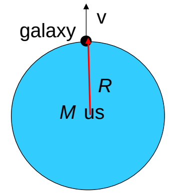
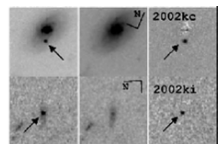
Weighing Univ.: Timing Expansion of Universe—28 Nov

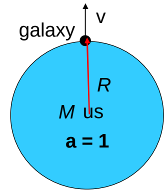


- "Though a good deal is too strange to be believed, nothing is too strange to have happened." Thomas Hardy
- How to weigh universe
  - Mass in a large sphere surrounding us pulls on a galaxy on the surface
  - Measure how much the galaxy slows.
  - Use supernovae
- What we will find: Galaxies speed up!
  - "Dark energy" is repulsive whereas matter and radiation are attractive.

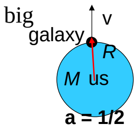


Distant supernovae
Riess et al, 2004, ApJ 607, 665.

If the motion takes longer, the mass is less.

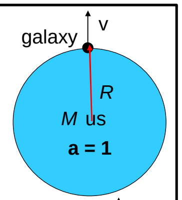


- Method for astronomical weighing:
  - Define a motion
    - Universe expands by a factor of 2, from a=1/2 to 1.
  - Time the motion: ??
  - If the motion takes longer, the mass is less. ☜
- Use a proxy: Supernova in a galaxy on surface of a big sphere centered on us.
  - Sphere contains many galaxies
  - 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 large.
   a. When R=1/2 R_{now} , was v larger, same, or smaller than v_{now}?
   b. Is time for U to expand by a factor of two larger, same, or smaller?

Timing the motion



- Method for astronomical weighing:
  - Define a motion
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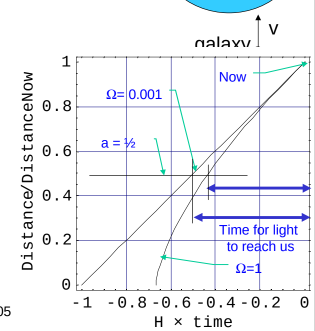
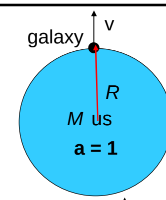
  - Time the motion ☜
  - If the motion takes longer, the mass is less.
    - For a greater mass density, the time for U to expand by a factor of two is smaller, because gravity is a bigger effect: proxy galaxy must have been moving faster in the past for it to have slowed to its present speed.



Timing the motion with supernovae



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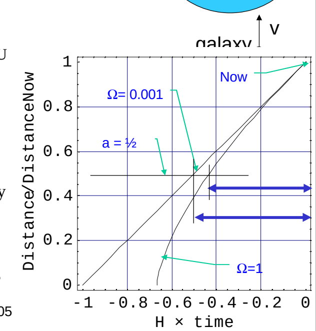
- Proxy is Type I supernova in a distant galaxy.
  - Type I supernovae have same luminosity

2. If we want the motion to be expansion by a factor of 2, we need a supernova with redshift z = ___.

- If supernova is brighter, then distance is less, and time is shorter, and mass density of U is greater.



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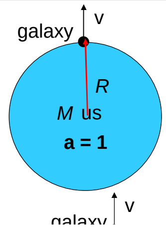

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2. If we want the motion to be expansion by a factor of 2, we need a supernova with redshift z = 1.

- Calibrate SN at small z where there is little dependence on Ω.

3. Suppose you discovered a SN at z=2 and found it to be faint. Then is Ω bigger or smaller. What on the graph gave you the answer?