Sex in Space: Astronomy 330

TR 1000-1050
Noyes Laboratory 217

This class (Lecture 3):

Expanding Universe

Next Class:

Cosmology

HW1 due tonight!
(grace period until Feb 3rd)
Presentation Synopsis due next Tuesday night.

Music: *Galaxies*– Laura Veirs

You need to Register You Clicker

- Go to link on syllabus to register your clicker.
- **Bring it to class every day.**

Discussion Class

Go to discussion class tomorrow:

- Section 1
  - 10-11, Foreign Languages Bldg, room G48
- Section 2
  - 11-12, Foreign Languages Bldg, room 1136
- Section 3
  - 12-13, Foreign Languages Bldg, room G30
- Section 4
  - 3-4, Astronomy Building, room 134

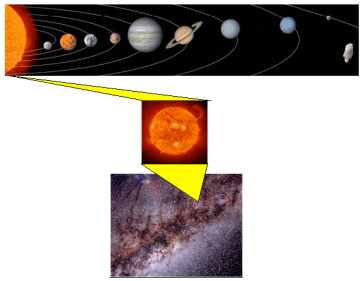
Outline

- What does our Galaxy look like?
- Where did HONC come from?
  i.e. where did the atoms in our bodies come from?
- How old is the Universe?

One of

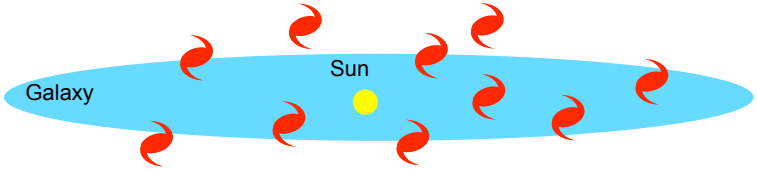
We are:

- 1 planet out of ~~9~~ 8 in our solar system.
- 1 stellar system of 100 billion stars in our Milky Way
- What's next? This took until the 1920s to suss.



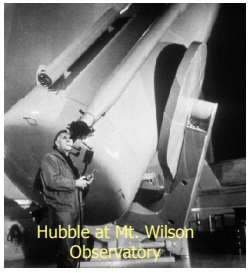
Those weird Spiral Nebulae?

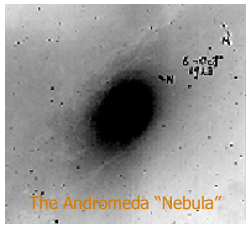
- Dim, diffuse, "interstellar" nebulae with spiral structure were seen in the 17th century.
- Some disagreement on what they were.
  - "A galaxy is a spiral "island universe" and the other spiral nebulae are the same and far away"
  - "Milky Way is all there is in the Universe, and the spiral nebulae are nearby."



Edwin Hubble: Solved It

- In 1923, Hubble resolved M31, the Andromeda "Nebula", into stars
- If these stars were like the stars in our Galaxy, then M31 must be far away!
- Estimated the distance to M31 to be 1 million light-years (modern estimate is 2.5 million light years)
- Andromeda is an "island universe" like our own Galaxy.





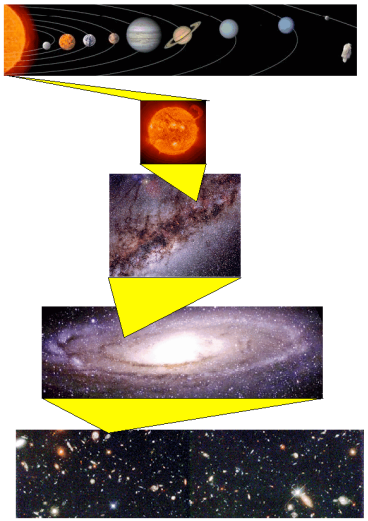
What's this All about Then?

- Planets are now defined
- Stars – Nuclear burning machines, usually turning hydrogen into helium
  - Colors (temperatures: cold/red to hot/blue),
  - Sizes (Jupiter-sized to 1000x the Sun)
  - Masses (80x Jupiter to 100x the Sun)
  - Ages (Just born to nearly the age of the Universe)
- Galaxies
  - Collection of stars, gas, and dust (huge!)
  - We now know of 100 billion galaxies in the observable Universe.

One of

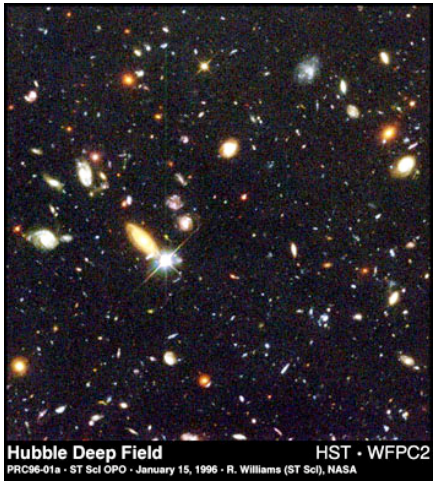
We are:

- 1 planet out of 8 in our solar system.
- 1 stellar system of 100 billion stars in our Milky Way
- 1 galaxy of the 100 billion galaxies in the observable Universe.



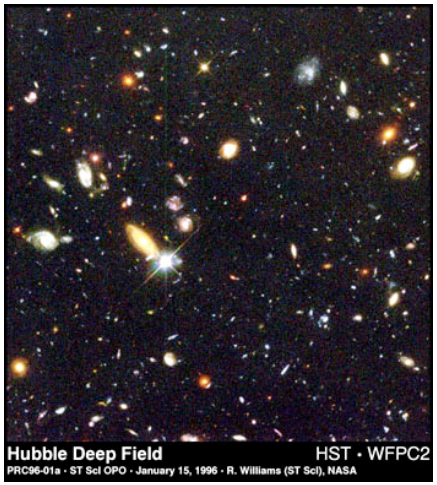
Galaxies – Fundamental "Ecosystems" of the Universe

- Galaxies "fill" universe.
- Typical separation **3 million light years!**
- Most distance galaxies are billions of light years away
- Range in size from large (Milky Way-like) to small "Dwarf"
  - 1 billion to 100's of billions of stars



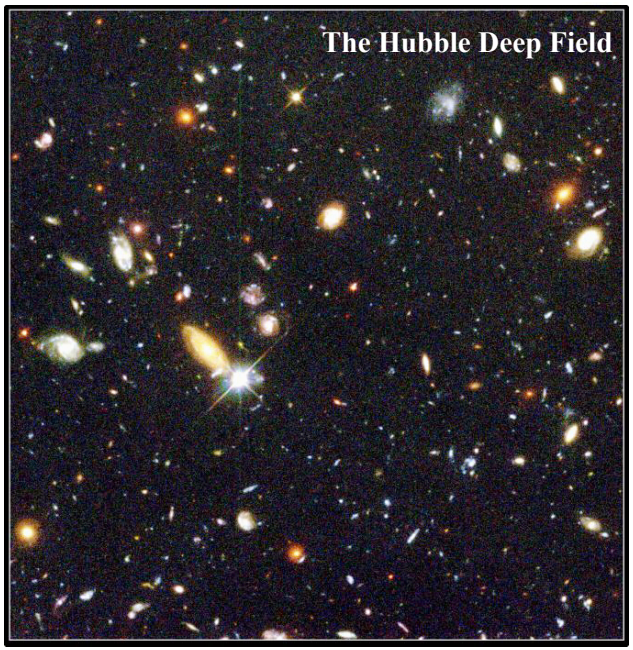
Galaxies – Fundamental "Ecosystems" of the Universe

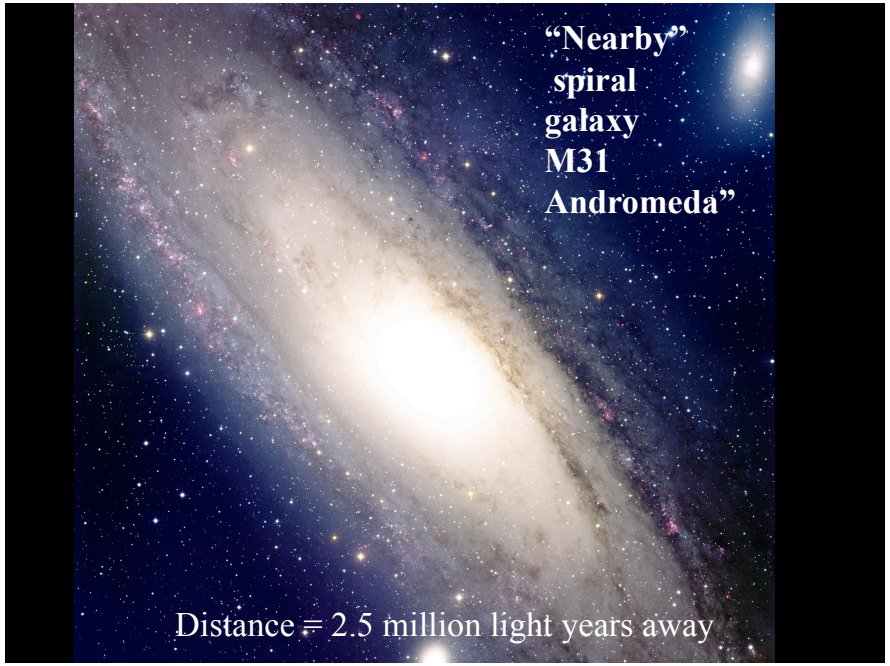
- Galaxies are the cosmic engines that turn gas into stars and recycles the gas the stars eject, back into stars
- In between, no star formation occurs – "nothing happens" in intergalactic space.

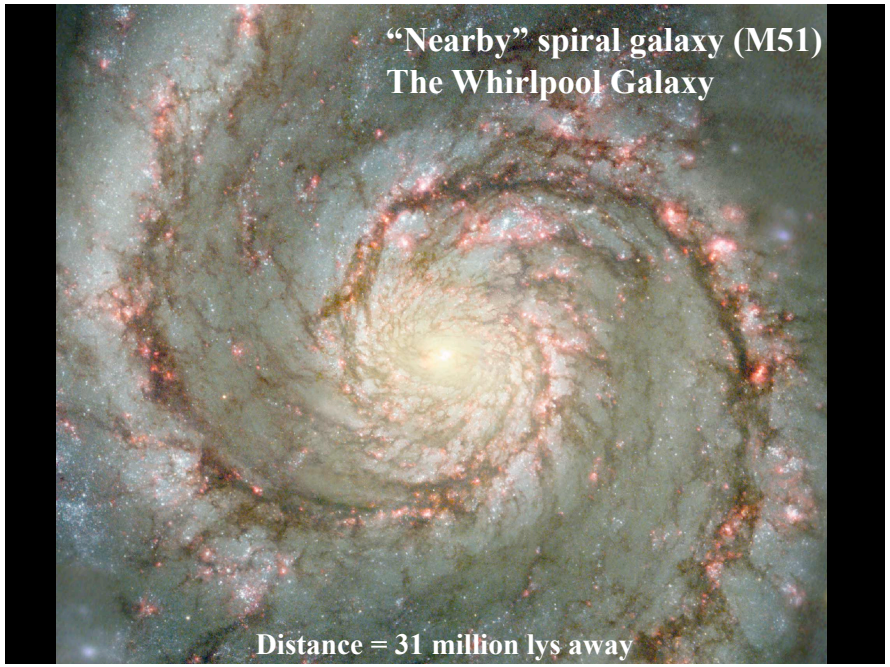


Distant galaxies:

- **The deepest optical image of a patch of sky**
  - **Like looking back in time …**
  - **Galaxies as they were, 1 to 10 billion years ago.**







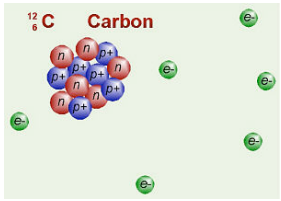
Defining Life

Defining life is very difficult. Traditional attributes of life define it as:

1. Comprised of organic molecules.
2. Engaged in metabolism– exchange of matter and energy.
3. Engage in reproduction– sex in space!
4. Able to mutate– offspring are not identical to parents.
5. Sensitivity to environment.

Elements of Life

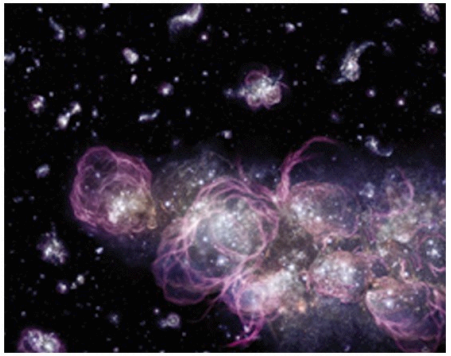
- Carbon is the most important element in life on Earth with oxygen and nitrogen coming in a close second. And there is a lot of hydrogen. **HONC**. But where did they come from?
- To understand this question, we need to address the origin of the Universe and the elements crucial to life.
- In other words, Cosmology.

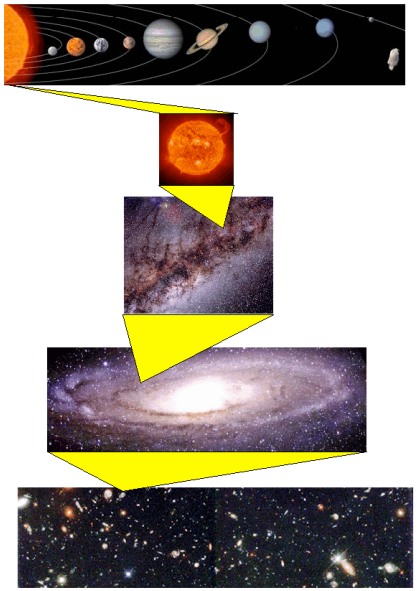


http://biology.clc.uc.edu/courses/bio104/atom-h2o.htm

Cosmology

- What is the Universe?
  - All the matter, energy, and spacetime we can ever detect
- **Cosmology** is the study of the origin, structure, and evolution of the Universe





Astronomy: The Big Picture

Arguably, the biggest fish of all: *Cosmology*

- What is the Universe made of?
- How big is it?
- How old is it?
- How did it form?
- What will happen to it?

The Night Sky: Group

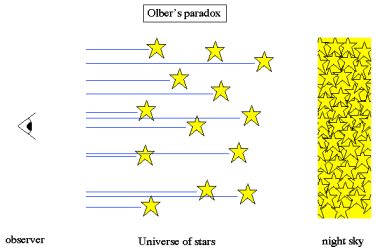
- What is special about the night sky?

What would it look like in an ageless and infinite Universe?

- Press A on your iclicker when your groups has a guess.

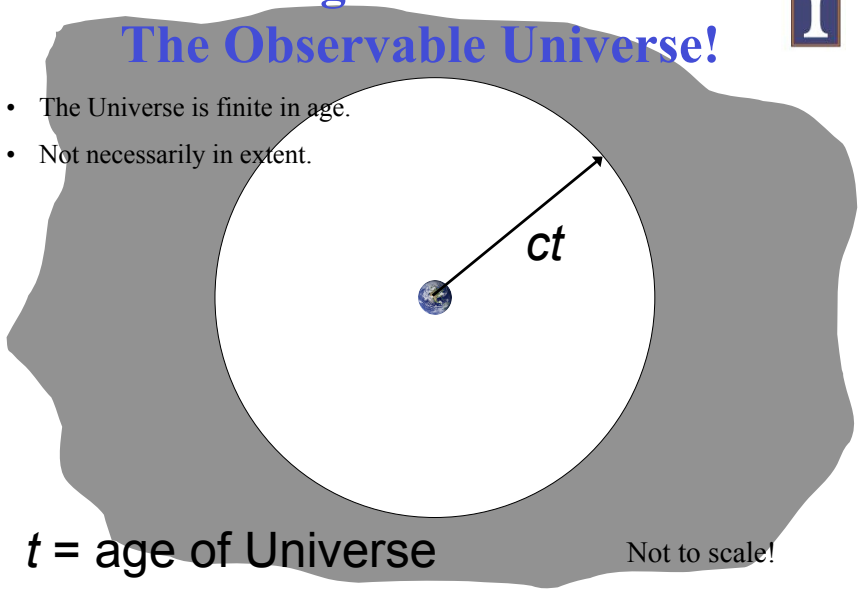
The Night Sky:
Olber's Paradox

- What is special about the night sky?
- Why isn't the night sky bright?
- If the Universe is infinite and ageless, why don't we see light everywhere from all the stars.
- Even if dust blocked the light, it would heat up and emit in the optical too.
- The Universe has not existed forever. It must have started from something.



Looking Back in Time:
The Observable Universe!

- The Universe is finite in age.
- Not necessarily in extent.



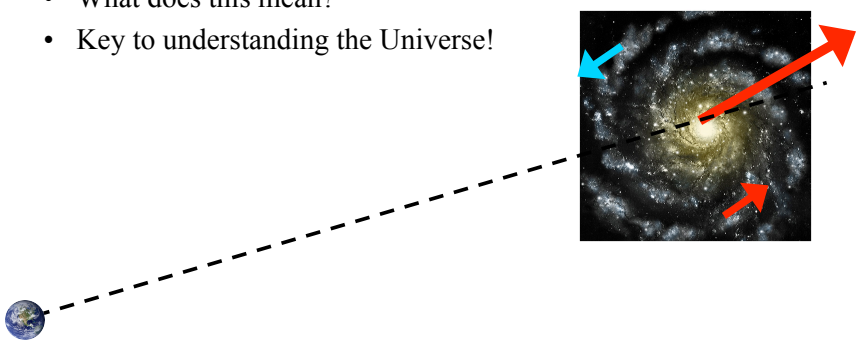
How are Galaxies Moving?

It's 1928 and Edwin Hubble is measuring how galaxies move. What does he find?

a) More galaxies receding than approaching.
b) More galaxies approaching than receding.
c) About equal numbers of each.

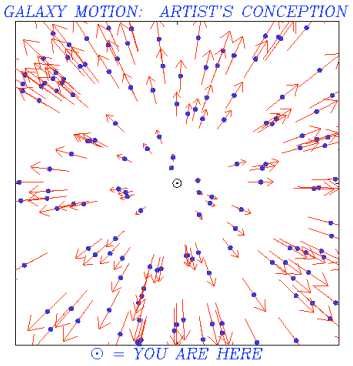
What Does This Mean?

- Most galaxies are moving away from us.
- The farther away, the faster they are moving away.
- Or $V = H_o \times D$
  - $H_o = 72$ km/s /Mpc
- What does this mean?
- Key to understanding the Universe!



Apply it?

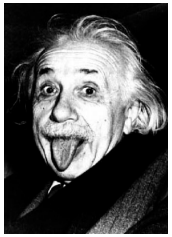
- In a homogenous Universe, what does the farther away the faster the galaxies move away mean?
- Draw it.



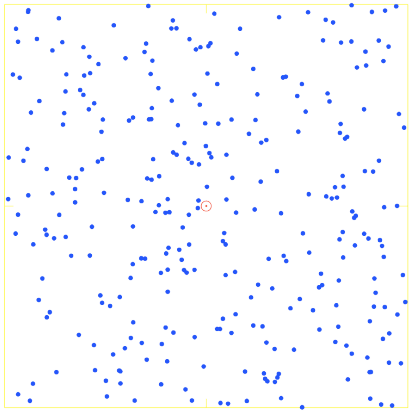
Interpretation: View of the Universe

Egoist view– We are at the center of the Universe.

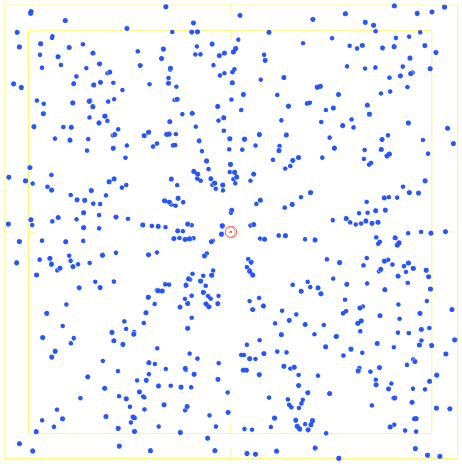
Einstein's view– The Universe is expanding, and there is no center!



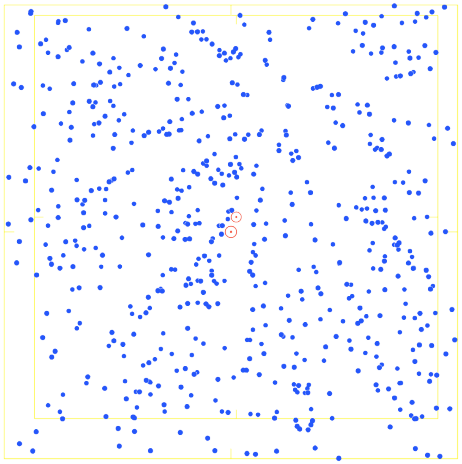
Gives the Impression of Being Special



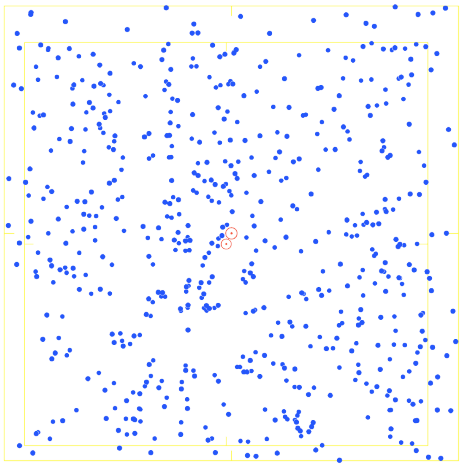
Gives the Impression of Being Special



Gives the Impression of Being Special



Gives the Impression of Being Special

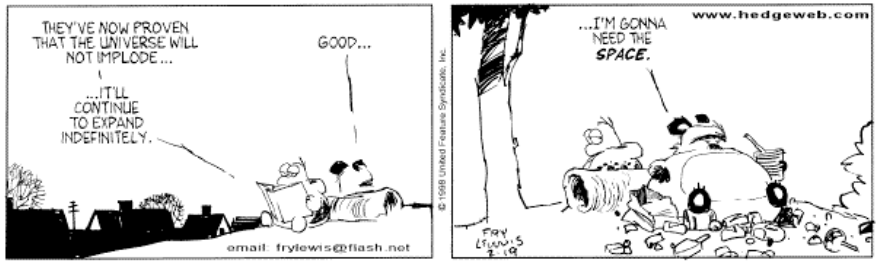


The Expanding Universe

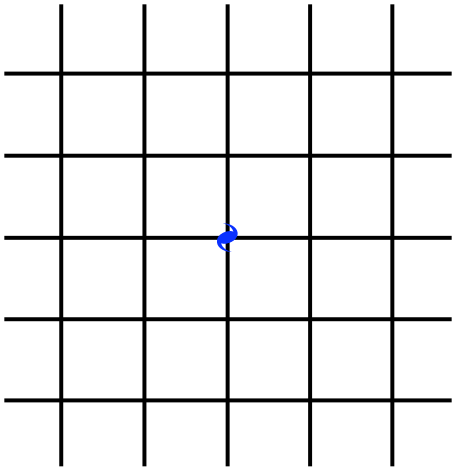
- To describe the motion of all the galaxies in the Universe, we use General Relativity (due to gravitation effects)
  - We'll talk about General Relativity more later, but it describes how the mass of objects (in this case all of the matter in the Universe) can distort space/time.

The Expanding Universe

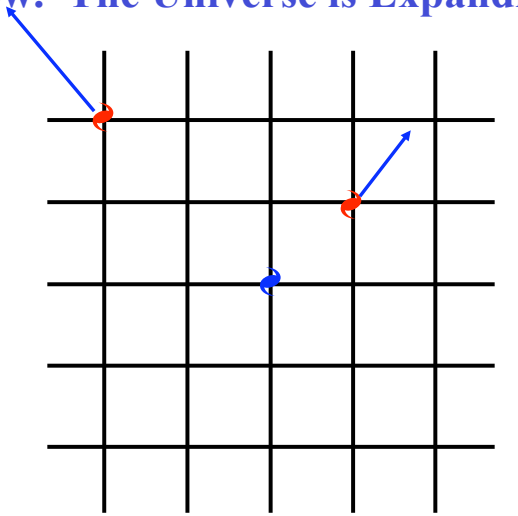
- To describe the motion of all the galaxies in the Universe, we use General Relativity (due to gravitation effects)
- General Relativity predicts that we live in an *expanding Universe*.
  - Einstein didn't buy it at first, so made a cosmological constant to get rid of it.
- In other words, space is stretching in all directions. This completely explains Hubble's Law.



Dude, The Universe is Expanding.



Wow. The Universe is Expanding.



Question

Nearly all galaxies are moving away from our Galaxy. What does this mean?

a) We are the center of the Universe.
b) We are actually the only moving galaxy.
c) No one wants to play with us.
d) All particles are repelling each other.
e) The Universe is expanding.

Hold on a minute there!

- Why don't we expand with the Universe?
- Other forces hold us together
  - Atoms - nuclear forces
  - Molecules & living beings – electromagnetic forces
  - Planets, stars, and galaxies – gravity
- But gravity can't hold galaxy superclusters together
  - Expansion grows stronger with distance (more expanding space)
  - Gravity grows weaker with distance (inverse square law)
- **Brooklyn isn't expanding!**

Brooklyn Is Not Expanding

Directed by
Woody Allen

Annie Hall (1977)

What do you think?

The Universe is expanding, how do you feel about that?

http://www.calresco.org/ewp/confuse.htm

A) 

B) 

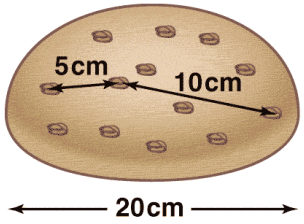
C) 

Expanding

- Hubble showed us that galaxies are moving away from us.
  - The farther, the faster
- This can imply an expanding Universe
- But, we aren't expanding, local forces hold us together

Analogy– Raisin Bread

The raisins are like galaxies.



Raisins stay the same size, like Brooklyn.

Question

The Universe is expanding, but we are not. Why?

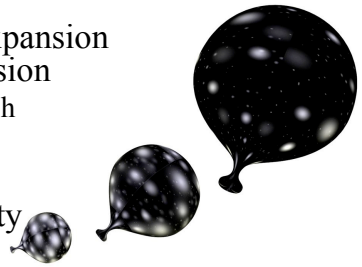
a) We are special.
b) We are grounded by our understanding of the Universe.
c) We are held together by stronger local forces.
d) What are you talking about, we are expanding.
e) The Universe is just no longer expanding.

~~Expanding into What?~~

What is North of the North Pole?

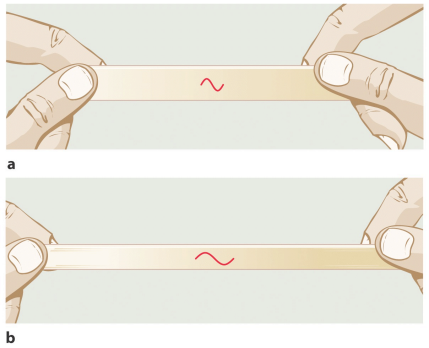
Common Misconception

- Its common to think of the expansion of the Universe like an explosion
  - Galaxies hurled away from each other through space
- This is incorrect!
- Einstein's Theory of Relativity tells us that spacetime itself is expanding!
  - Like an inflating balloon



Analogy - Rubber Band

- Spacetime expands, like stretching a rubber band
- Not only do distances grow…
- Even the photons' wavelengths get stretched!
  - Increasing wavelength = redshift!
  - **Cosmological redshift**



Reality

- The analogies are just to help us visualize, don't get stuck in the specifics.
- The Universe has no center.
- The Universe has no edge.
- Concept of time and space began with the Universe, can not apply the concepts so easily.

http://universe.gsfc.nasa.gov/images/reach-for-the-universe.jpg