

# PHY 795: Cosmology Spring 2012

Prof. Richard Schnee, Room 331 Physics, 3-2579, [rwschnee@physics.syr.edu](mailto:rwschnee@physics.syr.edu)

## Course Description

This class is a graduate course on the standard big-bang cosmological model. We will cover the homogeneous universe (kinematics, dynamics, big bang nucleosynthesis, production of relic particles, baryogenesis/leptogenesis) and the inhomogeneous universe (inflation, linear perturbation theory of the growth of fluctuations, cosmic microwave background, large scale structure, statistical measures). The amount of time spent on different topics will depend to some degree on student interests.

Some basic knowledge of general relativity and the Standard Model of particle physics would be helpful, though not required. I also expect that you are comfortable with programming in your language of choice.

## Textbook

The required text for this course is **Modern Cosmology**, by Scott Dodelson. Publisher: Academic Press. It is available at the SU Bookstore. It is a very nice, modern treatment of the subject (largely based on the Boltzmann approach). [Errata to Dodelson's textbook](#): Let me know if you catch any.

Additional useful textbooks include

- • **The Early Universe**, by Rocky Kolb and Michael Turner. This is the absolute classic on the connection between particle physics and cosmology.
- 
- **Cosmology**, by Steven Weinberg, Publisher: Cambridge. A modern cosmology textbook, but slightly advanced for a first reading.
- **The Large-Scale Structure of the Universe**, by Jim Peebles, publisher: Princeton University Press. The standard textbook on the statistics of Large Scale Structure.
- **Cosmological Physics**, by John Peacock, 2nd edition. Publisher: Cambridge University Press. A good reference, but rather thin at places as it covers an enormous amount of material.
- **Cosmological Inflation and Large-Scale Structure**, by Andrew Liddle and David Lyth, Publisher: Cambridge University Press. A thorough textbook on the origin and evolution of perturbations if you can go past their notation.
- **The Primordial Density Perturbation**, by David Lyth and Andrew Liddle, Publisher: Cambridge University Press. This is a newer version of the above textbook by the same authors.
- **Kinetic Theory in the Expanding Universe**, by Jeremy Bernstein, Publisher: Cambridge University Press. A very nice treatment of particle dynamics in the early universe (advanced).

- **Theoretical Astrophysics: Volume 3, Galaxies and Cosmology**, by T. Padmanabhan. Publisher: Cambridge University Press. Up-to-date treatment of numerous aspects of cosmology and large scale structure. It is a nice compilation of material found in other textbooks. Volume 1 contains a lot of the underlying physics associated with the topic.
- **Galactic Dynamics**, by James Binney and Scott Tremaine, Publisher: Princeton University Press. The standard textbook on the dynamics of collision-less systems.
- **Galaxy Formation and Evolution**, by Houjun Mo, Frank van den Bosch and Simon White. Publisher: Cambridge University Press. The one and only up-to-date book on galaxy formation.

Some useful undergraduate texts that treat cosmology in less detail are

- **Principles of Cosmology** by Eric Linder.
- **Introduction to Cosmology** by Barbara Ryden.
- **Introduction to Modern Cosmology** by Andrew Liddle.

Additional material in the form of review papers or other publications may also be useful.

## Course Work

The class will meet on Tuesdays and Thursdays from 12:30 to 1:50 p.m in Physics Building 105. Grading will be based on homework assignments due most Tuesdays (60% of your grade), in-class pop quizzes (10% of your grade), and the successful completion of a final project (the other 30%).

**Homework:** Late homework will receive 50% of the grade it would have received if submitted on time. No homework will be accepted more than one week late. You are allowed (and encouraged) to discuss homework with other students, but you must write up the solution on your own. I may choose to grade only a random selection of the homework problems (same problems for everybody). Homework sets and solution sets will be posted on blackboard. There will be no homework during the final weeks of the class (to give more time for your final project).

**Quizzes:** At various times, there will be a 10-minute quiz based on a derivation or concept from a recent class. The quizzes are meant to force you to go over your notes in great detail and to work through derivations in the assigned reading.

**Final project:** This will constitute 30% of the grade. The final product should be a write-up on a topic that I must approve by March 8, 2012. The final project must include the derivation of a result (not original work), at the level of the course text. The write-up should be 8-10 pages long, in the Physical Review format (see papers on <http://prd.aps.org/> and go to <https://authors.aps.org/revtex4/> and download and install REVTeX 4.1). The write-up should be complete with abstract, introduction, etc., plus figures and proper literature citations. The grading will be based on content as well as presentation.

You must present your project results to the rest of the class. The presentations should be approximately 40 minutes in length and you may choose to use PowerPoint or similar software

to present your topic. The level of the presentation should be such that it builds on topics discussed in class and such that the majority of the class can follow the logical arguments. The class will ask questions and critique your presentation. Five percent of your grade will be based on your participation (asking questions etc.) during the presentations of your colleagues. This is part of the learning process.

You will write your paper in two stages: a first draft due three classes (just over one week) before your scheduled presentation, and a final version due at the time of your presentation. The purpose of the first draft is to receive feedback from your instructor and from the two other students in the class. On the day your draft is due, you will distribute copies of your first draft to the instructor and to each student in your group. The instructor and the other students will then read your draft and give you feedback in the form of *written* comments either marked on your draft or on a separate sheet or by email. Commented drafts are due back to you the author by the next class (if you the author do not receive these comments on time, you should alert the instructor). You will then have time to revise your paper on the basis of the comments received. The final draft together with your classmates' comments on your first draft should be turned in to the instructor on the day of your presentation.

A partial list of viable term projects would include the following subjects:

- The Generation of Primordial Density Fluctuations During Cosmological Inflation.
- Light Element Nucleosynthesis Constraints on Particle Physics Beyond the Standard Model.
- Viable Dark Matter Candidates
- Contemporary Constraints on Dark Matter Properties.
- Cosmological Constraints from Cosmic Microwave Background Anisotropies.
- Cosmological Constraints from the Polarization of the Cosmic Microwave Background.
- Constraints on Dark Energy or Decaying Dark Matter from Type Ia Supernovae.
- Monopoles In Cosmology.
- The Generation of the Cosmic Baryon Asymmetry.
- Cosmological Reionization.
- Galaxy Formation in the Standard Cold Dark Matter Cosmology.
- Cosmological Constraints from the Clustering of Galaxies.
- The Late-time Integrated Sachs-Wolfe Effect
- Weak Gravitational Lensing as a Probe of the Properties of the Dark Energy.
- Baryon Acoustic Oscillations as a Probe of the Properties of Dark Energy.
- Galaxy Clusters as Probes of the Properties of Dark Energy.

## **Academic Integrity**

The Syracuse University Academic Integrity Policy holds students accountable for the integrity of the work they submit. Students should be familiar with the Policy and know that it is their responsibility to learn about instructor and general academic expectations with regard to proper citation of sources in written work. The policy also governs the integrity of work submitted in exams, in laboratories, and in assignments, as well as the veracity of signatures on attendance sheets and other verifications of participation in class activities. Serious sanctions can result from academic dishonesty of any sort. For more information and the complete policy, see <http://academicintegrity.syr.edu>

In this course, I encourage you to find other classmates with whom to study and discuss

homework. However, you must always generate your final homework solutions by yourself (do not copy homework solutions). Any course work to which you sign your name, whether it is a homework assignment or an examination, must represent your own work. I will take seriously any violations.

### **Academic Accommodation**

Our community values diversity and seeks to promote meaningful access to educational opportunities for all students. Syracuse University and I are committed to your success and to supporting Section 504 of the Rehabilitation Act of 1973 as amended and the Americans with Disabilities Act (1990). This means that In general no individual who is otherwise qualified shall be excluded from participation in, be denied benefits of, or be subjected to discrimination under any program or activity, solely by reason of having a disability.

If you believe that you need accommodations for a disability, please contact the Office of Disability Services (ODS), <http://disabilityservices.syr.edu> located at 804 University Avenue, Room 309, or call 315-443-4498 for an appointment to discuss your needs and the process for requesting accommodations. ODS is responsible for coordinating disability-related accommodations and will issue students with documented disabilities "Accommodation Authorization Letters," as appropriate. Since accommodations may require early planning and generally are not provided retroactively, please contact ODS as soon as possible.

### **Religious Observations**

SU's religious observances policy, found at [http://supolicies.syr.edu/emp\\_ben/religious\\_observance.htm](http://supolicies.syr.edu/emp_ben/religious_observance.htm), recognizes the diversity of faiths represented among the campus community and protects the rights of students, faculty, and staff to observe religious holy days according to their tradition. Under the policy, students are provided an opportunity to make up any examination, study, or work requirements that may be missed due to a religious observance provided they notify their instructors before the end of the second week of classes. For fall and spring semesters, an online notification process is available through MySlice/Student Services/Enrollment/My Religious Observances from the first day of class until the end of the second week of class. For this course, students with religious observance on a day that homework is due may turn in the homework on the next day without penalty, and students missing class due to a notified religious observance will not have their class participation score penalized due to the missed class.

## **PHY 795 Tentative Course Calendar (Spring 2012)**

Depending on interests and preferences of students in the class, or simply if we find that the schedule below is too fast to cover the material in sufficient detail, we may change the schedule

significantly. Advanced topics listed at the end will include in-class reports given by students as part of their final projects.

Tue 17 Jan	Overview	Dodelson, Ch 1, pp. 1-20
Thu 19 Jan	GR for Cosmology	Dodelson, 2-2.1, pp. 23-33
Tue 24 Jan	The Expanding Universe	Dodelson, 2.2-2.3, pp. 33-40
Thu 26 Jan	The Cosmic Inventory	Dodelson, 2.4-2.5, pp. 40-52
Tue 31 Jan	Big Bang Nucleosynthesis	Dodelson, 3-3.2, pp. 58-70
Thu 2 Feb	Recombination & Dark Matter	Dodelson, 3.3-3.4, pp. 70-79
Tue 7 Feb	Boltzmann Eq. for Photons I	Dodelson, 4-4.2, pp. 84-95
Thu 9 Feb	Boltzmann Eq. for Photons II	Dodelson, 4.3-4.4, pp. 95-101
Tue 14 Feb	Boltzmann Eq.'s for Matter	Dodelson, 4.5-4.7, pp. 102-112
Thu 16 Feb	Einstein Equations	Dodelson, 5-5.2, pp. 117-124
Tue 21 Feb	Tensor Perturbations	Dodelson, 5.3-5.6, pp. 124-135
Thu 23 Feb	Inflation	Dodelson, 6-6.3, pp. 139-155
Tue 28 Feb	Gravity Waves	Dodelson, 6.4, pp. 155-162
Thu 1 Mar	Scalar Perturbations	Dodelson, 6.5-6.6, pp. 162-173
Tue 6 Mar	Large-scale Inhomogeneities	Dodelson, 7-7.2, pp. 180-194
Thu 8 Mar	Small-scale Inhomogeneities	Dodelson, 7.3-7.6, pp. 194-211
Tue 20 Mar	Anisotropies	Dodelson, 8-8.3, pp. 216-230
Thu 22 Mar	Inhomogeneities to Anisotropies	Dodelson, 8.4-8.5, pp. 230-243
Tue 27 Mar	Interpreting the Anisotropy Spectrum	Dodelson, 8.6-8.7, pp. 243-255
Thu 29 Mar	Angular Correlations	Dodelson, 9.1, pp. 261-270
Tue 3 Apr	Probes of Inhomogeneities	Dodelson, 9.2-9.5, pp. 270-287
Thu 5 Apr	Weak Lensing I	Dodelson, 10-10.3, pp. 292-302
Tue 10 Apr	Weak Lensing II	Dodelson, 10.4, pp. 302-310
Thu 12 Apr	Polarization	Dodelson, 10.5-10.6, pp. 310-320
Tue 17 Apr	Future Power Spectra	Dodelson, 10.7-10.9, pp. 320-329
Thu 19 Apr	Advanced Topic TBA	TBA
Tue 24 Apr	Advanced Topic TBA	TBA
Thu 25 Apr	Advanced Topic TBA	TBA
Tue 1 May	Advanced Topic TBA	TBA