AS759 – Cosmology, Fall 2013

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Office hours: Mondays 2:00pm to 3:30pm, Wednesdays 2:30pm to 4:00pm

Lecture times: Tuesdays & Thursdays 11:00am to 12:30pm

This course is intended to introduce advanced astronomy graduate students to modern physical cosmology. Broadly speaking, cosmology is the study of the origin, evolution and structure of the universe. The course will draw heavily on recent observations (primarily from the past 20 years), but it will also have a substantial theoretical component. Twenty years ago it was common for astrophysicists to joke about "accuracy" in the measurements of fundamental cosmological parameters such as the expansion rate of the universe, the present-day mass density of the universe, and the age of the universe. Errors approaching 50% in some cases were not at all uncommon at that time. We are at present, however, rapidly approaching an era of true "precision cosmology" in which the fundamental cosmological parameters are expected to be known within 1%. Twenty years ago cosmologists were largely ignorant of the history of galaxy formation, to the point of not even knowing when the bulk of galaxy formation occurred in the universe. This situation has changed completely, and a fairly consistent picture has emerged. There is little doubt that we live in a rather bizarre universe that was born in a hot Big Bang and in which the vast majority of the present–day mass is in some form of exotic dark matter, while the vast majority of the present–day energy is in the form of some sort of exotic dark energy. Throughout the semester we will piece together the jigsaw puzzle that has led to this conclusion. Along the way we will confront popular theoretical models with a variety of observations in order to come to a reasonably complete understanding of the history of the universe.

Grading: Homework – 100%

Text: We will not be following any particular textbook closely, but John Peacock's book *Cosmological Physics* is recommended as a resource. Copies of this book are available at the BU bookstore.

Copies of PPT slides shown in class can be found at:

`http://firedrake.bu.edu/AS759/AS759.html`

Course Outline

History & Perspective

- what cosmology is, and is not
- the Cosmological Principle
- Olbers' paradox, the Shapley–Curtis debate, and the establishment of the extragalactic distance scale
- introduction to physical cosmology and Big Bang predictions
- summary of current constraints on cosmological parameters

Classical Cosmology Theory

- Newtonian cosmology
- introduction to general relativity
- geometry in non-Euclidean spacetimes
- Robertson–Walker metric and the Friedmann equation
- curvature–kinematics coupling in matter–dominated universes
- horizons, lookback times, and distances in cosmology
- radiation–dominated versus matter–dominated universes
- the cosmological constant
- Big Bang nucleosynthesis

Evidence for Universal Expansion

- Hubble's law
- calibrations of local distance indicators and indirect distance indicators
- direct determinations of H_0 from Hubble's law
- measurements of H_0 from gravitational lenses

Evidence for the Radiation Era

- discovery of the CMBR, roles of COBE and WMAP satellites
- temperature and blackbody nature of the CMBR
- the surface of last scattering
- temperature fluctuations in the CMBR and the determination of H_0, Ω_0, Ω_Λ, Ω_{b0}, t_0
- polarization of the CMBR
- abundances of the light chemical elements

Inflation

- horizon, monopole, and flatness problems
- introduction to the physics of inflation

Structure in the Universe

- groups, clusters, walls, voids, and superclusters
- measures of galaxy clustering, $\xi(r)$ and $P(k)$
- luminosity and morphology segregation
- non–linear mass versus light bias
- evolution of galaxy clustering over cosmic time

Dark Matter in the Universe

- evidence for dark matter
- baryonic versus non-baryonic dark matter
- cold versus hot dark matter
- role of dark matter in structure formation
- growth of super–horizon size fluctuations versus sub–horizon size fluctuations
- Navarro, Frenk & White halos
- mapping dark matter with gravitational lensing

Dark Energy in the Universe

- equation of state parameter
- residual Hubble diagram from Type Ia supernovae
- CMBR constraints
- ΛCDM versus OCDM

The Distant Universe

- redshift distribution of galaxies
- number counts and the Faint Blue Excess problem
- active galaxies and quasars
- submm galaxies, ULIRGs, protogalaxies, and the Madau plot
- biased galaxy formation
- reionization