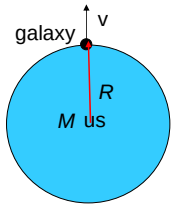
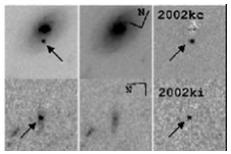
Weighing Univ.: Timing Expansion of Universe—19 Nov



- Warm-up question

1. Astronomers want to know the average mass density of the universe. What can we not figure out with this knowledge?
   - A. How much mass is in the Milky Way Galaxy.
   - B. The fate (expand forever or big crunch) of the U.
   - C. What the U is made of.

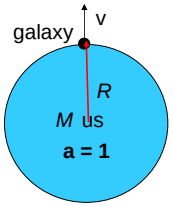


Distant supernovae
Riess et al, 2004, ApJ 607, 665.

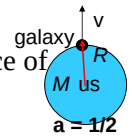
Announcements

- Astronomical Horizons Lecture
  - Pulsars: Cosmic Lighthouses
  - Ed Brown
  - Thurs, Nov 20, 7:30 pm
  - Abrams Planetarium
  - Free
- Test 3 is Nov 24th
  - See practice test on web site.
  - Mostly on material covered since Test 2 through Fri., 14 Nov. A little will be on earlier material.
  - 3 cheat sheets.

If the motion takes longer, the mass is less.



- Method for astronomical weighing:
  - Define a motion
    - Universe expands by a factor of 2, from a=1/2 to 1.
  - Time the motion: ??
  - If the motion takes longer, the mass is less.



- Use a proxy: Supernova in a galaxy on surface of a big sphere centered on us.
  - Sphere contains many galaxies
  - Is a "fair" sample of the Universe.
  - Mass inside sphere pulls on galaxy & slows expansion.
  - Present speed v_{now} & present distance R_{now} are fixed by Hubble's Law, v = H R.

1. Assume mass inside sphere is very, very small. When R=1/2 R_{now} , the speed of the galaxy v was __ than it is at the present time.

- What idea do you need to figure out the answer?
  - How does vel relate to density of mass?
    - F = m a.
    - Force of gravity = G M/$R^{2.}$
  - How long did this take?
  - Mass inside sphere does not change.
  - What are the galaxies surrounding the one?

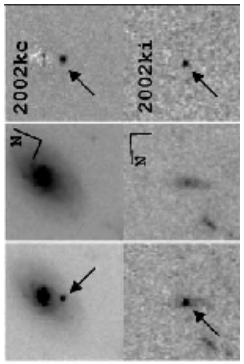
- F = m a
- If there is no force, the galaxy moves at the same speed.
- Force of the mass inside the sphere

  G M / R^2.

1. Assume mass inside sphere is very, very small. When R=1/2 R_{now} , the speed of the galaxy v was __ than v_{now}.
   A. larger
   B. same
   C. smaller

1. With a higher mass density, the time for U to expand by a factor of two is __.
   A. longer
   B. same
   C. shorter
- What idea or analogy do you need to figure out the answer?
  - With more mass, the force is bigger.
  - What forces are responsible for the expansion?
  - Principles of AW: If mass is greater, time is less.

1. With a higher mass density, the time for U to expand by a factor of two is shorter.
2. A supernova in a galaxy emitted some light when the U was half of its present size. We see that light. By looking the supernova, how do we know the U was half its present size? In a universe with a higher mass density, the supernova will be ___.
   A. brighter
   B. same
   C. fainter
- Ideas:
  - What makes SN brighter? Closer.
  - What affects distance to SN?
  - If time for U to expand is shorter, distance is shorter.



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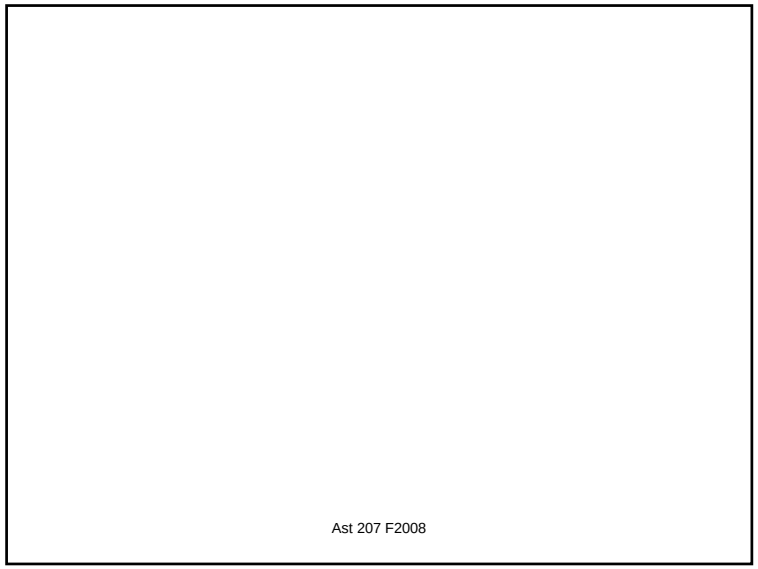
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