C161: Relativistic Astrophysics and Cosmology

UC Berkeley, Spring 2016

Elements of general relativity. Physics of pulsars, cosmic rays, black holes. The cosmological distance scale, elementary cosmological models, properties of galaxies and quasars. The mass density and age of the universe. Evidence for dark matter and dark energy and concepts of the early universe and of galaxy formation. Reflections on astrophysics as a probe of the extrema of physics.

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**GSI**: Morgan Presley

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**Office Hours**: Tu 1:30p – 2:30p Campbell TBD

**TALC**: W 5:00p – 6:30p, Campbell 121

**Lectures**: Tu/Th 11:10a – 12:30p, Campbell 131a

**Main Text**: Andrew Liddle “An Introduction to Modern Cosmology” (2nd Edition, Wiley)

**Other Readings**:

* Peter Schneider "Extragalactic Astronomy and Cosmology" (complementary material to Liddle, covering astrophysical properties of galaxies, clusters and other important observational facts)
* Barbara Ryden "Introduction to Cosmology" (Addison Wesley; similar to Liddle)
* M. S. Longair "Galaxy Formation" (for those interested in graduate-level cosmology)
* Steven Weinberg "The First Three Minutes" (a popular account of the thermal history of the universe)
* Kip Thorne "Black Holes and Time Warps" (a beautifully written popular book on black holes and relativity)

**Grading**: 50% Problem Sets; 25% Exam; 25% Project/in-class presentation

**Course Content**

1. **The Smooth Universe**
   1. The Cosmological Principle; Hubble parameter H; scale factor a [Ch 1,2]
   2. Friedmann equation; equation of state; radiation, matter, dark energy [Ch 3,4,5]
   3. Density parameter Omega; open, flat, closed cosmological models [Ch 6]
   4. Time evolution of H, Omega, and a [Ch 7]
   5. Rudiments of general relativity; the Robertson-Walker metric [Ch 8, A1]
   6. Basic kinematic properties: distance-redshift, time-redshift, age, angular sizes [A2]
2. **The Bright Side**
   1. The Planck mass; the ugliest number in physics
   2. Thermodynamics of Fermi and Bose gases in an expanding universe
   3. The longest 3 minutes of your life
   4. Big Bang Nucleosynthesis: helium, deuterium, lithium, baryon-to-photon ratio [Ch 12]
3. **The Dark Side**
   1. Evidence for dark matter [Ch 9]
   2. Evidence for dark energy
   3. Two dark matter problems: baryonic vs non-baryonic
   4. What can they be?
4. **The Lumpy Universe**
   1. Gravitational instability in a static universe
   2. Gravitational instability in an expanding universe
   3. Growth of cosmic structures
   4. Photon-baryon scattering physics; the cosmic microwave background [Ch 10, A5]
5. **The Baby Universe**
   1. Successes of the standard Big Bang model [Ch 11]
   2. Problems of the standard Big Bang model [Ch 13]
   3. How to fix it? Inflation
6. **Black Holes**
   1. Supermassive black holes at centers of galaxies
   2. Gravity waves: sources: binary black holes
   3. Gravity waves: detection
7. **Selected Topics** (student presentations)

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