

ASTR 3740 — Cosmology and Relativity

Time and Place: MWF 10:00–10:50, Duane G131

Course Web Page: We will use D2L for assignments, reading quizzes, and grades.

Instructor: Jeremy Darling (jeremy.darling@colorado.edu; Duane D-341; 2-4881)

Office Hours: M 11:00-12:00 and W 1:30–2:30, Duane D-322. Other meeting times can be arranged by appointment.

Aims: The goal of this course is to provide a solid foundation in special relativity, the principles (but not the mathematics) of general relativity, and cosmology (observational and theoretical). I will place strong emphasis on recent scientific results in all of these fields. *My aim is to provide you with the tools and knowledge to continue learning and to pursue your educational and career goals.*

Prerequisites: If you do not meet the prerequisites for this class or are not prepared for challenging and mathematical coursework, please see me after class or during office hours. Consider taking ASTR 2010, Modern Cosmology, instead of this course.

Topics:

- Galilean Relativity
- Special Relativity
- Principles of General Relativity
- Observations and Experiments in Special and General Relativity
- Theoretical Cosmology
- Observational Cosmology
- Big Bang Nucleosynthesis
- Cosmic Microwave Background
- Dark Matter and Dark Energy
- One or Two Special Topics (per student request)

Texts: There are two required texts: *Gravity: An Introduction to Einstein's General Relativity* (Hartle), and *Introduction to Cosmology* (Ryden, 2nd edition). Both texts are extremely accessible and great fun to read. Our treatment of special and general relativity will rely on Hartle and on my own notes, but those of you with exceptional interest in the topic can try *Gravitation* (Misner, Thorne, & Wheeler) or *Problem Book in Relativity and Gravitation* (Lightman, Press, Price, & Teukolsky).

Grading: Problem Sets — 50%; Midterm Exams — 10% each; Final Exam — 20%; Reading and Concepts Quizzes — 10%.

Problem sets and quizzes will be frequent and relevant. I will drop the lowest homework score and the lowest quiz score. Exams will be administered roughly after each third of the course, so there will be two midterm exams (around weeks ~ 5 and ~ 10) and a comprehensive final exam on Sunday, May 6, at 1:30–4:00 pm.

It is critical to come to class prepared and ready to participate. I will often assign preparatory reading for specific lectures and reading quizzes that will be due prior to class. I do not offer extra credit.

Homework Policy: Homework will be due at the start of class, usually on Fridays. Homework will not be accepted late unless you have made arrangements *before* the due date. You are strongly encouraged to work on the homework on your own, but if you do collaborate with a classmate or consult a source (book, paper, wikipedia, etc), please give credit where it is due: cite your references and list your collaborators. Show your work, state assumptions, use units, and employ words and sentences to elucidate your thinking.

Class Time Policy: I promise to respect your time and busy schedule by ending lectures promptly at the official time (50 minutes after the hour). In return, I ask that you be in class, prepared, and ready to participate *on the hour*. If you need to miss a class, please communicate this to me beforehand and make any necessary arrangements to cover your absence.

Participation and Respect: The classroom will be a place of civility, respect, collegiality, and learning. It will be a safe place to ask questions or to simply say that you don't understand something. I encourage you to ask questions and volunteer answers. An honest attempt at an answer is better than a correct answer (as you know, we generally learn more when we are wrong than when we are right).

University Policies

Students with Disabilities

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the Disability Services website (<http://www.colorado.edu/disabilityservices/students>). Contact Disability Services at 303-492-8671 or dsinfo@colorado.edu for further assistance. If you have a temporary medical condition or injury, see Temporary Medical Conditions under the Students tab on the Disability Services website and discuss your needs with your professor.

Observance of Religious Holidays

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. In this class, if you must miss an exam, assignment, lecture, or recitation because of observance of a religious holiday, please notify the professor in writing at least a week prior. See full details at <http://www.colorado.edu/policies/observance-religious-holidays-and-absences-classes-andor-exams>.

Classroom Behavior

Students and faculty each have responsibility for maintaining an appropriate learning environment. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. Class rosters are provided to the instructor with the student's legal name. I will gladly honor your request to address you by an alternate name or gender pronoun. Please advise me of this preference early in the semester so that I may make appropriate changes to my records. For more information, see the policies on classroom behavior (<http://www.colorado.edu/policies/student-classroom-and-course-related-behavior>) and the Student Code of Conduct (<http://www.colorado.edu/osccr/>).

Honor Code

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the academic integrity policy (<http://www.colorado.edu/policies/academic-integrity-policy>). Violations of the policy may include: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, resubmission, and aiding academic dishonesty. All incidents of academic misconduct will be reported to the Honor Code Council (honor@colorado.edu; 303-735-2273). Students who are found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code Council as well as academic sanctions from the faculty member. Additional information regarding the academic integrity policy can be found at the Honor Code Office website (<http://www.colorado.edu/honorcode/>).

Office of Discrimination and Sexual Harassment

The University of Colorado Boulder (CU Boulder) is committed to maintaining a positive learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct, discrimination, harassment or related retaliation against or by any employee or student. CU's Sexual Misconduct Policy prohibits sexual assault, sexual exploitation, sexual harassment, intimate partner abuse (dating or domestic violence), stalking or related retaliation. CU Boulder's Discrimination and Harassment Policy prohibits discrimination, harassment or related retaliation based on race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. Individuals who believe they have been subject to misconduct under either policy should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127. Information about the OIEC, the above referenced policies, and the campus resources available to assist individuals regarding sexual misconduct, discrimination, harassment or related retaliation can be found at the OIEC website (<http://www.colorado.edu/institutionalequity/>).

Table 1: *Approximate* Lecture and Reading Schedule

Lecture	Date	Topic	Textbook Reading	Due
0	Jan 17	Introduction and Syllabus	Hartle 1	
1	Jan 19	Galilean Relativity		
2	Jan 22	Conservation Equations	Hartle 3.1–3.2	
3	Jan 24	Postulates of Special Relativity		RQ 1
4	Jan 26	Lorentz Transform		HW 1
5	Jan 29	The Invariant Interval	Hartle 4	
6	Jan 31	“Paradoxes”		RQ 2
7	Feb 2	Spacetime		HW 2
8	Feb 5	4-vectors	Hartle 5.1–5.3	
9	Feb 7	Energy, Mass, and Momentum		RQ 3
10	Feb 9	Relativistic Conservation Equations		HW 3
11	Feb 12	Photons	Hartle 5.1–5.3	
12	Feb 14	Doppler Shift and Beaming		RQ 4
13	Feb 16	Particles, Pairs, and Mesons		HW 4
14	Feb 19	Postulates of General Relativity	Hartle 2	
15	Feb 21	(continued)		
16	Feb 23	Midterm Exam		
17	Feb 26	Equivalence Principle and corollaries	Hartle 6.1–6.5	
18	Feb 28	Metrics		RQ 5
19	Mar 2	Coordinate transformations		HW 5
20	Mar 5	Intervals	Hartle 9.1–9.2	
21	Mar 7	Schwarzschild Metric		RQ 6
22	Mar 9	Properties of the Metric		HW 6
23	Mar 12	How to Interrogate the Metric	Ryden 1, 2	
24	Mar 14	Introduction to Physical Cosmology		RQ 7
25	Mar 16	Basic Observations		HW 7
26	Mar 19	(continued)		
27	Mar 21	Hubble’s Law		
28	Mar 23	Midterm Exam		
...	Mar 26	<i>Spring Break</i>		
...	Mar 28	<i>Spring Break</i>		
...	Mar 30	<i>Spring Break</i>		
29	Apr 2	Metrics	Ryden 2, 3	
30	Apr 4	Robertson-Walker Metric		RQ 8
31	Apr 6	Redshift, Intervals, Distances		HW 8
32	Apr 9	Friedmann Equation	Ryden 5	
33	Apr 11	Fluid Equation		RQ 9
34	Apr 13	Acceleration		HW 9
35	Apr 16	Equations of State	Ryden 6	
36	Apr 18	Single-Component Universes		RQ 10
37	Apr 20	Multi-Component Universes		HW 10
38	Apr 23	Concordance Cosmology	Ryden 10	
39	Apr 25	Big Bang Nucleosynthesis		RQ 11
40	Apr 27	Cosmic Microwave Background		
41	Apr 30	Hot Big Bang Theory		HW 11
42	May 2	Special Topic(s)		