ASTR 452 (Spring 2016)

Astrophysics II: Galaxies and Cosmology
Tues & Thurs, 2:30-3:45 pm, HBH 423

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Course Description: Study of physical cosmology models. Description of the evolution of the universe, including nucleosynthesis, cosmic background radiation, large-scale structure, galaxy formation and evolution, and high redshift phenomena.

Learning Objectives:
By the end of the course, you (the student) should be able to to do the following:

- Describe and calculate the dynamics of the homogeneous universe, understand how the dynamics relates to its contents as well as observational probes of these dynamics.
- Be familiar with the thermal history of our universe and be able to calculate how different species of particles emerge from the thermal soup in the early universe.
- Calculate the evolution of density perturbations in our universe; from initial conditions during inflation to the present day and understand corresponding observations.
- Describe properties of our host galaxy including its morphology and kinematics
- Understand galaxy classifications, galaxy formation and evolution as well as properties of their groups (galaxy clusters)
- Be familiar with different scaling relations between different observables of galaxies
- Make order of magnitude estimates, apply concepts from many different areas of physics and perform detailed calculations of astrophysical/cosmological observables with an understanding of the approximations involved.

Prerequisites: A good base in electromagnetism, classical mechanics, statistical mechanics, special relativity, quantum mechanics, and of course prior exposure to astrophysics in general will be helpful. I will introduce relevant ideas as needed for (aspects of) general relativity and free field QFT, familiarity with these will make your life easier. I will assume familiarity with systems of ordinary differential equations, multivariable calculus, Fourier analysis and linear algebra. Formally, for undergraduate students at Rice the prerequisites include (ASTR 350 OR ASTR 360) and (PHYS 301 and PHYS 302).

Class Website: All course materials including problem sets, links to relevant websites, supplementary material, class updates and announcements will be posted on the ASTR 452 Owl Space page. It is your responsibility to check Owl Space regularly for the most recent information concerning the class.

Main Text(s):

- *Physical Cosmology* by Scott Dodelson: This is a detailed, graduate level text. We will weave in and out of this book as needed for the cosmology part of the course. It is particularly good in its treatment of the cosmic microwave background.
- *Part III: Cosmology Lecture Notes* by Baumann (U of Cambridge): An excellent shorter companion to Dodelson's textbook, particularly for the early chapters in Dodelson. We will follow Baumann's notes instead of Dodelson's book for the early part of this course.
- *Extragalactic Astronomy and Cosmology* by Peter Schneider: We will use this book for the galaxies part of the course. It has a good balance of relevant observational details along with the theory. It is also a gentler, less mathematical treatment for the cosmology part of the course.

Additional Resources:

- *Cosmology* by Steven Weinberg: If you want rigor, this is the place to go to. The presentation is "clean". It has most of the interesting things you can do "by hand" in cosmology. It might not be easy on the first reading but I recommend referring to it if you are confused elsewhere.
- *Physical Cosmology* by Mukhanov: I like the treatment of hydrodynamical perturbations in this book. It also has some more advanced topics relevant for the very early universe.
- *Spacetime and Geometry: An Introduction to General Relativity* by Carroll. This is an excellent textbook for GR at the graduate level.
- *An Introduction to Modern Astrophysics* by Carroll & Ostlie. Less advanced than the course, but comprehensive.

Caution: Notation varies across texts! Luckily, Weinberg, Dodelson and Carroll use the "mostly plus" $-+++$ metric convention, however, Baumann and Mukhanov use the $+---$ convention.

Exams and Problem Sets:
3 Homework Problem Sets
2 Oral Exams (a Midterm and a Final)

Grading Policies: Each homework and exam will account for 20% of the total grade. Late homeworks are annoying. For unexcused tardiness, there will be a 10% reduction/per day in credit, with no credit 4 days after the homework is due. If illness or other circumstances beyond your control lead to a delay in submission, please contact me as soon as possible (preferably before the deadline). The final grade for the course will be based on a curve, with additional discretion regarding the final grade based on class participation/interactions etc. Attendance is not mandatory, but highly recommended.

Collaboration and Help: For a better understanding of the material you are strongly encouraged to talk to other students, postdocs and faculty (including me!). For the problem sets, you should work on each problem independently first ($\geq$ 1 hr). If you collaborate/get help from others, they should be acknowledged in the problem sets. The write-up should always be done independently. While not recommended, at times you might end up using hints from online or other sources. Cite them as well. For the oral exams, you should not discuss any questions with your classmates. The Honor Code applies. You can review Rice's Honor Council documentation online at: honor.rice.edu/index.cfm

Special Needs: If you have a documented disability that requires special consideration for this class then please contact the me as soon as possible to discuss your needs. Students with disabilities should also contact the Disability Support Services Office in the Ley Student Center (dss.rice.edu).

Tentative Course Outline: The weekly/daily coverage might change depending on progress of the class. I will update this section with relevant reading material every week. B= Baumann, D=Dodelson, S=Schneider. The ordering in the table below reflects recommended order of reading. If you are time constrained, use this ordering.

Week	**Content**
Week 1	• Introduction to our Cosmos [B(1.1), D(1.1-2.1.1)] • *The Homogeneous Universe*: Spacetime Kinematics [B(1.2), D(2.1.2)]
Week 2	• Homogeneous Spacetime Dynamics • Cosmological Distances and Horizons
Week 3	• Inflation & Reheating • Thermal History I: Overview and Review of Statistical Mechanics
Week 4	• Thermal History II: Equilibrium • Thermal History III: Beyond Equilibrium
Week 5	• *Inhomogeneous Universe*: Cosmological Perturbation Theory with Newton • Cosmological Perturbation Theory with Einstein I
Week 6	• Cosmological Perturbation Theory with Einstein II • Structure Formation I: Early stages
Week 7	• Structure Formation II : Evolution of perturbations • Initial conditions inflation I
Week 8	• Quantum fluctuations from inflation II* • *Observations*: Cosmic Microwave Background (CMB) Anisotropies
Week 9	• Linear & Nonlinear Matter Power Spectrum • Other Probes of Inhomogeneities: Lensing & Redshift Space Distortions*
Week 10	• CMB Spectral Distortions & CMB Polarization* • Summary & Future Prospects
Week 11	• Galaxies: Our Milky Way • Milky Way Kinematics
Week 12	• The World of Galaxies: Morphology & Dynamics • The World of Galaxies: Scaling Relations
Week 13	• Population Synthesis • Clusters of Galaxies
Week 14	• "High" Redshift Phenomena • The Road Ahead

*might change based on interest in class.