Introduction to Cosmology

Course Description
This course is a technical but elementary introduction to the modern understanding of cosmology, intended for non-science students. We will cover advances in cosmology over the last 100 years, with special emphasis on more recent developments in the field. We will cover topics ranging from the early universe to galaxy formation in the present day universe, through the lens of the theory of relativity and the expanding universe. We will cover the Big Bang, the Cosmic Microwave Background, dark matter, dark energy and the associated evidence for these phenomena. Assumes a high-school level mathematics background. This course counts to the astronomy minor.

Course Text

Course Grades
Midterm Exam - 25%
Final Exam - 30%
Homework - 25%
Class Participation - 10%
Quizzes - 10%

Syllabus
- Week 1: Introduction: The fundamental observations in modern cosmology
  - No reading
- Week 2: Historical background: Cosmology becomes a field
  - Chapters 1-2
- Week 3: Background on Newton's mechanics
  - Chapter 3
- Week 4: Background on light and the cosmological distance ladder
  - Chapters 4-5
- Week 5: Spacetime and the Special Theory of Relativity
  - Chapter 6-7
• Week 6: General Theory of Relativity
  ○ Chapter 8
• Weeks 7-8: The expanding universe and the Friedmann Equation
  ○ Chapters 10-11
• Week 9: The Age and Geometry of the Universe
  ○ Chapter 12 and review of Chpt 5
• Week 10: Evidence for Cosmic Acceleration and Dark Energy
  ○ Chapter 13 and review of Chpt 5
• Week 11: The Early Universe and the Cosmic Microwave Background
  ○ Chapter 14
• Week 12: The Early Universe and the Theory of Inflation
  ○ Chapter 16
• Week 13: Evidence for Dark Matter and Large Scale Structure
  ○ Chapter 15
• Week 14: The Cosmic Web and Galaxy Formation
  ○ Chapter 15
• Week 15: Extrasolar planets and the prospects of life on other worlds
  ○ No reading
Goals of the Course

The goal of this course is to give students a working knowledge of the history of the universe. This knowledge will be non-technical but physically intuitive. By the end of the course, the students should be able to sketch out an expansion history of the current favored cosmology, labeling all the relevant features in such a graph: the Big Bang, inflation, radiation domination, matter-radiation equality, matter domination, the growth of structure, and the transition to cosmic acceleration. For each of these features, the students will be able to explain the meaning and importance of each event (or era), as well as understand the observations and data that reinforce that these events happened. In addition, the students will be able to understand how different universes evolve, in the sense of how changes to the matter-energy densities would make the universe grow faster or slower, be older or younger, and how the galaxies within each universe may look different.

The class emphasizes---to a greater degree than the book--the observational aspect of our current cosmological model. This starts from the fundamental observation that the night sky is dark, and proceeds forward to the apparent luminosity of distant supernovae and how they indicate that the expansion of the universe is accelerating. In between, we talk about observations of the CMB (which tell us that space is flat), age-dating of globular clusters (that tell us that the universe is old), and the construction of the astronomical distance ladder (with the SN data resolving the tension between the previous two observations by invoking dark energy). The emphasis on observation grounds the overall course in a tangible reality, rather than presenting material on theoretical cosmological models without showing the students why we believe these models to be correct.

Although the class with emphasize conceptual and intuitive physical understanding of cosmology, there is limited use of algebra in the class. Newton’s laws are reviewed, inverse square laws are used in multiple contexts, and there is a Newtonian derivation of the Friedmann equation, which is then used to understand expansion in single-component universes. Homework will generally require some calculations, but exams will focus on short answer questions that usually require sketching of graphs and physical explanations of the graphs or other cosmological phenomena.

The class will have a midterm and a final, as well as two more quizzes in between. There will be 6-8 homework assignments that should take 1 to 1.5 weeks to complete. Each week usually requires 1-2 chapters of reading in the book. There will be a small class participation component to the class grade as well. During the pilot class, it
worked well to go over the homeworks by having students come to the board and explain their solution to one problem to the class (or lead the class in finding the correct solution).