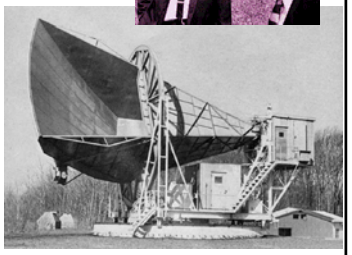
Discovery of Radiation from the Big Bang. About Hubble's Law – 22 Oct

- Some homework 5 papers that were mixed in with homework 4 have been graded.
- Homework 7 is due Wed, Oct 29.



What Penzias & Wilson wrote

- Penzias & Wilson, 1965, "A measurement of the excess antenna temperature at 4080Mc/s," ApJ 142, 419
  - "The excess temperature is … isotropic, unpolarized, and free from seasonal variation."
- Isotropic means we observe the same intensity in all directions
- Free from seasonal variations means same intensity in summer and winter.

- We are Bob Dicke in 1965 analyzing P & W's measurement. What are possible sources of the radiation?
  - Since Bob Dicke was building equipment to do what P & W had already done, it took him 1s to do this analysis.

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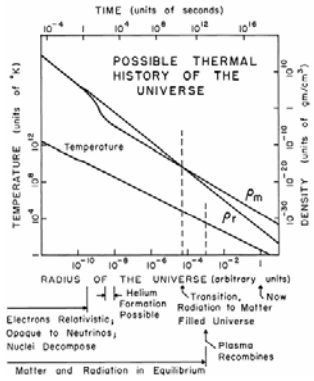
3. Would we observe radiation from the sun to be isotropic?
   A. Yes
   B. No
4. Is radiation from near the antenna free of seasonal variations?
5. Is radiation from the Big Bang isotropic?
6. Is radiation from the Big Bang free of seasonal variations?

Radiation is from BB

- Penzias & Wilson, 1965, "A measurement of the excess antenna temperature at 4080Mc/s," ApJ 142, 419
  - "The excess temperature is … isotropic, unpolarized, and free from seasonal variation."
- Dicke, Peebles, Roll, & Wilkinson, 1965, "Cosmic Black-body Radiation," ApJ 142, 414.
  - "Could the universe have been filled with black-body radiation from this possible high-temperature state?



Radiation is from the Big Bang

- Penzias & Wilson, 1965, "A measurement of the excess antenna temperature at 4080Mc/s," ApJ 142, 419
  - "The excess temperature is … isotropic, unpolarized, and free from seasonal variation."
- Isotropic means we observe the same intensity in all directions.
  - Stars or nearby galaxies cannot be the source of the radiation, since they are not isotropic in the sky.
- Free from seasonal variations means same intensity in summer and winter.
  - The environment (trees, grass, antenna) cannot be the source of the radiation, since their temperatures vary with the seasons.
- Could many distant galaxies with a high temperature emit this radiation?
  - Since there is no galaxy in every line of sight, the emissivity is less than 1.
- Later, in 1967, Dicke, Roll, & Wilkinson showed that the spectrum of the radiation is thermal. The source is "black."
- The only source that is black in every direction is the Big Bang.
- The radiation comes from the Big Bang.

About Hubble's Law—22 Oct

Edwin Hubble 1889-1953

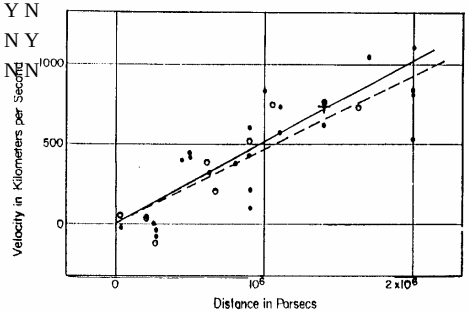
- Velocity V is proportional to distance D
  - $V = H \times D$
  - H is Hubble's constant
- Why are most galaxies moving away from us?
- Why are some galaxies moving toward us?
- What is expanding?
- Is Hubble's Constant a constant?

Dialogue Concerning Two Chief World Systems
Sagredo, Simplicio, and Salviati

Motion of galaxies

- Hubble 1929, Proc. Nat. Acad. Sci. 15, 168

1. Do any galaxies move toward us? Do any distant galaxies move toward us?
   - A. Y Y
   - B. Y N
   - C. N Y
   - D. N N



Why do most galaxies move away & a few move toward us?

- Andromeda & two companions are moving toward us at 200km/s.
- A history
  - In Big Bang, material follows Hubble's Law strictly. An explosion that happens at the same instant
    - I push against my neighbor; my neighbor pushes against me & my next-door neighbor. Therefore my next-door neighbor moves away twice as fast as my neighbor.
  - Andromeda was moving away.
  - Our local group of galaxies was slightly more dense than surroundings.
  - Gravity overcame motion and now Andromeda is moving toward us.

Andromeda M31, M32, & M33
www.noao.edu/image_gallery/images/d6/m31y.jpg

Universe is expanding. What is expanding?

- Hoag's Galaxy is 300 Mpc from us.

2. Why did Hoag's Galaxy move from 200Mpc to 300Mpc? Did that require some force? I throw a ball up, and it moves from a height of 20 ft to 30 ft. Did the ball require a force to move from 20 to 30 ft?
   A. Y Y
   B. Y N
   C. N Y
   D. N N

Is Hubble's Constant constant?

- At the present, the value of Hubble's constant is
  18,000km/s/(300Mpc) = 60 km/s/Mpc
  (Hoag's Object is moving at 18,000km/s, and it is 300Mpc distant.)

5. When Hoag's Object was 150Mpc from us, what was the value of Hubble's constant?
   A. Same
   B. Half
   C. Double

Simplicio

- Simplicio: Coma is 300MLy from us, and it is moving away from us because of the Big Bang. The sun is 1 AU from us, and it is moving away from us because it is part of the universe.

4. Is Simplicio's thinking correct?
   a. Yes
   b. No

Simplicio

- Simplicio: (a) Coma is 300MLy from us, and (b) it is moving away from us because of the Big Bang. (c) The sun is 1 AU from us, and (d) it is moving away from us because it is part of the universe.

5. What part of Simplicio's reasoning is incorrect?

Simplicio

- Simplicio: You tell me the universe is expanding, and some things do move away but other things do not. How does a thing know what to do?

6. Sagredo explains: The fundamental reason is
   a. Galaxies move away; other things do not.
   b. Big objects move away; little objects do not.
   c. If the force holding the object is big enough, it does not move away.
   d. Nearby objects do not move away; distant objects do.

Simplicio

- Simplicio: The Andromeda galaxy is coming toward us, not moving away. That must be a mistake.

7. Sagredo explains: The reason is
   a. Part of the Big Bang went the wrong way.
   b. Andromeda is a little galaxy.
   c. Over time, the gravitational force between Andromeda & the Milky Way has slowed and reversed the expansion.
   d. Andromeda is nearby.