1 Key Concepts

1.1 Review:

- The CMB (Cosmic Microwave Background) provides a picture of our Universe 400,000 years after the big bang, and it is extremely homogeneous.
- The Galaxy Distribution today has structure (galaxies are not randomly distributed in space).
- The Universe is dominated by dark matter, surrounding each galaxy and galaxy cluster.

1.2 The Universe’s Baby Picture

- The CMB is a uniform 3 degree background filling space, which arises from the light emitted at photon decoupling, 400,000 years after the big bang.
- The CMB is homogeneous, exactly the same temperature in every direction, to one part in 100,000. These similar regions are separated by much more than 400,000 light years.
- This leads to the “Horizon Problem”: How do disjoint regions of the sky know enough about each other to have the same temperature?
- The CMB has structure, fluctuations of 1 part in 100,000. How were these fluctuations generated? What does their size and spatial distribution tell us?
- The CMB indicates the Universe is very flat. Since this is an unstable point, how does it stay this way?
- Spots on the CMB sky correspond to small density fluctuations in the early Universe. The distribution of fluctuations (power) on various scales is referred to as the “power spectrum”.
- The details of these fluctuations, visible as the CMB power spectrum, give precise information about the geometry, contents, and age of the Universe.
1.3 Inflation

The Horizon: The distance light can travel over the age of the Universe. 
Inflation: A short period of rapid expansion driven by vacuum energy. This provides an elegant solution to several problems (none of which were its original motivation), including:

- The Horizon Problem: Before inflation, regions were in causal contact. They escape each other’s “horizon” because space expands faster than the speed of light.
- The Generation of Fluctuations: Quantum Fluctuations get created, and the Universe expands their wavelengths before they can get destroyed.
- The Flatness Problem: Inflation expands the universe so much that curved regions become very nearly flat.

1.4 Structure Formation

- The evolution of structure depends on the cosmological parameters (ie, the amount and type of matter and energy and the expansion rate).
- The evolution of large-scale structure in the Universe is governed by gravity.
- All structures today formed by gravitational amplification of the small fluctuations that we think were generated by inflation.
- We think our Universe is dominated by cold dark matter.
- In Universes dominated by cold dark matter (CDM), structure forms hierarchically, i.e., small things form first, and merge to form larger things.
- Structure on various scales in CDM is nearly self-similar (substructure in galaxies looks like substructure in clusters)

2 Further Reading

See the Further Reading link at http://kicp.uchicago.edu/fisa/compton

- WMAP Cosmology 101, http://map.gsfc.nasa.gov/m_uni/
- Introduction to the CMB, Wayne Hu: http://background.uchicago.edu/whu/beginners/introduction.html
- The Cosmic Symphony, Wayne Hu and Martin White, Scientific American, February 2005
- http://cosmicweb.uchicago.edu/ (Structure Formation, KICP)
- Martin White’s pages: http://astron.berkeley.edu/ mwhite/htmlpapers.html