Big Bang, Black Holes, No Math
ASTR/PHYS 109
Dr. David Toback
Lectures 21 & 22
Was due Today - L22

- **Reading:**
  - (Unit 5)

- **Pre-Lecture Reading Questions (PLRQ):**
  - Unit 4 Revision (if desired), Stage 2: Was due today before class
  - Unit 5, Stage 1: Was due today before class

- **End-of-Chapter Quizzes:**
  - Chapter 14 A&B

- **Papers:**
  - Paper 3, Stage 2: Due before class Monday April 17
    - 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)

- **General:**
  - Still behind the Syllabus Schedule, due dates will be extended

- **CPR:** Mis-graded on any Assignment? Let us know
Unit 5: Big Objects and Black Holes

1. Galaxies
2. Star Birth and Death
   • Black Hole Formation
3. Properties of Black Holes
Galaxy Formation: Overview

• Big picture: What Galaxies “look like”

• A gravity dominated Universe allows galaxies to form

• When do galaxies form?
Visualizing a Galaxy

• The light comes from the stars
• Most of the mass is Dark Matter

In some ways, Dark Matter surrounds the stars in a galaxy like the water in a fishbowl surrounds a fish in the middle of the bowl. Not exactly the same... denser in the middle because of the pull of gravity.
Two example “Types” of Galaxies

**Spiral Galaxy:**
- Bulge in the middle
- Disk on the sides
- Like the Milky Way

**Elliptical Galaxy:**
- One giant bulge, stars are like bees buzzing around the center, biggest galaxies are ellipticals
From the Early Universe to Galaxies

• After about ~3 minutes things are cool enough for nuclei to form

• After ~300,000 years things are cool enough for electrons and nuclei combine to form atoms

• Let’s move to a half a billion years after the bang
Where are we now in the history?

- Half a billion years after the bang
A Gravity Dominated Universe

• The gravitational attraction between massive things ONLY makes them move towards each other through space

• Dark Matter and atoms are neutral and massive

• Both are most attracted to the closest place with lots of mass
  - Biggest dent in space-time
Wait a Half Billion Years

• As the years go by, mass clumps together
• By a half a billion years after the bang, most of the mass is in one of a large number of "clumps"
• Huge numbers of these clumps, each helps form galaxies!
Galaxy Creation Over Time

A region of the universe soon after the big bang is filled with hot, dense gas and radiation.

The same region now has expanded and cooled, and the matter has formed galaxies.

Soon after the big bang

Now
Galaxy Formation Analogy: People Jumping on a Trampoline

If two people touch, then they will stick together.

If they fall they create a big dent in the trampoline (like a dent in space-time).

Once you get that first dent on the trampoline everyone starts falling into it.
More Analogies

1. Water being poured into a bowl and flowing to the bottom

2. Water swirling in a bowl

3. Water in a bathtub with the drain open (and ignoring what happens to the water that goes down the drain)
Water Flowing

- Think about water moving towards a drain in the bathtub
  - All falls in quickly → can get bubbling at the drain
  - Falls in slowly → Get swirling
- This is how different types of galaxies can form
Stars in Galaxies

• Atoms fall towards the center of the galaxy or orbit around it
• Stars form where there are lots of atoms
• Once the atoms form stars there is a large amount of distance between stars
  - About 4 light years between us and our nearest neighbor star
  - An important exception is binary stars where two stars formed together
• Stars can orbit around the center of the galaxy
Slow Atoms Outside the Galaxy

Where does the disk of the Milky Way come from?

Lots of atoms moving around, far outside the center of the galaxy
Spinning into Shape

- Gravity attracts mass to the densest place
  - Center of the Galaxy
- As the mass is pulled in, it starts moving slightly around the center
- Why does this happen?
**Analogy: Ice Skater**

- Matter far away from the center → Spins slowly
- Pull the Matter in → Spins faster

For those of you who have taken PHYS 218, this is Conservation of Angular Momentum

- You've seen this on TV
- Try this at home in a chair that rotates
- Get yourself spinning with your arms and legs stretched out, then pull them in

Can also think about water falling into a drain
Dark Matter Vs. Atoms

• Dark Matter and Atoms behave differently in galaxies

• When atoms get near each other they can bump into each other like people trying to exit a movie theater

• Dark Matter is more like two ships passing in the night
For Next Time - L22

- Reading:
  - (Unit 5)

- Pre-Lecture Reading Questions (PLRQ)
  - None

- End-of-Chapter Quizzes:
  - Chapter 15 (if we finished Chapter 15, else just Chapter 14 A&B)

- Papers:
  - Paper 3, Stage 2: Due before class Monday April 17
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Full set of Readings So Far

• Required:
  - BBBHNM: Chaps. 1-16

• Recommended:
  - TFTM: Chaps. 1-5
  - BHOT: Chaps. 1-7, 8 (68-85), 9 and 11 (117-122)
  - SHU: Chaps. 1-3, 4(77-93), 5(95-114), 6, 7 (up-to-page 159)
  - TOE: Chaps. 1-3