About Hubble’s Law—30 Oct

- Why are most galaxies moving away from us? Why are some galaxies moving toward us?
- Why is the universe expanding?
- Is Hubble’s Constant a constant?
- Wavelength of light expands the same as the universe.
- Missouri Club?
- No class on Wed. before Thanksgiving.
- Missing step in doing homework.
  - Doing the questions is only half your assignment.
  - A more important task is to think about what you learned.
  - After doing a problem, identify the big ideas and the details.
  - If you cannot identify what you learned immediately after doing a problem, you will certainly not be able to recall the ideas on a test.

Why do most galaxies move away, but a few move toward us?

- Andromeda & two companions are moving toward us at 200km/s. The distance is 0.7Mpc.
- According to H’s Law, what should the speed of Andromeda be? (H=64km/s/Mpc)
  \[ v = H D = 64\text{km/s/Mpc} \times 0.7\text{Mpc} \]
  \[ = 45\text{km/s} \]
- Why does A not obey H’s Law?
- Imagine a history
  - Immediately after Big Bang, material follows Hubble’s Law strictly.
  - Big Bang is 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 faster than my neighbor.
  - Our local group of galaxies was slightly more dense than surroundings.
  - Gravity overcame motion, and caused A to reverse direction and come toward us.

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

4. What prevents Earth from expanding? Why did the material on earth forget about the outward-movement of the Big Bang?
   • Use Andromeda as a template for the explanation.
   • Immediately after Big Bang, material follows Hubble’s Law strictly.
   • Our local group of galaxies was slightly more dense than surroundings.
   • Gravity overcame motion, and caused A to reverse direction and come toward us.
   • Immediately after Big Bang, material follows Hubble’s Law strictly.
   • What became our Milky Way Galaxy was slightly more dense than surroundings.
   • Gravity pulled it together to form the MWG. This erases the motion from the Big Bang.
   • Stars form & die. Sun & Earth form. Gravity and properties of rocks determines size of Earth.

Universe is expanding. What is expanding?

• Hoag’s Galaxy is 300 Mpc from us.
• Why did Hoag’s Galaxy move from 200Mpc to 300Mpc? Did that require some force?
Why is the universe expanding?

1. At Tiger Stadium I see a b’ball moving toward left field (and away from C Granderson). Why is the b’ball moving?
   A. C Granderson hit the ball.
   B. Something keeps pushing on the ball.
2. We see Hoag’s Galaxy moving away from us. Why is it moving?
   A. Something pushes on Hoag’s Galaxy.
   B. The Big Bang set proto-galaxies in motion.
3. What would have to happen for Hoag’s distance to change? For Hoag’s speed to change? (Newton: Natural motion is motion at the same speed in the same direction.)
   A. Gravity must pull. Gravity must pull.
   C. Nothing. Gravity must pull.
   • Conclusion: The distance between the Milky Way and Hoag’s Galaxy increases, because they remember the motion set in place by the Big Bang.

Is Hubble’s Constant Constant?

• At the present, the value of Hubble’s constant is
  \[ \frac{18,000 \text{ km/s}}{300 \text{ Mpc}} = 60 \text{ km/s/Mpc} \]
  (Hoag’s Object is moving at 18,000 km/s, and its distance is 300 Mpc.)
5. When Hoag’s Object was 150 Mpc from us, what was the value of Hubble’s constant? What key idea is needed?
   A. 60 km/s/Mpc
   B. 120 km/s/Mpc
   C. 30 km/s/Mpc
Expansion stretches wavelength of light

- Principle: Wavelength of light stretches by the same factor as the universe expands.
- Why?
  - Universe is observed to be the same in all directions.
  - A standing wave permeates the U. (Two waves going left & right add up to a standing wave.)
  - At the present time, galaxies A and B sit on nodes of the standing wave.
  - Later, galaxy B has moved farther away.
  - B must remain on a node. If it is to the left of the node, then the direction toward A is special.
  - Therefore wavelength stretches by the same factor that the universe expands.