Big Bang, Black Holes, No Math
ASTR/PHYS 109
Dr. David Toback
Lecture 4
Prep For Today (is now due) - L4

• Reading:
  - No new reading

• Pre-Lecture Reading Questions:
  - PLRQ Unit 1: Was due Tuesday before class
    • Grading in progress/will be posted soon (let us know if you were misgraded)
    • This assignment is Pass/Revise: You must get a 10/10. If you need to do a Revision, please submit a revision before class on Monday
    • Send mail to 109help if you need an extension

• eCampus Stuff:
  - All Warm-up quizzes (including AMS): Was due Tuesday before class
    • Extensions granted if needed. Email 109help
  - EOC 2: Was due before class

• Papers
  - Paper 0 (Reviewer Training): Will be assigned when we finish Chapter 4
  - You must do all the required parts of this assignment to pass it
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
- Then we can get to the "Why and how did it get to be the way it is?"
Starting out with small things

A baseball is a size we know from everyday experience.

10 centimeters, or 0.1 meters, or \(10^{-1}\) meters. About 3 inches.
Getting smaller

Something smaller you can see with your eyes

0.01 meters, \((10^{-2} \text{ m})\) or 1 cm, or about a \(1/3\) of an inch
Much smaller

A simple dust mite is barely visible with the naked eye

Into the realm of biology

10^{-3} meters or 1 millimeter

Much smaller
A human hair

Looking at the side view of a single hair

10^{-4} meters
Closer still...

A single red blood cell

10^{-5} meters
Further still

An HIV virus which is one of the bigger known viruses

10^{-6} meters
A polio virus which is known to be one of the smaller viruses

10^{-7} meters
The Double Helix

A close up of the helical structure of DNA

Starting to get into Chemistry

10^{-8} meters
Introduction

Topic 3: Going Small

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An Atom

- What we’re seeing is the electron “cloud” as it goes around the atom
- Kinda like the blades of a fan
- The realm of Physics

10^{-9} meters or 1 nanometer

10 million in a cm
Inside an Atom

- Snapshot in time of 2 electrons "orbiting" the nucleus
- Atoms are "composite" things, not fundamental

![Diagram of an atom showing electrons and nucleus](image)

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Introduction

Topic 3: Going Small
The Central Part of the Atom

- The electrons are outside our field of view

The Central Part of the Atom

• The electrons are outside our field of view

10^{-11} meters

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Introduction

Topic 3: Going Small
Homing in on The Nucleus

- Still zooming into the center of the atom
- The atom is mostly empty space

\[ 10^{-12} \text{ meters} \]
The Structure of the Nucleus

Can just start to see the “stuff” inside the nucleus

The nucleus is not fundamental

10^{-13} meters
Protons and Neutrons

- A carbon atom has 6 protons (blue) and 6 neutrons (grey)
- VERY tightly packed

\[ 10^{-14} \text{ meters} \]
Inside the Proton

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

Quarks not to scale

10^{-15} meters
Other Fundamental Particles?

- Electrons and quarks (as far as we know) are fundamental
- Lots of other fundamental particles
- Recently discovered the Higgs Boson
Anti-Matter

Each fundamental particle has an anti-matter version which is also fundamental.
Stable and Unstable Particles

Protons are stable → live forever
Neutrons outside a nucleus are unstable → can decay
Neutron → 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…

• Are we SURE they are fundamental? Could they made of something smaller? Strings?

• Are there other fundamental particles we haven’t discovered?
Lecture on Chapter 3 now complete
Prep For Next Time - L4

• Reading:
  - No new reading

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  - EOC 2: Was due before class
  - EOC 3: Due before class Tuesday

• Papers
  - Paper 0 (Reviewer Training):
    • Nothing to write!
    • Will be assigned when we finish Chapter 4
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Full Set of Readings So Far

- **Required:** BBBHNM: Chap 1-4
- **Recommended:**
  - BHOT: Chap. 1-3
  - SHU: Chap. 1-2
  - TOE: Chap. 1