Was Due Today - L16

- Reading:
  - (BBBHN M Unit 3)
- Pre-Lecture Reading Questions (PLRQ)
  - Unit 3, Stage 2: Due before class this coming Wednesday
- End-of-Chapter Quizzes:
  - Chapter 10
- Papers:
  - Paper 1 Revision (if desired), Stage 2: Due before class this coming Wednesday
    - Check on regrades to before submitting
    - Turn in to both CPR and turnitin on eCampus even if the text is the same (that way we know that it’s the same)
  - Paper 2, Stage 2: Due before class this coming Wednesday
    - Make sure you have submitted to both CPR and turnitin on eCampus
Overview

• Finished: The Exploding Universe

• This Time: Expansion of Space-Time and General Relativity

• After That: Photons and Hydrogen in the Universe
Outline

• General Relativity and Expanding Space-Time

• Expanding Space and Red-Shifts
Recapping the Data

Galaxies are moving away from us, faster if they are further away AND we see this to be true in ALL DIRECTIONS

Simple-but-wrong explanation: We are the center of an explosion!
Another Example of Expanding Space
The Expanding Universe

It’s not just galaxies moving through space

*Space is expanding, carrying the galaxies along!*

Big Bang, Black Holes, No Math

Evidence for the Big Bang

Topic 2: Expanding Space-Time
Galaxies Moving in Space

- Space is like a river carrying boats along
- Line is like the speed of the river
- Stuff above the line
  - Galaxies that are moving “away” from us in space
- Stuff below the line
  - Galaxies moving “towards” us
How does this explain why things are moving faster the further away they are?
Expanding Space

Analogy:
A loaf of raisin bread where the dough is rising and expanding, taking the raisins with it
More on Expanding Space-Time and Raisin Bread

http://bigbang.physics.tamu.edu/ Figures/StolenAnimations/RaisinBread.swf
Expanding Space-Time and Red-shifts
Photons in Expanding Space-Time

• Since space is so empty, light from 10 billion years ago can reach us just fine

• *What happens to photons as they travel in the Universe?*

• The wavelength gets stretched as space expands → The wavelength gets longer
What do photons look like in Expanding Space-Time?

A distant galaxy emits a short wavelength photon towards our galaxy billions of years ago.

The Grid shows space.
Space-Time Expands

The expansion of space-time stretches the photon to longer wavelengths as it travels.
The farther the photon has traveled, the more it is stretched.
How We Observe It

When the photon arrives at our galaxy we see it with a larger wavelength.

- The bigger the distance the more red-shifted it has become!

Even bigger as time goes by!
Red Shifts in an Expanding Universe

http://bigbang.physics.tamu.edu/ Figures/ StolenAnimations/ originredshifts1. swf
Galaxies Moving in Space again

- Red-shift due to expanding space
  - Stuff above the line
    - Additional red-shift due to galaxies moving away from us through space
  - Stuff below the line
    - Slightly less red-shift for galaxies moving "towards" us through space

- Galaxies Moving in Space again
  - Red-shift due to expanding space
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Expanding Space-Time

• Explains all the data (and more in next Chapter)

• Note: Implies that the Universe looks the same to “everyone” in the Universe “everywhere”
  
  - Said better: Everyone would observe all the distant galaxies moving away from them the same we do here on Earth

• Call this the Cosmological Principle
No Center of the Universe?

- Nowhere on the surface can be called the center
  - No “center” of the Universe
  - Or can consider “Everywhere” to be the “center” of expansion
  - Yes... As we’ve always known, Aggieland IS the center of the Universe

- There may well be no “Before” the Big Bang
  - General Relativity says space and time come into existence together
How big IS the Universe?

We can’t really know how big the Universe is, since all we can see is back a certain distance in time.

Could be infinite.

We talk about the Visible Universe.
Next... Move to more evidence we live in an expanding space-time by looking at photons and hydrogen in the Universe.
Lecture on Chapter 11 now complete
For Next Time—L16

- Reading:
  - (BBBHN M Unit 3)

- Pre-Lecture Reading Questions (PLRQ)
  - Unit 3, Stage 2: Due before class Wednesday

- End-of-Chapter Quizzes:
  - If we finished Chapter 11 then end-of-chapter quiz 11
    (else just up to Chapter 10)

- Papers:
  - Paper 1 Revision (if desired), Stage 2: Due before class
    Wednesday
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Evidence for the Big Bang
Topic 2: Expanding Space-Time
Full set of Readings So Far

• Required:
  - BBBHNM: Chaps. 1-12

• Recommended:
  - TFTM: Chaps. 1-3
  - BHOT: Chaps. 1-7, 9 and 11 (117-122)
  - SHU: Chaps. 1-3, 4(77-86), 5(95-104), 6, 7 (up-to-page 153)
  - TOE: Chaps. 1 & 2