Was due Today - L23

- Reading:
  - Unit 5: Due Today
- Pre-Lecture Reading Questions (PLRQ)
  - For all PLRQ assignments: Let us know if you think you were misgraded
  - Unit 4: Grades posted
  - Unit 4 Revision (if desired): Due Today
  - Unit 5: Can submit questions or take the quiz. (Still working out the kinks)
- End-of-Chapter Quizzes:
  - (Chapter 13 parts A, B, and C)
  - Chapter 13D: Dues Today before class
  - Chapter 14 Parts A-D: Due Today before class
- Papers
  - All Regrades and Revision grades done as far as I know. Let me know if not.
  - Send mail to 109help if:
    - If your score doesn't look right (if you see a 0 for Writing Grade, assignment is probably open)
    - If your grade dropped because of back-evaluations
    - If you didn't/couldn't get something in on time
  - Paper 3:
    - Text: Was due Friday
    - Reviews: Due Tonight (Tuesday) at 11:55PM
    - Back-evaluations: Due Thursday at 11:55PM
Quick Review: Various Times

Walking through what happens during each of a number of different periods in time

- The VERY early universe (Chap 13)
- The first three Minutes (Chap 14)
- The next 300,000 years (Chaps 15-17)
- The next billion years (Unit 6)
- ~13 billion years later (now)
- The ultimate fate of the universe?
Unit 5 Overview

• Next, spend more time on what happens from 500 million years until today: Stars, Galaxies and Black Holes

• It turns out that the way Galaxies and Stars form have similarities... start there

• The way stars die depends on the star itself... sometimes they die to form a Black Hole

• Black Holes are some of the weirdest things in the Universe...
  - In many ways the formation of Black Holes is like the Big Bang in Reverse
Unit 5: Big Objects and Black Holes

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

- **Big picture:** What Galaxies "look like"
- **How do galaxies form?**
- **When do galaxies form?**
What are galaxies like?

All have common properties

1. Stars (produce the light we see)
2. Gas (atoms not in stars)
3. Dark Matter (most of the mass)
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:** like the Milky Way
- Bulge in the middle
- Disk on the sides

**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 about half a billion years after the bang.
Where are we now in the history?

Half a billion years after the bang

Big Objects and Black Holes

Topic 1: Galaxies

Big Holes, No Math
Big Picture

A half a billion years after the bang we get

• Galaxies forming
• Stars forming
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
Grossly Oversimplified

Matter falls to the center over time. There is also spinning, but we'll get to that in a bit.
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.
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
Big Picture: 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.
Need 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 $\rightarrow$ can get bubbling at the drain
  - Falls in medium $\rightarrow$ Get swirling
  - Falls in slowly $\rightarrow$ Just goes straight down

- This is how different types of galaxies can form
Visualize the process

Start right after things start to contract…

A slowly rotating cloud of gas begins to contract.
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**

- **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**

For those of you who have taken PHYS 218, this is *Conservation of Angular Momentum*.
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
Why is there a disk? Analogy

- Think about atoms in the outer part of the galaxy as being like racecars going around a track.
- Since they are all going basically the same speed and direction, there aren't that many crashes.
  - They can just keep going around and around.
- If a car tried to cross the track, or go the wrong way we'd quickly get a wreck, and neither would move with the main flow anymore.
  - Because of gravity, just falls to center.
- After all the wrecks, we are just left with the bulge and the cars that are basically going the same speed and direction.
Why is there a disk on the outside?

- Focus on the atoms in the outer part of the galaxy... Not very dense out there, so stars don't form quickly
- As atoms fall toward the center they are like the water from the outer part of a sink
  - They start bumping into other atoms, which changes the direction they move
- Once enough atoms are going in different directions a swirl CAN start; atoms moving WITH the swirl can keep moving nicely and can orbit like a planet around the sun
  - Like in a sink, an effective swirl can continue
  - Atoms that go into other directions bang into the swirl and lose energy (fall down the drain, or go off into space)
- Eventually, most of the atoms have either fallen to the center or become part of the swirl
- Eventually, the cloud gets drawn in close enough that the atoms get close enough that they form stars
  - Stars just stay in the disk orbit
- Call this the disk
Visualize: As time progresses

As the galaxy contracts, things can start moving very quickly

A spherical cloud of turbulent gas gives birth to the first stars and star clusters.
More time Passes

Things start to “flatten out”

Said differently, the flat part can continue, but the non-flat-part (the stuff going in other directions) gets bumped out of orbit.

The rotating cloud of gas begins to contract toward its equatorial plane.
More time...

Stars and clusters are left behind in the halo as the gas cloud flattens.
Even more time...

New generations of stars have flatter distributions.
Even more time..

The disk of the galaxy is now very thin.
Stable Galaxies

The stuff in this stable state forms Stars: Call this a Galaxy
- Can give us disk-like rotating galaxies
- Can also form other types like elliptical galaxies
- Galaxies often collide and get even more complicated
Fun video

• Move from the simple view of a galaxy forming to a more complete computer model from NASA

• How a disk galaxies gets created

https://www.youtube.com/watch?v=_Ssc1GsqHds
For Next Time – L23

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    - No revision plan except for quizzes
- End-of-Chapter Quizzes:
  - Chapter 15 (if we finished Chapter 15, else just Chapter 14 A-D, 13D)
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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