Astronomy 596 PC
Physical Cosmology
Spring Semester 2010

Astronomy 134 MWF 2:00–2:50 pm

Course web page URL

`http://courses.atlas.uiuc.edu/spring2010/ASTR/ASTR596/`

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1 Introduction

Cosmology is science on the grandest of scales. It is one of the hottest areas of research today, weaving together a wide range of disciplines, including observational astronomy, theoretical astrophysics, nuclear and particle physics theory and experiment, and quantum gravity.

At this moment, cosmology is enjoying a "golden age" in which observation and theory come together to settle longstanding questions but in doing so stumbling upon unexpected and profound new mysteries. We now have an increasingly precise understanding of the basic kinematics of the universe, and its basic composition in terms of the relative amounts of matter and energy. But in detail, we find that most of the matter in the universe must take an exotic and experimentally elusive non-baryonic form, and thus points to new physics beyond the Standard Model of elementary particles and their interactions. We are even more staggeringly ignorant the nature of the dark energy, despite the fact that it comprises the bulk of the present mass-energy content of the cosmos; similarly, our understanding of the cosmic acceleration caused by dark energy is primitive.

Yet despite these enormous open questions, we can already say a surprisingly great deal about the history of the universe. We have detailed, quantitative understanding of several pivotal epochs in the global, zeroth-order evolution of the homogeneous universe, and a growing understanding of how tiny departures from homogeneity grow with time to form the structured cosmos of the present day.

In this course, we will survey these topics, and their interrelations. The emphasis will be on applying physical principles to understand observations, and on using observations to constrain the nature of matter and spacetime on cosmic scales–viewing the universe as a laboratory for fundamental physics. Course work will focus heavily on problem solving. The intended audience is first-year graduate students and beyond; prior knowledge of cosmology, general relativity, or particle physics is not required.

It is my hope that students leave the course with an understanding of the state of the field, of open questions, of observational and theoretical tools. Moreover, the University of Illinois hosts a great deal of cosmology research. Another goal of this course is to highlight the different research areas at Illinois, and to place them in the context of cosmology as a whole.

2 Course Requirements

Grading Scheme

Requirement	Unit Weight	Total Weight
Preflights	6 at 5% each	30%
Problem Sets	7 at 10% each	70%

3 Readings and Resources

Course Texts:

J. Peacock *Cosmological Physics* (1999)
Required. A fairly recent and introduction to modern cosmology. This text is impressive in its comprehensive breadth, as it covers all major areas in cosmology, and also includes substantial discussion of related physics and astrophysics topics such as general relativity, quantum field theory, active galaxies, and black hole accretion. Such an encyclopedic sweep makes this an excellent reference, though it perhaps is daunting to some as an introductory textbook; i.e., 65 pages pass before Hubble's law appears. To complement this broad text, two more focussed works are recommended.

E.W. Kolb and M.S. Turner *The Early Universe* (1990)
Recommended. As the name suggests, extensive coverage of the early universe. Excellent discussion of basic physics; already somewhat dated with respect to the observations.

A.R. Liddle and D.H. Lyth *Cosmological Inflation and Large-Scale Structure* (2000)
Recommended. A thorough but approachable introduction to inflation, with extensive discussion of large scale structure observations and their role in testing the theory.

All of these are placed on Reserve in the Engineering Library.

Other useful books have also been placed on reserve:

- Kolb and Turner, *The Early Universe: Reprints*
- Peebles, *Principles of Physical Cosmology*
- Peebles, *The Large-Scale Structure of the Universe*
- Zel'dovich and Novikov, *Relativistic Astrophysics Vol. 2: The Structure and Evolution of the Universe*

In addition to these texts, research and review articles will occasionally be assigned.

A large body useful material is available online, and will be useful for homework problems and for researching your report. See the `links` page on the course website.

4 Preflights

Class time is best spent when you have already read about the material, so that we can focus on the points that you found difficult and/or interesting. To encourage this reading, and to guide your thinking during the reading, "preflights" will be assigned on weeks when no problem set is due. These will be available online via the `preflights` link off of the course page. Each one will give the reading assignment for the upcoming week, and will include questions on the reading. These questions will be due, with a hard deadline. Your responses will be graded pass/fail: the point is not that you always understand fully all of the issues, but rather that you be prepared for class, and that I get an idea of what is difficult for you.

5 Problem Sets

I will assign 7 problem sets throughout the course. The high frequency is intended to keep you up-to-date on the material. Problem sets are due in class; late homework will be deducted 25% for every calendar day late.

Science is a collaborative enterprise, and you are encouraged to discuss the class material and the problems with your classmates and the instructor. However, you are responsible for your own answers, which you should understand and write up in your own words.

6 Final Exam

The Final Exam will take the form of the final Problem Set, assigned the last week of class.

Course Schedule

Planned topics listed below. Lecture material may vary, but due dates are fixed. See course webpage for updates.

Date	Topic	Assignment Due
Jan 20	Introduction	
Jan 22	History and Observational Overview	
Jan 25	Newtonian Cosmology	
Jan 27	Cosmodynamics	
Jan 29	Friedmann Universes	**Preflight 1**
Feb 1	General Relativity	
Feb 3	General Relativity	
Feb 5	Relativistic Cosmology	**Problem Set 1**
Feb 8	Lifestyles in FRW Spacetimes	
Feb 10	Lifestyles in FRW Spacetimes	
Feb 12	Dark Energy: Evidence	**Preflight 2**
Feb 15	Dark Energy: Implications	
Feb 17	Dark Energy: (Un?)physical Models	
Feb 19	Dark Energy: Future	**Problem Set 2**
Feb 22	CMB: Overview	
Feb 24	Recombination Physics	
Feb 26	Recombination Physics	**Preflight 3**
Mar 1	CMB Anisotropies	
Mar 3	CMB Anisotropies	
Mar 5	Early Universe: Thermal History	**Problem Set 3**
Mar 8	Primordial Nucleosynthesis: Theory	
Mar 10	Primordial Nucleosynthesis: Observations and Implications	
Mar 12	Particle Dark Matter: Production and Candidates	**Preflight 4**
Mar 15	Particle Dark Matter: Direct and Indirect Detection	
Mar 17	Inflation: Motivation	
Mar 19	Inflation: Scalar Fields	**Problem Set 4**
Mar 22–26	*No Class Meeting: Spring Break*	
Mar 29	Inflation: Simple Models	
Mar 31	Inflation: Perturbations	
Apr 2	Inflation: Current and Future Tests	**Preflight 5**
Apr 5	Cosmic Density Fields	
Apr 7	Gravitational Instability	
Apr 9	*No Class Meeting*	**Problem Set 5**
Apr 12	Structure Formation: Nonlinear Growth	
Apr 14	Hot and Cold Dark Matter	
Apr 16	Structure Formation: Press-Schechter	**Preflight 6**
Apr 19	Structure Formation Simulations	
Apr 21	Weak Lensing	
Apr 23	Weak Lensing	**Problem Set 6**
Apr 26	Cosmology with Quasars	
Apr 28	Intergalactic Medium	
Apr 30	Cosmic Star Formation	
May 3	Cosmic Star Formation	
May 5	Finale	
May 13		**Final Problem Set**