ASTR/PHYS 328/428 - Cosmology and the Structure of the Universe

This course will explore modern cosmology from both a theoretical and observational perspective. The essential framework of the Friedmann model, the Robertson-Walker metric, and the Newtonian approximation will be given. Important parameters will be introduced and examined: the expansion rate and age of the universe; the density and deceleration parameters and the cosmological constant; nucleosynthesis of the light elements and the cosmic density of baryons; the microwave background and structure formation; and the missing mass problem. Emphasis will be placed on observations which motivate, measure, and test the standard modern world model.

Outline

1. Introduction
    1. Historical perspective: cosmologies of ancient and medieval peoples
    2. Overview of the genesis of modern cosmology in General Relativity
2. Cosmological Essentials
    1. Simple Newtonian Cosmology
    2. The Robertson-Walker metric and Friedmann models
    3. Empirical Pillars of modern cosmology
    4. Cosmological Parameters: H_0, t, Ω, q, Λ, T(CMBR), Y_p, Ω_b, Ω_{CDM}, σ_8, n
3. The Size scale of the Universe
    1. The Hubble relation
    2. The expansion rate (H_0) and age (t) of the Universe
    3. Calibration: the distance scale ladder
    4. Large Scale Structure: mapping the Universe
4. The Age of the Universe
    1. Globular Cluster ages
    2. White dwarf age limits
    3. Radioactive decay and interstellar grain limits
5. The Density Parameter (Ω)
    1. The role of density parameter (Ω) in specifying world model
    2. Importance of Ω to H_0 and t
    3. Relation of Ω to deceleration parameter (q) and cosmological constant (Λ)
    4. Measures of Ω, q, and Λ
6. Primordial Nucleosynthesis
    1. Photon to baryon ratio (entropy)
    2. Abundances of the light elements: Y_p, D/H, Li/H
    3. Entropy and the density of baryons (Ω_b)
7. Cosmic Microwave Background
    1. Backround Radiation; T(CMBR)
    2. Temperature Anisotropies
    3. Structure formation; growth of fluctuations
    4. The acoustic power spectrum
8. The Mass Discrepancy Problem
    1. Cosmological and dynamical motivations
    2. The need for cold dark matter (CDM)
    3. Alternative possibilities: WDM, SIDM, MACHOs, MOND, etc.
9. The Dark Ages
    1. Recombination and Reionization
    2. The Saha equation in cosmic context
    3. Cosmic Dawn: the first stars
10. The Very Early Universe
    1. Inflation
    2. The Particle Zoo
11. Exoitca
    1. Multiverses
    2. The Far future: a Big Rip?
       as time permits

Course Work

Assignments will be posted on the course web page: http://astroweb.case.edu/ssm/ASTR328/

Course work will consist of

- Problem sets
- Midterm and Final exams
- A class project (428 only)

In addition to the class project, students registered for ASTR/PHYS 428 will encounter additional problems on the problem sets and homeworks.

Grades

Grades will be on a curve. The highest performing students will receive the highest grades, and vice-versa. The absolute scale is irrelavant.

Weighting:

Course	Problem Sets	Midterm Exam	Final Exam	Project
ASTR/PHYS **328**	30%	30%	40%	N/A
ASTR/PHYS **428**	20%	30%	40%	10%

I will review the situation at the end of the semester to check whether this weighting scheme remains fair.

The **lowest score** among the problem sets will be **dropped**.
If you're sick at an inconvenient time, you may skip one.
If you're happy with your first four, you may skip the last one.

Missed Assignments

The first rule of missing assignemnts and exams is **don't**. If you do fall ill or suffer some other tragedy at exam time, let me know ASAP (before the exam happens) that you will be unable to attend, and we'll see what can be arranged. This is to be avoided if at all possible. There will be no **extra credit** outside the regular assignments.

Learning Outcomes

After taking this course, students should be able to

- Quantitatively describe the dynamical evolution of the universe under different cosmological models.
- Distinguish between and employ quantitative metrics for luminosity distance and angular size distance under different cosmological models.
- Desrcibe and distinguish between the various cosmological parameters that define the cosmological model.
- Name the three pillars of the hot big bang cosmology.
- Describe observational evidence for the quantitative values of the various cosmological parameters that define the cosmological model.
- Describe and apply observational cosmological tests.
- Compare and constrast different cosmological distance estimators.
- Critique the quality of and uncertainties in cosmological distance estimators.
- Describe qualitatively the growth of structure under various cosmological models.
- Employ quantitative metrics for measuring structure in the universe.
- Describe physical models for galaxy formation and hierarchical galaxy evolution.
- Describe the observational constraints on models of galaxy evolution over cosmic time.
- Analyse observational datasets to infer cosmological information.
- Quantiatively describe the temperature evolution of the universe.
- Describe big bang nucleosynthesis and how it is constrained by observations of the abundances of the light elements.
- Qualitatively describe the cosmic microwave background and its relation to large scale structure.
- Describe the cosmic dark ages and reionization.
- Describe the motivations for non-baryonic cold dark matter.
- Describe the motivations for dark energy.