Big Bang, Black Holes, No Math

ASTR/PHYS 109

Dr. David Toback

Lectures 6, 7 & 8
Prep For Today (is now due) - L8

- **Reading:**
  - BBBHNM Unit 2 (already due)

- **Pre-Lecture Reading Questions (PLRQ):**
  - Unit 1: Pass/Revise grades on eCampus. Let us know if you were misgraded.
  - Unit 2: Let us know if you were misgraded.
  - Unit 2 - Revision (if desired), Stage 1: Was due before class today

- **End-of-Chapter Quizzes**
  - Chapter 4 (already due)

- **Papers**
  - None assigned

**Biholes, No Math**

**Topic 1: Light and Doppler Shifts**
The Topics

• Some stuff we need learn a little about:
  1. Light and Doppler Shifts
  2. Gravity, General Relativity and Dark Matter
  3. Atomic Physics and Quantum Mechanics
  4. Nuclear Physics and Chemistry
  5. Temperature and Thermal Equilibrium

• We won’t spend too long on each, just enough to get back to the big picture...

• Since there is no perfect way to present them (they all tie into each other) we’ll just start somewhere and get going...
Look at Light from Galaxies

- The light from galaxies moving away from us will appear to have longer wavelength light
  - The light is more Red, or shifted to the Red side of the light spectrum
  - “Red Shifted”
- The light from galaxies moving towards us will appear with shorter wavelength
  - The light is more Blue, or shifted to the Blue side of the light spectrum
  - “Blue Shifted”
Look at some cases

Next lets look at two cases where an “explosion” occurs and things expand from that point

1. I’m stationary and the exploding things are moving away from me (I’m the center of the explosion)

2. I’m moving along with the exploding things

   1. How would this look to an outside observer?

   2. How it would look to me in my reference frame?
Case 1: Two Objects Moving Away from Me

What it looks like when I’m stationary (or in my reference frame)
Case 2: Two Objects Moving Away from the explosion, including Me (viewed by someone else)

What it looks like when I’m moving relative to the objects

Redshift
Case 2: Two Objects Moving Away from the explosion, including Me (from my perspective)

Why were these cases important?
Sorry... you'll have to wait until we look at galaxies sending us light
Doppler Effect and Light: Summary

Compare the light coming from a car that's parked and one that's coming towards you. If a car is coming toward you with its lights on:

1. The color of the light changes
2. The speed of the light does not!
Putting It All Together

Since stars can be billions of light-years away, and are moving quickly, we can use the Doppler effect on light to measure the speed and direction of all objects in the night sky - More in Chapter 10

(Can also use it to tell us what Stars are made of, but for that we need to learn about quantum mechanics...)
Lecture on Chapter 5 now complete
Outline for Unit 2: Physics We Need

1. Light and Doppler Shifts ← Done

2. Gravity, General Relativity and Dark Matter ← Next

3. Atomic Physics and Quantum Mechanics

4. Nuclear Physics and Chemistry

5. Temperature and Thermal Equilibrium
Heads Up: Paper 1

• What is the evidence for Dark Matter?
• This will be the topic of Paper 1

• In order to understand the evidence, we next talk about gravity and Dark Matter
• Will be due 1 week after we finish Chapter 6
Next few slides are on course organization, grades etc...

And

• Papers
Help Available for Stage I

- For Papers you can submit a draft for feedback from the TA if desired
  - Submit on eCampus in “Rough Drafts (Optional)”
  - Drafts due Friday at 11:55PM
  - If you submit late, we can try to give feedback but we can’t guarantee it
- We also recommend going to the Writing Center
Style of the Paper

• Explain it to someone who isn’t taking the class (no jargon)
• ~600 words (This is the equivalent of both sides of a sheet of paper, double spaced)
• No citations! Use your own words
• Only use information from the book
• Text should be professional. You are “trusted guide” not a “buddy” or “comedian”
Paper Format

- Must follow expected Format
- Each paper is usually 5 paragraphs:
  - Introduction paragraph that outlines the evidence
  - 1 paragraph per piece of evidence (3 total?)
  - Conclusion paragraph that ties it together

http://people.physics.tamu.edu/toback/109/WritingAssignments/samplepaper.shtml
When papers will be assigned

- Papers will announced before we start the chapter
- Assigned after we finish the chapter
- Will have 1 week for Stage 1, and 1 week for Stage 2
- 4 Papers
  - Paper 1:
    - Assigned after Chapter 6, Typically week 5
  - Paper 2:
    - Assigned after Chapter 8, Typically week 7
  - Paper 3:
    - Assigned after Chapter 12, Typically week 10
  - Paper 4:
    - Assigned after Chapter 17, Typically week 14
Example Notes: Paper 1

• Abbreviated description: What is the evidence for Dark Matter?
  - More detail on CPR, you REALLY need to read ALL the instructions
• Explain it to someone who isn’t taking the class (no jargon)
• Follow the required Format:
  - Introduction paragraph
  - ~1 paragraph per piece of evidence
  - Conclusion paragraph that ties it together
• Help:
  - Example of good paper
    http://people.physics.tamu.edu/toback/109/WritingAssignments/samplepaper.shtml
  - The first 9 Rubric questions
Biggest reason people don’t do well

1. Read ALL the instructions on CPR
   - See the FAQ on papers
2. Don’t forget to submit to turnitin.com
3. We are NOT giving you the Rubrics for the papers, but lots of hints about what the Rubric questions will contain are in the Writing Prompt and Goals sections
Outline for Unit 2: Physics We Need

Topics
1. Light and Doppler Shifts ← Done
2. Gravity, General Relativity and Dark Matter ← Today
3. Atomic Physics and Quantum Mechanics ← After that
4. Nuclear Physics and Chemistry
5. Temperature and Thermal Equilibrium
Why Gravity Next?

- By looking at photons/light we can learn about things here on Earth as well as about inner/outer space.
- What else do we need to describe/understand the Universe? → Quantum Mechanics and Gravity.
- To understand the answer to these questions we need to learn more.
The Two Great Theories

• **General Relativity:** (Gravity) Predictions about the very large, from sizes of a few meters to the size of the universe ($10^{24}$ miles across)

• **Quantum Mechanics:** Predictions about the very small (atoms, particles, $<10^{-10}$ m)

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Physics We Need

Topic 2: Gravity
Overview of Gravity for the Course

1. What's so important about Gravity?
2. Newton's Theory of Gravity
3. Einstein's more-correct version - Curved Space-Time, and evidence for it with Dark Matter

We Need 2: Gravity
Gravity: Why do we care?

• **Gravity:** The great attraction in the Universe
• Gravity is the theory that predicts the attraction and the motion of BIG things over large distances:
  - Planets
  - Suns
  - Galaxies
  - How Galaxies form etc.
Newton and Gravity

1. Everything moves in a straight line unless acted upon by a force
2. Gravity is a force
   - Every object in the universe attracts every other object in the universe
   - The further the distance between the objects, the smaller the attraction
   - The bigger the mass, the bigger the attraction
   • Light is massless \( \rightarrow \) not affected by gravity
Large Number of Scales

Kinda amazing!

Gravity covers the attraction between
- An apple near the Earth
- The Earth and the Moon
- The Earth and the Sun
- The Sun and our galaxy
- Our galaxy and the universe
- Every particle in the universe and an apple
- The Earth and you
- Bevo and Reveille
Gravity continued...

The force of Gravity makes the Moon "fall" towards the Earth

→ Call this an orbit

- Does a great job of explaining how the planets move around the Sun

Without gravity, the Moon would fly off into space and ignore the Earth completely
What’s next?

Tell you the different, and surprising, way that Einstein describes space, time and gravity

Then tell why his description of why the Earth goes around the Sun is better than Newton’s
Einstein in the 1910’s

- In the early 1910’s Einstein was thinking about some recent experimental results that didn’t make any sense to him using Newton’s theories.
- Decided we need new ways of thinking about space, time, and Gravity.
- Einstein says that Newton’s Laws aren’t really quite right...
- Einstein’s theory is known as the “General Theory of Relativity.”
Observational Fact

Light *ALWAYS* moves at the speed of light to all observers

So what?
What happens if I'm driving a car moving at half the speed of light and I turn the headlights on?
Two observers get different answers

From the perspective of the person on the side of the road, the car moves at half the speed of light and the photon moves at the speed of light. After 2 nanoseconds, the photon is 1 foot ahead of the car.

From the perspective of the driver, the car is stationary and the photon moves at the speed of light. After 2 nanoseconds, the photon is 2 feet ahead of the car.

The light is one foot ahead of that car!

The light is two feet ahead of me!
Prep For Next Time - L8

- **Reading:**
  - BBBHNM Unit 2 (already due)

- **Pre-Lecture Reading Questions (PLRQ):**
  - Unit 1: Pass/Revise grades on eCampus. Let us know if you were misgraded
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- **End-of-Chapter Quizzes**
  - If we finished Chapter 6 then End-of-Chapter Quiz 6 (else just Chapter 5a&b)

- **Papers**
  - Paper 1 will be assigned when we finish Chapter 6