1 Key Concepts

1.1 Review

- About 100,000 years after the big bang, the Universe was very smooth, with fluctuations about one part in 10000 (Compare to one part in 100 billion at the centers of galaxies today).

- These fluctuations grow under the force of gravity.

- Eventually, the density in a small region gets large enough so that the gravity can counteract the expansion of the Universe. These regions then decouple from the Hubble flow.

- Gas particles can cool when they collide. Dark matter particles do not interact with each other.

- This cooling allows gas particles to sink to the center of dark matter halos.

1.2 Formation of Spiral Galaxies

- Early merging of dark matter halos creates small amounts of angular momentum.

- The rotation of the gas is amplified by the contraction (cooling), which allow the gas to settle into a disk.

- When gas gets dense enough, it can form stars.

- As gas continues to cool, it settles onto this disk. Stars can form in the densest regions of the disk.

- Star formation requires cool, high density gas: most star formation happens in the spiral arms of galactic disks, or in dense regions formed during galaxy interactions.
1.3 Galaxy Merging
- Galaxies are thought to form hierarchically: small things form first and merge to create larger things.
- Elliptical galaxies and galactic bulges are thought to be created in mergers of galaxies of similar sizes. Such mergers destroy any existing galaxy disks, and use up most of the available gas.
- Typical galaxies in the field had their last major mergers about 10 billion years ago. Such galaxies would have created a bulge at this time, and have then had adequate time to develop spiral disks through new gas accretion after this last merger.

1.4 Galaxy Interactions
- While major mergers are thought to create elliptical galaxies, smaller interactions, or interactions that are still in progress, can create a wide variety of galaxy shapes, including tidal tails and ring galaxies.
- Interactions typically trigger massive bursts of star formation.
- The interaction rate of galaxies decreases rapidly with time: mergers were roughly 5 times as common when the universe was 1/4 of its present age.

2 Further Reading
See the Further Reading link at http://kicp.uchicago.edu/~risa/compton
- Check out the excellent “Galaxy Crash Java Lab” at: http://burro.astr.cwru.edu/JavaLab/GalCrash
- The Lifecycle of Galaxies, Guinevere Kauffmann and Frank van den Bosch, Scientific American, June 2002
- A Midlife Crisis in the Cosmos, Amy Barger, Scientific American, January 2005