Universe at 400,000yr: Weighing the universe—4 Dec

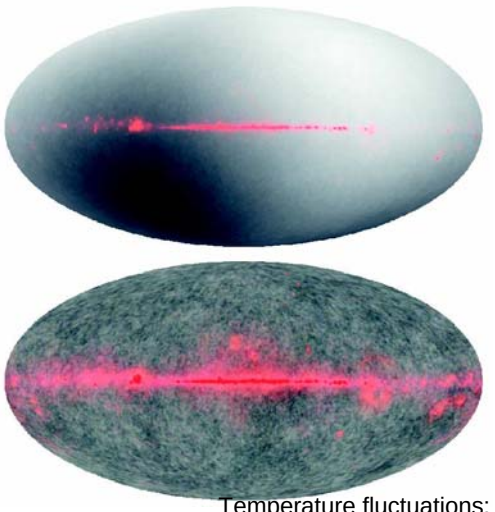
- Test 3 has been graded. Will be returned on Mon.
- Final exam
  - Covers entire course with emphasis on 20th century cosmology (Oct 28 to end of term, Hwk 7–10)
  - One 8.5×11" cheat sheet
  - Mon, 14th, 3:00-5:00, 1410 BPS (large classroom next door)
- Please fill out on-line SOCT (Student Opinion of Courses and Teaching) http://rateyourclass.msu.edu
  - Will close when grades are submitted.
- Review
  - Map of radiation from the Big Bang is mottled with an angular scale of 1°.
  - Physical size of hotter, denser regions is c×(age of U).
  - If universe has lots of matter, expansion is fast at beginning and slows down.
- Today
  - angle = physical size / distance ⇒ weighing the universe

Map of radiation from the Big Bang is mottled with an angular scale of 1°.

- Largest fluctuations are at an angular scale of 1º.
- Fluctuations are dense & sparse regions
  - Dense regions are hotter by 0.0002K.
  - Sparse regions are cooler.
- Effect of gravity can only go as fast as speed of light. Universe was not old enough to grow at larger scales.
- Size of largest fluctuations is

  1/3 (Age of universe)×(speed of light)

  About 400,000 light years

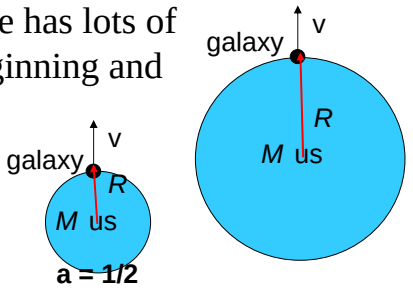


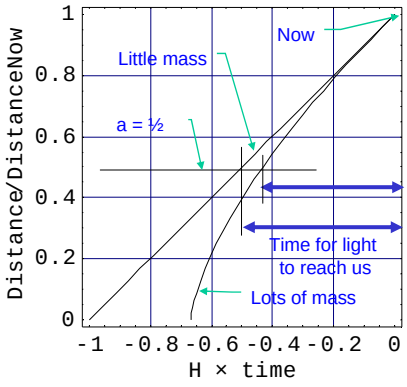
Temperature fluctuations: Light & dark mottling

Weighing Universe: If universe has lots of matter, expansion is fast at beginning and slows down.

- Principle for astronomical weighing:
  - Define a motion
  - Time the motion
  - If the motion takes longer, the mass is less.
- Consider a big sphere centered on us, which contains many galaxies
  - Mass inside sphere pulls on galaxy & slows expansion.
- Present speed & present distance are fixed by Hubble's Law.
- Consider this motion: Sphere (and U) expands from ½ present radius to present radius. If the time to expand by a factor of 2 is long, the mass density of the U is low.

1. Suppose you can measure the age of the U. If you get a high value (compared with 1/H), you conclude that the mass density of the U is ___. Hint: What is the motion?
   A. high.
   B. low.





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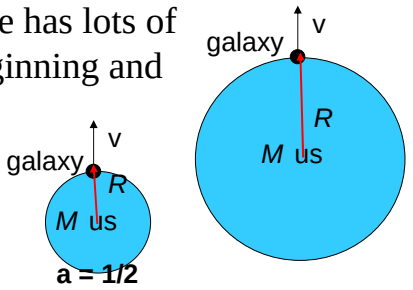
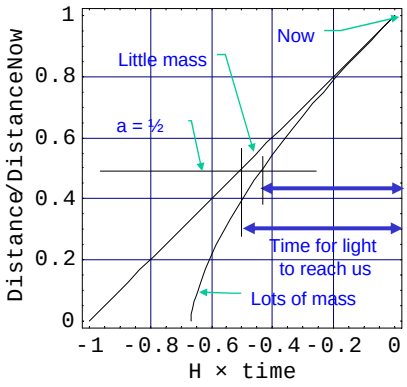
1. Suppose you can measure the age of the U. If you get a high value (compared with 1/H), you conclude that the mass density of the U is ___. Hint: What is the motion?
   A. high.
   B. low.
2. WMAP observed the radiation from the BB and saw blobs of hot gas. Consider the distance of these blobs. If the distance is higher, the mass density of the U is
   A. higher.
   B. lower.

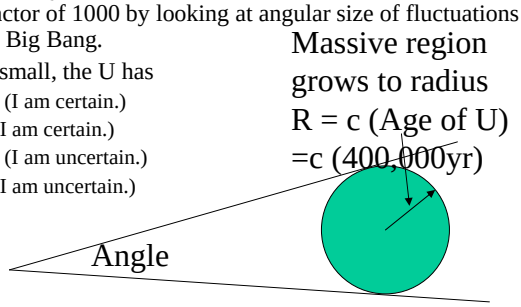




Weighing Universe using fluctuations in radiation from Big Bang

- Principle for astronomical weighing:
  - Define a motion
  - Time the motion
  - If the motion takes longer, the mass is less.
- To find mass density of the universe, measure the time it takes for the U to expand by a factor of 1000 by looking at angular size of fluctuations in radiation from Big Bang.

3. If the angle is small, the U has
   A. more mass. (I am certain.)
   B. less mass. (I am certain.)
   C. more mass. (I am uncertain.)
   D. less mass. (I am uncertain.)



Angle = 2R / Distance
Distance = c × (time for u to expand by factor of 1000)

Weighing Universe using fluctuations in radiation from Big Bang

- Principle for astronomical weighing:
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  - Time the motion
  - If the motion takes longer, the mass is less.
- To find mass density of the universe, measure the time it takes for the U to expand by a factor of 1000 by looking at angular size of fluctuations in radiation from Big Bang.

3. If the angle is small, the U has less mass.

- Result: Angle is large ⇒ Age of U is less than 1/H
  - The inference "⇒ Mass density is high" is incorrect.
  - The correct statement is "⇒ Sum of mass density and dark energy is high"
- Gravity is more complicated than what Newton thought and we have discussed.
  - More complete description of gravity next week.