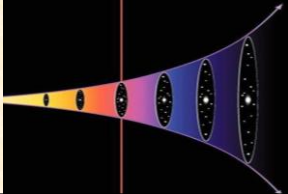


ASTR 1020: Stars & Galaxies

December 2, 2013

- Reading: Chapter 22; section 22.1-22.2.
- *Mastering Astronomy* homework **The Fate of the Universe** due on Dec. 6.
- Please complete on-line Faculty Course Questionnaire by Dec. 10. You can also go to: https://fcq.colorado.edu/ucb_fcq.htm
- SBO Extra Credit Observing session: Wednesday, Dec. 4 at 7 pm.



Astronomy Picture of the Day



Distant galaxies form a dramatic backdrop for disrupted spiral galaxy Arp 188, the Tadpole Galaxy. The cosmic tadpole is a mere 420 million light-years distant toward the northern constellation Draco. Its eye-catching tail is about 280 thousand light-years long and features massive, bright blue star clusters.

Today

- Chapter 23, Section 4: Dark Matter, **Dark Energy**, and the fate of the Universe.
- Preview of Chapter 22: The Creation of the Universe
(the creation of all matter, light and energy)

Reading Clicker Question: If the density of the universe is less than the critical density and there is dark energy, what is the expansion pattern of the universe?

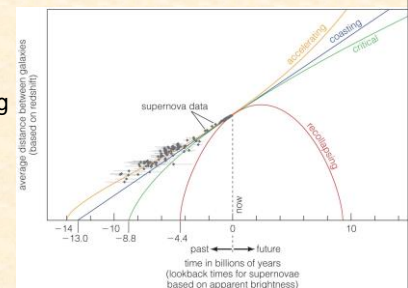
- an accelerating universe
- a coasting universe
- a critical universe
- a recollapsing universe
- a repeating universe

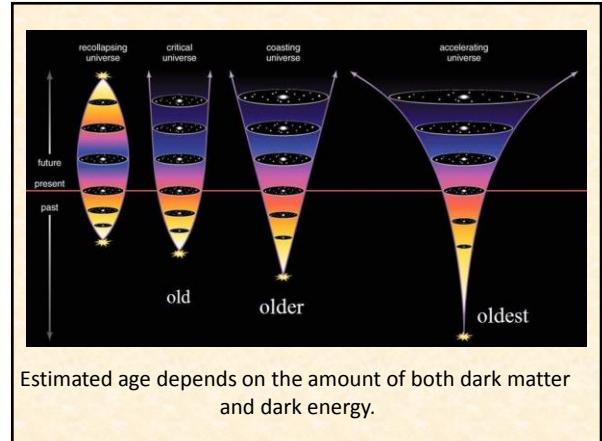
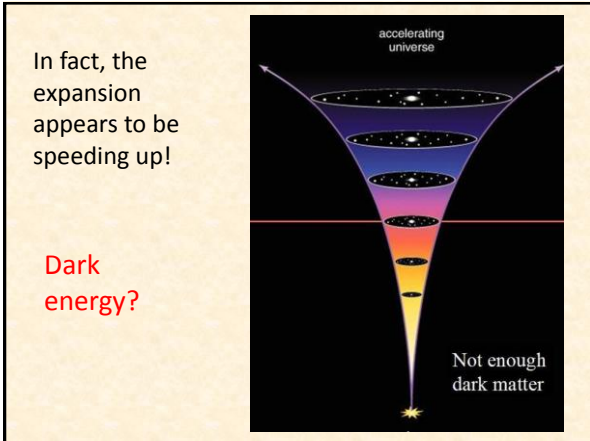
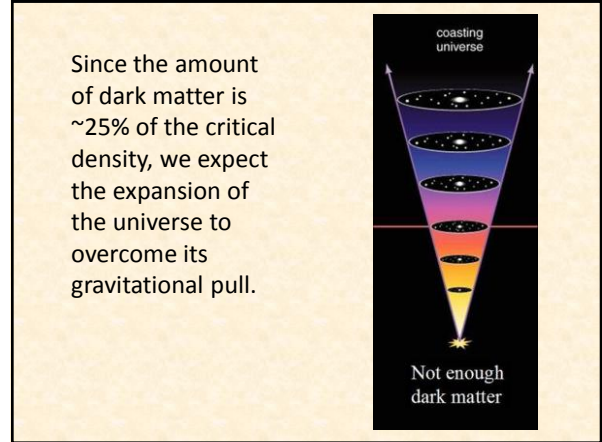
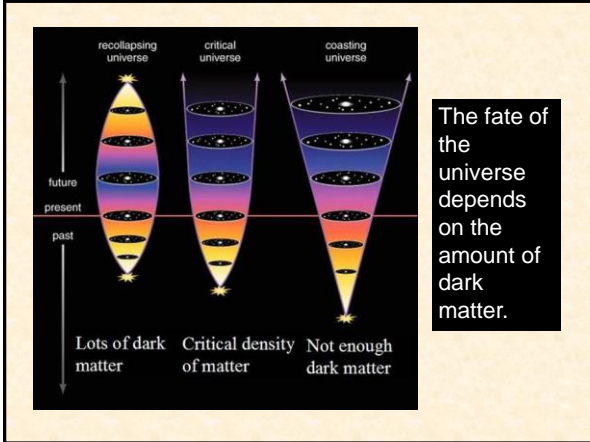
Reading Clicker Question: If the density of the universe is less than the critical density and there is dark energy, what is the expansion pattern of the universe?

- an accelerating universe**
- a coasting universe
- a critical universe
- a recollapsing universe
- a repeating universe

Dark Matter and the Fate of the Universe

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

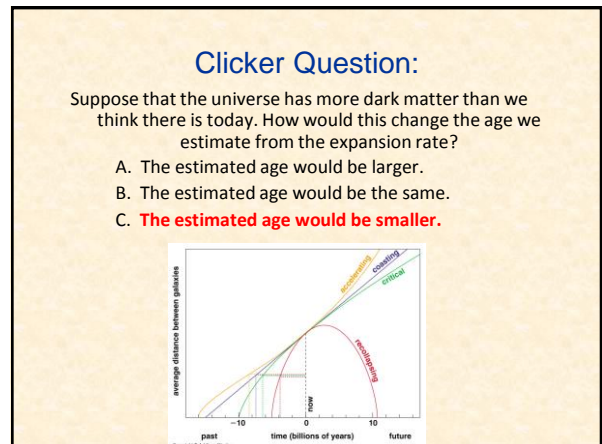




Clicker Question:

Suppose that the universe has more dark matter than we think there is today. How would this change the age we estimate from the expansion rate?

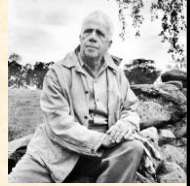
- A. The estimated age would be larger.
- B. The estimated age would be the same.
- C. The estimated age would be smaller.



What is the fate of the Universe?

- =>Eternal expansion: cold, galaxies dimming
- star formation slowing
 - everything winds up as a brown dwarf, black dwarf, neutron star or black hole

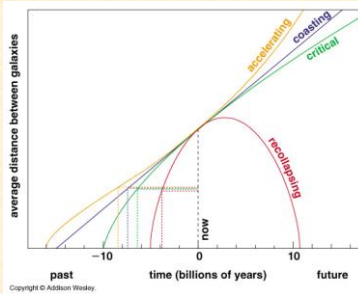
Some say the world will end in fire
 Some say with ice
 From what I've tasted of desire
 I hold with those who favor fire
 But if I had to perish twice
 I think I know enough of hate
 To say that for destruction ice
 Is also great
 And would suffice



-- Robert Frost

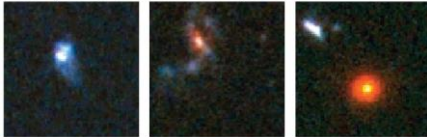
Clicker Question: If there was really ZERO dark matter in the universe, which model would be the closest to reality?

- a) Coasting
- b) Critical
- c) Recollapsing



- Baryonic matter is ~4 percent of the critical density.
- Closest model would be the **Coasting Model** (no deceleration from gravity).

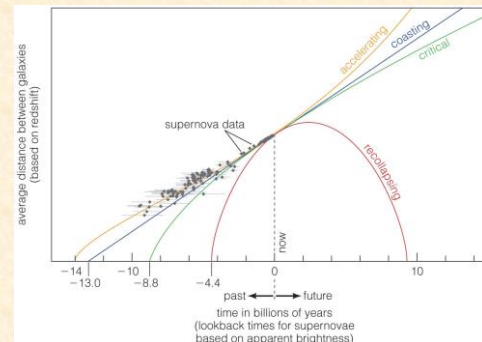
Distant galaxies before supernova explosions



The same galaxies after supernova explosions



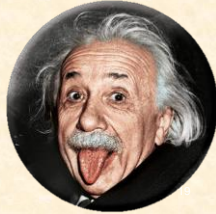
The brightness of distant white dwarf supernovae tells us how much the universe has expanded since they exploded.



An accelerating universe best fits the supernova data

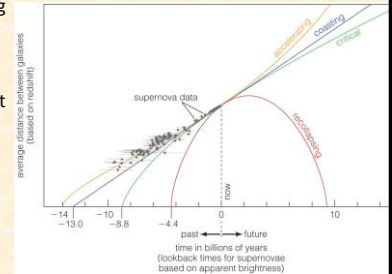
How can the universe be accelerating???????

- A force that counteracts gravity?
- “Dark energy”– outweighs every other form of mass/energy!
- Truly an unknown force in all of physics!
- Einstein’s “greatest blunder” may not have been a blunder after all!

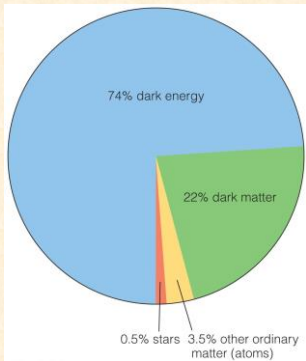


Accelerating model universe

- Longest time since Big Bang (13.7 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



Chapter 22: In the VERY Beginning

