Study Guide for the Final
ASTR340 – Fall 2008

Will cover lectures from lect12 to lect24: from the lecture on black holes (excluded) to the last lecture on structure formation. Depending on the available time to review, do the following (in order of effectiveness):

1. Study class power point presentation available on the class website
2. Study homework and solutions available online
3. Read the book

Tips for Calculations:

There will be very few calculations in the final: it will be mainly conceptual. However, when calculations are required:

1. Check units: eg, redshift is dimensionless, velocity=space/time, Hubble time= time, critical density=mass/volume, etc..
2. Check unit conversions
3. Result makes sense?
4. Bring scientific calculator!

Summary of important concepts:

The expansion of the Universe:

- Determination of distances of distant objects:
  1 – parallax: angle=baseline/distance
  2 – standard candles
  3 – Cepheid variables
  4 – SN type 1a

- Hubble discovery of the expansion of the Universe
- Hubble diagram, Hubble law and Hubble constant
- Concept of gravitational redshift and Doppler redshift
- Interpretation of Hubble law in terms of GR
- Redshift: $z=(\lambda_{obs}-\lambda_{em})/\lambda_{em}$
  $v=cz$
- Concept of cosmological redshift in terms of the size of the Universe
  $z+1=R_{obs}/R_{em}$

Cosmological models:

- Cosmological principle

- Robertson-Walker geometry
- Friedman equations: analogy to rock escaping gravity of earth
  $H=(dR/dt)/R$ = rate of expansion of the Universe
- Hubble time $t_H=1/H$ (what it means?)
- Hubble radius $r_H=c\ t_H$ (what it means?)
- Deceleration and acceleration of the expansion rate of the Universe
- Cosmological constant and dark energy

Hot Big Bang and early Universe:

- Evolution of the density and temperature of the Universe
- Evolution of the radiation and matter density: redshift of equality
- Creation and annihilation of particles
- Threshold temperature
- Unification of forces
- Epochs of the Universe: from the Planck time to reionization
- Big bang nucleosynthesis: how much normal matter (baryons) in the Universe?
- The epoch of recombination and the CMB
- What is the CMB? How was discovered? Why is important?
- Spectrum of the CMB
- Anisotropies of the CMB and their importance for determining the geometry of the Universe
  1. Dipole anisotropy
  2. Anisotropies at redshift of recombination
  3. Origin of density perturbations as quantum fluctuations before inflation

Measuring Cosmological Parameters:

- Cosmological parameters: H (expansion rate), $\Omega=\rho/\rho_{crit}$ (density parameter).
- Density of Universe=mass/volume. Need to count and measure the mass of objects in a given volume to measure density. Divide by the critical density to derive the density parameter omega.
- Weighting the Universe:
  1 – mass in stars in the Universe: very small even in comparison to baryon density from big bang nucleosynthesis
  2 - dark matter from the rotation of galaxies
  3 – dark matter using clusters
  4 – dark matter from gravitational lensing

- $\Omega_m=0.26$, $\Omega_b=0.04$. Thus, $\Omega_{dm}=0.22$
- Measuring the geometry of the Universe: the Universe is flat after all!
- The need for a Cosmological constant: flatness of the Universe and acceleration.

Dark matter and structure formation:

- Dark matter candidates: MACHOS from microlensing, mini black holes, elementary particles
- Hot and cold dark matter
- Neutrinos: hot dark matter
- WIMPS: cold dark matter
- Bottom-up and top-down galaxy formation
- Galaxy and redshift surveys
- Cosmic web
- Galaxy types and clusters
- Simulations of galaxy formation
- Dark halos and galaxies
- First galaxies and the dark ages
- Galaxy collisions and quasars
- Reionization of the Universe