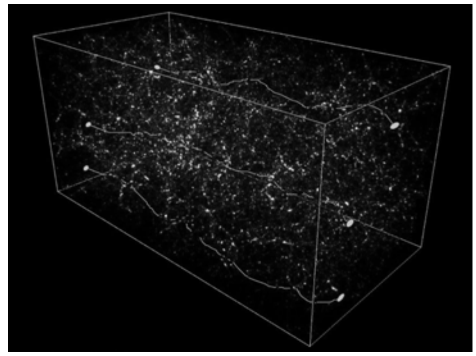
ASTR 1020: Stars & Galaxies

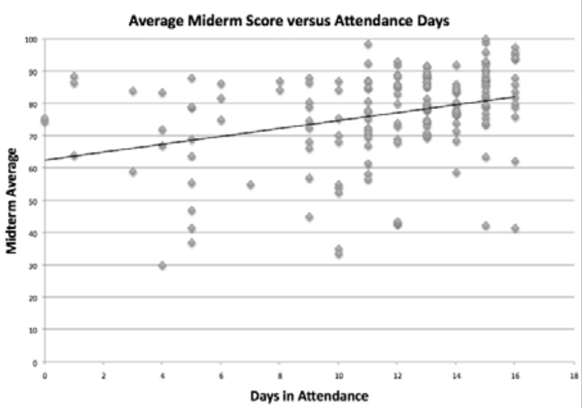
April 2, 2008

- Reading: Chapter 21, sections 21.3.
- *MasteringAstronomy* Homework on Galaxies and Hubble's Law is due April 7th.

Astronomy Picture of the day

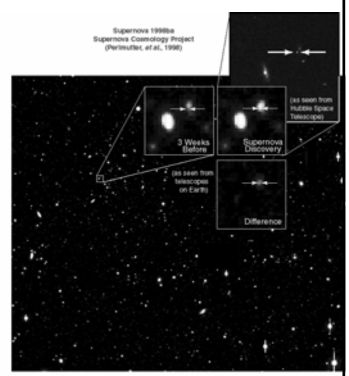


Weak Lensing Distorts the Universe



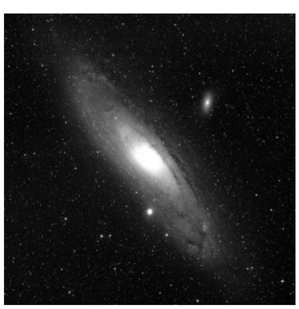
Today

- Lookback time.
- More on redshifts.
- Cosmological Expansion.
- The evolution of galaxies.



Lookback time

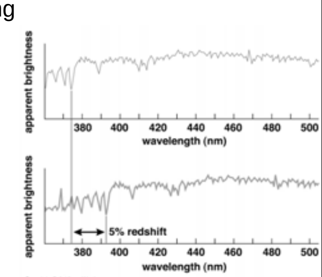
- Astronomers can look back into time by observing distant objects
- Example: Andromeda is about 2 million light years away
- We see Andromeda as she appeared 2 million years ago, not as she is today!



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

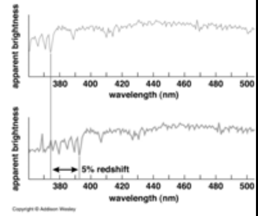
= larger lookback time

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

Cosmological Redshifts

Definition of Redshift:

Z = redshift;



observed wavelength / “rest” wavelength = 1+Z

Redshifts always have Z>0
(redder light has larger wavelengths)

Clicker Question

We observe a distant galaxy where we see a bright emission line at wavelength =1312 nm. After some thought, we decide that this is probably Hydrogen “alpha”, which is usually a pink line at 656 nm in the Lab. What is the redshift of the galaxy?

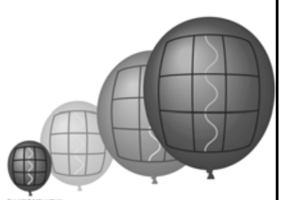
a) Z=1.0
b) Z=1.3
c) Z=2.0

- Observed/ “rest” wavelength = 1+Z
- 1312 nm / 656 nm = 2, so
- Redshift = Z= 1
- We see this galaxy as it appeared “back at redshift =1”

Redshift also = expansion factor

1 + Z also measures how much universe has expanded

As universe expands, wavelength of light is also lengthened



1 + Z =

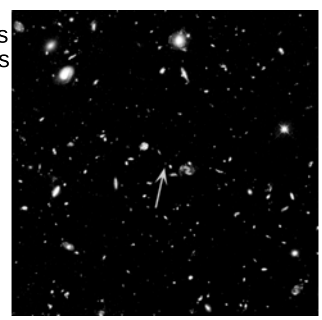
$$\frac{\text{distance between galaxies now}}{\text{distance between galaxies then}}$$

Example:

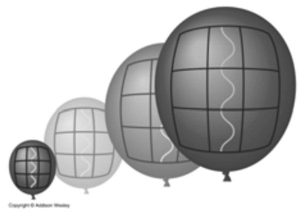
- Most distant galaxies known have redshifts of Z ~ 6
- H-alpha has a wavelength of

1+Z = 7 times normal

(this is a BIG redshift! Pink is now far into IR)



- These galaxies are very distant
- Lookback time is large
- Universe has expanded by a factor of 7 since then!



- NOW = redshift =0

1+Z = observed/ “rest” wavelengths
So Z=0 means that the wavelengths are not redshifted

1+Z = expansion factor
The universe is its present size NOW

Example: a galaxy is observed at a redshift of 1

- By the what factor has the universe expanded since the light left that galaxy?

- Expansion factor is 1+Z = 2, so the universe has expanded by a factor of 2 since then
- Note that the galaxies are no longer where we see them now, but at Z=1 were at the exact place for their light to arrive at Earth today

Over the largest scales, think of the cosmological redshift as an expansion factor that is related to time since the Big Bang, and not as a velocity

The Cosmic Horizon

- What is the biggest redshift that is possible to see? How far back in time can we see?
- Redshift = infinity → the Big Bang

Can we look all the way back and see the Big Bang?

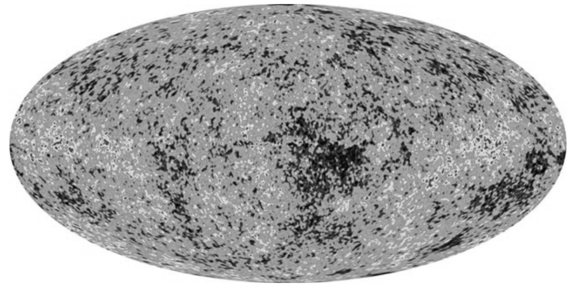
Almost!!

- Z~ 1000
  universe much denser →so dense it was opaque

- ~100,000 yrs = 0.0001 billion years after the Big Bang)

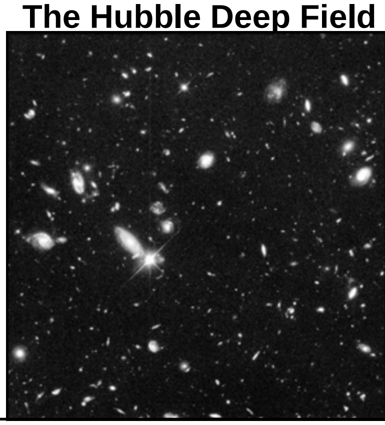
We see an opaque "wall" of highly redshifted (factor of ~1000) light all around us

Cosmic Microwave Background



Lots more on this later!

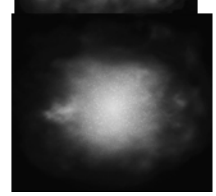
The Hubble Deep Field



Galaxies to z=4!

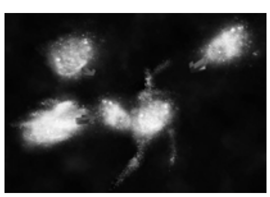
Making a spiral galaxy

- Start with a mostly uniform cloud of hydrogen
- Gravitational collapse to a protogalactic cloud
- First stars born in this spheroid (spheroid stars are billions of years old → "fossil record")



A slight variation?

- Several smaller protogalactic clouds may have merged to form a single large galaxy
- May explain slight variations in stellar ages in the Milky Way



- As more material collapses, angular momentum spins it into a disk
- Stars now formed in dense spiral arms– disk stars are younger!

Clicker Question: The primary reason that massive O-type stars are not found in the galactic halo is because they are:

a) too massive to be kicked into the halo from the disk.
b) so massive that they settle into the thinner disk.
c) too short-lived to have persisted from halo formation until today.
d) too far away for us to see them.

- **C) Too short lived to be in the halo.**

Halo stars were born billions of years ago; the most massive stars don't live nearly that long

Will have disappeared by now (after having "enriched" the proto-galaxy gas with heavy elements)

Making ellipticals

- For some reason, star formation uses up all the gas fast
- Nothing left to make a disk
- Now we see a sphere of old stars

Or maybe….

- Galaxy collisions destroy disks
- Burst of star formation uses up all the gas
- Leftovers: train wreck
- Ellipticals more common in dense galaxy clusters