

# Physics 100 - November 19, 2007



■ No class on  
Wed., Nov. 21

Have a great  
Thanksgiving Break!

## ■ Presentations

- 1<sup>ST</sup> come  
1<sup>ST</sup> served
- Dec 3
  - Dec 5
  - Dec 10
  - Dec 12

2 per day

20 min + disc./quest.

GPS

Nucl. Bombs

Nucl. Terrorism

Music

Asteroids + Extinct.

Historical Figure

Cosm. Micr. Backgrd

Pages 8-26 in Hobson - nice brief review  
of highlights of human view of  
universe and Earth's place in it



Tycho Brahe  
1546-1601  
(Dane)

Careful observations  
of positions  
of Sun, Moon, planets



Sir Isaac Newton  
1643-1727  
(England)

universal law of gravitation

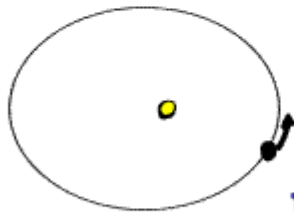
$$F = G \frac{M_1 M_2}{r^2}$$

+  
Laws of Motion

derived Kepler's  
3 laws of planetary motion



Johannes Kepler  
1571-1630 (German)  
Elliptical orbits  
Kepler's 3 laws of  
planetary motion



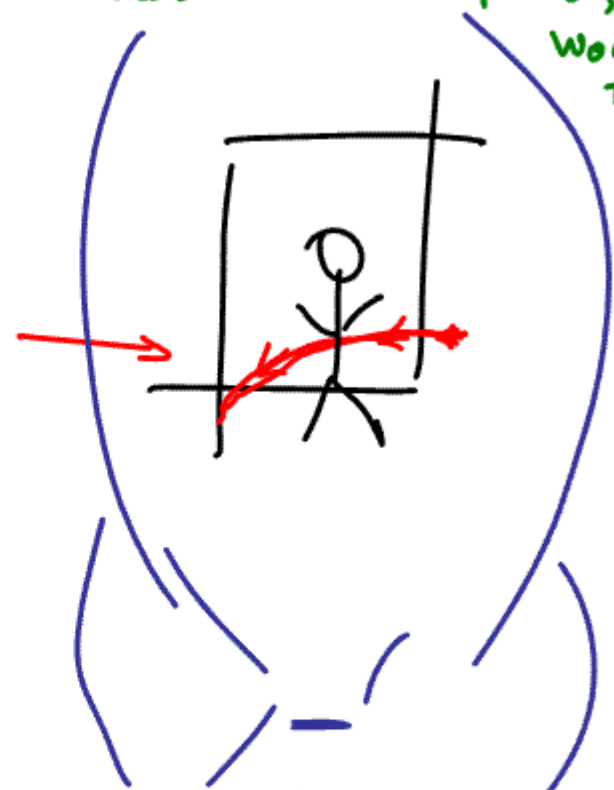
Equivalence of gravity  $\Leftarrow$  In accelerated rocket ship case, light would seem to travel on curved path  
Means grav. field must curve spacetime



Along came Einstein



Earth



Accel.  
 $\uparrow 1g$

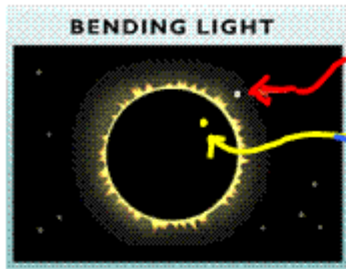
General Theory of Relativity

GRAV  $\equiv$  Accel. frame

light moves on a geodesic  
 $\uparrow$

Shortest dist. between two points

So, Einstein interprets gravitation as a curvature of spacetime

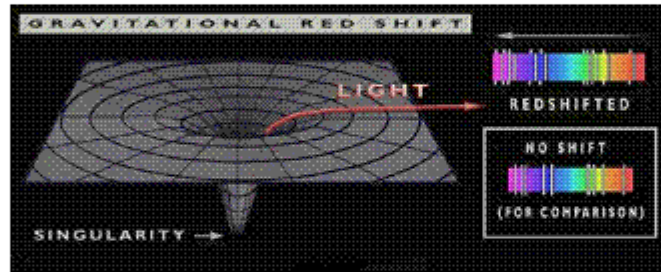


Apparent position

■ Bending of light by gravitational field ✓

Actual position

■ Gravitational redshift of light ✓



■ Perihelion advance of Mercury ✓



■ Gravitational Waves ?

Amplitude  $\sim 10^{-16}$  m

LIGO



# Cosmology

Scientific Study of the large Scale Structure of the universe — Attempt to understand to origin, evolution and fate of the universe

[http://wmap.gsfc.nasa.gov/m\\_uni.html](http://wmap.gsfc.nasa.gov/m_uni.html)

good online reference for this class

Not quite the same thing

# Cosmetology

The business of being a beautician — The treatment of skin, hair and nails

<http://careerplanning.about.com/cs/occupations/p/cosmetology.htm>

While we're at it ...

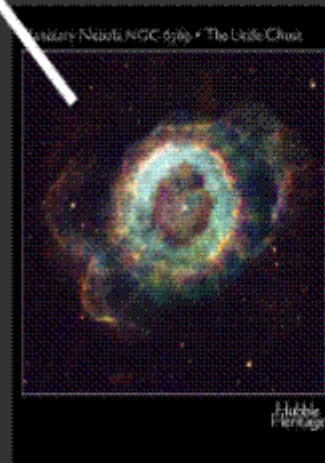
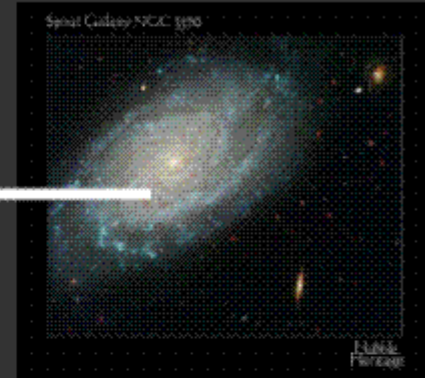
Astronomy



Astrology

Light travels at a finite speed

On to the very big ...



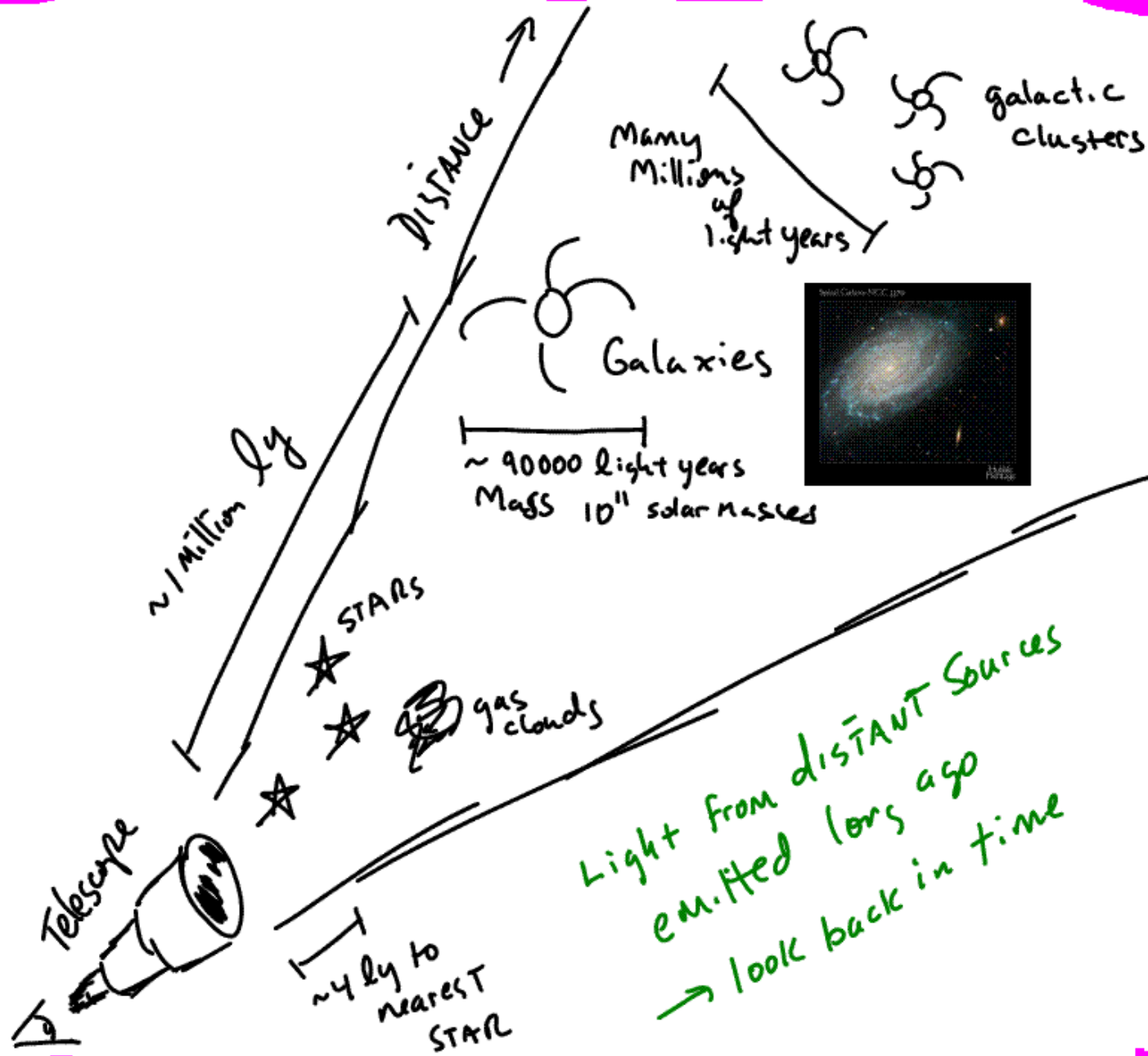
Telescopes are  
time machines

1 Mpc = 1 Megaparsec =  $3 \times 10^{22}$  m

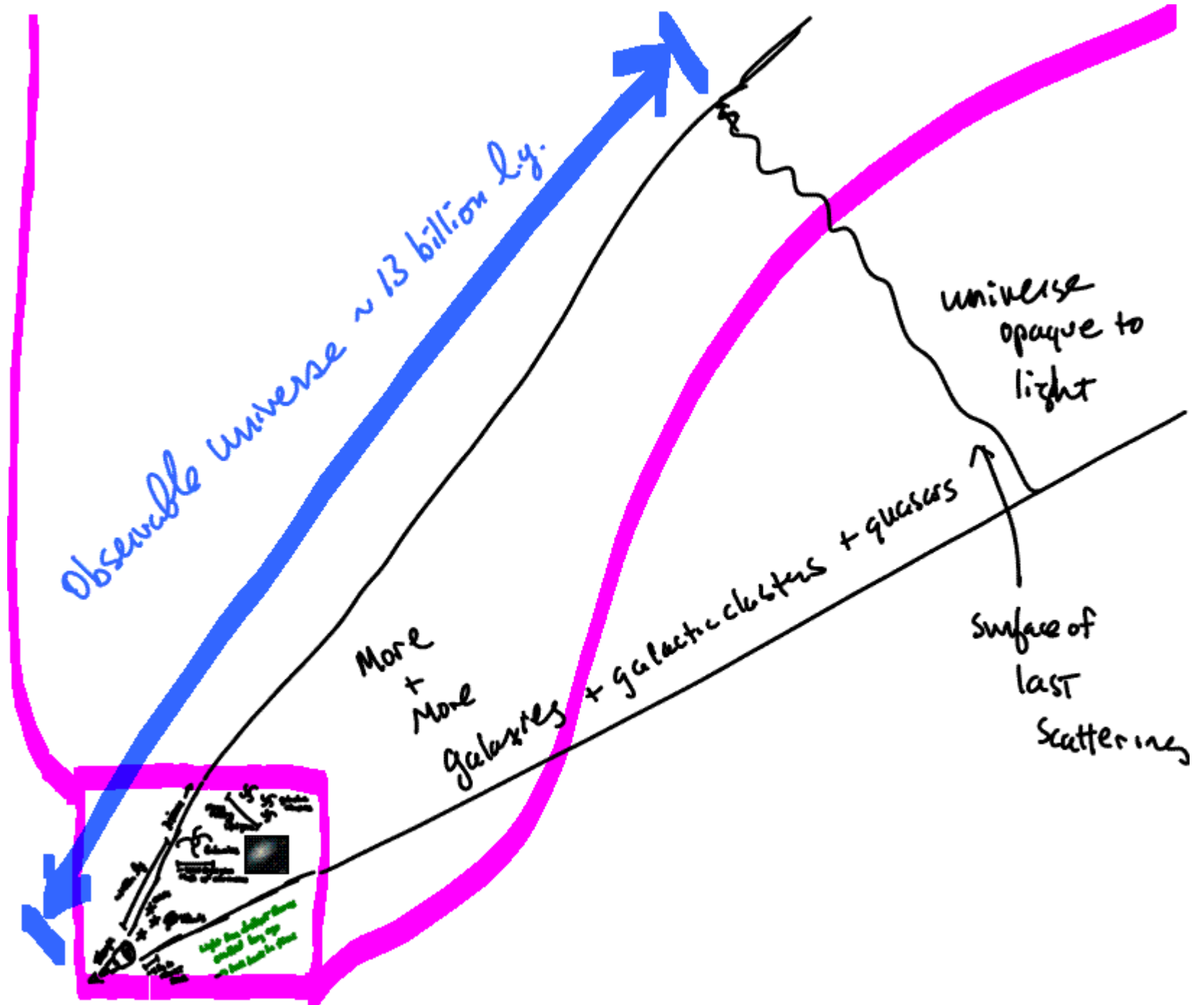
1 light year =  $9 \times 10^{15}$  m

Light travels from NYC to San Francisco in 1/100 second  
.... and it travels 1 Mpc in 3 million years

Farther away the object ... longer ago light emitted.









**Edwin Hubble (1889-1953)  
discovers a surprise in 1929**

**Galaxies that are further away  
appear redder**

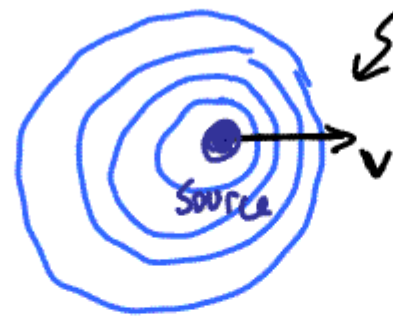
**Apparent Doppler shift**

check out doppler shift Applet :

[http://galileoandeinstein.physics.virginia.edu/more\\_stuff/flashlets/doppler.htm](http://galileoandeinstein.physics.virginia.edu/more_stuff/flashlets/doppler.htm)

"Redshifted" light

frequency appears lower to objects in direction away from direction of motion



frequency appears higher to observers in direction of motion



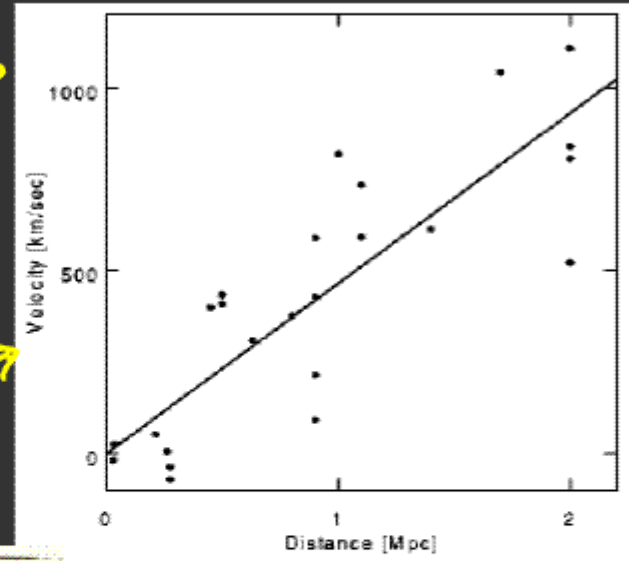
"Blueshifted" light

larger  $v$  — larger the red and blueshifts.

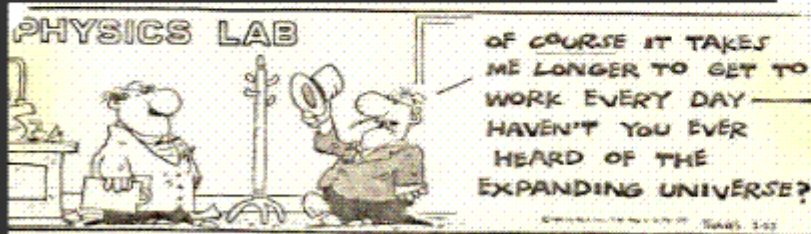


How fast galaxy  
moves  
away  
from  
us

Early  
Measurement



↑  
Distance to galaxy

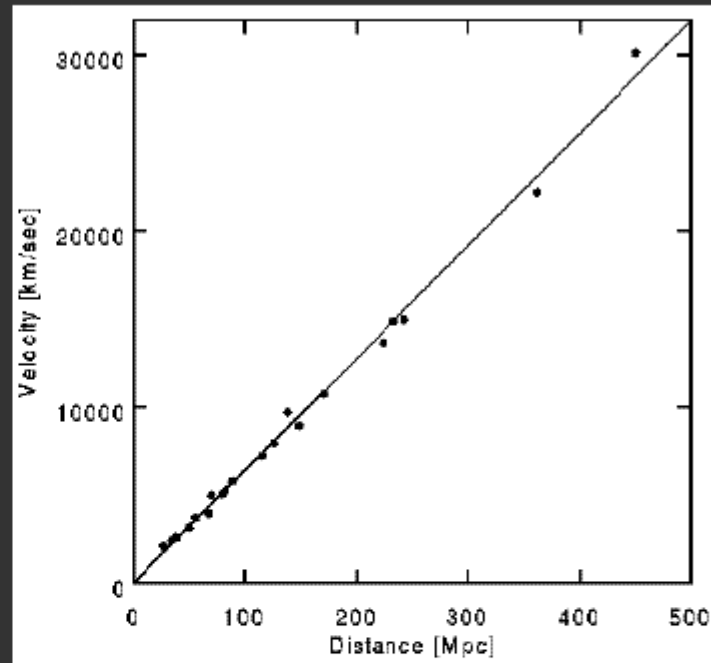


Hubble notes that the galaxies all recede from us  
... more distant galaxies recede from us faster

Light travels from NYC to San Francisco in 1/100 second  
.... and it travels 1 Mpc in 3 million years

**Welcome to the  
“expanding universe”!!**

**extrapolate back in  
time find the age of the  
universe → 13 billion  
years.**



Type Ia SNe from Riess, Press and Kirshner (1996)

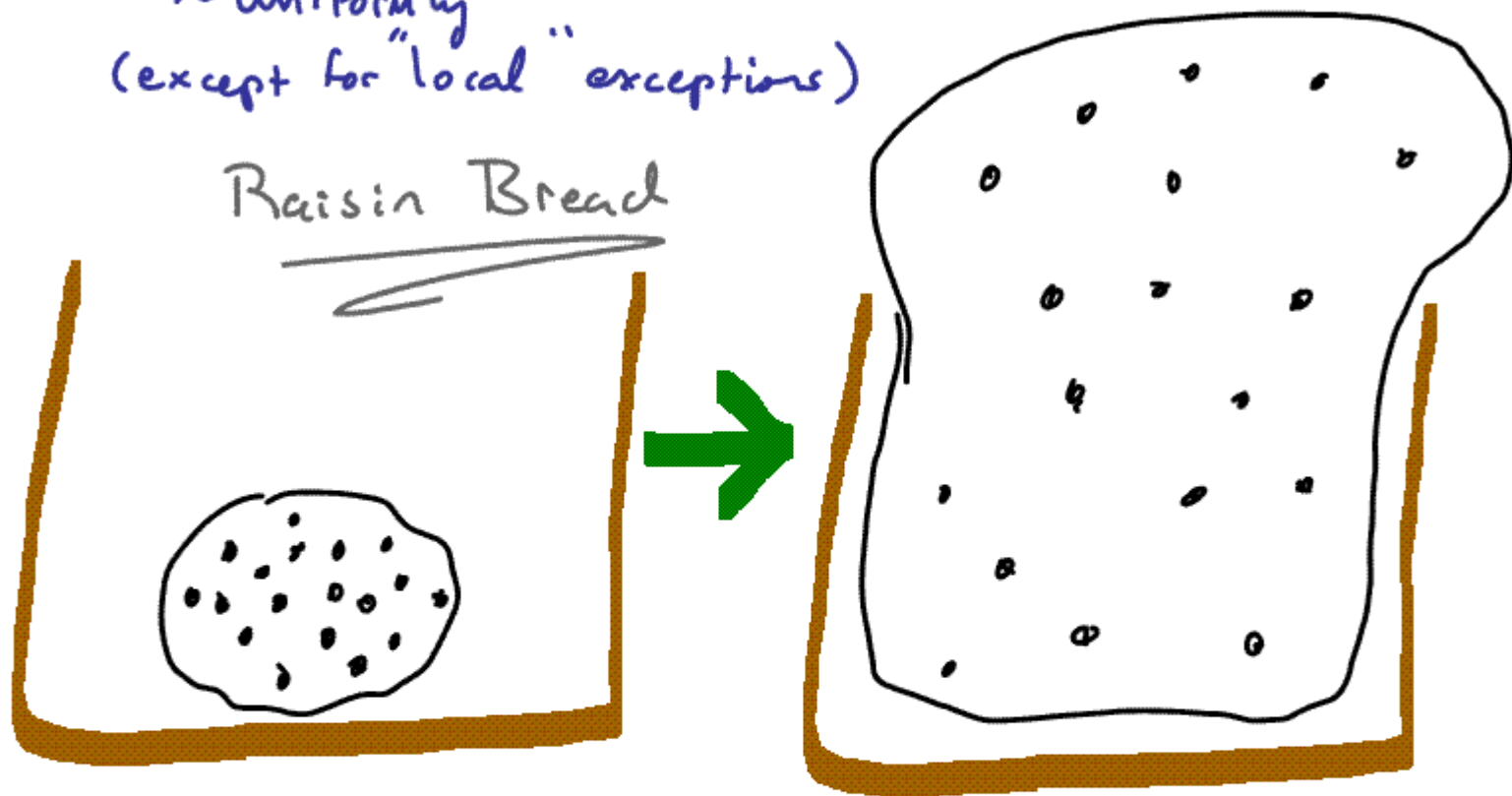
more modern data ... looking at galaxies much farther away

Space in the universe is expanding!

Think of Raisin bread or dots on balloon.

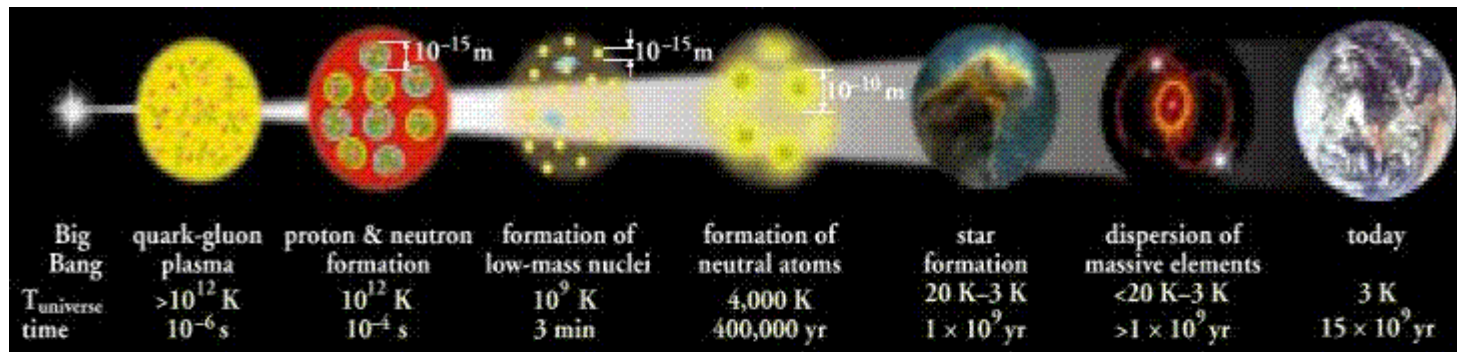
Galaxies Receding in all directions  
~ uniformly  
(except for "local" exceptions)

Raisin Bread



No need to think our galaxy is at center  
of universe.

Expansion of space makes effect same to all  
observers throughout universe.



Hot Big Bang predicts this

light should travel to us from time  $\sim 400$  k yr to now ... massively redshifted

$t = 4000$  K  $\longrightarrow$   $t = 4$  K

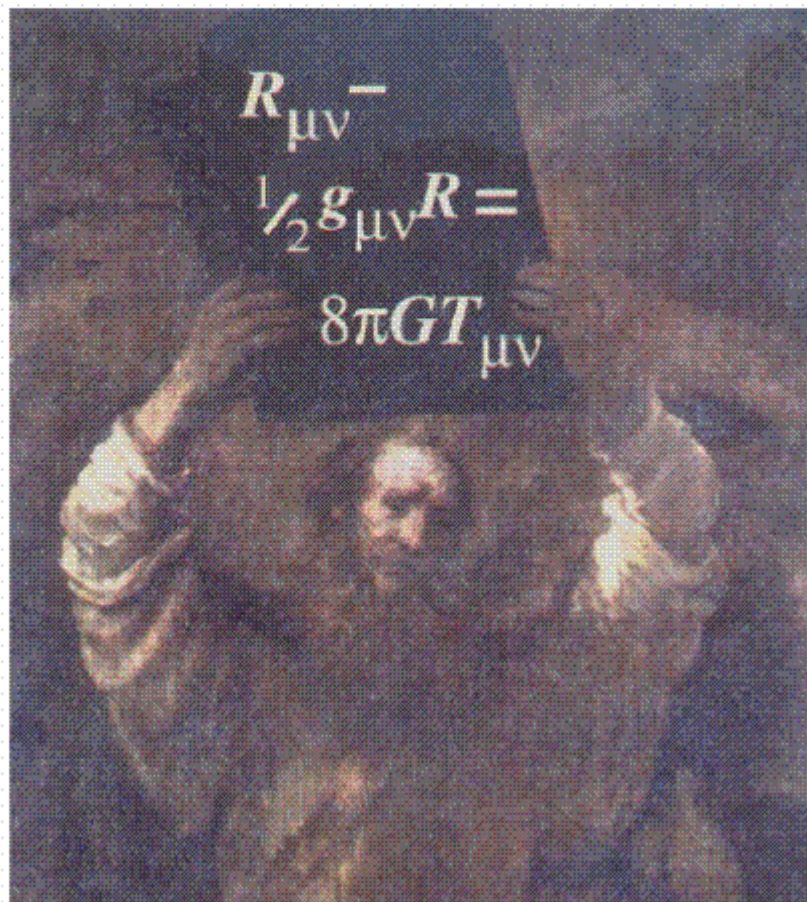
"perfect Blackbody"

Should come to us from all directions

"CMB"

Cosmic Microwave Background

# Why Believe? ...



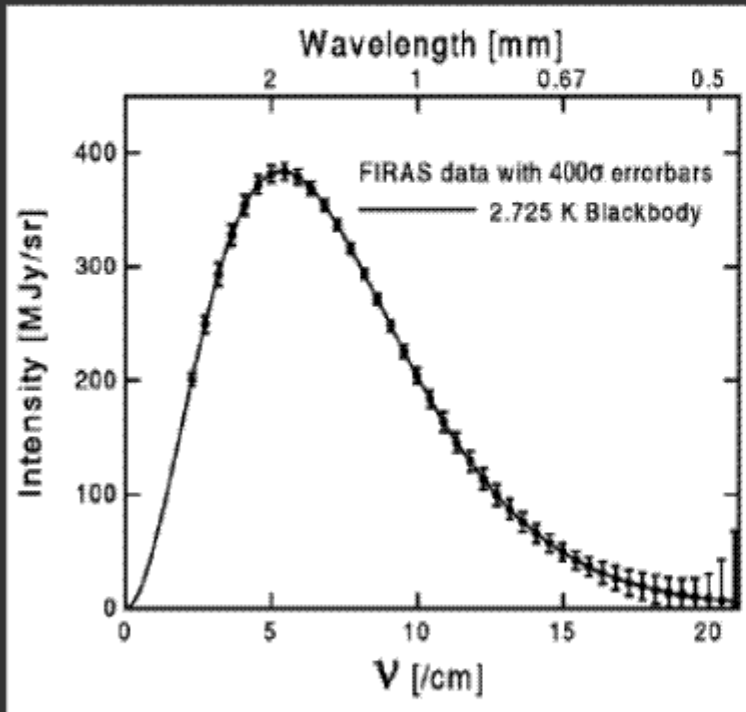
- R. Kolb



Evidence for Big Bang

## Cosmic Microwave Background

### Penzias and Wilson - 1964

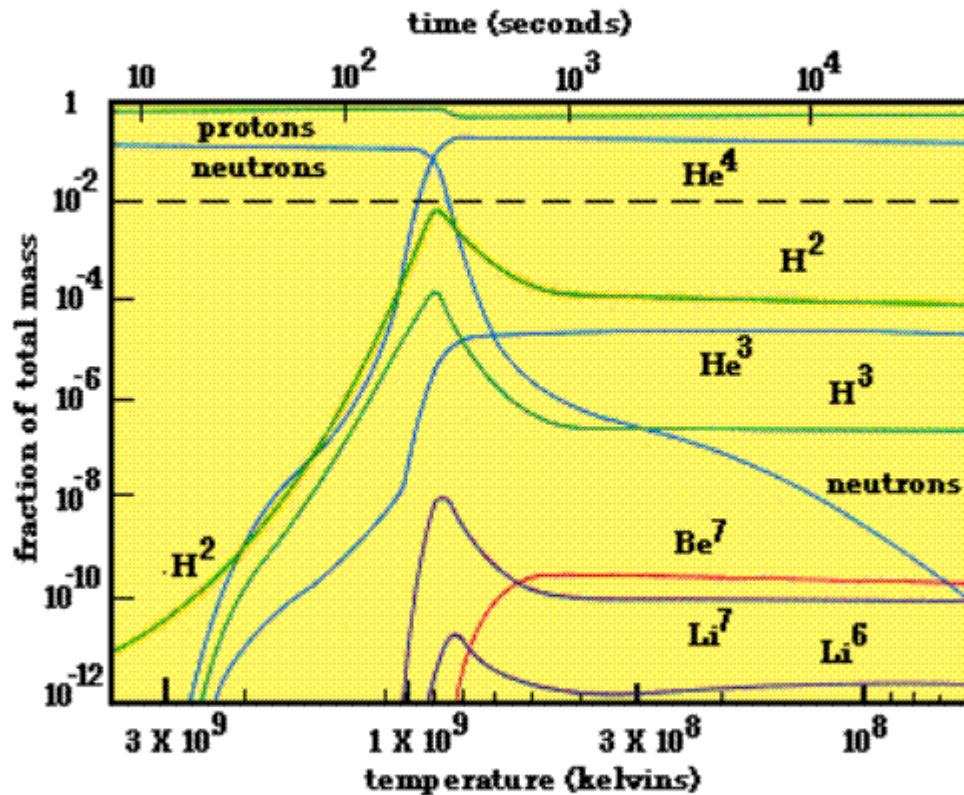


Uniform and isotropic  
– in as far as they could measure

1978 Nobel prize

# Big Bang Nucleosynthesis

$t \approx 100$  seconds



<http://www.astro.ucla.edu/~wright/BBNS.html>

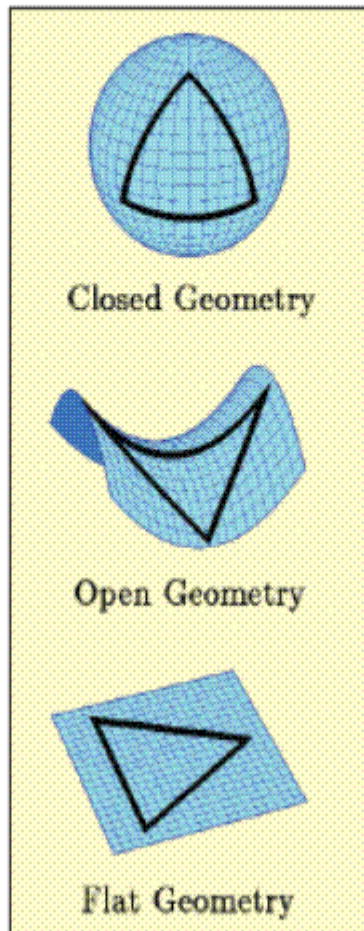
We see ~expected distribution of light nuclei in universe.

# Problems w/ Big Bang

NON-STATIC universe expected from Relativity

Relativity allows space to have different curved geometries?  
Which is our universe?

Flat space is a very special case!



Sum of angles in triangle

$$> 180^\circ$$

$$< 180^\circ$$

$$= 180^\circ$$