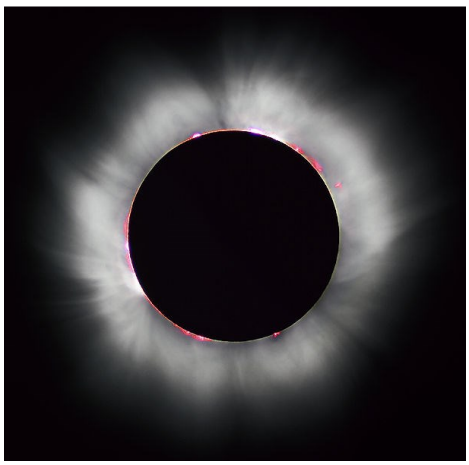
ASTRONOMY 1610

THEORIES OF THE UNIVERSE

SPRING 2023



Not everything "astronomical" will make the cut. Planets disappear from our story in 1687, never to return... stars are really only interesting in their deep interiors, where elements are made... and galaxies make only a brief appearance in 1929, with Hubble's Law. And you won't be hearing anything about astrology, UFOs, or alien abductions — unless I am personally abducted during the semester... in which case I'm open to reconsidering the matter.



Office hours:

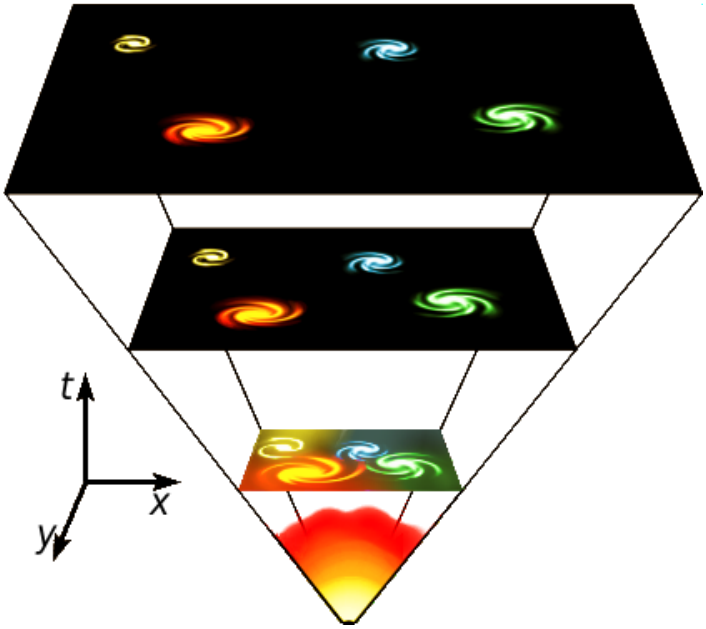
You can drop in any time, no appointment needed... with a good probability of finding me. Just for the record, though, let's anoint W 8:30 – 10:30 am as the official hours.

There will be a final, a midterm, and probably 5 problem sets. Class attendance would be awfully nice, and participation in discussion even better. Grades will result from a formula something like this:

Final	Midterm	Problem Sets	Discussion
35%	25%	20%	15%

There will be an option for a research paper on a topic of your choice (germane to the class). This option will change the formula somewhat.

A few other "extracurricular" activities will occur: rooftop stargazing; a playreading of Brecht's play *Galileo*; class lunches and dinners. These are all optional, but participation would enhance the "discussion" component.



The recommended textbook for this class is *Astronomy: At Play in the Cosmos*, by Adam Frank; it should be available in quantity at the CU bookstore. Also recommended is *Coming of Age in the Milky Way*, by Timothy Ferris; this one is a best seller and therefore probably available cheap online.

You can save some $$ by using a different textbook. Astronomy textbooks are sufficiently similar that the material treated is pretty standard; you just have to figure out the equivalence of Chapter numbers. Frank's book excels, in my opinion, by virtue of greater conciseness and better writing.

In addition, I will distribute 200–300 pages of my notes, which will essentially *define* the class — but often without the full descriptive detail that only a textbook can offer.

Lecture Schedule

Dates	Topics	Readings
TBD	Basic positions and motions on the celestial sphere. Myths of creation and the sky. The fascination with eclipses. Time, the calendar, and how not to get lost at sea: some of the basic driving forces for all this apparent activity.	Frank, chapters 1–2. Ferris, chapter 1.
TBD	Greek cosmology. "Number rules the Universe" (Pythagoras). Eudoxus and the crystal spheres. Plato and the dictate of perfect circular motion. Hipparchus and Ptolemy struggle to "save the phenomena": to reconcile the observed nonuniformities of planetary motion with Plato's dictates.	Frank, chapter 3. Ferris, chapter 2.
TBD	The "scientific revolution". Copernicus sets the Earth in motion, and thus creates the need for a new physics, Galileo and Newton supply that new physics. The science/religion chasm as it quickly widened in the 17th century. The 18th century ("Newtonian" or "Deist") scientific view of the world: a giant whirring machine presided over by God, a master mechanic.	Frank, chapter 3. Ferris, chapters 4–6: great stuff!
TBD	The great conservation principles of energy and momentum. Energy in its many guises. Heat and temperature. Atoms and light.	Frank, chapter 4. A ton of notes.
TBD	Likely midterm exam.	
TBD	The astronomical universe, circa 1920. Planets, stars, and galaxies. The physics of stars. The great debates over the age of the Earth, and the distances to galaxies... and how they were settled.	Frank, chapters 10–12. Ferris, chapters 8–9, 12–13.
TBD	Space, Time, and Matter: the revolutions of relativity and quantum theory in 1900–1932, and beyond. The structure of the atom. The role of indeterminacy in modern physics. Black holes.	Frank, chapters 13–14. Ferris, chapters 10, 14–15.
TBD	The discovery of the expanding Universe (Hubble's Law). The prediction and subsequent discovery of the "Cosmic Microwave Background" — the relic radiation left over from the Big Bang. Dark matter.	Frank, chapters 15–16. Ferris, chapters 11, 14.
TBD	Supernovae: the key to extending Hubble's diagram out to great distances. The discovery of dark energy ("the accelerating Universe"). Absolute motions in the Universe. A theorist's view of cosmic evolution. String theory and cosmic inflation.	Frank, chapters 17–18. Ferris, chapters 16–18.