Big Bang, Black Holes, No Math
ASTR/PHYS 109
Dr. David Toback
Lectures 25 & 26
Was Due Today – L26

- Reading:
  - Unit 6
- Pre-Lecture Reading Questions (PLRQ)
  - Unit 6, Stage 1: Due before class Monday (shown wrong on CPR)
  - Unit 6, Stage 2: Due before class Wednesday
- End-of-Chapter Quizzes:
  - Chapter 16
- Papers:
  - Paper 3 Revision (if desired), Stage 2: Due Monday before class
    - 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)
  - Paper 4, Stage 1: Due Wednesday, May 3rd
  - Paper 4, Stage 2: Due Tuesday May 9th by 11:55PM
- General:
  - CPR: Mis-graded on any Assignment? Let us know
  - If you are interested, we are trying a new system on Peerceptive. Extra credit for students who do this instead or in addition to the regular assignment for PLRQ Unit 6 and Paper 4 (and revisions)
Chapter 13 and 14 worksheet

• Found at http://people.physics.tamu.edu/toback/109/

• Make sure you enter in “Negligible” or “Abundant” in all boxes. There is feedback for you if you didn’t enter in things correctly
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 and due dates as usual

- Text due 1 week after we finish Chapter 17
- Calibration, reviews and self-assessment due a week after that
A Black Hole

Bullet can’t leave

A Black Hole, by definition, has an escape velocity greater than the speed of light, 300,000 km/sec

Photons can’t leave

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Big Objects and Black Holes

Topic 3: Properties of Black Holes
Gravitational
Lensing of
light around a
black hole

Stuff orbiting
it, and light
from stars
behind it

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Different Types of Black Holes

- Two different types
  1. Stellar Black Holes (the types we have been discussing)
  2. Supermassive Black Holes
- Both have been observed and are now known to be common
  - Closest known stellar Black Hole is about 3,000 light years away
- Supermassive Black hole at the center of the Milky Way with a mass more than four million times that of our sun
  - At the center of many (all?) large galaxies
Some pictures from Chapter 2

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Big Objects and Topic 3: Properties of black holes
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
Event Horizon

- A rocket with a speed of 11 km/sec can escape from the Earth
  - Needs a lower speed if it starts up high in the atmosphere
  - The higher it is, the smaller the escape velocity is
- We call that special distance from the center of a black hole where the escape velocity is equal to the speed of light the EVENT HORIZON
A Way to Observe Stellar Black Holes

• Let's say we have two stars orbiting each other (a binary pair), and one has already turned into a black hole.

• We can “see” light “from” a Black Hole by watching them “eat” their companion.
Black Holes Suck

- Can think of the stuff sucked in like crumbs on the surface of the water as it goes down the sink → swirl faster and faster until it reaches the drain and gets sucked down.
- As the matter moves more quickly the atoms collide.
- These collisions produce light that we can see → x-rays.
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
Can also measure the mass of a stellar black hole if it's in a binary pair by watching the speed of its "partner" orbit.
Lecture on Chapter 17
now complete
Paper 4: The Assignment

• **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 and due dates as usual**
  - Text due 1 week after we finish Chapter 17
  - Calibration, reviews and self-assessment due a week after that
Course Evaluations

Course evaluations will be done online:

- *I believe you should have gotten an email about this already*

The Spring 2018 evaluation period:

- *Already Begun*  
  [http://evaluation.tamu.edu/](http://evaluation.tamu.edu/)
- *Ends Fri May 19th, 5PM*

Please do them... won't take long
End of Semester

- **Monday May 1\textsuperscript{st}:**
  - Last day of class
  - Unit 6, Stage 1 Due
  - Paper 3 Revision (if desired), Stage 2 is due
  - Chapter 17 EOC quizzes due
- **There is no final**
- **Wednesday, May 3\textsuperscript{rd}**
  - Unit 6, Stage 2 due
  - Paper 4, Stage 1 due
- **Monday, May 8\textsuperscript{th}**
  - Remaining EOC quizzes due.
    - Let me know if you need an extension
- **Tuesday, May 9\textsuperscript{th}**
  - Paper 4, Stage 2 due at 11:55PM
- Revisions for Unit 6 and Paper 4 will be by request only.
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
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
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.

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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

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

Big Bang Expansion: 13.7 billion years

Accelerated Expansion
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
Dark Energy and Dark Matter related?

• Not clear dark matter and dark energy have anything to do with each other
  - Just because we use the word DARK for both doesn’t mean we know how they are related

• Probably IS something fundamental that is similar, but we don’t know enough about either to say anything useful yet
It all adds up!

- Add up all the mass/energy in the Universe
  - Atoms account for ~5%
  - Dark Matter is about 5 times more mass in a galaxy than atoms \(\rightarrow\) ~23%
  - Dark Energy is about ~72%
For Next Time - L26

• Reading:
  - (Unit 6)

• Pre-Lecture Reading Questions (PLRQ)
  - Unit 6, Stage 1: Due before class Monday May 1st (that’s what it said on CPR)
  - Unit 6, Stage 2: Due before class Wednesday, May 3rd

• End-of-Chapter Quizzes:
  - Chapter 18 if we finished Chapter 18 (else just Chapter 17)

• Papers:
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Topic 1: Possibilities