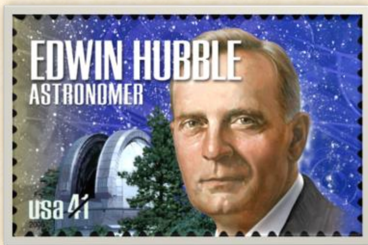
ASTR 1020: Stars & Galaxies

November 4, 2013

- Reading: Chapter 20, sections 20.3.
- *Mastering Astronomy* Homework on Galaxies is due Nov. 8th.
- Go to Fiske on Wednesday for *"Hubble's Expanding Universe."*



Astronomy Picture of the day

HST picture of NGC 346 in the Small Magellanic Cloud

What's ahead for the rest of the semester?

- *This week*: Hubble's Law & the evolution of galaxies.
- *Nov. 11-15*: Dark Matter
- Nov. 18-22: Dark Energy & the Fate of the Universe. Exam 3 on Nov. 20.
- *Nov. 25-29*: Fall Break
- *Dec. 2-6*: The Big Bang
- *Dec. 9-13*: Inflation, lunar telescopes, & wrap-up.

Today

Edwin Hubble: Cosmology's *Superman*

- Hubble's Law
- Redshifts and the expanding universe: *Introduction to Cosmology*

Reading Clicker Question: How did Hubble show that the Andromeda Galaxy was, in fact, a distant galaxy?

A. He observed a white dwarf supernova in the galaxy.
B. He observed Cepheid variables in the galaxy.
C. He measured the rotation speed of the galaxy.
D. He observed the main-sequence of stars in a cluster in the galaxy.

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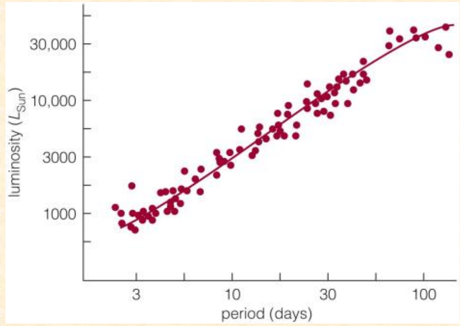
Measuring Distances via Standard Candles

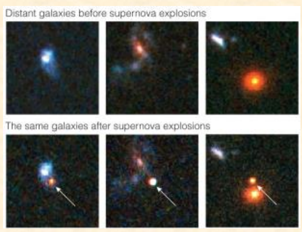
- We assume we know their luminosity.
- Measure apparent brightness and infer the distance
- Can use this with ANYTHING if we think we know its true luminosity

Luminosity estimated via Period-Luminosity Relation for Cepheids



Used by Hubble to determine distance to the Andromeda Galaxy.

White Dwarf Supernovae: bright enough to be seen halfway across the Observable Universe



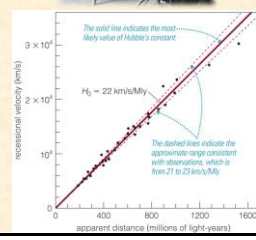
Useful for mapping the universe to the largest distances

Hubble's Law

- Velocity = H_o x distance
- Slope is
  H_o = Hubble's "constant"
  ~ 22 km/sec per Mly
  (million light year)

=>Measures the expansion rate (larger for faster expansion)

- Velocity is in km/sec (also called redshift)
- Distance is in millions of light years (Mly)



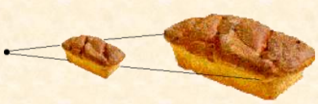
Raisin Bread Model of the Universe

All raisins expand away from all other raisins as the dough rises

The more dough between the raisins, the more they move apart during the rise (Hubble's Law)

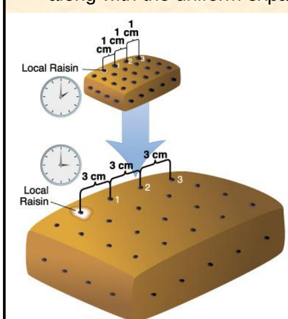
The loaf is VERY large, perhaps infinite → no center

Every raisin will see Hubble's Law



How do galaxies move within the universe?

How do we interpret Hubble's Law? Galaxies are carried along with the uniform expansion of the Universe.



- Raisin 1 starts out 1 cm away & moves to 3 cm after 1 hr => velocity of 2 cm/hr.
- Raisin 2 moves from 2 cm to 6 cm after 1 hr or velocity of 4 cm/hr.
- So, velocity or redshift is proportional to distance!

- **Clicker Question**: Two galaxies, Letterman and Leno, are both found to have Cepheid stars with periods of 20 days. Leno's stars appear brighter to us. Which will likely have the greatest velocity (redshift)?

a) Letterman
b) Leno

a) Letterman

- Cepheid stars of the same period should have the same luminosity.
- Leno's look brighter, so Leno is closer. According to Hubble's law, then Letterman should also have the higher velocity (redshift).

Age of the Universe

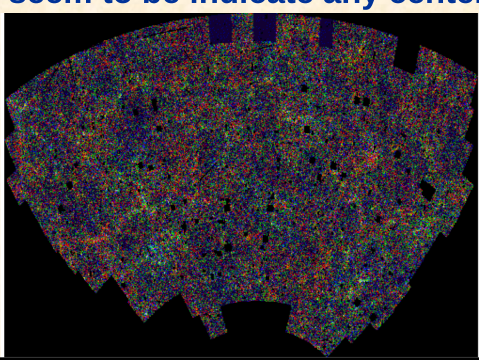
- Age = $1/H_o$ = 13.7 billion years.
- If H_o is decreased, the age will be larger.
- Expansion is slower, so it has been a longer time since everything was in one point (Big Bang).

Cosmological Principle

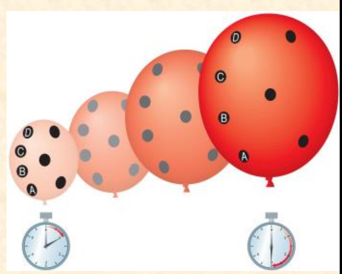
The universe looks about the same no matter where you are within it.

- Matter is evenly distributed on very large scales in the universe.
- It has no center or edges.
- The cosmological principle has not been proven beyond a doubt, but it is consistent with all observations to date.

The "Cosmic Wallpaper" doesn't seem to be indicate any center



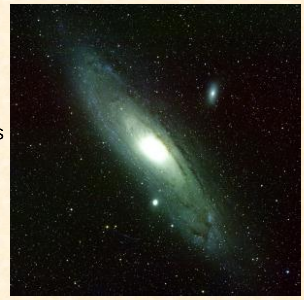
- On an expanding balloon, no galaxy is at the "center" of expansion
- Expansion happens into a higher dimension (2-D surface into a 3-D space)
- Is our 3-d space expanding through a 4^{th} dimension?



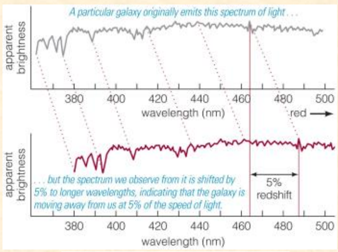
- Latest results (2013)- space overall appears to be very flat
- Either the universe is infinite, or much, much larger than the part we can see (observable universe ~ 13.7 billion light years' radius)

Lookback time

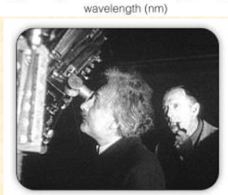
- Astronomers can look back into time by observing distant objects
- Example: Andromeda is about 2 million light years away
- We see Andromeda as she appeared 2 million years ago, not as she is today!



- Measuring distances to far away galaxies is difficult but measuring Doppler shifts (velocities) is easier from spectra



- Use Hubble law to estimate distances!
- $V = H_o \times d$



Larger redshift
(what is usually measured)

= larger velocity

= larger distance

= larger lookback time

So, redshift can used used as a time reference– that is, "this happened back at redshift=6"