Prep For Today (is now due) - L5

• Reading:
  - No new reading
  - Unit 2 reading assigned today

• Pre-Lecture Reading Questions (PLRQ)
  - Boot Camp quizzes in eCampus: was due before class
  - Unit 1, Stage 1 in CPR: was due before class

• End of Chapter Quizzes
  - Chapter 2: Was due already

• Papers
  - None assigned
  - First one will be assigned when we do Chapter 6
Next Topic: Going Small

- Finished looking at various things in the universe going from the sizes we know to the VERY big
- Next we do the very small
- Why? If we want to understand the universe we need to know what’s in it and what it’s made of
- Why and how did it get to be the way it is?
Inside the Proton

Three quarks inside the proton
- Protons are composite
- Quarks are fundamental

Quarks not to scale

Three quarks inside the proton:
- u
- u
- d

A scale is shown in meters:
- 0 m
- 0.5 x 10^{-15} m
- 10^{-15} m

10^{-15} meters

Big Bang, Black Holes, No Math
Introduction
Topic 3: Going Small
Other Fundamental Particles?

- Electrons and quarks (as far as we know) are fundamental
- Lots of other fundamental particles
- Recently discovered the Higgs Boson
Protons are stable $\rightarrow$ live forever

Neutrons outside a nucleus are unstable $\rightarrow$ can decay

Neutron $\rightarrow$ Proton + Electron + Neutrino

Note that this only happens when Neutrons are by themselves (not in an atom)
Questions...

• How large are electrons and quarks?
  - We don't know... that's what I (and others) do for a living...

• What are they “made of”? Are they made of anything? Strings?

• Are there other fundamental particles we haven't discovered?
Lecture on Chapter 3 now complete
Next Topic: Scientific Methods

Unit 1:
1. Introduction \(\leftrightarrow\) Done
2. Going Big \(\leftrightarrow\) Done
3. Going Small \(\leftrightarrow\) Done
4. Evidence and the Scientific Method \(\leftrightarrow\) Today

Today we move on to the Questions and How we go about answering them
Plan for the Next Few Weeks

1. More on the **Questions** and **How** we go about answering them

2. Some of the history to teach us about the method

3. Need to learn some physics

Today

Unit 2
(Chapters 5-9)
Next few Weeks Continued...

To learn Cosmology will need to learn a bit 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

Won't spend too long on these, just enough to get back to the big picture...
Evidence and The Scientific Method

• Finished: What are some of the clues at the scene of the crime?

• Next: How can we use the clues to figure out what happened? Any WHY?

• Scientific Method
  - How do we know what we know?
  - What is the evidence for some of the “true things” we heard growing up?

  • E.g. Earth goes around the Sun
How do we know what we know?

• We have a lot of experience in the world around us

• Unfortunately, our experience is really lousy in guiding us to really understanding the bigger (and smaller) things in nature unless we’re really careful
  
  – We can misinterpret the clues

• As you’ve already seen, the world is incredibly complex and much of it is different from what we experience
  
  – Good clues are hard to find,

  Bi... sometimes even harder to interpret
Single example to Show the Scientific Method in Action

- People have watched the sky and noticed that the stars (the dots of light in the sky) basically all move together over the course of the night and over years.
- Five of them behave differently.
  - Start this story in the 2nd century.
Fun Videos of Just the Stars

Start with things you can see with your own eyes!

Video of stars moving with Polaris (north star) at the center
https://www.youtube.com/watch?v=XTTDWhky9HY

Video of stars moving, including the Milky Way (from Chile)
https://www.youtube.com/watch?v=JEHm-XUHwNw
Ptolemy’s Universe (2nd century)

The Sun, Moon and Stars go around once a day, but a few (the planets) change their position relative to the other stars a little every night.

Every so often the planets move backward through the stars for awhile

Hypothesis: They orbit the Earth in mostly circular paths.

Best guess: these are mini-orbits way out there (epicycles)... Hmmm...
Looking at Mars in the Stars

![Diagram of Mars from Earth](https://example.com/mars_diagram.png)
How Ptolemy envisioned it

• The big circle is the main orbit, and the little circle is the epicycle
• This explains why the planets seem to go back and forth out there in space (retrograde motion) every so often

http://bigbang.physics.tamu.edu/Figures/StolenAnimations/ptolemy.model.swf
Cracks in the `early cosmology'

In 1514, Copernicus hypothesized that the Planets and the Earth orbit the Sun.

Much simpler in some ways

- no epicycles

More complicated in others

- Says Earth is rotating
Copernicus’s “Hypothesis”

A more modern view of the motion of the Earth and Mars and the stars behind them (from the point of view of the center)

How would this explain the epicycles that people saw?

http://bigbang.physics.tamu.edu/ Figures/StolenAnimations/mars_retrograde_motion.swf
If we lived in the 1500’s, should/would we have believed Copernicus?

The Earth isn't at REST and rotates?

• Shouldn't we FEEL this?
• If the Earth is rotating, why don't we fall off like an ant on a bicycle wheel?
• Why don't we feel a wind as we rotate?
• Why doesn't the rotating Earth move under our feet when we jump?
Cracks in the `early cosmology’

Should his view have just “been accepted”?

Perhaps his theory was just a “different interpretation” of the same data?

- Both models are consistent with observations

Need more evidence!

Need a better TOOL to test, experimentally, which is correct

Early 1600’s: Kepler and Galileo started gathering data from telescopes
Data Provides Evidence

Discover moons orbiting Jupiter! ➔
Solid evidence that not EVERYTHING orbits the Earth!
Another Piece of Evidence

- Can understand the phases of the Moon because of the locations of all three

- Not eclipses

![Diagram of the phases of the Moon]

- Waning crescent
- Moon
- Waning gibbous
- New
- Waxing crescent
- Earth
- Waxing gibbous
- Full
- Sun

Not to scale
Venus

- Consider the two different predictions of how Venus moves in space
The Phases of Venus

- Venus has a full set of phases, like the moon
  - Sunlight shining off Venus and to our eyes
- No good way to explain this if Venus goes around the Earth

Big Bang, Black Holes, No Math
More data

• With more accurate data Kepler realizes an even better description of the data is that all planets orbit the Sun in an ellipse, not a circle.

• Sun-centered model now agrees with the high-quality observational data, Earth centered model does not.

• No good REASON for ellipses though... then again, no good reason they should be circles (except people LIKE circles, and they are more “perfect”)
Need to separate the issues

• The fights at this point were about HOW the planets move

• There was no good explanation of WHY they move that way

• If some one could explain WHY they move that way, then maybe we can learn something close to the truth about the universe/nature
The next generation...Newton

• Newton puts forward his theory of **Gravity** and describes it as a **Force**

• **So what?** The same force that pulls an apple to the ground from a tree **ALSO** pulls the planets towards the Sun and keeps them in orbit

• This “explains” why both the orbits are ellipses **AND** why we don't fall off a spinning Earth

Isaac Newton 1687
Scientific Method

The history is fun, but we have a problem:

• **How do we separate true stories from stories we’d like to believe, but aren’t actually true?**

• **Need EVIDENCE and a good Scientific THEORY**
  - Good hypothesis testing
Lecture on Chapter 4 now complete
Outline for Unit 2: Physics We Need

Topics

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
Prep For Next Time - L5

- **Reading:**
  - Required: BBBHNM Unit 2 (Chapters 5-9)
  - Recommended Reading:

- **Pre-Lecture Reading Questions (PLRQ)**
  - Boot Camp quizzes in eCampus: was due before class
  - Unit 1, Stage 2 in CPR: due before class Monday
  - Unit 2, Stage 1 in CPR: due before class Monday

- **End-of-Chapter Quizzes**
  - If we finished Chapter 4 then End-of-Chapter Quiz 4 (else just Chapter 3)

- **Papers**
  - None assigned
  - First one will be assigned when we do Chapter 6