

Astronomy 507 Physical Cosmology Spring Semester 2020

Astronomy 134 MWF 2:00–2:50 pm

Course web page URL

http://go.illinois.edu/ASTR507

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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 observational astronomy, theoretical astrophysics, nuclear and particle physics theory and experiment, quantum gravity, and more.

At this moment, cosmology is enjoying a golden age, with observation and theory coming 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)

Recommended. A wide-ranging and self-contained 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.

S. Dodelson *Modern Cosmology* (2003)

Recommended. After a relatively succinct treatment of the basics, there is a thorough, detailed, and insightful treatment of inflation, cosmological perturbation theory, the cosmic microwave background, and modern methods to compare theory and data. The careful and practical discussion is invaluable for doing real calculations.

E.W. Kolb and M.S. Turner *The Early Universe* (1990)

Recommended. As the name suggests, extensive coverage of the early universe. Excellent and very readable discussion of basic physics. Inevitably and fortunately, it is glaringly dated with respect to the observations and to some major topics that have emerged in the past 24 years, particularly dark energy.

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 must understand and write up in your own words.**

It should go without saying, but obviously you may not consult any solutions from previous versions of this course.

6 Final Exam

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

7 Schedule

The course website contains the course schedule, along with webpages and notes for each lecture.