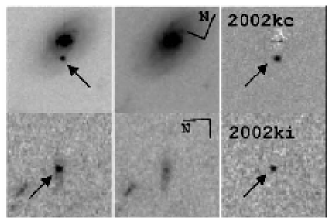
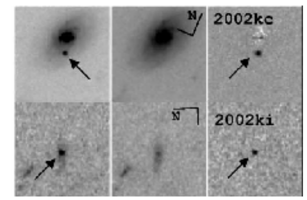
Repulsive Gravity—22 Apr

- “Though a good deal is too strange to be believed, nothing is too strange to have happened.” Thomas Hardy
- “Nothing is too wonderful to be true.” Michael Faraday
- Data on supernovae: distant supernova are faint, even for a universe with no mass.
- Dark energy/ cosmological constant
- Astronomical weighing
  - Define a motion
  - Time the motion
  - If a supernova is faint, the expansion took longer, and the universe has less mass.



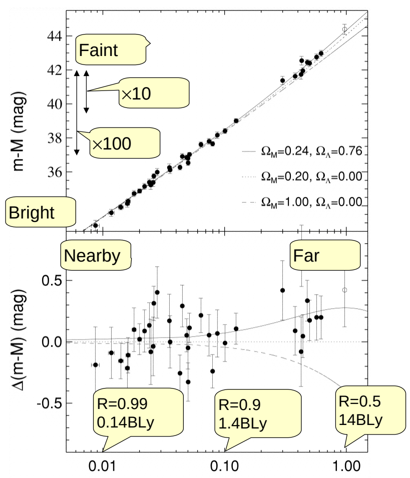
Weighing the Universe: Time the motion

- 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.)
- If the motion takes longer, the mass is less.
- If SN2002ki is bright, then the universe has lots of mass.



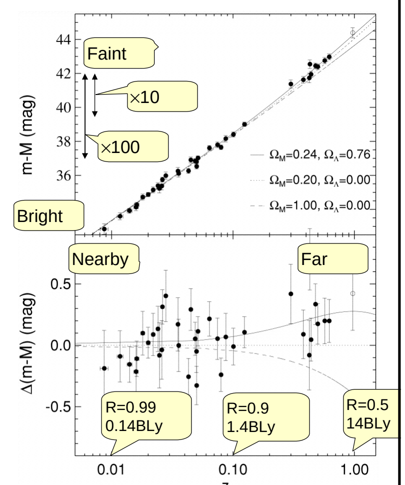
Observations

- Distant SN from Riess et al, 1998, ApJ 116, 1009. Nearby SN from several surveys
- Redshift z, scale R, and wavelength are related
  - R is distance between two galaxies when light was emitted compared with distance now.
  - $R = 1/(1+z)$
  - $R = \lambda_{emit} / \lambda_{now}$.

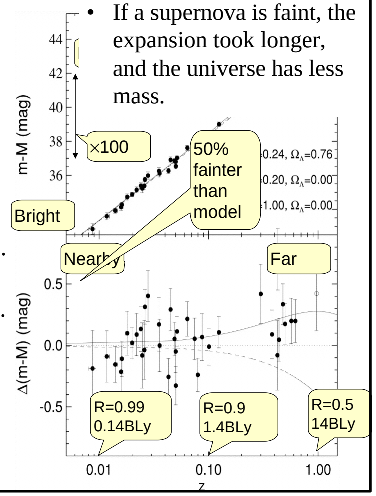


Observations

1. On upper plot, nearest SN is at
   a. upper right.
   b. upper left.
   c. lower right
   d. lower left.
2. For the most distant SN, the wavelength of light has ___ since the SN emitted it.
   a. doubled.
   b. halved.
   c. increased by 1%
   d. decreased by 1%.
3. If the universe had more mass, the distant SN would move
   a. up in the plot
   b. down in the plot



Interpreting



- If a supernova is faint, the expansion took longer, and the universe has less mass.

- Lower plot compares data to a model with density parameter Ω = 0.2.
  - Ω=PE/KE

4. The universe will expand forever if Ω = 0.2. a) T; b) F.
5. The data show U has less mass than Ω = 0.2. a) T; b) F.

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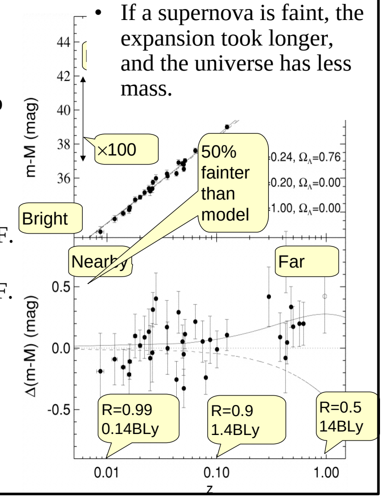

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- Distant SN are 20% fainter than model with Ω = 0.2.
- Distant SN are 15% fainter than model with Ω =0! No mass at all!

Huh?

- Distant SN are 15% fainter than model with Ω =0! No mass at all!
- If a supernova is faint, the expansion took longer, and the universe has less mass.
- If motion takes longer than model with no mass, need “negative gravity” or “repulsive gravity.”

Einstein’s General Relativity

- What causes gravity?
- Newton’s answer: mass.
  - Force of gravity on a little mass m
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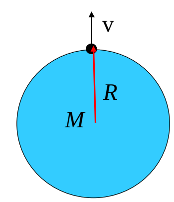
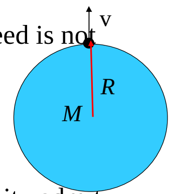


Cosmological Constant

- Einstein's answer: mass and pressure

  $F = G (M + 3P/c^2)\ m/R^2$.

- Ordinary matter is little pressure b/c speed is not near c.



- Radiation has positive pressure
  - Pressure is 1/3 mass.

    $F = G\ 2M\ m/R^2$.

- Einstein in 1920s: My equations of gravity admit "cosmological constant" where pressure is negative and equal to mass

  $F = G (M-3M)\ m/R^2$

  $F = -G\ 2M\ m/R^2$.

  - Repulsive gravity