

Physics 100 - April 8, 2009

■ Presentation time Preferences to date

Group	topic	15-Apr-09	20-Apr-09	27-Apr-09	29-Apr-09
A	Nuclear physics and society				
B	String theory				
C	Global Positioning System				
D	Search for extra-terrestrial life	1	2	3	4
E	Music	3	4	1	2
F	Life and times of a great physicist	3	1	2	4
G	Radiation - dangers and uses	4	1	2	3

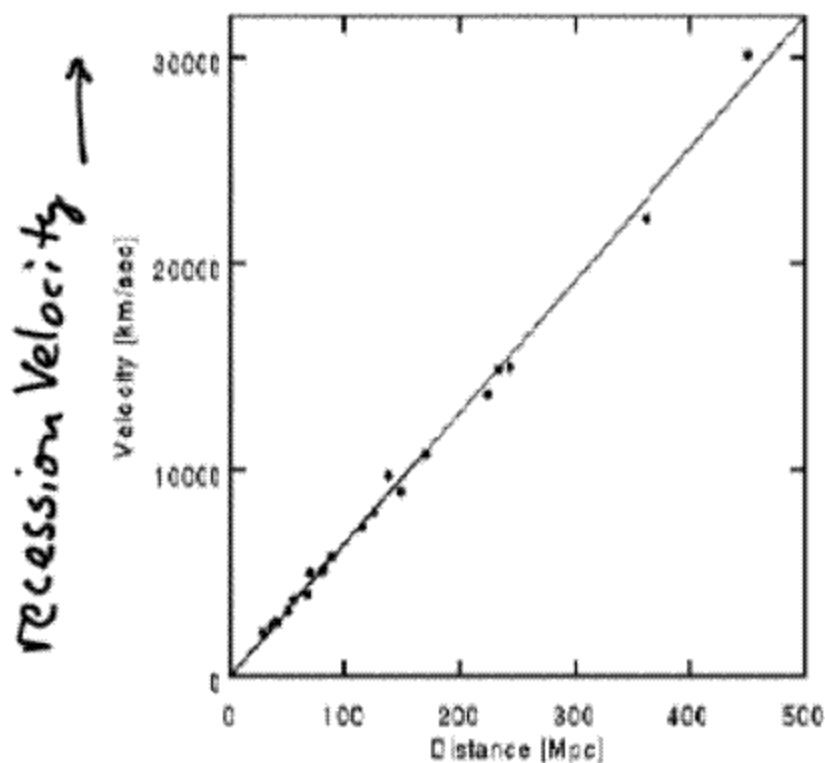
■ EXAM 2 April 22

Will be in touch Today/Tomorrow w/ details

We live in an expanding universe



Edwin Hubble
(1929)



Slipher
early 20's

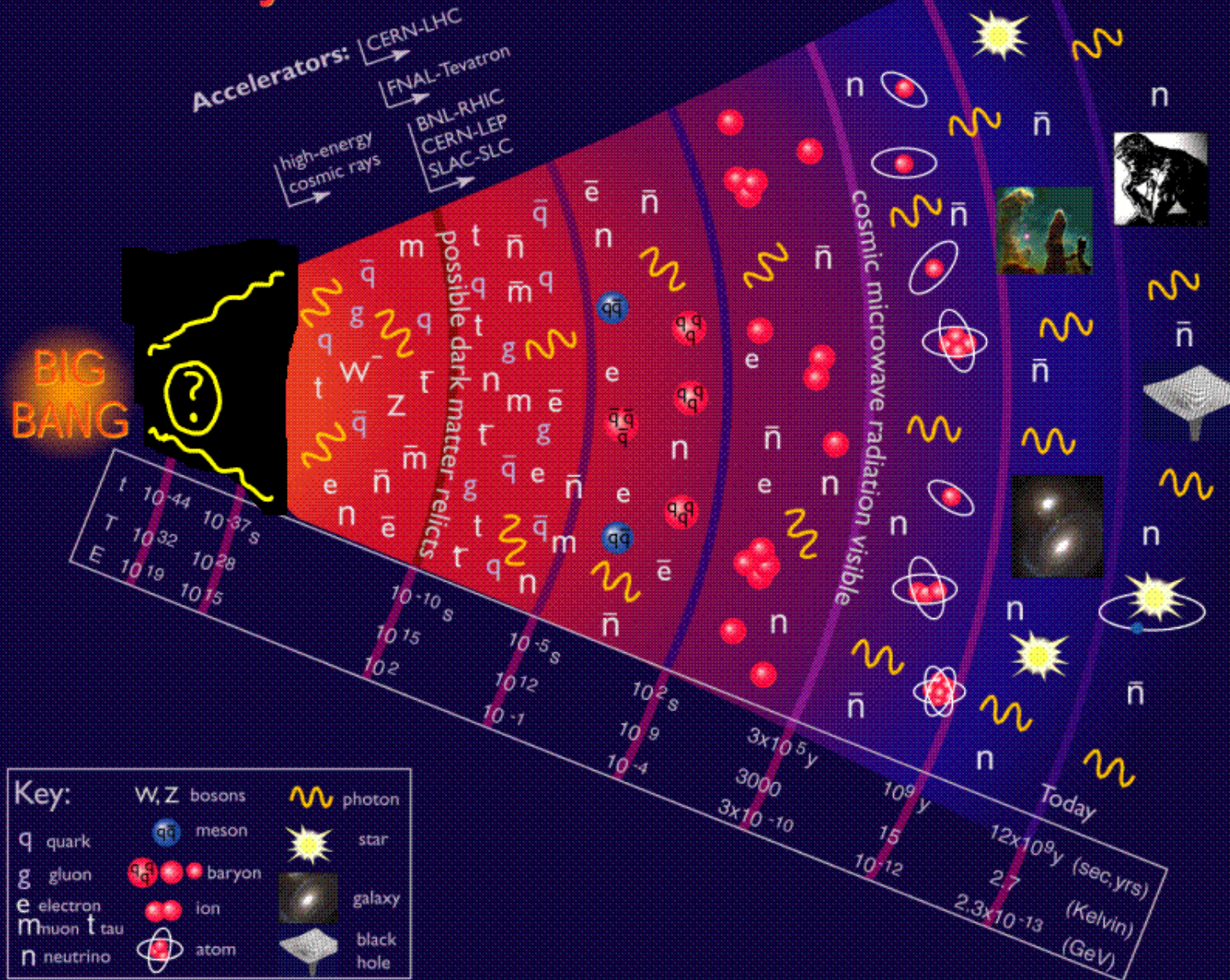
Also
Milton
Humason

Distance to galaxy

Determined by
redshift of Atomic
Spectral lines

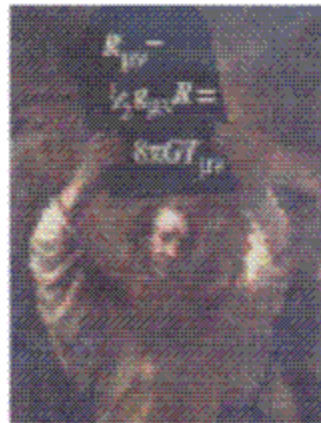
Determined by brightness
(Supernova in distant galaxy)

History of the Universe



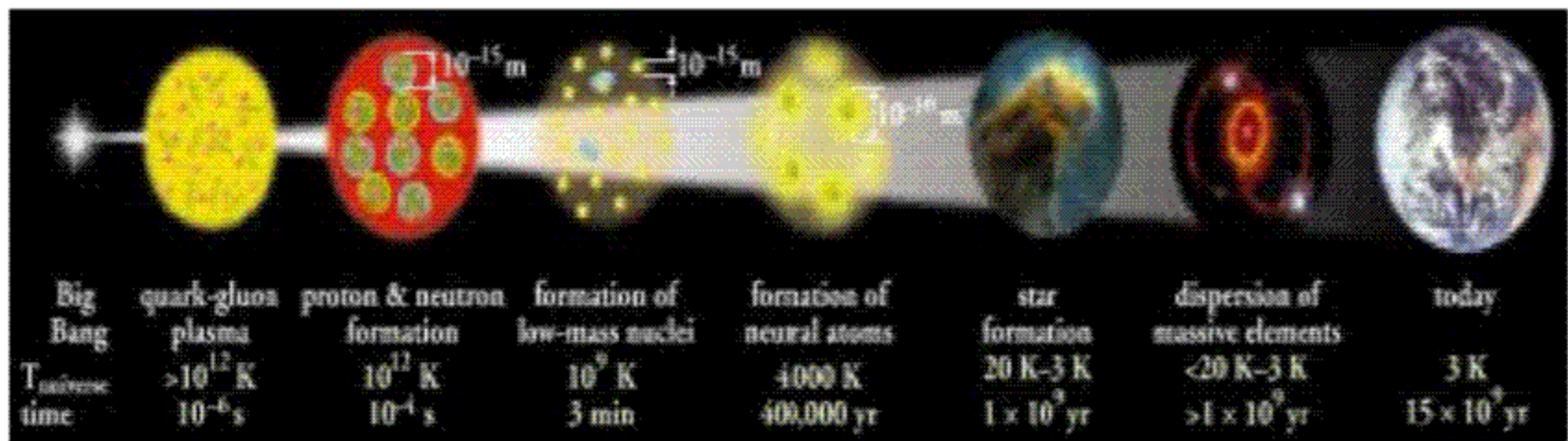
Particle Data Group, LBNL, © 2000. Supported by DOE and NSF

Why Believe? ...



-A. Kolb

... in the
Hot Big BANG?

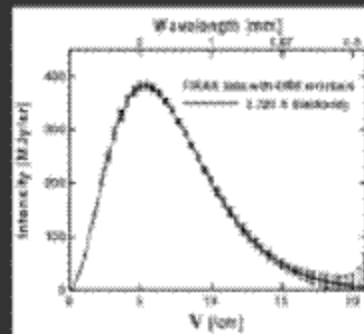


Observe light from
Time universe became
Transparent
 $T \sim 400,000$ years

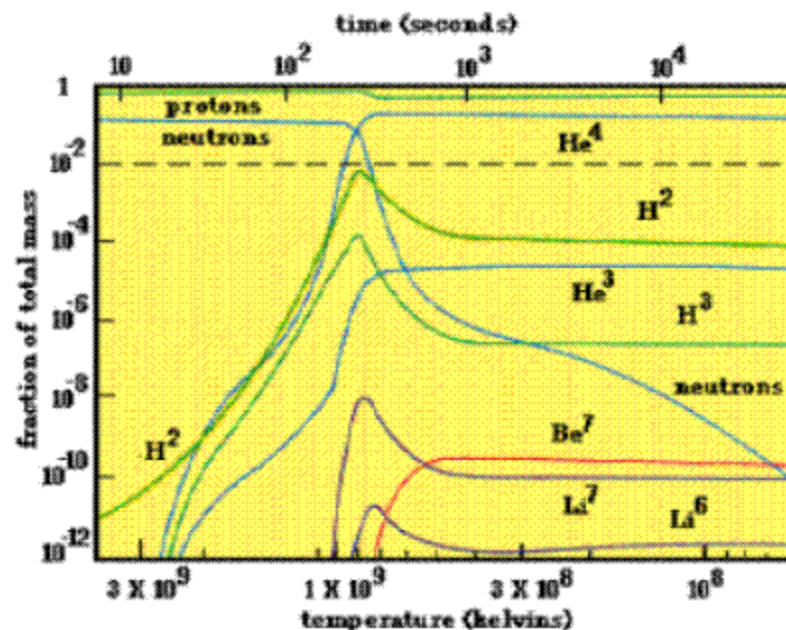
Perfect blackbody
all directions in sky

Amount of light
nuclei in
interstellar / intergalactic
space agrees w/
expectation from Big
Bang Nucleosynthesis
 $T \sim 3$ minutes

Cosmic Microwave Background Penzias and Wilson - 1964



Uniform and isotropic
- in as far as they could measure

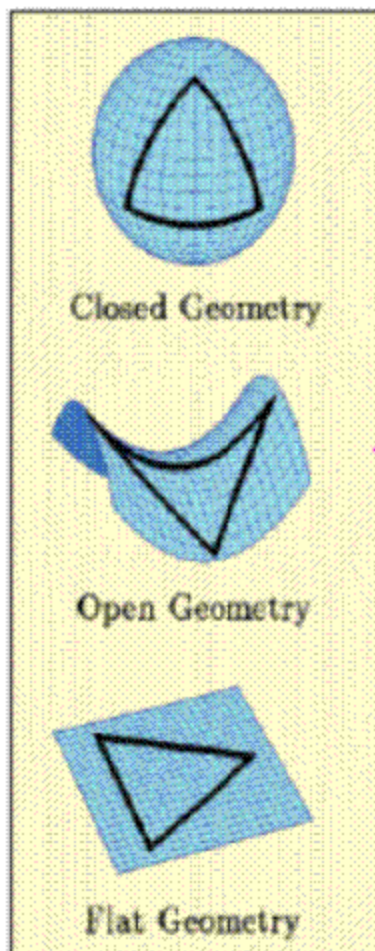


Problems w/ Big Bang

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

$$> 180^\circ$$

← universe EXPANDS...
Slows down + collapses

$$< 180^\circ$$

← universe expands forever

$$= 180^\circ$$

← universe expands to
a stop

Very special case

■ Singularity Problem - YIKES !! All of the universe at a Point?

■ Horizon Problem - Why is universe so smooth and isotropic on large scales?

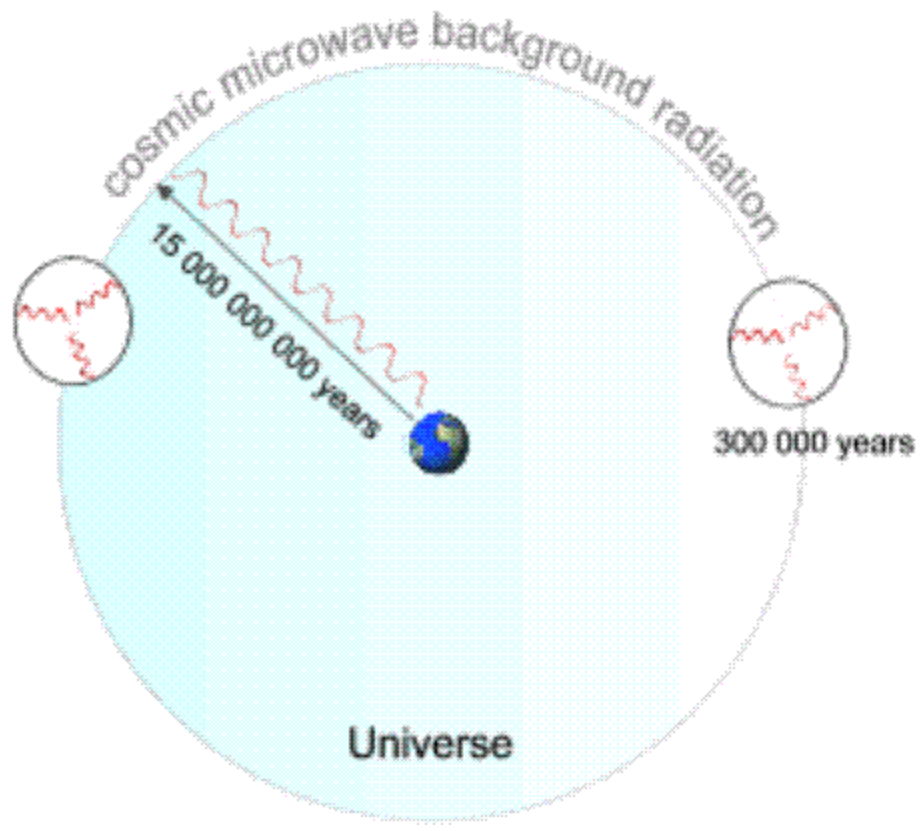
Why CMB so smooth and isotropic

at $T = 400,000$ yrs

only parts of universe as large as
400,000 light years could be causally connected
yet all at same temperature ??

■ Flatness problem - universe appears to be very close to "flat" ... very special case.
Requires fine tuning of basic Model

Horizon Problem



- drawing by
Theresa Knott
Taken from Wikipedia

- large Scale Structure problem - how do galactic structures form in a perfectly homogenous universe?



Hubble Deep Field South
PRC98-41a • STScI OPO • November 23, 1998
The HDF-S Team • NASA

HST • WFPC2



Andrei Linde
(Stanford)

Cosmic
Inflation
~1979



Paul Steinhardt
(Princeton)



Andy
Albrecht
(UC Davis)

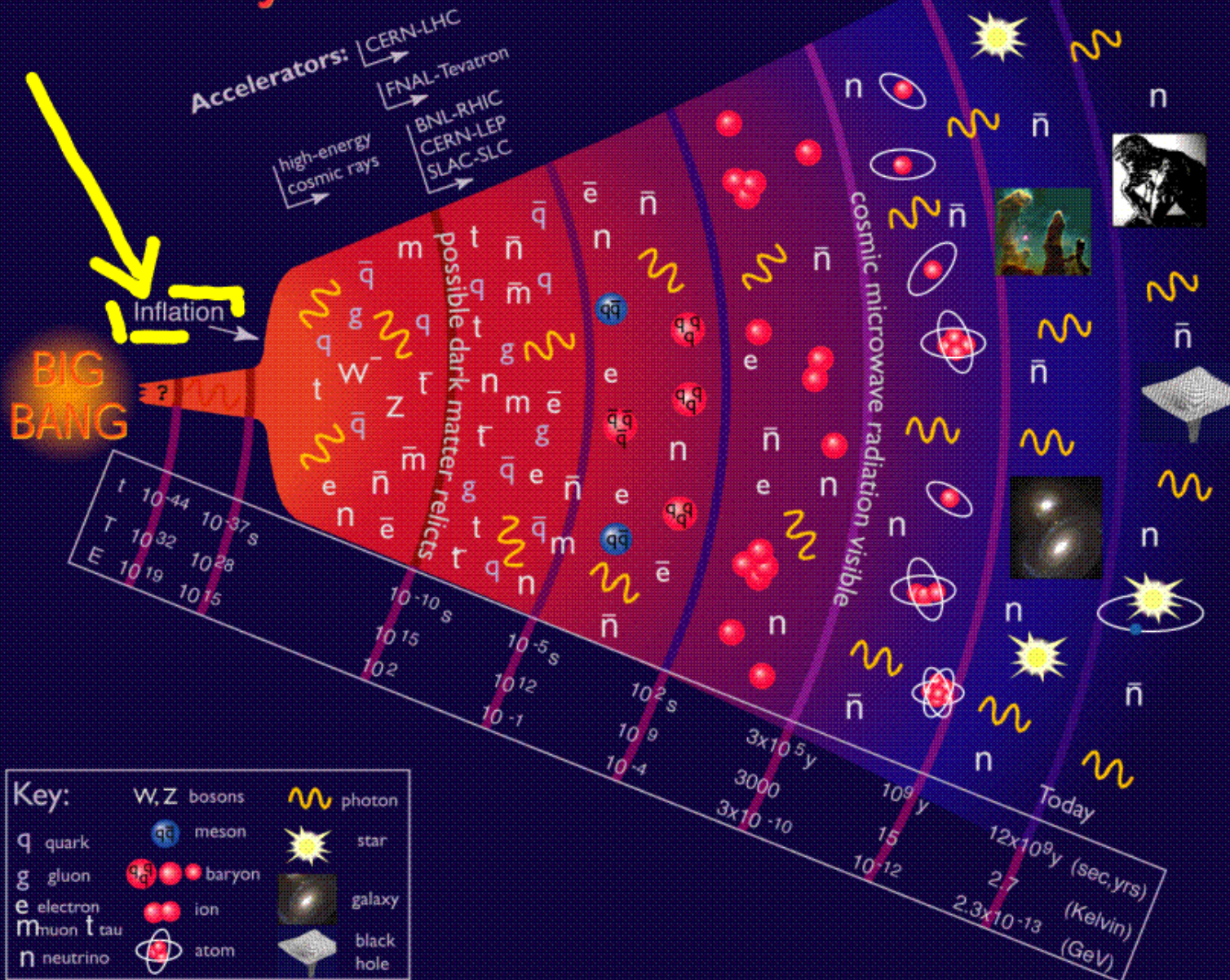
Idea used by
many cosmological theories
to solve basic
problems w/
Big Bang Model

Inflationary
Big Bang
Models



Alan Guth (MIT)

History of the Universe



Inflation

- Universe starts very small
- Perhaps as a tiny fluctuation in a spacetime foam of tiny fluctuations
maybe $\sim 10^{-26}$ m in size
- Properties of such a fluctuation can be constructed so as to create an unstable repulsion filling the space of the fluctuation — some "field" or particle is created in a quasi-stable excited state $\rightarrow$ inflaton what was it exactly?
- Leads to inflation — The ultimate understatement!
Vast exponential superluminal expansion of the universe as inflaton "relaxes" expansion slows. Energy driving inflation dumped into matter + radiation and we have initial conditions for Big Bang model as we know it

Singularity

Flatness

Inflation concept
Solves major problems
w/ Big Bang cosmology

quantum fluctuation
possibly in endless
fractal-like stream
of universes

Inflation

No matter how
curved is space,
Blow it up large enough
and will look flat

Structure

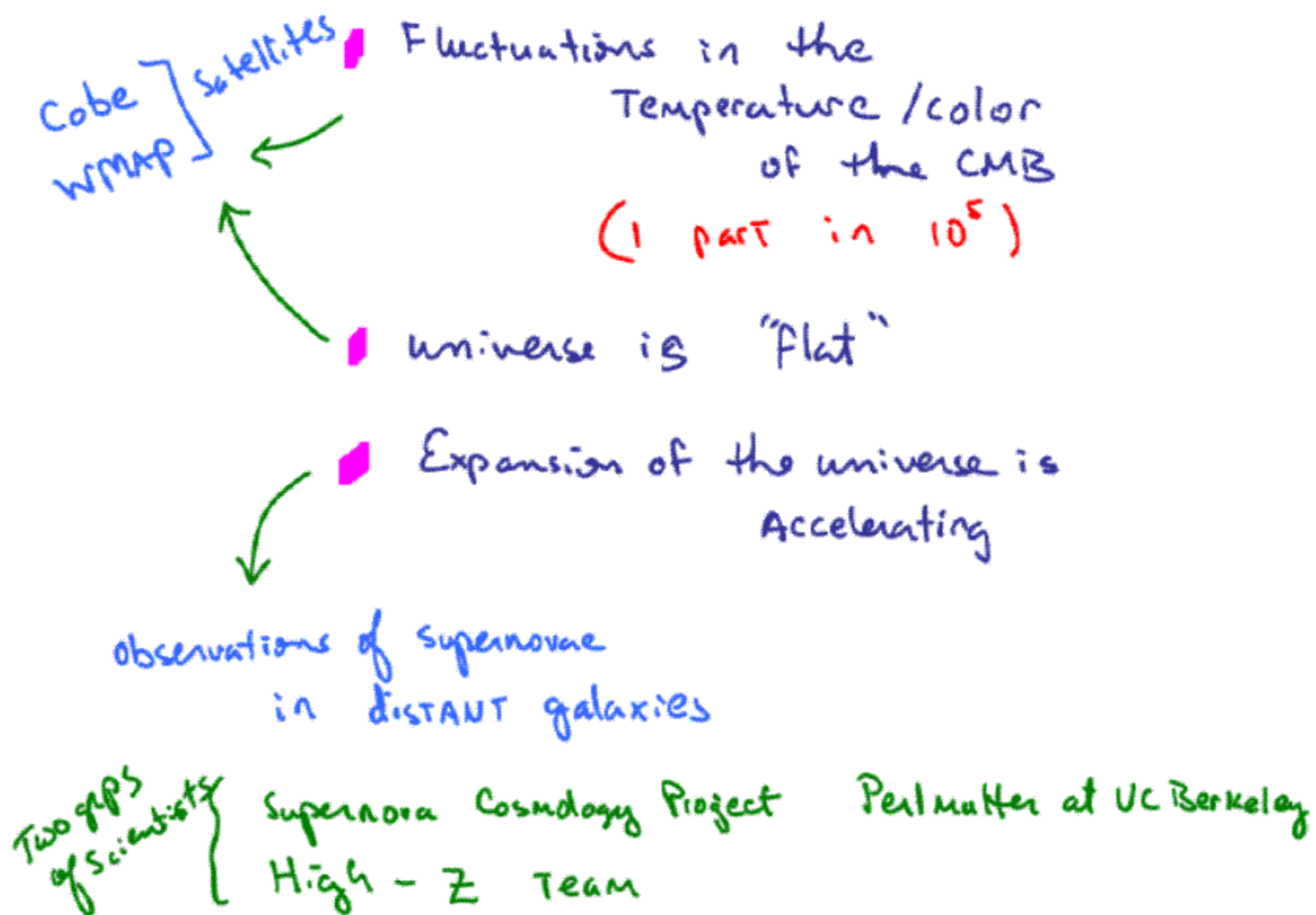
quantum
fluctuation
during + before
inflation become

density fluctuations in
CMB + Early universe
leading to large-scale
Structure

universe starts out
very small
and causally
connected

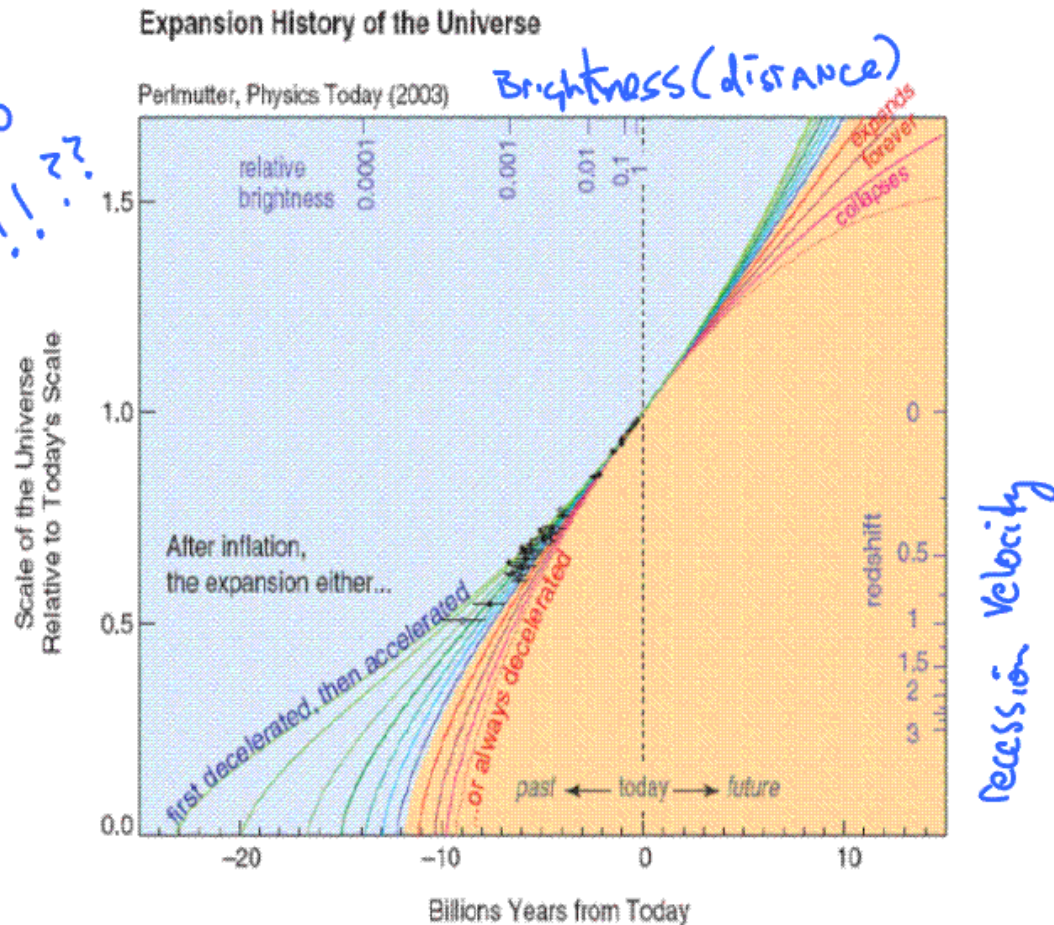
Horizon

Incredible new data in the last 10 years



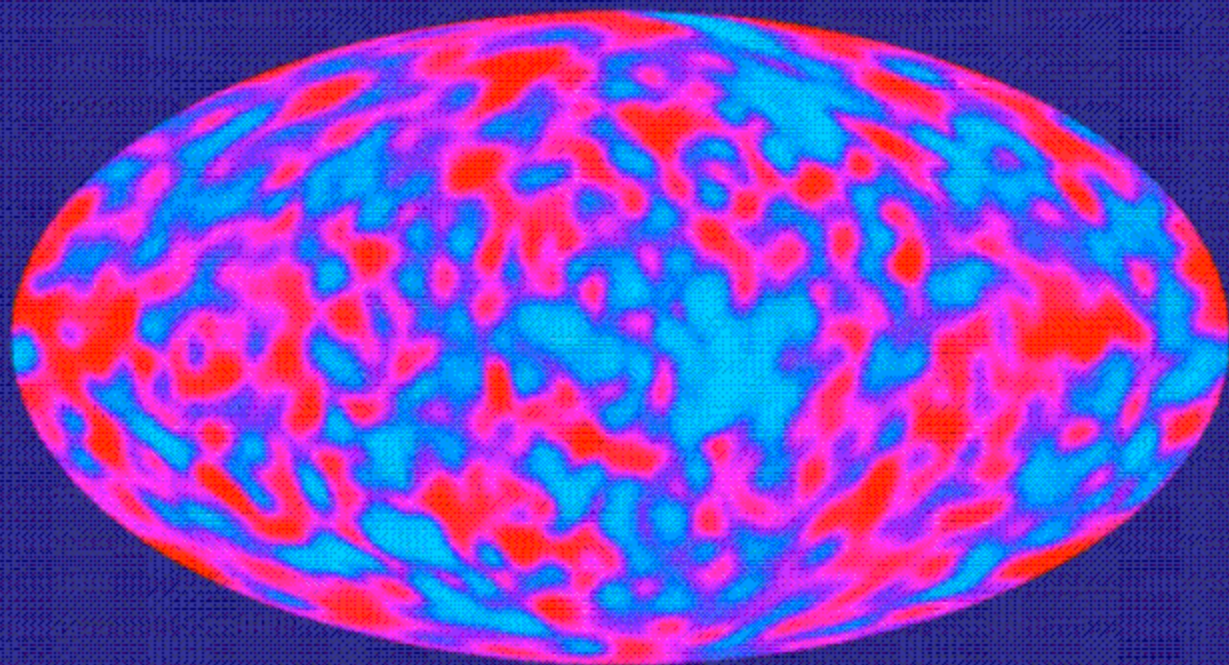
Do "Hubble" Study Velocity vs. Distance over vast distances (Time) by using Super Novae as "STANDARD candles"

Expansion rate of universe is increasing !! ??



Billions Years from Today

DMR's Two Year CMB Anisotropy Result

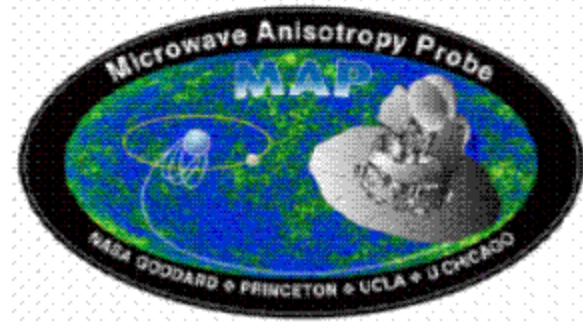
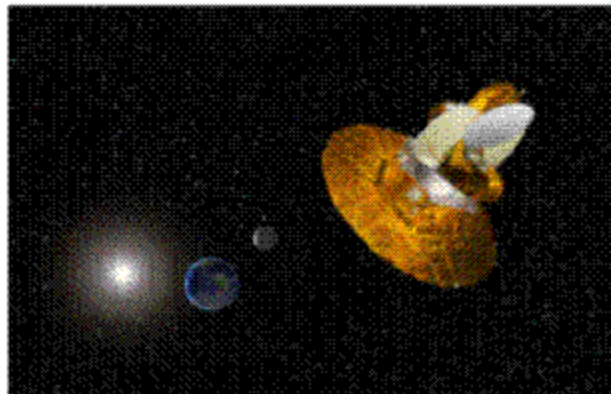
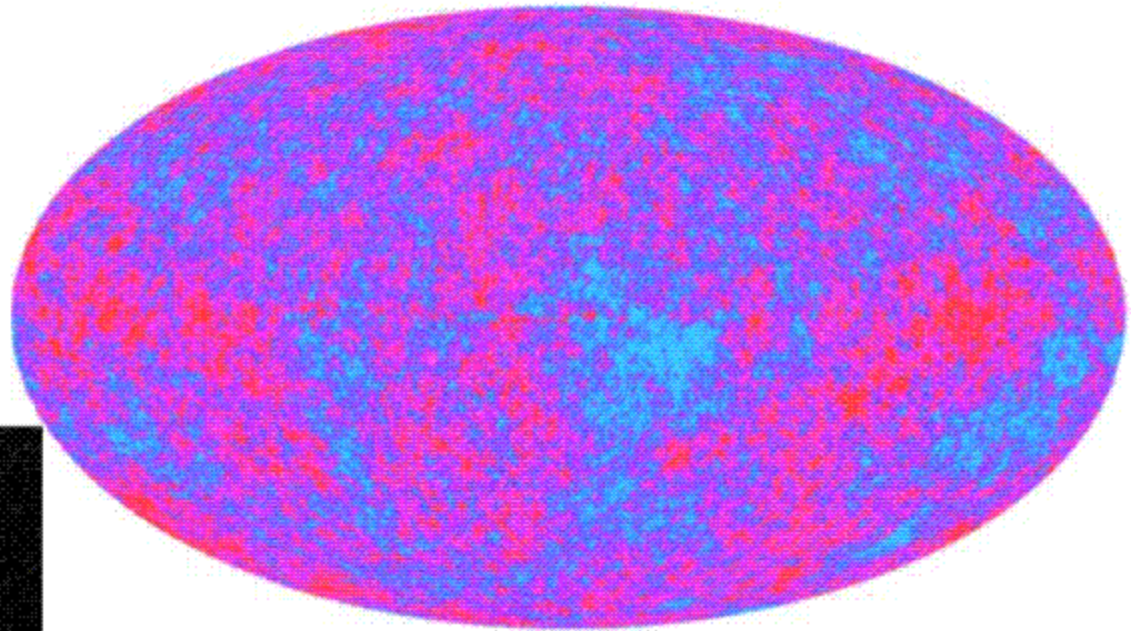


CMB "color" or Temperature seen to vary by 1 part in 100,000

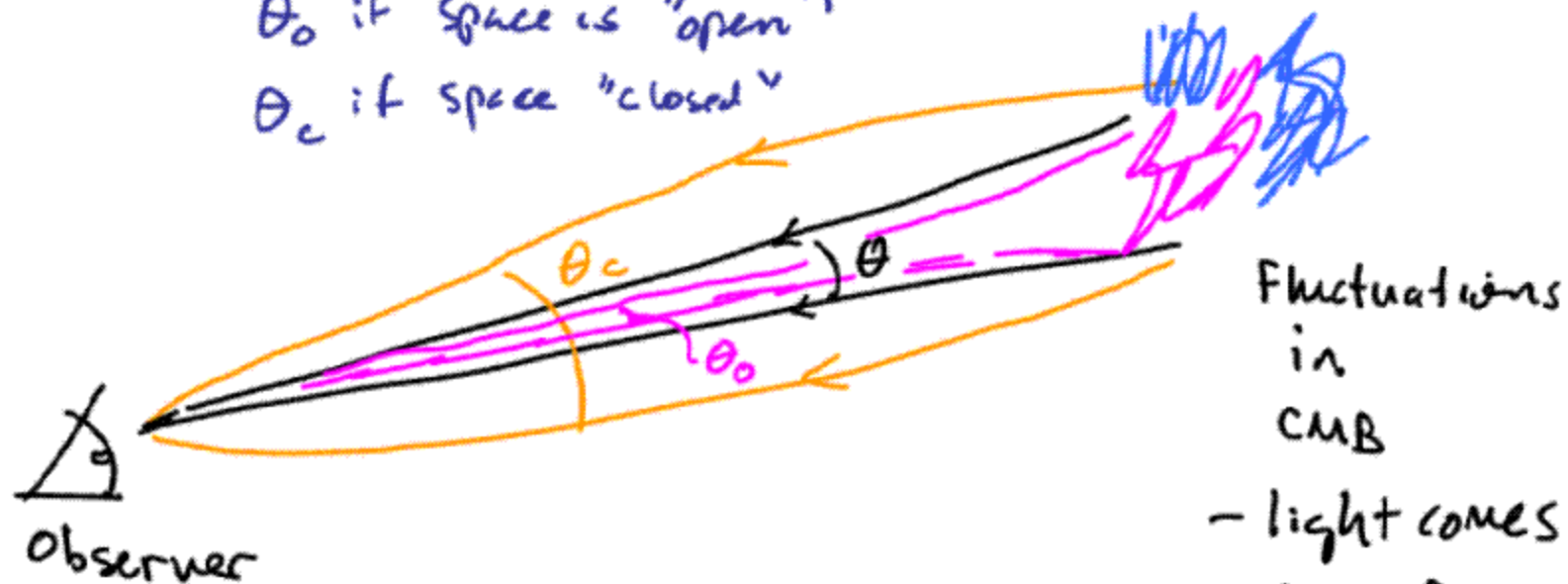
1992 COBE Satellite observation of CMB over all sky

Cosmic Background Explorer

WMAP - Wilkinson Microwave Anisotropy Probe (2003) High Resolution Study of CMB



Measure θ_f if space is flat
 θ_o if space is "open"
 θ_c if space "closed"

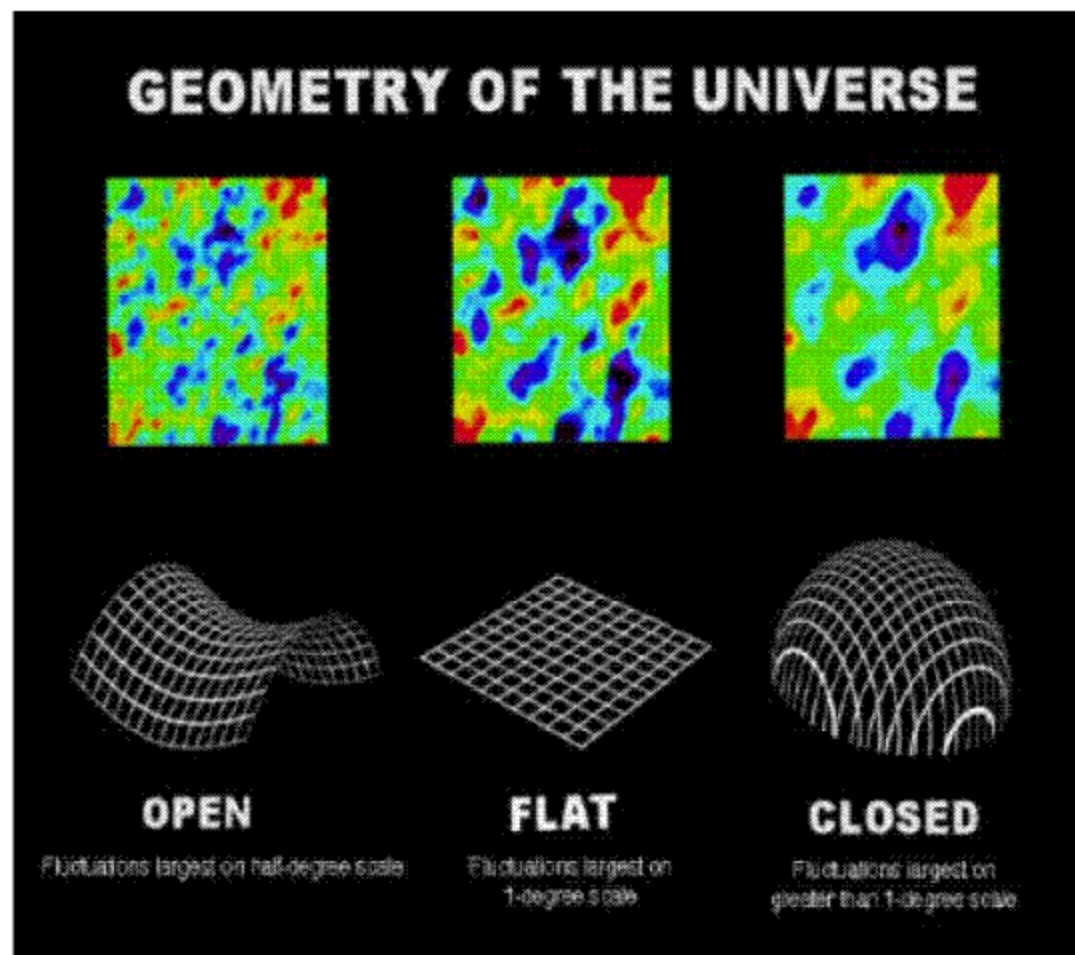


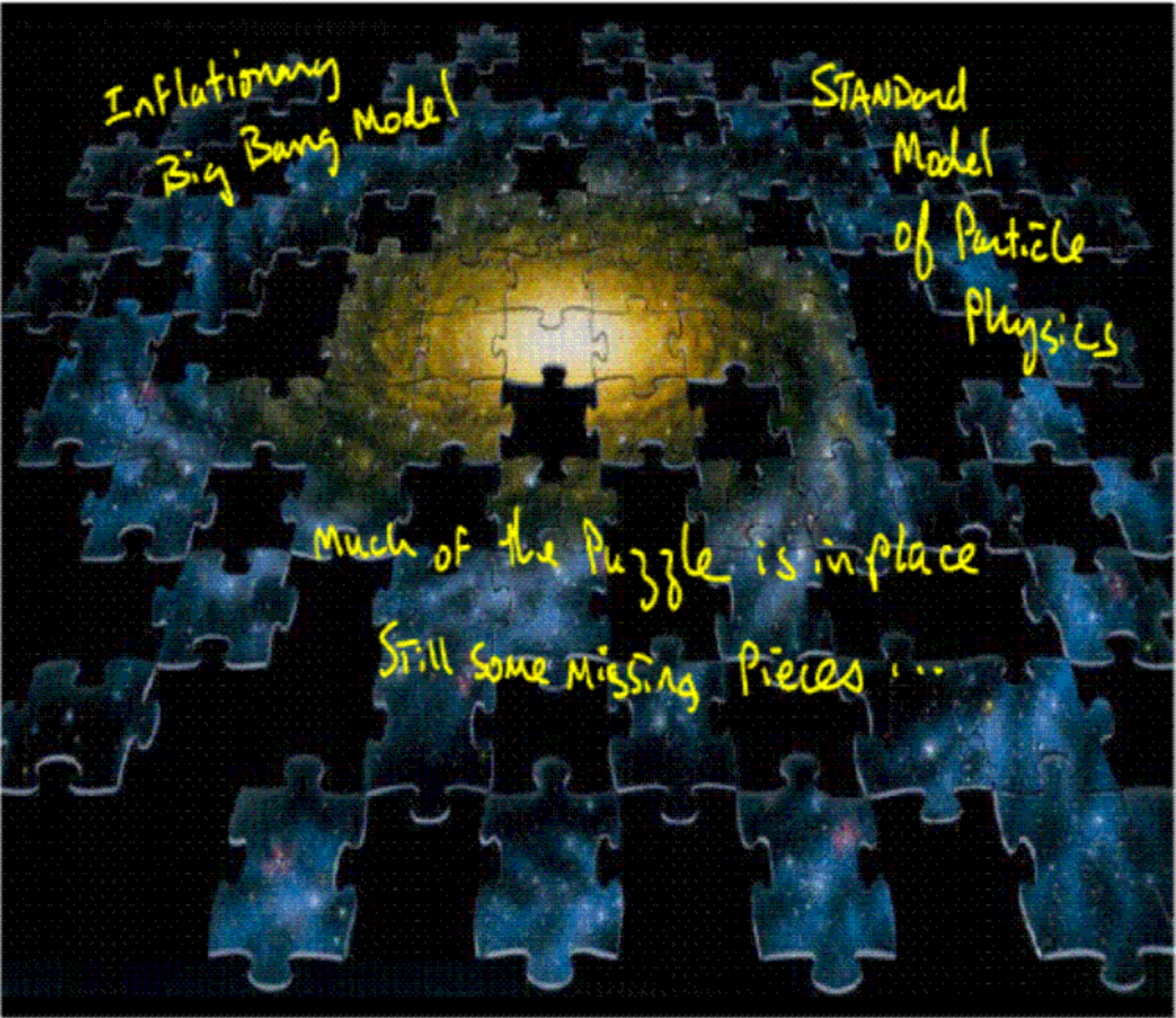
Look at Angular size of
 fluctuations in
 CMB

(Age of universe - 100,000)
 light years

Path light takes depends on geometry
 of universe. We measure different angular
 sizes depending on geometry of space between

Size of fluctuations / structure in the CMB
is sensitive to the geometry of
the universe



A large puzzle made of pieces showing various galaxies. The central piece is a bright, yellowish-white, glowing sphere, representing the Big Bang. The surrounding pieces show blue and purple galaxies with star clusters.

Inflationary
Big Bang Model

STANDARD
Model
of Particle
Physics

Much of the Puzzle is in place
Still some Missing Pieces ...

Dark Matter

ORBITS

$$F = \frac{mv^2}{R}$$

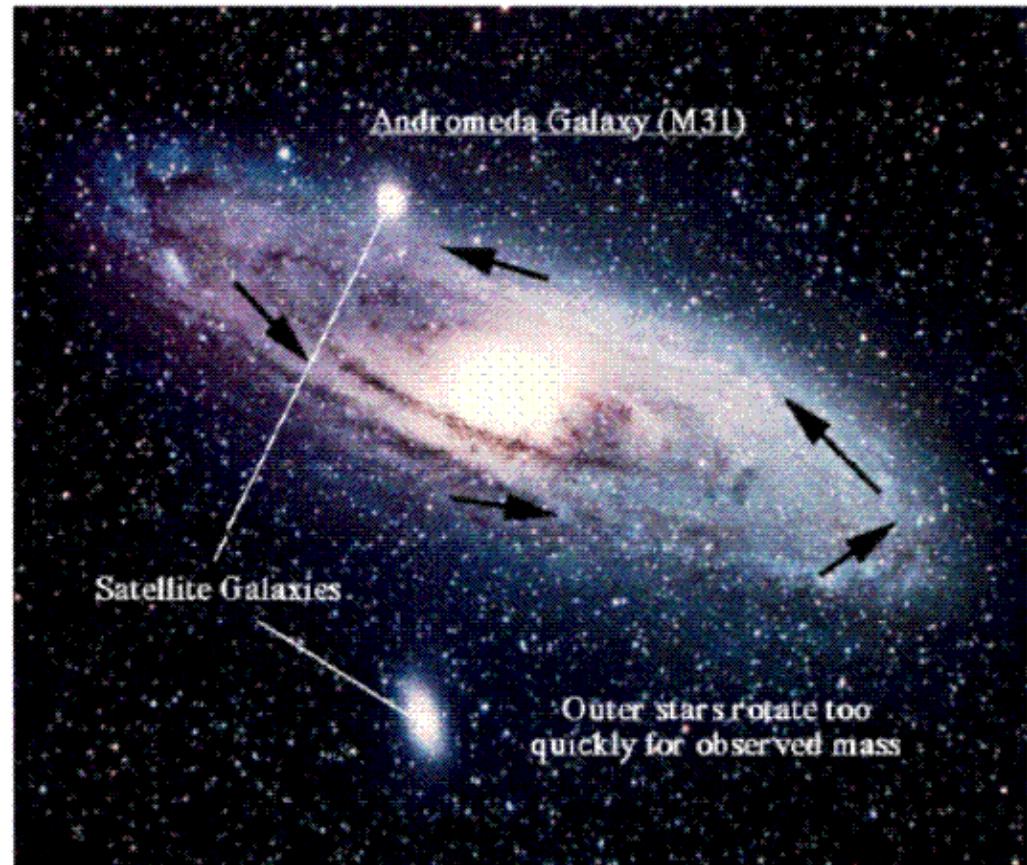
$$F = \frac{GMm}{R^2}$$

Circular
Motion

$$\frac{mv^2}{R} = \frac{GMm}{R^2}$$

Can relate velocity
radius and force
in orbits.

Have seen that
orbits in stars
and galactic clusters
Require stronger
Gravitational force
than can be explained
by conventional
Observable "visible"
matter



-P. Cushman