From the Big Bang to the Formation of the Galaxy

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The Big Bang Model

Two Pillars:

General Relativity

- Matter tells space how to curve
- The curvature of space tells matter how to move
- Space is not absolute but
 Defined in terms of relative distance between two objects
- Large scale homogeneity



APM Survey picture of a large part of the sky, about 30 degrees across, showing almost a million galaxies out to a distance of about 2 billion light years.

Mass Density / Geometry of the Universe



Discovery of the Expanding Universe



MAP990044





The Cosmic Microwave Background





Quick History of the Universe

- Universe starts out hot, dense and filled with radiation
- As the universe expands, it cools.
 - During the first minutes, light elements form
 - After 300,000 years, atoms form
 - After 100,000,000 years, stars start to form
 - After 1 Billion years, galaxies and quasars



Cosmic Microwave Background Fluctuations

- Atoms formed about 300,000 years after the big bang
- Tiny variations in the density of the universe generate temperature fluctuations
- These fluctuations grow to form galaxies



W - 94GHz





From the CMB to Galaxies

Lets consider a shell of thickness δr and radius r. The mass within the shell is $\delta M = 4\pi \rho r^2 \delta r$ and the mass inside the shell is $M(r) = 4\pi \rho r^3/3$.

As long as the shell doesn't cross other shell, then its energy is conserved. The total energy of the shell is

$$E = \frac{\delta M v^2}{2} - \frac{GM(r)\delta M}{r} \tag{1}$$

If the total energy is greater than 0, the kinetic energy exceeds the gravitational energy and the region expands for ever and forms a void.

If the total energy is less than 0, the gravitational energy wins and the region collapses to form a cluster.





Numerical Simulations



Milky Way Galaxy: Home



 Milky Way is a spiral galaxy
 We live in the disk of the galaxy: 24,000 light years (8,000 pc) from the Center
 Central bar is composed of old stars
 Star formation is taking place mainly in the disk

Spiral Arms



- Most of the cold gas in spiral galaxies are in the spiral arms
- These spiral arms are sites of active star



13 28 00

50 45 RIGHT ASCENSION



Molecular Clouds



Molecular clouds are cold, dark, giant condensations of dust and molecular gas which serve as "stellar nurseries".

All stars are born in molecular clouds, including our Sun. Molecular clouds are the "stuff" we're made of!

Because of their dusty content, visible light cannot penetrate into a molecular cloud. Thus, infrared and submillimeter observations are needed to "see" the star-forming process.



Dense fragments collapse under gravity, making protostars. These accumulate infalling matter and form circumstellar disks and powerful outflows and jets.



Things That We Do Not Know

- What makes up most of the mass of our Galaxy?
- What makes up most of the energy in the universe?
- What determines the properties of galaxies?
- How do molecular clouds form?