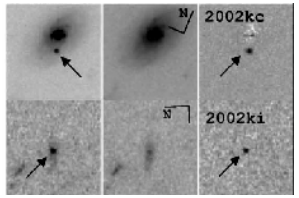
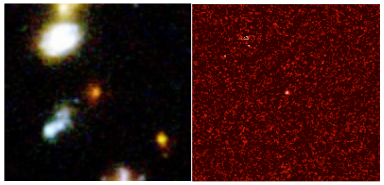
Weighing Earth, Sun, & Universe—20 Apr



Riess et al, 2004, ApJ 607, 665.



Hubble Deep Field: All HDF: 1st – 2nd half

- Fill out SIRS; then get 3 bonus clicker points on angel. (18-29 April)
- Weighing the earth
  - Time the fall of a ball
- Weighing the sun
  - Time the orbit at 1 AU.
- Weighing the universe
  - Time the doubling of the size of the universe
  - Same as measuring the brightness of a supernova that occurred when U was half its present size.

Weighing the Earth

- Define a motion
  - Release a ball and let it drop 4 feet
- Time the motion
  1. The time for a ball to drop 4 feet is about
     a. 1/8 s
     b. 1/2 s
     c. 2 s
     d. 8 s

Weighing the Earth

- Define a motion
  - Release a ball and let it drop 4 feet
- Time the motion
  1. The time for a ball to drop 4 feet is about ½ s.
  2. If the earth were made of foam rather than rock, the time for a ball to drop 4 feet from rest is
     a. Longer than ½ s.
     b. Shorter than ½ s.
     c. About ½ s.

Weighing the Earth

- Define a motion
  - Release a ball and let it drop 4 feet
- Time the motion
  1. The time for a ball to drop 4 feet is about ½ s.
  2. If the earth were made of foam rather than rock, the time for a ball to drop 4 feet from rest is longer than ½ s.
- Principle for astronomical weighing:
  - Define a motion
  - Time the motion
  - If the motion takes longer, the mass is less.

Weighing the Sun

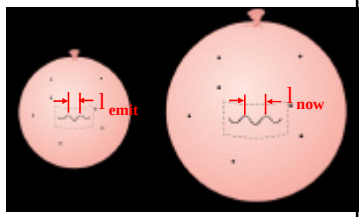
- Principle for astronomical weighing:
  - Define a motion
  - Time the motion
  - If the motion takes longer, the mass is less.

3. A planet orbits a star at a radius of 1 AU. One orbit takes ½ of an earth year. The mass of the star is ___ the mass of the sun.
   a. more than
   b. less than
   c. same as

Weighing the Universe: Define a motion

- Principle for astronomical weighing:
  - Define a motion
  - Time the motion
  - If the motion takes longer, the mass is less.
- Define a motion: Supernova emits some light and I see the light. Between these two events, Universe expands by a factor of 1.5 (or 1.1 or 2. Determined by the supernova.)
- Expansion stretches light same as distances between galaxies
- "Scale of universe" when light was emitted.

  $R = l_{emitted} / l_{now}$

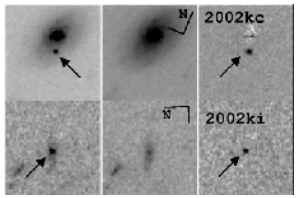


Weighing the Universe: Define a motion

4. SN 2002ki emits light with Fe absorption at 380 nm. We observe the wavelength of the Fe absorption at 800 nm. The U has expanded by a factor of
   a. 0.5
   b. 1.1
   c. 2.1
   d. 420

- Expansion stretches light same as distances between galaxies
- "Scale of universe" when light emitted

  $R = l_{emit} / l_{now}$



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Weighing the Universe: Define a motion

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   a. 0.5
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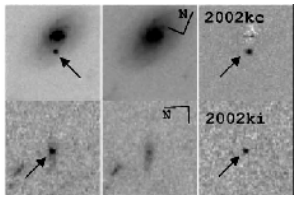
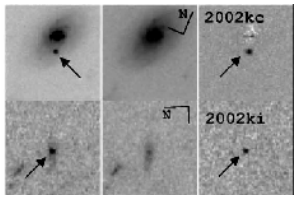
- For SN2002ki, the motion is the expansion of the universe by a factor of 2.1
- Expansion stretches light same as distances between galaxies
- "Scale of universe" when light emitted

  $R = l_{emit} / l_{now}$



Weighing the Universe: Time the motion

- For SN2002ki, the motion is the expansion of the universe by a factor of 2.1
- Timing the motion
  - Supernova (specifically Type Ia) is a standard candle. All have the same luminosity.
  - If SN is faint, then it is far away
  - If distance is far, time is great. (Light travels at the speed of light.)
- Flux = Luminosity / Distance^2.



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- If the motion takes longer, the mass is less.

5. If SN2002ki is bright, then the universe has a) lots or b) little mass.