Weighing the universe—6 Dec

- Homework 11 will be due on the last day of classes (Fri, 10th). Answers will be posted after class. No late papers.
- Final exam
  - Covers the entire term with more emphasis on 20th century cosmology
  - Wed, 15th, 3:00-5:00 in 1415
  - Missouri Club: BPS-1420 on Mon, 12/13, 11:30am - 12:30pm
- Use fluctuations in the temperature of the cosmic background radiation to weigh the universe (determine the mass density).
- Weighing the universe with supernovae.
- What we will find: Expansion of universe speeds up!
  - "Dark energy" is dominant. Dark energy repulses whereas matter and radiation attract.

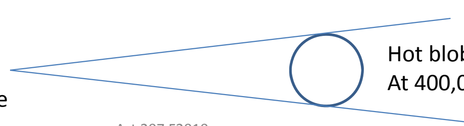
Angle subtended by hot blob is related to mass density of universe

- The size of the largest fluctuation is about 100,000 light years.
- The angle of the largest fluctuation is 1°.
- The motion is expansion of the U by a factor of about 1000.
  - $Temperature_{recombination}$=3000K; T_{now}=2.7K. Factor=3000/2.7=1100.
- Can measure the time for the motion.

1. The universe has a higher mass density if the angle of the largest fluctuations is____.

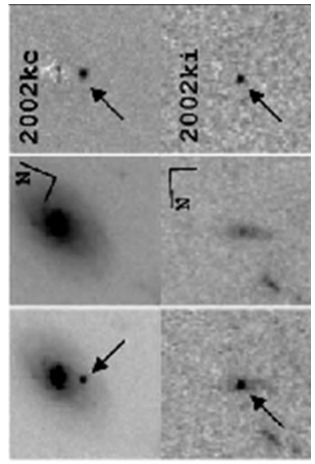
- Reasoning:
  - The motion is expansion of the U by a factor of 1000.
  - With a higher mass density, motion takes a ___ time.
  - With a higher mass density, distance to hot blob is ___.
  - With a higher mass density, angle subtended by the hot blob is bigger.

1. Blanks are
   - A. Shorter for both
   - B. Shorter and longer
   - C. Longer and shorter
   - D. Longer for both



Supernova

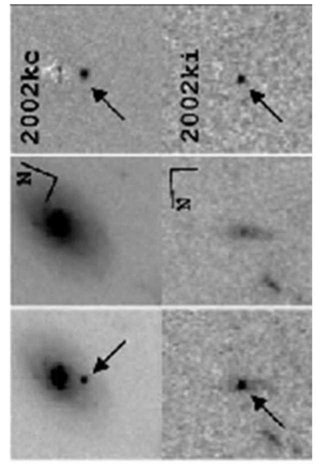
- A Type II supernova is a massive star that explodes when it runs out of fuel and pressure is insufficient to counter gravity.
- A Type I supernova is a white dwarf that explodes.
  - A WD and giant orbit each other.
  - Mass moves from the giant to the WD.
  - WD explodes when it gets so much mass from the giant that degeneracy pressure can no longer oppose gravity.
- Type I supernovae are “standard candles.” They have the same luminosity.
- How to find supernovae
  - Look at many galaxies.
  - Look again later. Find objects that were not there earlier.



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

1. When the U was half of its present size, a supernova in a galaxy emitted some light, which we see. What do we measure to determine that the U was half its present size when the light was emitted?
   A. Measure flux of supernova.
   B. Measure flux of galaxy.
   C. Measure wavelength of a spectral line emitted by the galaxy.
2. Example: The wavelength of the OII line is 372.7nm in the laboratory and 745.4nm in a galaxy with a supernova. The expansion parameter at the time the star exploded was
   A. 2
   B. 1
   C. 0.5

1. In a universe with a higher mass density, the supernova at redshift 1 (expansion parameter 0.5) will be ___. (Supernovae emit the same luminosity independent of the mass density of the U.)
   A. brighter
   B. fainter
- Ideas:
  – Why would the brightness of a SN depend on mass density of the universe?
  – Flux = Luminosity / Distance^2.
  – What affects distance to SN?
  – If time for U to expand is shorter, distance is shorter.
  Distance = time $\times$ speed of light



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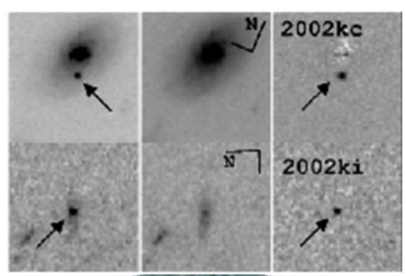
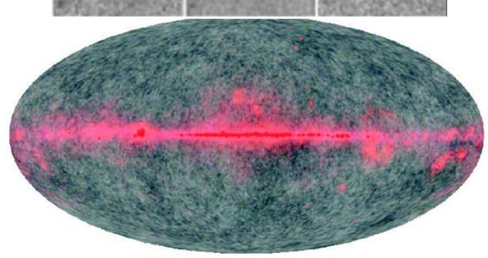
Ways to weigh the U

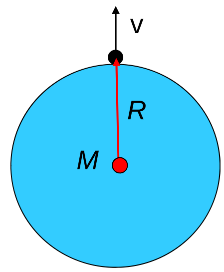
- Measure angular size of hot blobs in the radiation from the Big Bang.
  – Bigger angle (closer) means higher mass density.
- Measure flux of supernovae
  – Higher flux (closer) means higher mass density.





Effect of gravity on expansion of the universe

- We assumed the force of gravity had a negligible effect on the expansion of the universe, so that the speed of galaxies remained the same. Now we include the force of gravity.
- How to think about the effect of gravity on the expansion of the universe.
  - We are at the center of a big sphere. Many galaxies (and other stuff) fills the sphere. Even more galaxies are outside the sphere.
  - The galaxy of interest is on the edge of the sphere.
  - Sphere expands and galaxy moves because universe expands.



Analyze the effect of gravity on the motion of the one galaxy to find the effect of gravity on the expansion of the universe.

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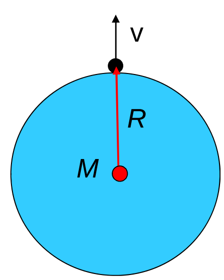
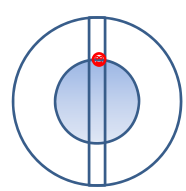
Do the galaxies outside the sphere affect the motion of the galaxy?

1. The little guy is in a well that runs through the earth. If a giant hand scraped the top 10miles off earth, the force on the guy ___. The galaxies outside the sphere ___ the motion of the galaxy.
   A. Decreases. Do affect
   B. stays the same. Do not affect
   C. increases. Do affect





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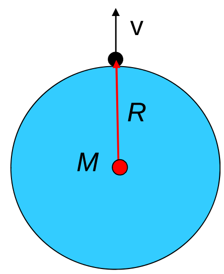
Effect of gravity on expansion of the universe

- Analyze the effect of gravity on the motion of the one galaxy to find the effect of gravity on the expansion of the universe.

- Newton says: The galaxy feels the pull only of the mass inside the sphere.
- If there is much mass, the galaxy will slow down, and the expansion of the U will slow down too.



1. Consider H's constant H=v/D. If there is little mass in the sphere, v was constant and D was smaller in the past. If there is more mass, would Hubble's constant in the past be ___?
   A. even bigger
   B. same as with little mass
   C. not as big

Hint: Consider change in v due to acceleration. Ignore change in D due to acceleration, since that is the sum of the changes in v, which is smaller than the change in v itself.