ASTR 1020: Stars & Galaxies

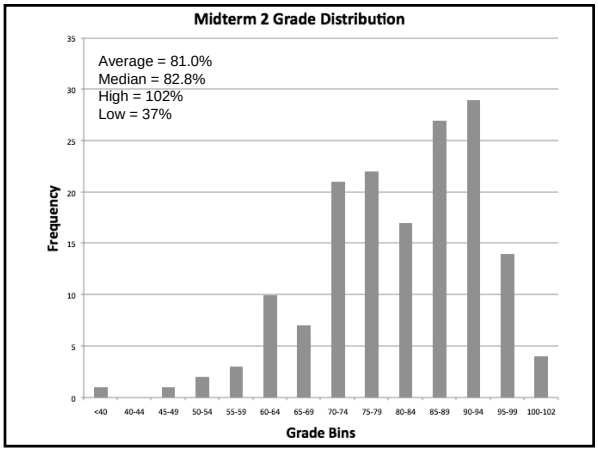
March 31, 2008

• Reading: Chapter 21, sections 21.1 – 21.2.

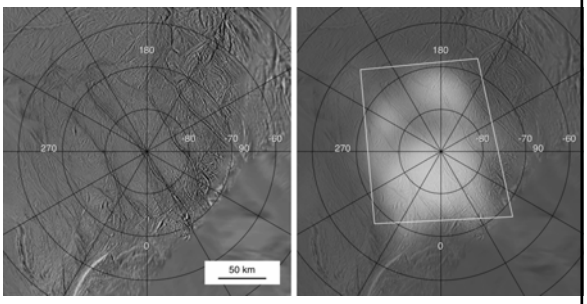
• *MasteringAstronomy* Homework on Galaxies and Hubble's Law is due April 7th.

Clicker Question:
What I did on Spring Break

a) Stayed home and studied Astronomy
b) Went to Cancun and laid on the beach
c) Helped to feed the needy or built houses for the homeless
d) Went to Los Alamos where I learned to love the bomb
e) What happens in Vegas, stays in Vegas or you wouldn't believe me if I told you what I did over Spring Break



Astronomy Picture of the day



Cassini's March 12, 2008, flyby of Enceladus provided the best view yet of the heat radiation from the active south pole of the satellite.

What's ahead for April?

- *This week*: Hubble's Law & the evolution of galaxies.
- *April 7-11*: Dark Matter
- *April 14-18*: Dark Energy & the Fate of the Universe
- *April 21-25*: The Big Bang
- *April 28 – May 2*: Exoplanets, lunar telescopes, & wrap-up.

Today

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

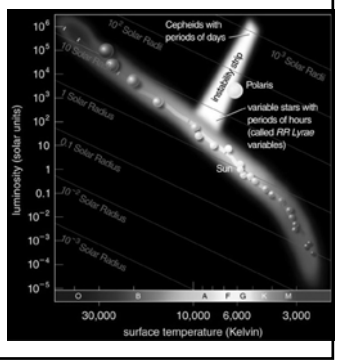
Edwin Hubble: Cosmology's *Superman*

Measuring Distances via Standard Candles

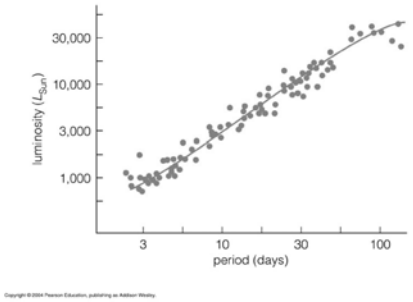
- We assume we know how bright they are
- Measure apparent brightness and infer the distance
- Can use this with ANYTHING if we think we know its true luminosity

Cepheid Variable Stars

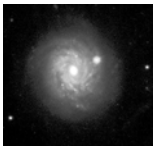
- Cepheids are some of the most luminous stars

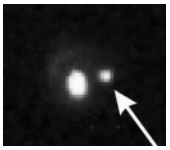


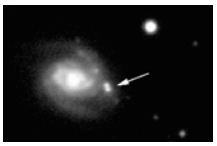
Luminosity estimated via Period-Luminosity Relation



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

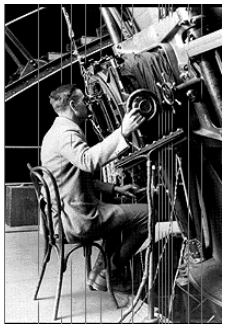


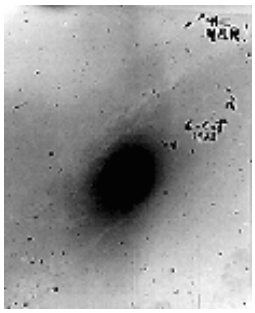




Useful for mapping the universe to the largest distances

In 1924 Edwin Hubble identified Cepheids in Andromeda→ outside of Milky Way!





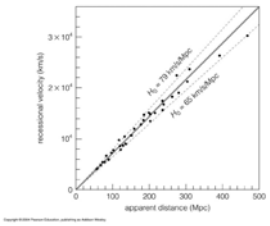
Hubble's Law

- Velocity = H_o x distance
- Slope is

H_o = Hubble's "constant"
~ 70 km/sec per Mpc

Measures the expansion rate (larger for faster expansion)

- Velocity is in km/sec (also called redshift)
- Distance is in Megaparsecs (Mpc)



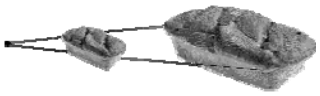
Raisin Bread Model of the Universe

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)

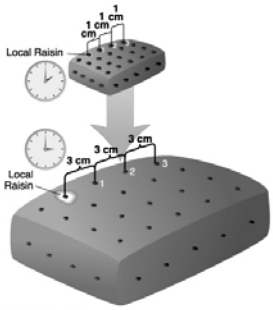
The loaf is VERY large, perhaps infinite → no center

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 = $1/H_o$
- 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)

Imagining the Expanding Universe

- NOT like an explosion of galaxies THROUGH space from a center place
- The space between galaxies is expanding, carrying the galaxies way from each other

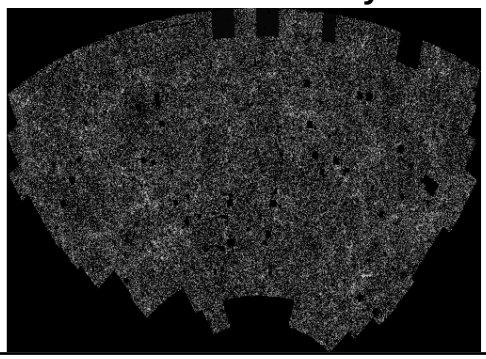
The Cosmological Principle

There is no center.

Every part of the universe is pretty much like every other part (homogeneous & isotropic)

A PHILOSOPHY-- based on our findings ever since Copernicus (Earth is not the center of the solar system)

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

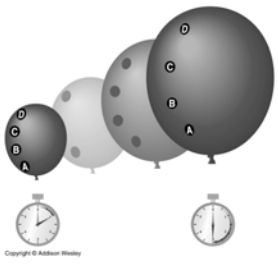


How can the Universe not have a center and an edge? What are we expanding INTO?

- Analogy: how did Magellan describe an Earth with no "edge"?

- Space, like the surface of the Earth, can curve
- If it curves enough, space can join back on itself: no edge!

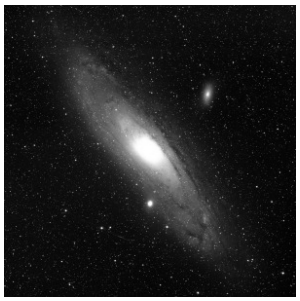
- On an expanding balloon, no galaxy is at the "center" of expansion
- Expansion happens into a higher dimension (2-D surface into a 3-D space)
- Is our 3-d space expanding through a 4th dimension?



- Latest results (2008)- space overall appears to be very flat
- Either the universe is infinite, or much, much larger than the part we can see (observable universe ~ 14 billion light years' radius)

Lookback time

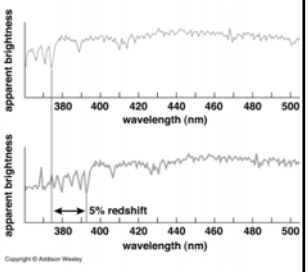
- Astronomers can look back into time by observing distant objects
- Example: Andromeda is about 2 million light years away
- We see Andromeda as she appeared 2 million years ago, not as she is today!



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”