Astronomy 6 – Introductory Cosmology
Fall 2013

Syllabus plus review questions

Week 7 = first week after break (W, Oct 23; long meeting, no class Friday)

Reading: Sec. 23.1, 20.5
Topics: Hot Big Bang as the basic framework for understanding cosmology; Olber's paradox and the finite age of the Universe; the concept of the horizon distance; types of particles in the universe and their properties; galaxy as basic unit; inverse square law, Doppler shift, Hubble law and expansion of the Universe, including the concept of the Hubble time.

How do the darkness of the night sky and the Hubble law (proportionality between a galaxy's distance and its velocity) provide evidence for the Big Bang scenario (that the universe had a beginning a finite time in the past)?

Week 8 (W, F Oct 30, Nov 1)

Reading: Various background articles on blackbody radiation; my own multi-paragraph summary, now on the Old Assignments page; Steven Weinberg's article on cosmology and particle physics from the NYRB
Topics: More on the Hubble law; the CMB; intro to the Friedmann equation (Newtonian version).

What are the theoretical arguments that the early universe should have been hot? How does the CMB show us, observationally that it was hot? The CMB consists of blackbody photons radiated by matter in the universe at the time of recombination ($z \sim 1100$; about 400,000 years after the big bang).

$T_{CMB} = 2.7$ K now, and its temperature scales as $1/a$ or $1/(1+z)$. Why should the energy density of the CMB scale as a^{-4}? And why does that lead to a direct, inverse scaling between T and a?

How do you interpret the various terms in the Newtonian version of the Friedmann equation? What is the analogy with the trajectory of a projectile launched upward off the surface of the Earth and what plays the role of the escape velocity in that analogy?

Week 9 (W, F Nov 6, 8)

Reading: Sec. 23.2; Wendy Freedman article on measuring H_o
Topics: More on the Friedmann equation: Einstein (curvature) vs. Newtonian (energy) interpretations. Angular size. The Robertson-Walker metric incorporates the expansion of the Universe.

What's the difference between Einstein's Friedmann equation and Newton's? How does curvature of spacetime enter the picture? How is the expansion of the universe incorporated into the metric equation? …what is a "metric" – qualitatively?

How are angular size, distance, and length related? How does that relationship change if space isn't flat?

How is the Hubble constant determined? What quantities are actually measured?

How do we think, physically, of the cosmological redshift in the context of the expanding universe?

How is the proper distance defined and what does it mean?

Week 10 (W, F Nov 13, 15)

Reading: Sec. 23.3, 23.4
Topics: Non-Euclidean geometry and how the geometry of spacetime could be measured. The evolution of the scale factor with time (and the age of the Universe) based on integrating the Friedmann equation, including the age of the Universe (or various universes). The metric equation and the proper distance.

What is the critical density (how is it defined)? How can we characterize the various components of the universe by relating them to the critical density (via the Omega notation)?

How can we solve the Friedmann equation for various special cases, in order to derive a functional form for a(t)? How can we relate these solutions to the age of the universe in each case?

Week 11 (W, F Nov 20, 22)

Reading: Sec. 24.1; 23.5; short reading on visualizing dark matter, from *American Scientist*.
Topics: Reviewing geometry, fate of the Universe, but including the possibility of non-zero cosmological constant. Mass-energy census and dark matter; rotation curves of spiral galaxies. Consensus model and evidence for it.

How do we know (observationally) the density of matter in the universe? What are the different ways of estimating or measuring it? Which are sensitive to baryonic matter and which to all kinds of matter?

When did radiation dominate the mass-energy of the universe? What about matter? And Lambda? How do you go about computing the ranges of these eras?

How do we know that space is close to being geometrically flat?

(Week 12: Thanksgiving week; no class meetings at all)

Week 13 (W, F Dec 4, 6)

Reading: Two dark matter articles (Bullet Cluster and efforts on direct detection); Sec. 24.2
Topics: Dark matter: more evidence; time scales over which one component (radiation, matter, cosmological constant) dominates the expansion of the Universe; the accelerating Universe and dark energy and revisiting the consensus model.

What is the evidence for the acceleration of the expansion of the universe? What is the "consensus model" of the universe? What are the independent lines of evidence for it?

How is the (expansion) fate of the universe determined from the Friedmann equation and our knowledge of the various component densities?

How does the Bullet Cluster provide strong evidence for dark matter (and for that dark matter being non-baryonic, non-collisional)?

Week 12 (*or 14?*; M, W Dec 9, 11)

Reading: Sec. 24.3, 24.4; short article on multiple universes
Topics: The early universe and big bang nucleosynthesis; inflation. The big picture.

What distance goes into the Hubble law? How is it computed? How do we expect brightness of a galaxy to depend on distance when the distances are huge (z is significant)?

How were nuclei formed in the first few minutes of the universe? How do the light element abundances provide evidence for the hot big bang model? And further, what do they tell us about the density of baryonic matter (and by implication, about the nature of dark matter)?

What is the horizon problem and how does inflation solve it?

You should be able to analyze a given universe in the Omega_m vs. Omage_Lambda plane (e.g. will the universe expand forever? What's its geometry?) and you should be able to explain why only a small fraction of that parameter space leads to universes where complexity can develop.