From the Big Bang to the Formation of the Galaxy

AST 205
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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

$\Omega_0 > 1$

$\Omega_0 = 1$

$\Omega_0 < 1$
Discovery of the Expanding Universe

\[ V = H_0 \cdot D \]
Supernova Ia: standard candles

\[ F = \frac{L}{(4\pi d^2)} \]

\[ m = -2.5 \log_{10} F \]

\[ M = -2.5 \log_{10} F_0 \]
The Cosmic Microwave Background

Microwave Receiver

Graph showing the intensity of the Cosmic Microwave Background as a function of wavelength. The graph includes a best-fit curve for a 2.725 K blackbody and error bars for FIRAS data.
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
Let's consider a shell of thickness $\delta r$ 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

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

(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.
Evolution of Structure in a Low Omega Universe

200 Mpc across

Time = 0.05 Gyr

University of Washington Astronomy

Stadel 1998
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 formation
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.

A newborn star (obscured from view) illuminated its disk (seen edge-on here) and outflow jet.
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?