Big Bang, Black Holes, No Math

ASTR/PHYS 109

Dr. David Toback

Lectures 35, 36 & 37
### Rest of the Semester-L37

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- Stage 5, First Draft due Mon May 3<sup>rd</sup>
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Unit 5: Big Objects

1. Galaxies
2. Star Birth and Death
3. More on Black Holes

Today
Abbreviated Description: What is the evidence for Stellar Black Holes? Note there is an emphasis on what is a black hole and how it forms.

- Explain it to someone who isn't taking the class (no jargon)

Make sure you read ALL the instructions

Same format as usual
Supermassive Black Holes

- Still learning about how they came to be. Some people think they started as a stellar Black Hole near the center of the galaxy when the galaxy was forming a half a billion years after the bang
  - “Ate” material that fell towards the center of the galaxy
  - Lots of light came from the atomic interactions as the material fell in
  - Called a Quasar
- Today: nothing falling in since everything either already fell in or is now rotating around the center of the galaxy
  - Quasars only observed in “distant” galaxies
A way to observe Supermassive Black Holes

- Can observe supermassive black holes by looking at stars as they orbit “nothing” at the center of a galaxy
- Can even measure their mass like the way we measure the mass of the Sun
Unit 6

Going back in time and going forward in time

Before the first millionth of a second and the Fate of the Universe
Outline of Unit 6

1. Possible Fates of the Universe, Dark Matter and Dark Energy

2. Particle Physics, Dark Matter and the Very Early Universe

3. Inflation

Big Bang, Black Holes, No Math
Caveats

While the data is VERY powerful, some of the interpretations of the data are not fully “proven” or understood.

Still need data to tell us about the theory, and theory to tell us about the data.

New data and theoretical advances have recently changed our understanding of the Universe.
The Fate of our Universe

Will the Universe continue expanding forever?

• That depends, mostly, on a few things:

  1. How fast is it expanding now
  2. How much STUFF there is in the Universe
  3. How big it is now
  4. Are the laws of physics really understood?
Why the first three are so important

- Gravity is trying to pull space-time back together again
  - Attractive force
  - Expansion of the Universe should be slowing down or decelerating
- Either it’s strong enough to pull the universe back together again, or it isn’t
What about that last issue?

- Dark Energy fits into this story, but it is an effect that only impacts on the largest scales.
- Takes 10 billion years and HUGE distance scales to have ANY effect.
- Start by discussing all-but-Dark Energy first (gravity), then come back to it.
  - Kinda like when we did the expanding universe.
Gravity: Two Possibilities

There are only a few possibilities
Use an analogy...
Shooting a bullet into the air at the surface of the Earth
Possibility 1: Small Speed → Universe ends in a Big Crunch

- If the bullet is shot up with a **small speed**, gravity will eventually stop it and it will fall back to the Earth.
- Can think of the gun shooting the bullet as an explosion (our big bang).
- If the “Bang” is too small, all the stuff in the Universe will eventually all fall back together as the space-time collapses on itself...like an extra-super supermassive black hole.
Continue the analogy...

It's a balance between the speed of the bullet and the density of the object the bullet is trying to leave.

Does the bullet have a speed below the escape velocity?
A bullet has a speed smaller than the escape velocity.

A person shooting a rifle in the air on the surface of the Earth can't shoot bullets with high enough speed to leave the Earth.
The Sun

Bullet can’t leave

The escape velocity for the Sun is about 620 km/sec
Possibility 2: Big Speed \(\rightarrow\) Universe expands forever

If the bullet has a speed greater than the escape velocity, gravity will not be strong enough to pull it back

\(\rightarrow\) Will keep on going away from the Earth forever

\(\rightarrow\) Like launching a rocket into outer space but using a slingshot, not thrusters-that-keep-keep-firing
A person shooting a rifle in the air on the surface of an Asteroid

Rifles can shoot bullets with high enough speed to leave an Asteroid
The Moon has a “small” escape Velocity

The escape velocity for the Moon is about 2.4 km/sec

Bullet can leave

The Moon

Photons can leave
To infinity and beyond

- As the bullet gets further and further from the moon the gravitational attraction gets smaller and smaller... It still slows the bullet down, but less and less...

- Eventually, the gravitational attraction is so small (since they are so far away from each other) that the bullet effectively moves off into space at the same speed forever
Back to the Universe with Our Examples

• Since there is a lot of mass in the Universe, if it were expanding slowly enough, the force of gravity would cause it to eventually stop expanding and then start contracting again.

• Even with a large speed today, gravity might force it to stop expanding and then contract.
Possibility 1: A Universe Ending in a Big Crunch

- Remember, this is only an analogy – there is no center or edge.
Possibility 2:
A Universe That Expands Forever
How do we tell which is right?

- Looking at distant galaxies shows that the Universe is expanding.
- Since there is lots of mass in the Universe, the expansion should be slowing down.
  - Like a ball thrown up into the air, it should slow down.
  - Question: How much is it slowing down? Let's gather some data!
How do we measure the deceleration?

- Look at Supernovae since they are REALLY bright for about a month so we can see them from far away.

- We believe we understand these explosions really well.

Big Bang, Black Holes, No Math

Early Times & Fate of the Universe

Topic 1: Possibilities
Measuring the “Deceleration” of the Universe

• Can use the brightness of Supernova to tell how far they are away
• Can use spectral lines to tell how fast they are moving
What Does the Data Say?

- The most distant things in the Universe are further away than we think they should be.
- The Universe doesn’t appear to be slowing down, it’s speeding up!
  - Accelerating!
- It’s like there was an explosion and then something CONTINUES to force the stuff further apart
  - Throw a ball into the air and the ball speeds up!??!
The Accelerating Universe

- Big Bang
- Afterglow Light Pattern 400,000 yrs.
- Inflation
- Quantum Fluctuations
- Dark Ages
- 1st Stars about 400 million yrs.
- Development of Galaxies, Planets, etc.
- Accelerated Expansion

Big Bang Expansion
13.7 billion years
What the ???

• Is there some **Force** that is pushing things apart faster?

• Gravity, as we know it, only attracts... Give the “whatever-it-is” a name: **Dark Energy**
Why do we call it Dark Energy?

- Can't see it
  → Call it Dark
- Doesn't seem to interact like mass
  → Not mass or matter, but is forcing the Universe apart so it has energy \( (E=mc^2) \).
  Not Dark Matter
- From the acceleration can measure how much energy must be “doing the forcing” ~72% of the mass/energy of the Universe
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End of Semester Notes

- End of Chapter quizzes
  - While the EOC quizzes are due before then, I’m planning to do my final download on Tuesday May 4th at 11:55PM
  - This includes AMS 2
    - End of semester measure of some of the things you learned
    - Not part of your grade, but you will need to do it before you can attempt the rest of the end of chapter quizzes
  - If you don’t pass the EOC quizzes for all 20 Chapters the EOC quizzes (50%), you cannot get a passing grade for the course
    - If you need an extension, let me know ahead of time
    - Please do the Course Evaluations
- We will accept Revisions for all papers, but you need to do them with enough time for you to get a grade before the 4th
- There is no statue of limitation on mis-graded items. If you think you were mis-graded on ANYTHING, we will work to make sure you get the grade you deserve

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Early Times & Fate of the Universe
Topic 1: Possibilities