


AST1002




***Galaxies and Beyond***

Chapter 17  
A Universe of Galaxies

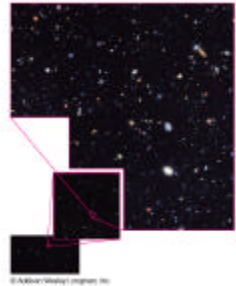
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***A Universe of Galaxies***

- Hubble Deep Field
  - Hubble Space Telescope
  - Near the north galactic pole
  - A total of 10 days of exposure time



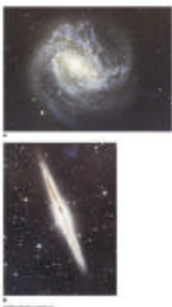
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***A Universe of Galaxies***

- Spiral galaxies
  - Up to 100,000 light years in diameter
    - Disk with spiral arms and central bulge
    - Spherical halo
  - 75-85 % of the large galaxies are spiral
  - Frequently found in groups or clusters



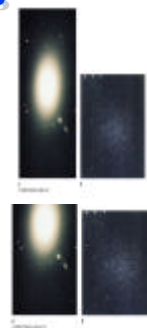
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***A Universe of Galaxies***

- Elliptical galaxies
  - No disk component
  - Little dust or cool gas
- Two major types
  - Giant ellipticals
  - Dwarf ellipticals
- Almost always found in clusters or groups




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***A Universe of Galaxies***

- Irregular
  - "none of the above"
  - Lots of dust and cool gas
  - Little organized structure
  - Range of sizes
  - Nearby examples: Large and Small Magellanic Clouds
  - Distant galaxies are more likely to be irregular




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***A Universe of Galaxies***

- Clusters of galaxies
  - 100s or even 1000s of galaxies
  - Spread over millions of light years
  - Usually several large galaxies and many smaller galaxies



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## A Universe of Galaxies

- Measuring distances
  - Main sequence fitting
    - Compare main sequences
    - Need cluster of known distance (Hyades)
    - Difference in apparent brightnesses give difference in distance

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## A Universe of Galaxies

- Measuring distances
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## A Universe of Galaxies

- Measuring distances
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## A Universe of Galaxies

- Cepheid variables
  - Period related to luminosity
  - Well calibrated
  - Very bright (up to  $30,000 L_{\text{sun}}$ )
  - Visible in other galaxies

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## A Universe of Galaxies

- White-dwarf supernovae
  - about  $10^{10} L_{\text{sun}}$
  - Well calibrated by other techniques
  - Visible in distant clusters of galaxies

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## A Universe of Galaxies

- Tully-Fisher relation
  - Spiral galaxies
  - Rotation rate from radio observations (doppler effect)
    - Rotation depends on mass
    - Luminosity depends on mass
  - Luminosity depends on rotation

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## A Universe of Galaxies

- Summary of distance measures

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## The Hubble Law

- Mt. Wilson astronomer Edwin Hubble
- distance *estimate* for galaxies
  - Cepheid variables
  - from size of galaxy
  - from brightness of stars; clusters; whole galaxy
- velocity determination for galaxies
  - doppler shift of spectral lines
- Hubble Law: a relationship between galaxy distance and velocity

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## The Hubble Law

- Redshift is proportional to distance

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## The Velocity-Distance Relation

- Nearby galaxies have both red and blue doppler shifts

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## The Velocity-Distance Relation

- more distant galaxies all seem to be receding (with **red shifts** only)

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## The Velocity-Distance Relation

- more distant galaxies all seem to be receding (with **red shifts** only)

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### The Velocity-Distance Relation

- the *Hubble Law* is the relationship between *distance* and *velocity*

velocity (km/sec)

distance (Mpc)

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### The Velocity-Distance Relation

- the *Hubble Law* is the relationship between *distance* and *velocity*
- the slope of the line is the Hubble constant ( $H_0$ )
- example:  
 $H=75 \text{ km/sec per Mpc}$

velocity (km/sec)

distance (Mpc)

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### The Hubble Law

- Redshift is proportional to distance
- The slope is called the *Hubble Constant*  $H_0$

recession velocity (km/s)

Distance (billions of parsecs)

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### A Universe of Galaxies

- Another look at Cosmology
  - The astronomer's time machine
    - The speed of light is large but still finite
    - The farther away we look, the farther back in time we see
      - Stars in our galaxy: up to 100,000 years
      - Nearby galaxies: a few million years
      - Nearby clusters: a few 100 million years
      - Distant clusters: a few billion years
      - Hubble deep field: up to 10 billion years

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### A Universe of Galaxies

- Universal expansion (Hubble Law)
  - Everything moving away from everything else
- Individual things are tied together by gravity and do not expand
  - Planets
  - The solar system
  - The Milky Way galaxy
  - Clusters of galaxies

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### A Universe of Galaxies

- Universal expansion
  - Everything moving away from everything else
  - A three dimensional model

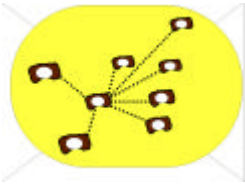
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## A Universe of Galaxies

- Universal expansion
- Everything moving away from everything else
- A three dimensional model




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## A Universe of Galaxies

- Universal expansion
- Everything moving away from everything else
- A two dimensional model is "better"
  - No center
  - No edges



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## A Universe of Galaxies

- Hubble Constant and Age
  - If the universe is expanding, how long has this been going on?
  - The Hubble Constant is currently found to be between 55 and 75 km/sec per Mpc (megaparsec)
  - This leads to an age between 12 and 18 billion years (probably about 16 billion)

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## A Universe of Galaxies

- Hubble Constant and Age
  - If the universe is expanding, how long has this been going on?
  - The Hubble Constant is currently found to be between 55 and 75 km/sec per Mpc (megaparsec)
  - $75 \text{ km/sec} = 0.077 \text{ Mpc/billion years}$   
so  $H_0 = 0.077 \text{ Mpc/billion years/Mpc}$   
and  $1/H_0 = 13 \text{ billion years}$

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## A Universe of Galaxies

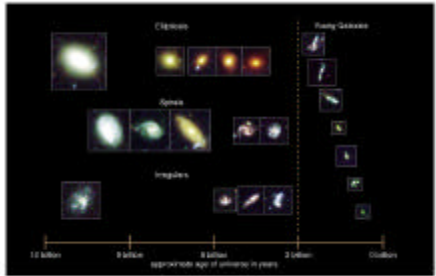
- Lookback time
  - The farther away an object is, the farther back in time its light left it
  - The length of time since the light we see left an object is the **lookback time**.
- The Horizon of the Universe
  - The Universe may be infinite in extent
  - We are limited to viewing only out to a lookback time equal to the age of the Universe

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## A Universe of Galaxies

- A family album



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### **A Universe of Galaxies**


- Formation of a Spiral galaxy
  - Assumptions
    - Early universe filled with H & He
    - Some regions were slightly more dense

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### **A Universe of Galaxies**

- Formation of a Spiral galaxy
  - Denser regions contracted to form protogalactic clouds

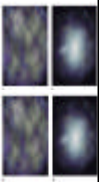


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### **A Universe of Galaxies**

- Formation of a Spiral galaxy
  - Denser regions contracted to form protogalactic clouds
  - Initial rapid star formation went on in these clouds

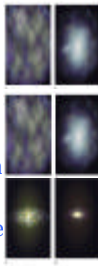


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### **A Universe of Galaxies**

- Formation of a Spiral galaxy
  - Denser regions contracted to form protogalactic clouds
  - Initial rapid star formation went on in these clouds
  - Star formation slows as supernovae cause temperature increase

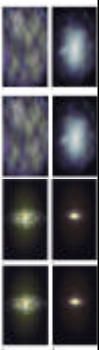


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### **A Universe of Galaxies**

- Formation of a Spiral galaxy
  - Denser regions contracted to form protogalactic clouds
  - Initial rapid star formation went on in these clouds
  - Star formation slows as supernovae cause temperature increase
  - Cloud continues to contract and flattens into spinning disk

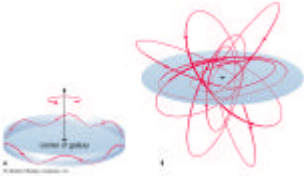


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### **A Universe of Galaxies**

- Formation of a Spiral galaxy
  - So the halo stars have random orbits
  - And the disk stars have circular orbits



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 **A Universe of Galaxies**

- Why do galaxies differ?
  - Where did the elliptical galaxies come from?
    - Very little angular momentum
    - Higher density = more rapid star formation

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 **A Universe of Galaxies**

- Why do galaxies differ?
  - Collisions may be important



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 **A Universe of Galaxies**

- Quasars (Quasi-stellar Radio Source)
  - Discovered in early 1960s
  - Very luminous
  - High redshifts = large distances
  - Sometimes have strong radio emission
  - Emission comes from very small region (perhaps a small a our solar system)
  - Energy source probably a massive black hole

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**Questions and/or Comments?**

**Let me know at [oliver@astro.ufl.edu](mailto:oliver@astro.ufl.edu)**

**or visit <http://www.astro.ufl.edu/~oliver/>**