

## 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.

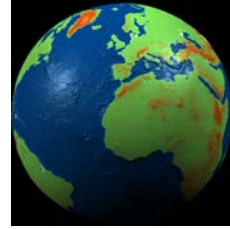
- Andromeda & two companions are moving toward us at 200km/s. The distance is 0.7Mpc.
- According to H's Law, what should the speed of Andromeda be?  
( $H=64\text{km/s/Mpc}$ )  
$$v = H D = 64\text{km/s/Mpc} \cdot 0.7\text{Mpc}$$
$$= 45\text{km/s away from us.}$$
- Why does A not obey H's Law?
- Imagine 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.

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



Andromeda M31, M32, & M33  
[www.noao.edu/image\\_gallery/images/d6/m31y.jpg](http://www.noao.edu/image_gallery/images/d6/m31y.jpg)

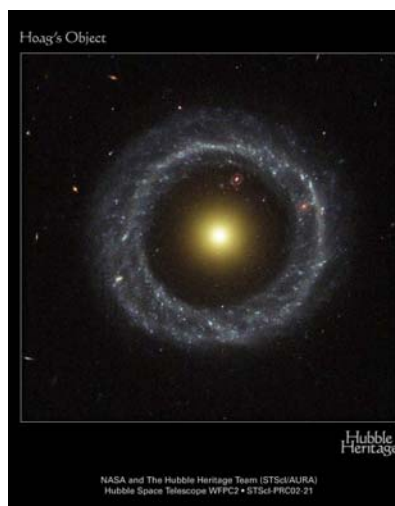
## Is everything expanding?



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.
  - B. Gravity must pull. Nothing.
  - C. Nothing. Gravity must pull.
  - D. Nothing. Nothing.
- 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  $18,000\text{km/s}/(300\text{Mpc}) = 60\text{ km/s/Mpc}$  (Hoag's Object is moving at  $18,000\text{km/s}$ , and its distance is  $300\text{Mpc}$ .)
5. When Hoag's Object was  $150\text{Mpc}$  from us, what was the value of Hubble's constant? What key idea is needed?
    - A.  $60\text{ km/s/Mpc}$
    - B.  $120\text{ km/s/Mpc}$
    - C.  $30\text{ km/s/Mpc}$

## 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.

