ASTR 704: Cosmology
MWF 10:00-10:50, Phillips Hall 220

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Office Hours: Tuesdays 3:00-5:00 and by appointment

Course Description:
An introduction to modern cosmology: the study of the contents and evolution of the Universe. Covers expanding spacetime, the thermal history of the early Universe including nucleosynthesis and the cosmic microwave background, the inflationary model for the origins of cosmic structure, and the growth of that structure through time.

This will provide students with an overview of modern cosmology. Starting from the basic principles of general relativity, we will develop models of our expanding spacetime and connect its expansion to the contents of the Universe. We will then follow the evolution of the Universe from its fiery origins to the synthesis of the light elements and the emission of the cosmic microwave background. Finally, we will trace the evolution of cosmological structures from the production of density fluctuations during inflation to the formation of bound halos. This course draws from several sub-fields of physics, including gravitational physics, classical field theory, and quantum mechanics. The course will emphasize quantitative problem solving and will equip students with the background knowledge required to interpret and participate in modern cosmological research. To demonstrate this competency, students will work in teams to investigate an outstanding cosmological problem and will prepare written summaries and an oral presentation of its current status.

Course Goals:
1. To obtain a working knowledge of general relativity as it pertains to expanding spacetime and the evolution of cosmological perturbations.
2. To understand how astronomical observations allow us to trace evolution of the Universe from the hot Big Bang to the current dark-energy dominated era.
3. To understand the inflation paradigm for the origin of our Universe: its motivations, its predictions, and the observations that will further test it in the future.
4. To obtain the quantitative skills required for cosmological computations.
5. To interpret the primary literature that communicates progress at the frontier of cosmological research.

Course Resources:
Required Text: Modern Cosmology, Scott Dodelson, Academic Press, 2003. (Dod.)
Optional Texts (copies will be put on reserve): The Early Universe, Edward W. Kolb and Michael S. Turner, Westview Press, 1990. (K&T); Cosmology: The Origin and Evolution of Cosmic Structure, Peter Coles and Francesco Lucchin, Wiley & Sons Ltd, 2002. (C&L)
Journal articles available online:
Liddle, Parsons and Barrow. *Phys. Rev. D* 50, 7222 (1994) (LPB)
Bertshinger "Cosmological Dynamics" astro-ph/9503125 (Bert)

Course Requirements:

1. Completion of 10 problem sets.
2. An individual written report (5-10 pages) and an oral team presentation (10 minutes) that summarizes the status of a current outstanding cosmological problem by drawing on at least three different published journal articles and presenting worked derivations of key results.
3. Participation in the in-class problem-solving sessions that will be incorporated into several lectures. Participation grade will be based on solutions shared with the class.

Grades:

Problem Sets	50%
Midterm	10%
Final	15%
Research Summary	15%
Class participation	10%

Course Policies: Collaboration on problem sets is encouraged, but each student must submit an independently prepared solution set. Unless prior arrangements have been made or there is a university-excused absence, late problem sets will be accepted until the Friday following their due date, but will receive a 20% penalty. Students will have the opportunity to correct and resubmit two problem sets. The exams will be closed book, but the students may refer to notes that they personally prepare on one side of a letter-sized sheet of paper.

Class	Topics	Reading	Assignments Due
Week 1: January 6	**Introduction**		
Wed.	Intro and overview of observations	Dod 1	
Fri.	Hubble's Law and metrics		
Week 2: January 13	**General relativity in cosmology**		
Mon.	GR overview and FRW metrics	Dod 2.1	
Wed.	Connections and geodesic equation		
Fri.	Curvature and Friedmann's equations		
Week 3: January 20	**The Expanding Universe**		
Wed.	Cosmic history and inventory	Dod 2.4	PS #1: GR and FRW
Fri.	Probes of expansion	Dod 2.2	
Week 4: January 27	**Thermodynamics and Freeze-out**		
Mon.	Distribution functions, density, and pressure	Dod. 2.3, K&T 3.3	
Wed.	Conservation of entropy, Boltzmann equation	Dod. 3.1, K&T 3.4	PS #2: Expansion
Fri.	Dark matter freeze-out and	Dod. 3.4,	

	candidates	K&T 5.1-5.2	
Week 5: February 3	**Big Bang Nucleosynthesis (BBN)**		
Mon.	Helium formation	Dod. 3.2, K&T 4	
Wed.	Other elements and observations		PS #3: Thermo
Fri.	Baryogenesis	K&T 6.1-6.4	
Week 6: February 10	**The CMB & Inflation**		
Mon.	Recombination and Saha equation	Dod. 3.3	
Wed.	Observations: horizon and flatness problems	Dod. 6.2	PS #4: BBN
Fri.	Scalar field theory and slow-roll inflation	Dod. 6.3, LPB I-III	
Week 7: February 17	**Inflation dynamics**		
Mon.	Duration of inflation, inflationary models		
Wed.	Reheating after inflation		PS #5: CMB/Inflation
Fri.	Decomposition of metric and gauges	Dod. 5, Bert 4	
Week 8: February 24	**Metric Perturbations**		
Mon.	The curvature perturbation	Dod. 6.4-6.5	
Wed.	MIDTERM		MIDTERM
Fri.	Perturbation field equations		
Week 9: March 3	**Inflationary perturbations**		
Mon.	Quantizing scalar fields		
Wed.	The inflationary power spectrum	Dod. 6.6	PS #6: Metric Perturbations
Fri.	Spectral tilt and observations		
Week 10: March 17	**Boltzmann Equations**		
Mon.	Boltzmann equations for dark matter	Dod. 4.5	
Wed.	Boltzmann equations for photons	Dod. 4.2-4.4	PS #7: Inflationary Perturbations
Fri.	Boltzmann equations for baryons & photons	Dod. 4.6	
Week 11: March 24	**Evolution of Perturbations**		
Mon.	Superhorizon perturbations	Dod. 7.1-7.2	
Wed.	Subhorizon perturbations	Dod. 7.3-	PS #8: Boltzmann

		7.4	Equations
Fri.	Growth function and matter power spectrum	Dod. 7.6	
Week 12: March 31	**CMB Anisotropies**		
Mon.	Sachs Wolfe and Acoustic Oscillations	Dod 8.1-8.4	
Wed.	The CMB power spectrum	Dod 8.5-8.7	PS #9: Evolution of Perturbations
Fri.	CMB polarization	Dod 10.5-10.9	
Week 13: April 7	**The Halo Model**		
Mon.	Mass Variance & Top-hat Collapse	C&L 13.3, 14.1	
Wed.	Press-Schechter formalism & halo bias	C&L 14.5	PS #10: CMB Anisotropies
Fri.	Halo properties, TSZ effect, dark matter	Dod. 9.5	
Week 14: April 14	**Probes of Nonlinear Structure**		
Mon.	Angular power spectra, velocity fields	Dod. 9.1-9.3	
Wed.	Redshift space distortions	Dod. 9.4	Resubmitted problem sets
Week 15: April 21	**Models and Tests of Dark Energy**		
Mon.	Observational Probes of DE		
Wed.	Dark Energy Models/Student Presentations		Presentations
Fri.	Student Presentations		Presentations, Written research summaries
TBA	FINAL EXAM		FINAL EXAM