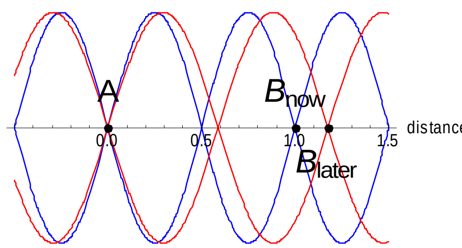
Radiation from the Big Bang—2 Nov

- Finish Hubble's Law
- Examples of expansion of the universe
  - Distant galaxy
  - "Gamma-ray burster," the farthest object.
  - What was measured? What was deduced?
- Four big discoveries in cosmology
  - Hubble's Law, expansion of universe 1929
  - Radiation from BB 1965
  - Dark matter 1930s
  - Accelerated expansion 1998
- BB radiation inspires questions and offers some answers
  - Where did helium come from?
  - Where did radiation come from?
  - What is universe made of?
  - When did the first stars form?
- Discovery (today)
- Radiation drives early history of the universe (rest of week)

Expansion stretches wavelength of light

- Principle: Wavelength of light stretches by the same factor as the universe expands.



Example: Very distant galaxy

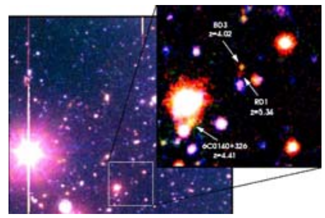
- Galaxy found by looking for red objects
- Key idea: Universe expands the same as wavelength of light.

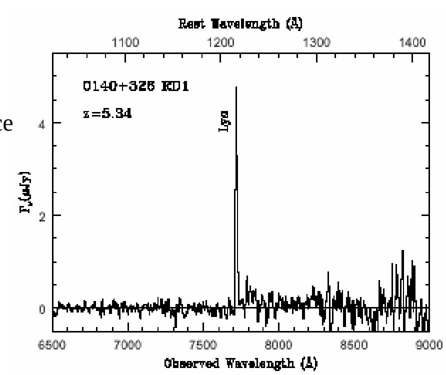
1. When the light that we see left Galaxy 0140+326 RD1, its wavelength was 1215 Å (121.5nm). We see its wavelength to be 7710Å. By what factor has the universe gotten bigger?
   A. between 2 & 3 times bigger
   B. between 3 & 4
   C. between 4 & 5
   D. between 5 & 6
   E. between 6 & 7

- U has expanded by a factor of 6.35 since the time the light left that galaxy.

  $D_{now}/D_{lightEmitted} = \lambda_{received}/\ \lambda_{emitted}$
  $= 7710/1215 = 6.35.$

- Redshift $z = \lambda_{received}/\ \lambda_{emitted}-1$
- $D_{now}/D_{lightEmitted} = 1+z$





Example: Gamma ray burst

- Gamma-ray burst is a short pulse of gamma rays (more energetic than X-rays).
- Some gamma-ray bursters are stars that collapse at the end of their life to produce a black hole.
  - Animation http://www.nasa.gov/mission_pages/swift/bursts/cosmic_record.html

Gamma ray burster 090423

Light coming to us from such a distance is stretched because the universe is expanding. The greater the stretching — called redshift — the more distant the object. The previous most-distant object, a galaxy, has a redshift of 6.96. GRB 090423 has a redshift of 8.2 and appears to observers as an extremely red point of light. When that explosion took place, the universe was more than times smaller than it is now. It's one thing to explore such remote recesses of time in theory.

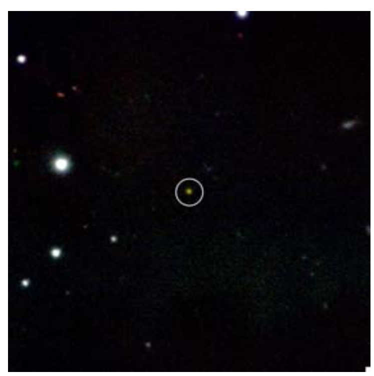
It's something else again to witness their afterglow. And GRB 090423 is an invitation for all of us to unfetter our imaginations. We imagine looking outward from that distant point knowing that our own exploration still lies some 13 billion years in the future.—NY Times Editorial 10/30/09

- How big was the universe when the star died?
  - Key idea: U expands the same as wavelength of light
  - Definition of redshift z

    $1+z = \lambda_{received} / \lambda_{emitted}$.

1. By what factor has the universe gotten bigger?
   A. between 5 & 6 times bigger
   B. between 6 & 7
   C. between 7 & 8
   D. between 8 & 9
   E. between 9 & 10

- $D_{today}/D_{starDied} = 1+z = 1+8.2 = 9.2$



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  - Key idea: U expands the same as wavelength of light
  - Definition of redshift z

    $1+z = \lambda_{received} / \lambda_{emitted}$.

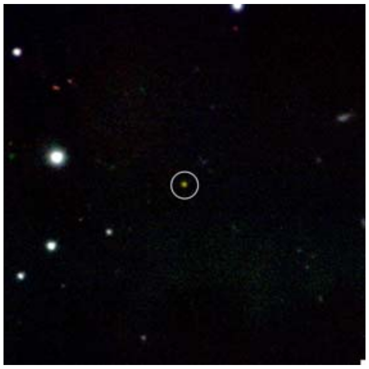
1. By what factor has the universe gotten bigger?

- $D_{today}/D_{starDied} = 1+z = 1+8.2 = 9.2$
- How old was the universe when the star died?
  - Key idea: H's Law: v = H D
  - Key idea: speed does not change much.
  - Key idea: Age of U is approx. 1/H.
  - Present age of U is 13Byr.

1. Hubble's constant was
   A. same as present value
   B. 9.2 times its present value
   C. 1/9.2 of its present value

- Not completely accurate b/c speed changes.
- The U was younger by a factor of 9.2 when star died b/c of key idea that age of U is approx. 1/H.
  - A better calculation: U was 600Myr old when star died.

Gamma ray burster 090423



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