ASTR 1020: Stars & Galaxies  
April 18, 2008

- Reading: Chapter 23; section 23.1-23.2.  
- Extra credit: Fiske Planetarium shows every Thursday and SBO observing.

Today

- Chapter 22, Section 4: Dark Matter, Dark Energy, and the fate of the Universe
- Preview of Chapter 23: The Creation of the Universe

(creation of all matter, light and energy)

Dark Matter and the Fate of the Universe

- Expansion begins with the Big Bang
- Several different models for Past and Future

What is the fate of the Universe?

- Recollapse: crushing heat, destruction of all matter, ?rebirth?
- Eternal expansion: cold, galaxies dimming  
  - star formation slowing  
  - everything winds up as a brown dwarf, black dwarf, neutron star or black hole
Some say the world will end in fire
Some say with ice
From what I’ve tasted of desire
I hold with those who favor fire
But if I had to perish twice
I think I know enough of hate
To say that for destruction ice
Is also great
And would suffice

-- Robert Frost

Clicker Question: Which universe predicts the largest age for the universe today?

a) Recollapsing
b) Critical
c) Coasting

(Ignore accelerating for now)

C) Coasting

• Age of the universe is how far to the left the curves hit the horizontal axis (distance between galaxies =0)

Which is it?

Is there enough dark matter to recollapse the universe?

Baryonic matter: only a few percent of critical density
Dark matter: only about 25% of what is needed
Universe is in between the “coasting” and “critical” models
The Universe will expand forever

Clicker Question: If there was really ZERO dark matter in the universe, which model would be the closest to reality?

a) Coasting
b) Critical
c) Recollapsing

• Baryonic matter is < 5 percent of the critical density.

• Closest model would be the Coasting Model (no deceleration from gravity).
A New Twist for the 21st Century

- White dwarf supernovae: standard candles at $z \approx 1$
- Explosions bright enough to see very far away

Redshifts of the supernova plot their vertical position

- $Z=1$ means about halfway down from the “NOW” level
- Expansion factor $= 1 + Z = 2$

Their brightness plots their horizontal position

Dimmer = more distant = longer ago

- Supernovae are DIMMER than expected for a coasting universe
- Universe is accelerating!

How can the universe be accelerating??????

A force that counteracts gravity?

“Dark energy” – outweighs every other form of mass/energy!

Truly an unknown force in all of physics!

(Read “Einstein's Biggest Blunder” p 679)

Accelerating model universe

- Longest time since Big Bang (14 billion years)
- Oldest stars are about 13 billion years old – other models fall short!
- Universe will expand forever still……
- Will there be more surprises to come?????

Summary: Contents of Universe

- “Normal” Matter: ~ 4.4%
  - Normal Matter inside stars: ~ 0.6%
  - Normal Matter outside stars: ~ 3.8%
- Dark Matter: ~ 25%
- Dark Energy ~ 71%
Chapter 23: In the VERY Beginning

Hot stuff!

Everything in the Universe was hotter at earlier times, and then cooled as it expanded.

The temperature at the earliest times was more than the energy we create in particle accelerators.

Cosmology at the earliest times is explored via particle physics!

Matter and Energy

- $E=mc^2$

- Matter and energy are the same, can transform from one to another

Matter + antimatter $\leftrightarrow$ photons