Big Bang, Black Holes, No Math

ASTR/PHYS 109

Dr. David Toback

Lectures 3 & 4
No one in back 2 rows and no laptops or cellphones
Send email if you need help/an extension. All this is in the lecture notes!!

• Reading:
  - (BBBHNM Unit 1/Chapters 1-4)

• eCampus Stuff
  - (Warm-up Quizzes Part I, Quiz 1, 2 and AMS I)
  - (Warm-up Quizzes Part II, Quiz 1-5)
    - Optional help quizzes available
  - Warm-up Quiz Part III: Will be assigned today

• Pre-Lecture Reading Questions:
  - (Unit 1 Quiz parts A & B)

• End-of-Chapter Quizzes:
  - Nothing assigned (Will assign EOC 2 when we finish Chapter 2)

• Honors Section:
  - Be working on Stage 0, send your weekly email

• Other Prep
  - Bring lined paper and your iClicker to class
The Very Big: Why Start Here?

• If we want to understand the universe and where it comes from (and what’s going to happen to it) we need to know:
  1. What’s in it
  2. What it’s made of

• Said differently, “What are we trying to explain?” or “If the Big Bang is the answer, what is the question”?
  - If we were detectives trying to explain what happened, we’d need to gather evidence:
    - What evidence do we gather by looking at the scene of the crime?
More Earth

The Earth is a ball (sphere) in space

10^8 meters!
More Drawings

Orbit of the Moon (27.3 days)

The Earth

10^9 meters, a billion meters (a gigameter), a million miles

Introduction
Topic 2: Going Big
The Earth orbiting the Sun

- The Earth on its trajectory around the sun
- The Moon going around the Earth
- $10^{10}$ meters!
Earth around the Sun

Orbit of the Earth
- Yellow circle is the Moon's orbit
- Orbit of Venus

10^{11} meters!
The Inner Planets

- Mars, Earth, Venus and Mercury orbiting the Sun
- All the planets move in the same direction (counterclockwise in this picture)
- A clue that something important is/was going on?

\[ 10^{12} \text{ meters}! \sim \text{A billion miles!} \]
The Outer Planets

- Jupiter, Saturn, Uranus and Neptune

- Again all move in the same direction!

Look from the side: All move in the same plane!

Another clue?

$10^{13}$ meters!
Aside on why Pluto isn't a planet

The Not-Planets

Many large objects in space, once classified as planets, are now classified as asteroids or Kuiper Belt objects. These are the ones spacecraft have visited.

Earth's Moon:

Saturn satellites:
Mimas  Enceladus  Tethys  Dione  Rhea

Uranus satellites:
Miranda  Ariel  Umbriel  Titania  Oberon

Jupiter satellites:
Io  Europa  Ganymede  Callisto

Pluto system:
Pluto  Charon

Asteroids:
Vesta  Ceres

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Introduction
Topic 2: Going Big
The Whole Solar System

- Mostly empty space, but some stuff
- Typically only 1 hydrogen atom per cubic centimeter (size of a standard die)
- There is other stuff we’ll talk about like cosmic background radiation and dark matter

10^{14} meters!
Mostly Empty Space

• More interstellar space

The small circle is the orbit of Pluto

$10^{15}$ meters!

~trillion miles
Introduction

Topic 2: Going Big

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On this scale the solar system is a tiny dot

$10^{16}$ meters!
The Nearest Stars

- Alpha Centauri A, Alpha Centauri B and Proxima Centauri
- Proxima Centauri is the closest at $4.0 \times 10^{16}$ meters from the sun
- Same as 4.2 light-years away
  - (it takes light 4.2 years to get there)
  - 1 light-year is about 25 trillion miles

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Introduction
Topic 2: Going Big
The Brightest Stars in Our Sky

- Only the brightest stars are shown
- Almost 2000 in reality

10^{18} meters!
~Quadrillion miles

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Introduction
Topic 2: Going Big
Next Round...

- Again, only the brightest
- ~2 million total in this space

10^{19} meters!
The Milky Way

So many stars that they appear to be “clouds” of stars.

Much of the space between stars contains “Dark Matter” we can’t see directly.

- About 5 times more mass in Dark Matter than the stars.

10^{20} meters!
Our Galaxy

- Central Bulge
- Spiral arms

The sun is in one of the spiral arms, ~1/3 of the way inward from edge of the disk towards the center.

10^21 meters!
~Quintillion Miles

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Two Different Views of our Galaxy

Looking down at the center

Very flat… like our Solar system.
Outer stars rotating the same direction… like our solar system

Could the galaxy and the solar system have something in common?
Created in similar ways?

Looking at it from the side

100,000 ly

50 times wider than tall!

2000 ly

Our Sun
Looking at the “Mass” in the Galaxy

- In the previous picture, we showed the location of the stars
- There is a LOT more mass in the dark matter than in the stars
  - More on dark matter in Chapter 6
  - Shown here in blue, but we can’t see it with our eyes
Our Neighbor Galaxies

• There are dwarf galaxies just outside our own

• Didn’t even know there were other galaxies until the 1920’s

10^{22} meters!
The Full Size Neighbors

- Many galaxies nearby
- Galaxies are often found in “clusters”
  - Can be just a few, up to thousands

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Introduction
Topic 2: Going Big
The Local Group

- Our galaxy (the Milky Way) is part of a cluster of galaxies called the “Local Group”
- These distant galaxies are moving away from us VERY quickly
  - Big Bang

10^{24} meters!
~Sextillion miles
Our “Observable” Universe

- $10^{11}$ galaxies (about the same number of stars in our galaxy)
- We’re on the fringe of a very large cluster of galaxies called the “Local Supercluster”
- Don’t know the true shape and size of the universe so we can’t go any further

**Introduction**

**Topic 2: Going Big**
Lecture on Chapter 2 now complete
Prep For Next Time – L4

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• Reading:
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• eCampus Stuff
  - (Warm-up Quizzes Part I, Quiz 1, 2 and AMS I)
  - (Warm-up Quizzes Part II, Quiz 1-5)
    - Optional help quizzes available
  - Warm-up Quiz Part III: Due before next class

• Pre-Lecture Reading Questions:
  - (Unit 1 Quiz parts A & B)

• End-of-Chapter Quizzes:
  - If we finished Chapter 2 then End-of-chapter quizzes 1 and 2 (else just above)
  - Folder doesn’t open until you are done with Parts 1-3 of Warmup and PLRQ Unit 1

• Honors Section:
  - Be working on Stage 0, send your weekly email
Useful Links

- **Course Website**

- **Course Organization**

- **Class Schedule**

- **eCampus Instructions**

- **PLRQ Instructions**

- **Lecture Notes**

- **Papers and Peerceptiv**

- **FAQ Page**
Full Set of Readings So Far

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