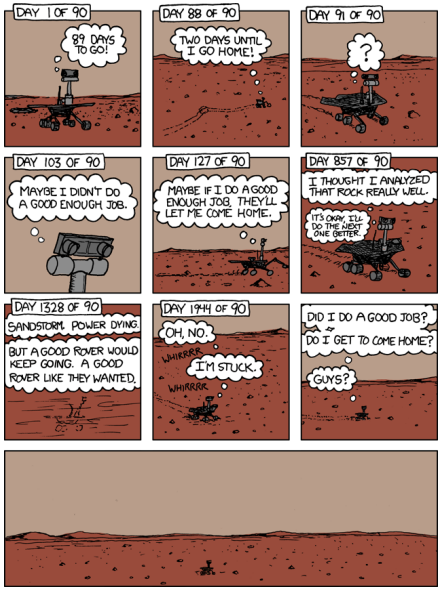


Astronomy 330

This class (Lecture 6):

The End of the Universe

Next Class:

Why does the Sun shine?

Synopsis Due!

Music: *Carl Sagan -Glorious Dawn*– Colorpulse
http://www.youtube.com/watch?v=zSgiXGELjbc&feature=fvw

Outline

- The end of the Universe
- The first stars

What is the Universe's Fate?

Today: Universe is expanding. What do you expect to happen next?

Competition: gravity vs inertia

Compare: Pop fly and rocket!

- Quantitative question
- Launch speed vs speed to escape Earth

or

?

What is the Universe's Fate?

For Universe it is still gravity vs speed.

- Gravity acts on mass of galaxies (pulling back)
- The speed is the speed of expansion

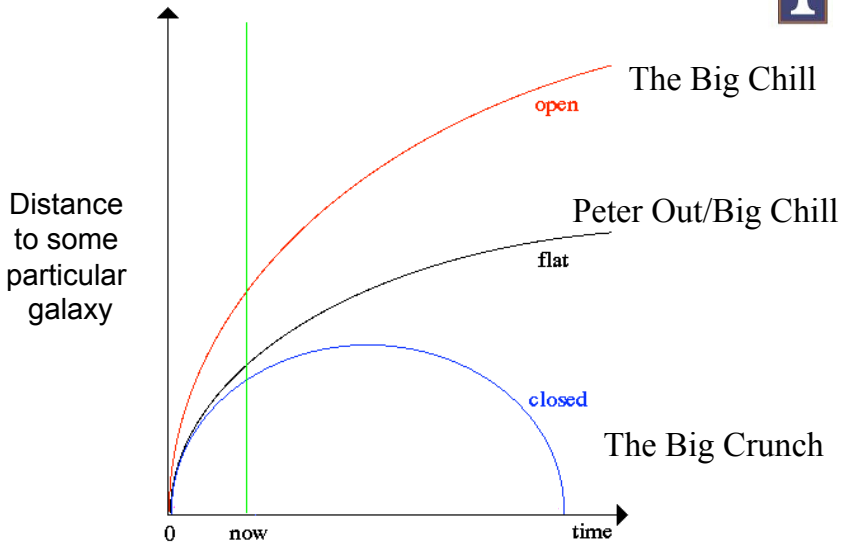
Both are observable!

or

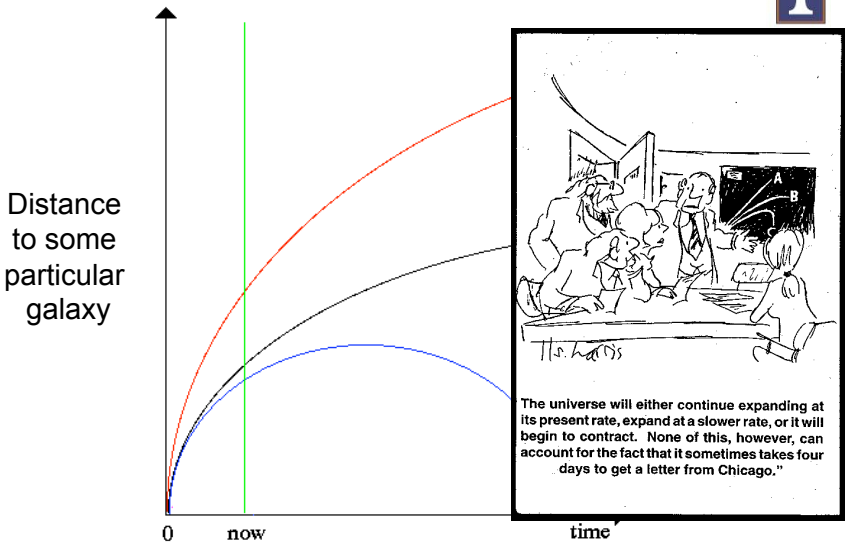
Our fate is a **quantitative** question :

- **If our mass is small enough we expand forever.**
- **If our mass is large enough expansion halts, and we collapse back.**

What kind of Universe do we live in?



What kind of Universe do we live in?



Big Chill/Big Crunch

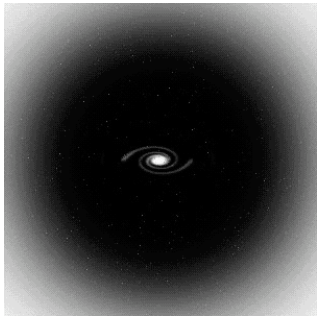
- **Less mass:**
  An open or flat Universe will end in a **Big Chill**:
  - Galaxies exhaust their gas supply
  - No more new stars
  - Old stars eventually die, leaving only dust and stellar corpses
- **More mass:**
  A closed Universe will end in a **Big Crunch**:
  - Expansion will stop, and the Universe will re-collapse
  - Ends as it began, incredibly hot and dense

Question

Our Universe could be one of three types: Open, Closed, or Flat. What would happen to a closed Universe?

a) No one else could get in.
b) It would expand forever.
c) It would just barely expand forever.
d) It would expand for a while, then eventually begin to re-collapse on itself.
e) It would expand, then slow down, then expand faster.

Dark Matter

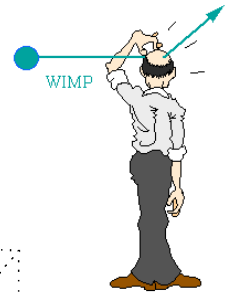


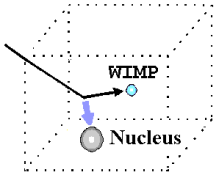
- There is unseen mass in our Galaxy!
- Needed to explain stellar orbits.
- The dark matter in the Galaxy is in greatly extended halo
  - Up to 90% of the Galaxy's mass is dark matter!
- Most of our Milky Way is Dark Matter
  - We can't see it (only interacts via gravity)
  - We aren't sure what it is, but it is much more common than "normal matter"

Dark Matter

- Dark matter is likely streaming through us right now!
- Probably some heavy exotic particle created during the Big Bang. (Weakly Interacting Massive Particle– WIMPs?).
- Recent suggestion of a detection. Stay tuned!

How to search for WIMPs?





http://www.shef.ac.uk/physics/research/pa/DM-introduction-0397.html

How Much Do We Weigh?

% of mass for closed Universe

22% Dark matter

Needed to explain:
galaxy rotation curves
clusters of galaxies

4.5% Ordinary matter

Made of protons, neutrons, and electrons

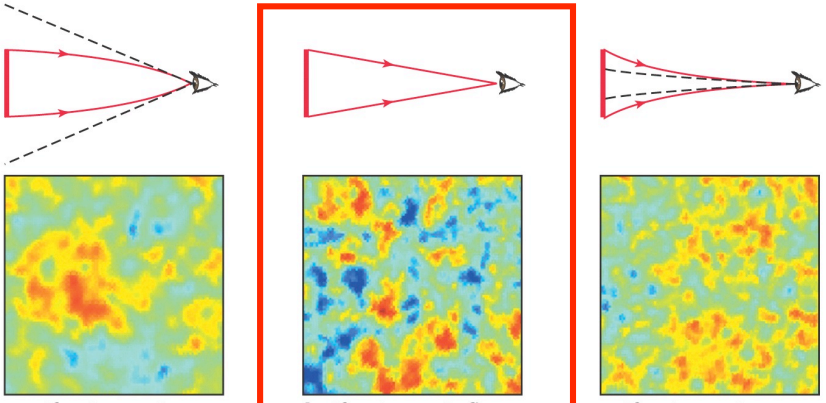
<1.5% Neutrinos

28% Total Not enough to close the Universe

So we live in an open Universe?

CMB Measurements

Universe is Flat!!!!



a If universe is closed, hot spots appear larger than actual size

b If universe is flat, hot spots appear actual size

c If universe is open, hot spots appear smaller than actual size

Peter Out/ Big Chill

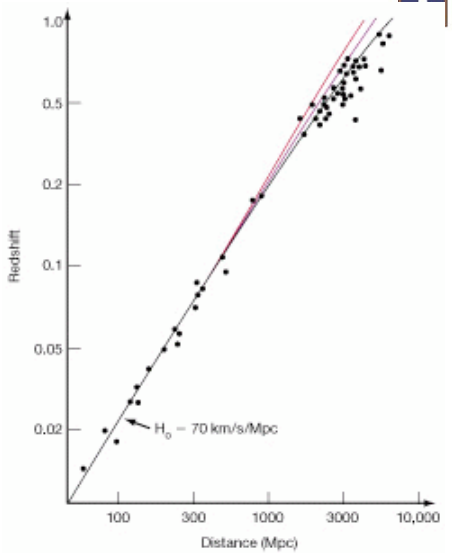
- The Universe will just barely expand forever, getting cooler and cooler.
- If all of the mass, dark+regular, isn't enough, **then what's up**?
- The fate of the Universe is really dependent on the amount of matter and energy in the Universe → $E = mc^2$

We must be missing some extra mass/ energy?

The Accelerating Universe!!!

The universe is not slowing down at all. In fact, it's speeding up!!! We live in an accelerating universe!

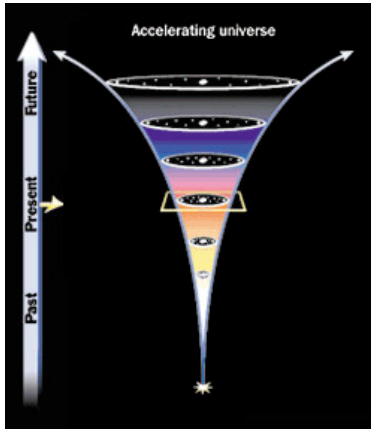
It's as if there's another force pushing the universe apart – a Cosmological Constant!!!

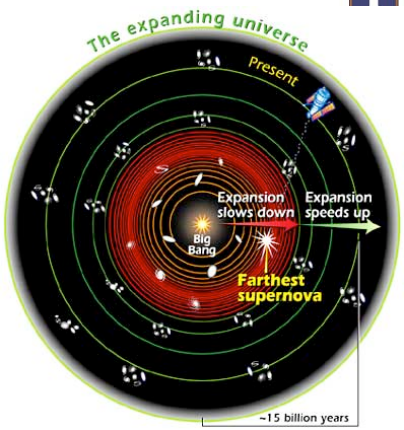


Dark Energy

- The matter census isn't enough to be flat and the expansion is accelerating!
- So, a new type of energy called ***dark energy*** must exists
  - Not related to dark matter
  - Acts as repulsive gravity, pushing apart.
- Dark energy is actually *accelerating* the expansion of the Universe!

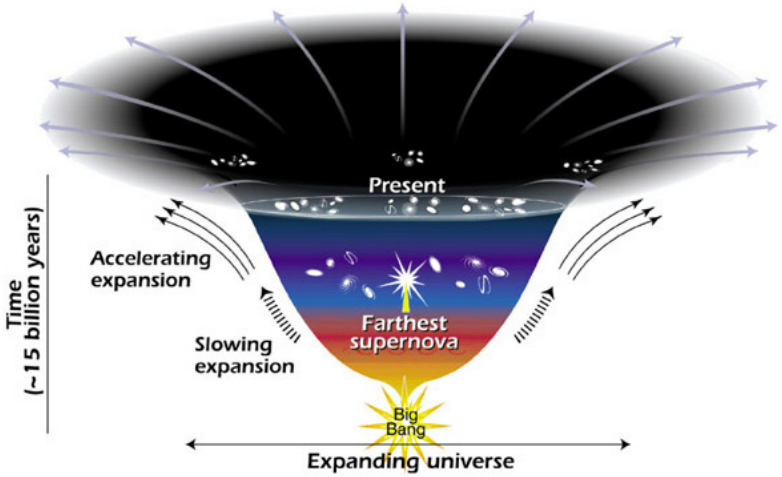
The Accelerating Universe!!!





Whatever this force is, we *think* that it is growing stronger as the universe evolves. The more empty space in the universe, the greater the acceleration – as if the vacuum of space has energy.

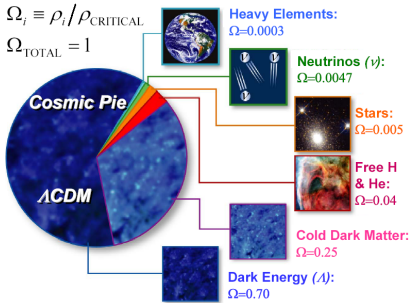
Effects of Dark Energy

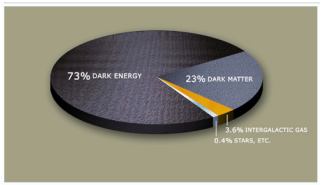


http://www.lbl.gov/Publications/Currents/Archive/Apr-06-2001.html

The Accelerating Universe!!!

The universe is 13.7 billion years old, and it is now dominated by dark energy.





Dark Energy even dwarfs dark matter! Regular matter is really insignificant. We *really* don't know anything about what's going on!!

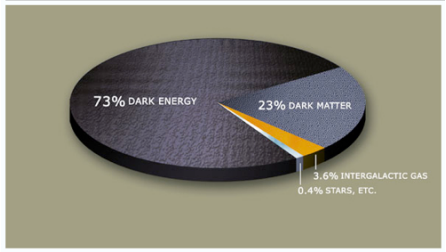
Question

Based on measurement of the CMB, we live in a flat Universe. But there is not enough known mass to account for this. What's up?

a) We must be underestimating the amount of Dark Matter.
b) It would expand forever.
c) It would just barely expand forever.
d) We have something called Dark Energy.
e) It would expand, then slow down, then expand faster.

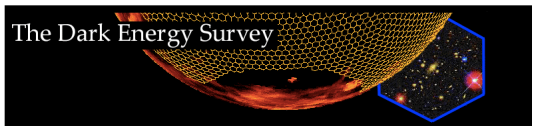
The Accelerating Universe!!!

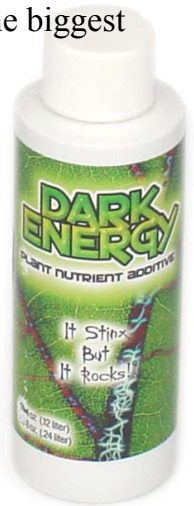
- But, we are still in very speculative times here.
- How the Universe ends will depend on the nature of Dark Energy.
- If it really acts like a cosmological constant (go Einstein!), then we live in a flat Universe that will keep expanding forever, but if not then we don't know yet.



The Accelerating Universe!!!

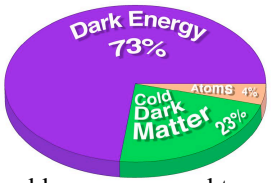
- Understanding dark energy is one of the biggest questions for humankind today.
- There are many experiments underway to accomplish this. So we have to wait and see.
- But what are the options?





The Distant Future: The Big Rip

- Although this is not very popular, and the chances of it occurring is small, what if Dark Energy is not a cosmological constant?
- One extreme case is that it gets carried away, and rips the Universe apart.



  - If repulsive force increases– Brooklyn may expand too.
  - Gravity/E&M forces can not hold Galaxies rip apart
  - Could rip the Milky Way apart in ~1-100 billion years
  - Earth gets ripped apart soon after
  - You'd get ripped apart!

http://www.youtube.com/watch?v=oGVYG0ce1Ps

The Early Universe?

- So, in the early Universe, the first elements formed were mostly Hydrogen (75%) and Helium (25%) by mass. What does that mean for life in the early Universe?
- Globular clusters contain the oldest stars in the Milky Way– about 10 to 13 billion years old. Should we look for life around these stars?

http://www.shef.ac.uk/physics/research/pa/DM-introduction-0397.html

What is the Earth made of?

- Very little hydrogen and helium. They make up less than 0.1% of the mass of the Earth.
- Life on Earth does not require any helium and only small amounts of non-H_2O hydrogen.
- All of these elements must be formed in stars. That means 2^{nd} or 3^{rd} or n^{th} generation of stars are required before life can really get going. These elements were not originally formed in the Big Bang.
- **"We are star stuff!"**
- How did that come about?

What are Galaxies?

- They are really giant re-cycling plants separated by **large** distances.
- Stars are born in galaxies out of dust and gas.
- Stars turn hydrogen into helium, then into heavier elements through fusion for millions or billions of years.

What are Galaxies?

- Stars die and eject material back into the galaxy.
- New stars are formed.
- And so on.
- Crucial to the development of life!

Stellar Evolution Re-Cycle