

Physics 102 - April 11, 2011

Make up(s) for Apr. 8 recitation happening this week
STAY tuned

April 18 class Review/Q+A

EXAM 2 - April 20, 2011

During normal class time

Covers

- From de Broglie thru inflation
(lecture Feb. 16 → start of Today's lecture)
- Recitations 5-10

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

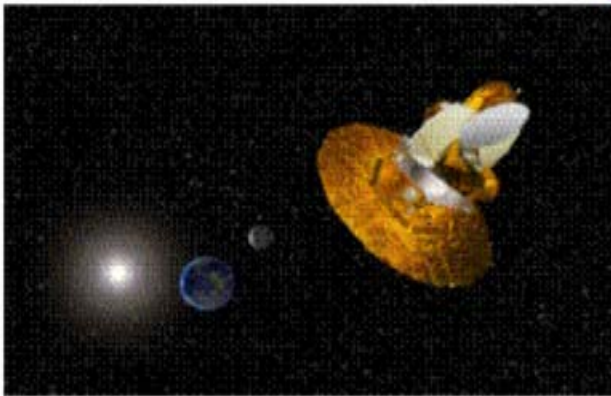
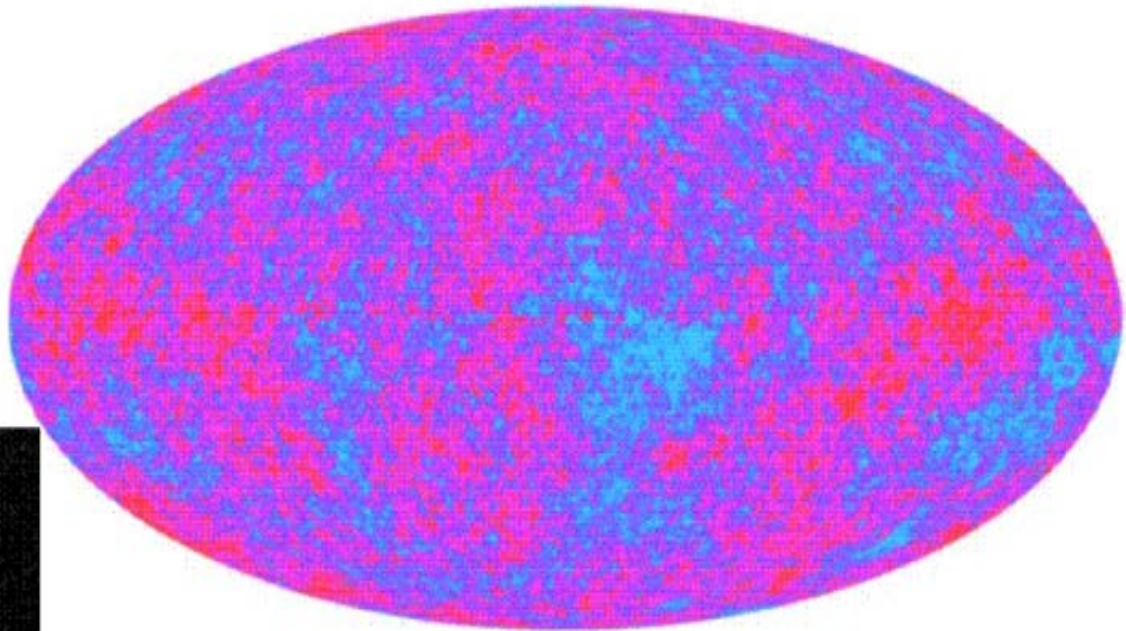
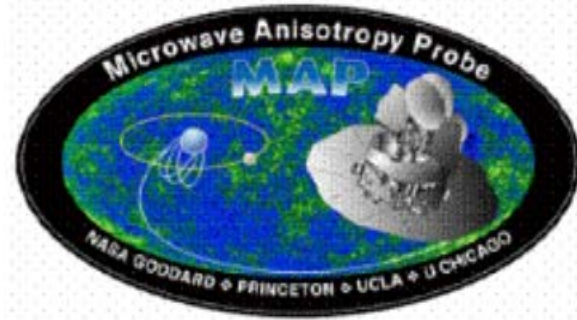
quantum
fluctuation
during + before
inflation become

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

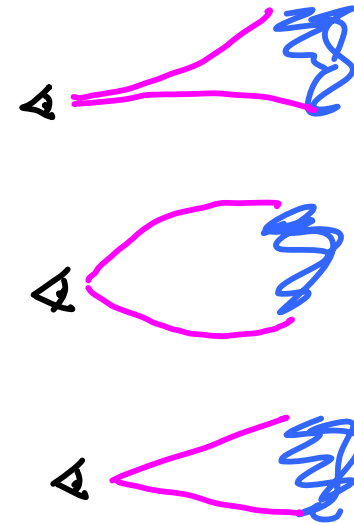
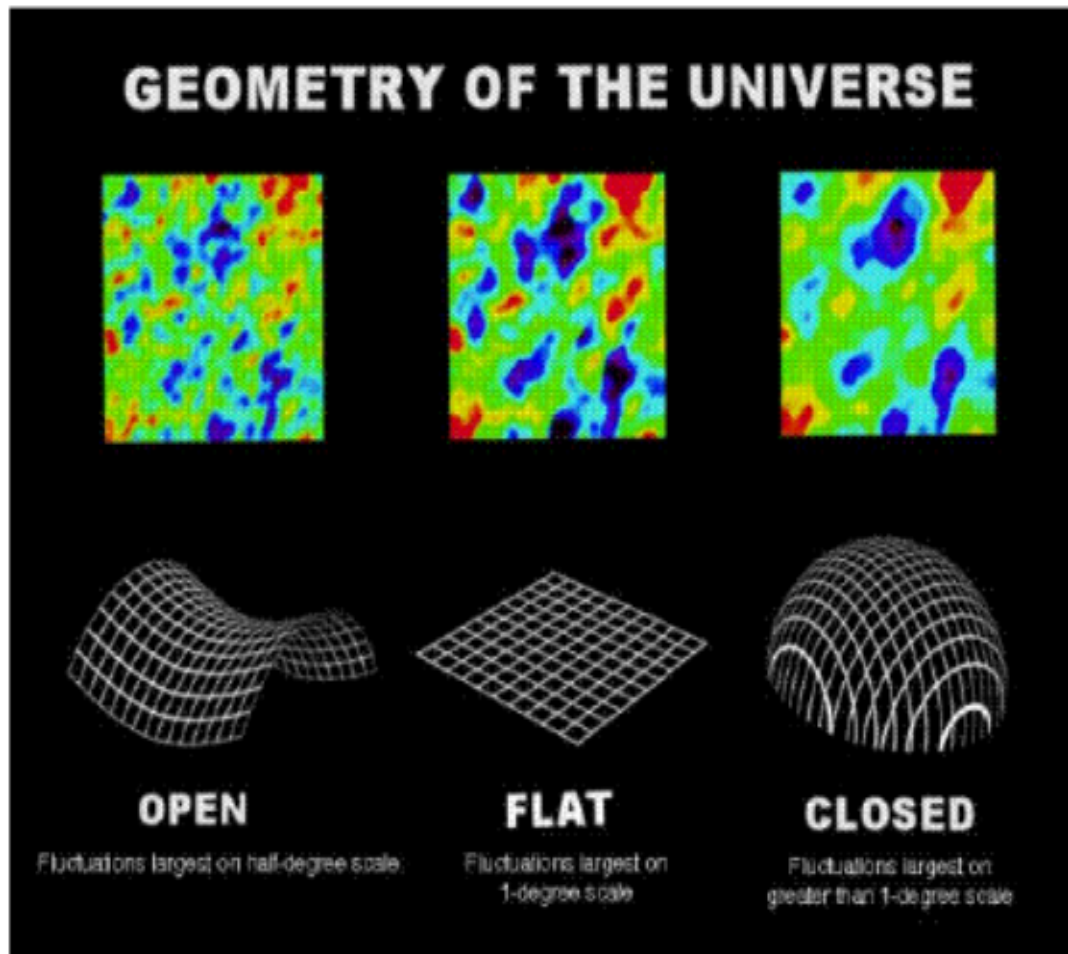
universe starts out
very small
and causally
connected

Horizon

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



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



Dark Matter

ORBITS

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

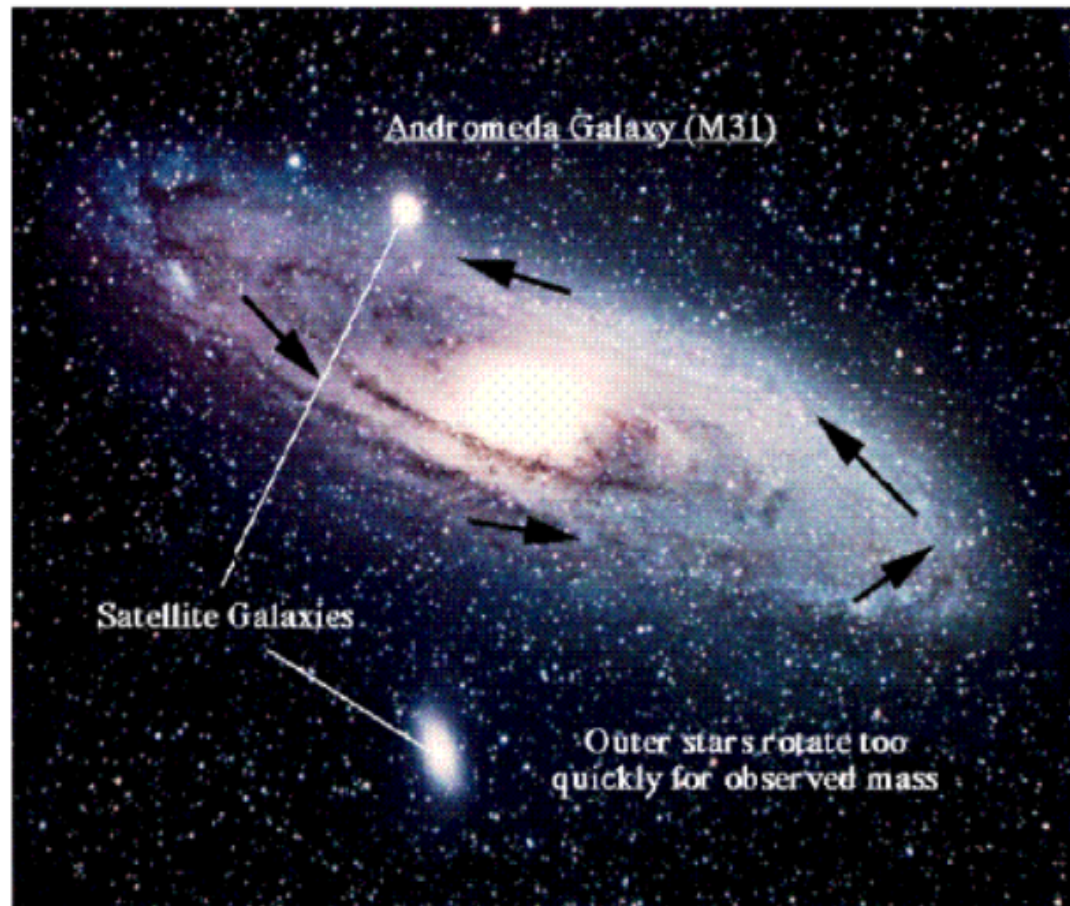
$$F = \frac{GMm}{R^2}$$

Circular Motion

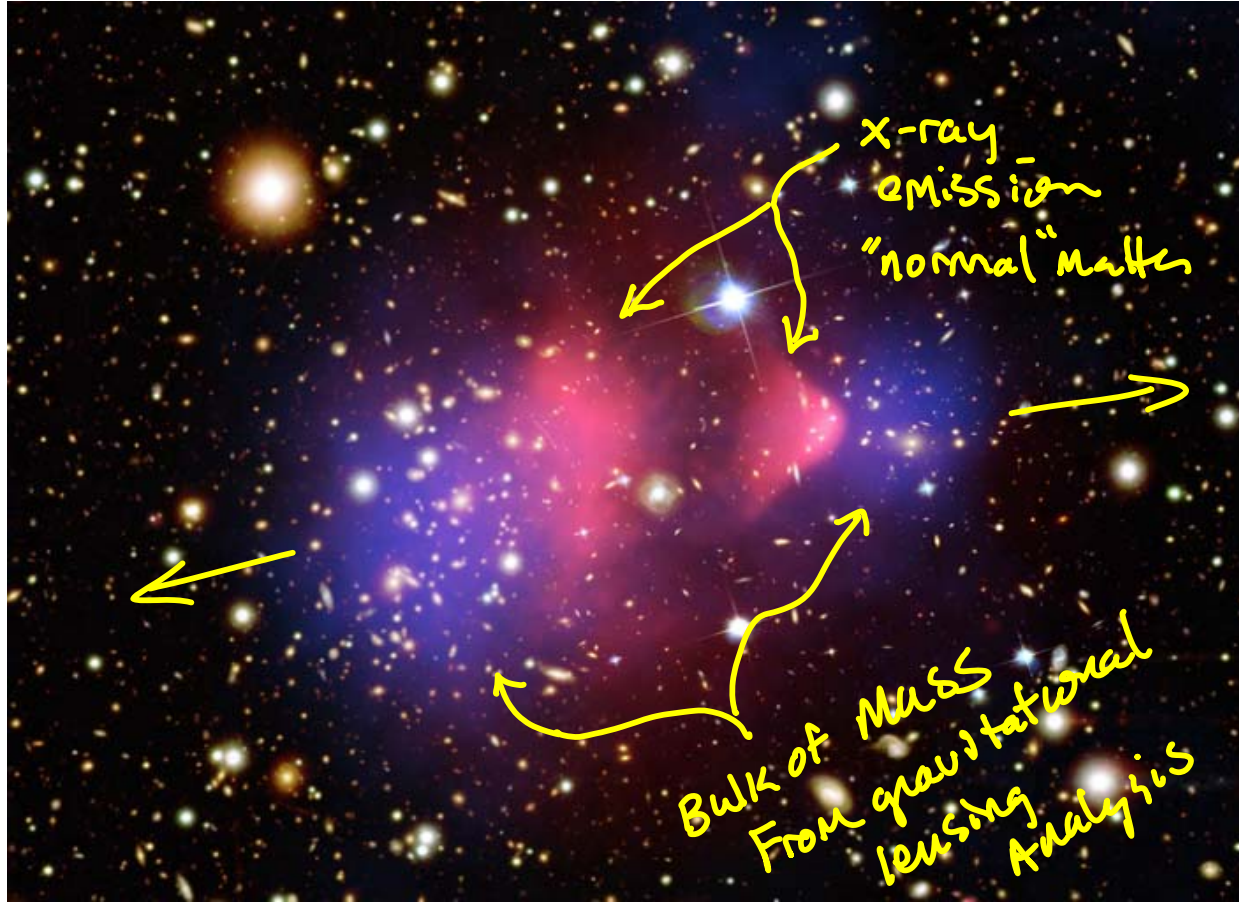
$$\frac{mv^2}{R} = \frac{GMm}{R^2}$$

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



Bullet cluster
colliding galactic clusters

galaxies + Dark matter
zip past

intergalactic gas slowed down

Do "Hubble" Study velocity vs. distance over vast distances (Time) by using Super novae as "STANDARD candles"

Expansion rate of universe is increasing !! ??

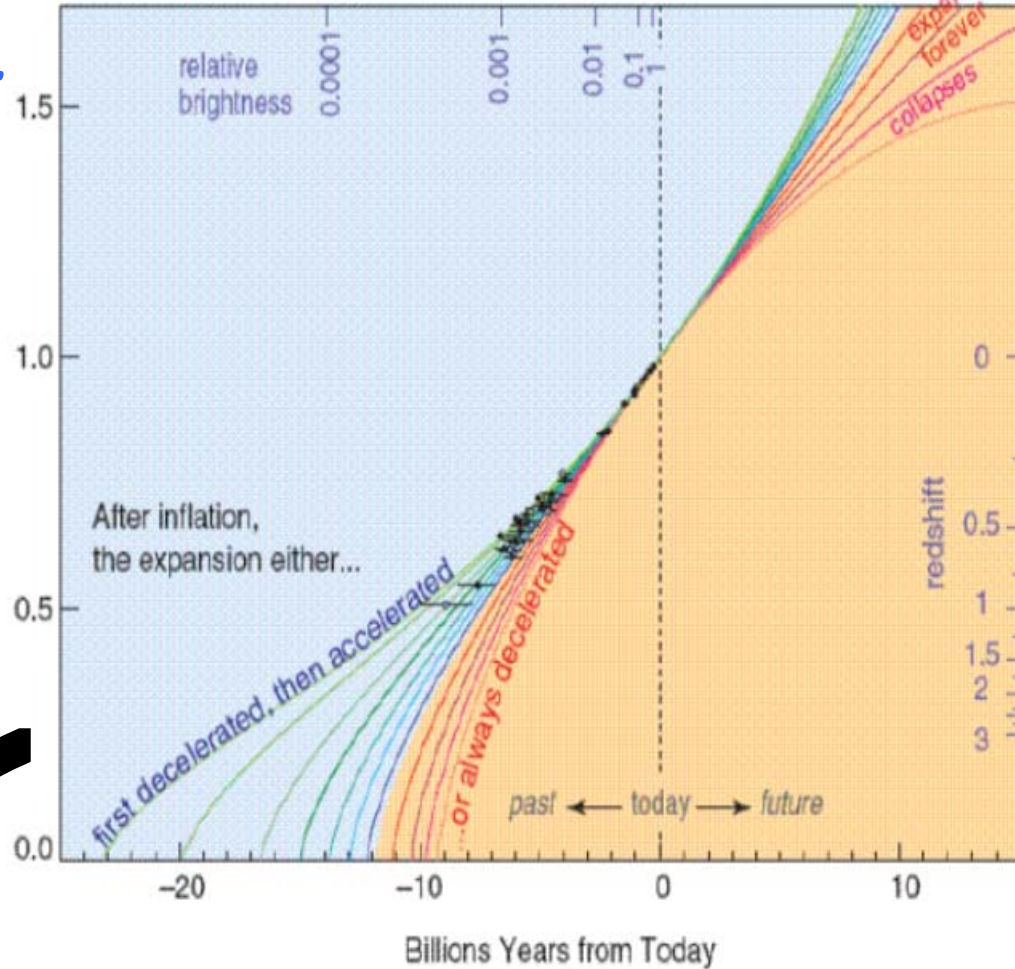
DARK ENERGY

Expansion History of the Universe

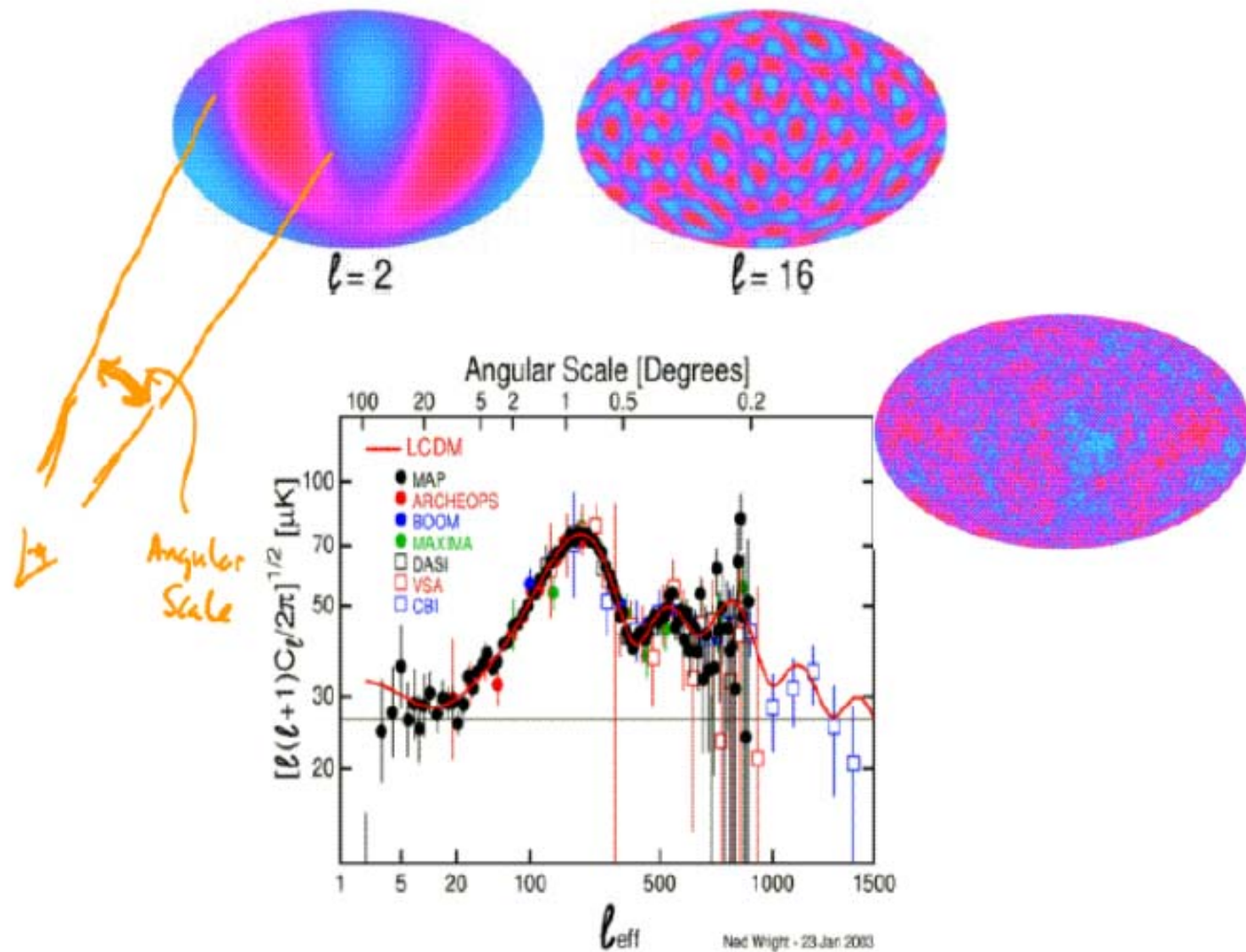
Perlmutter, Physics Today (2003)

Brightness (distance)

Scale of the Universe Relative to Today's Scale



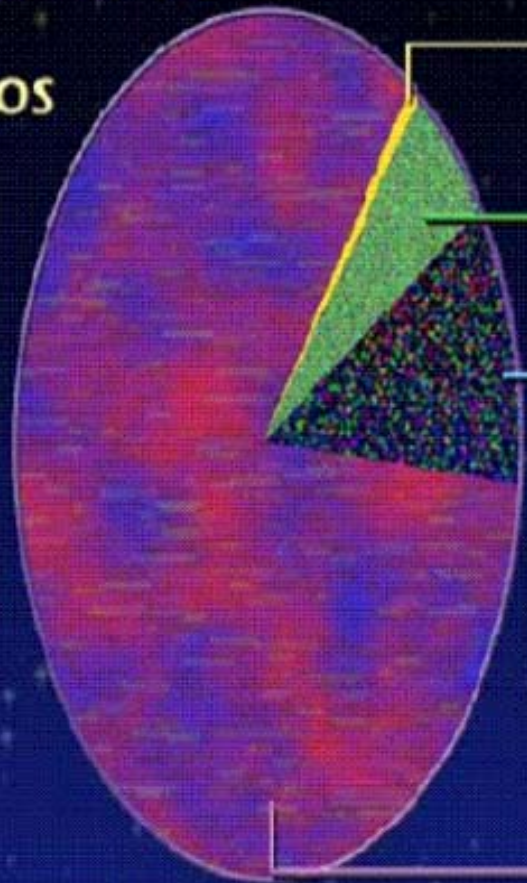
recession velocity



“Power spectrum” (size) of temperature fluctuations
 sensitive to different matter/energy components of the
 universe

The Cosmic Pie

Composition of the Cosmos



Neutrinos:
0.6%



Baryons (atoms):
comprising stars,
heavy elements, and
helium and free hydrogen:
4.4%



Dark matter:
22%



Dark energy:
73%

Us

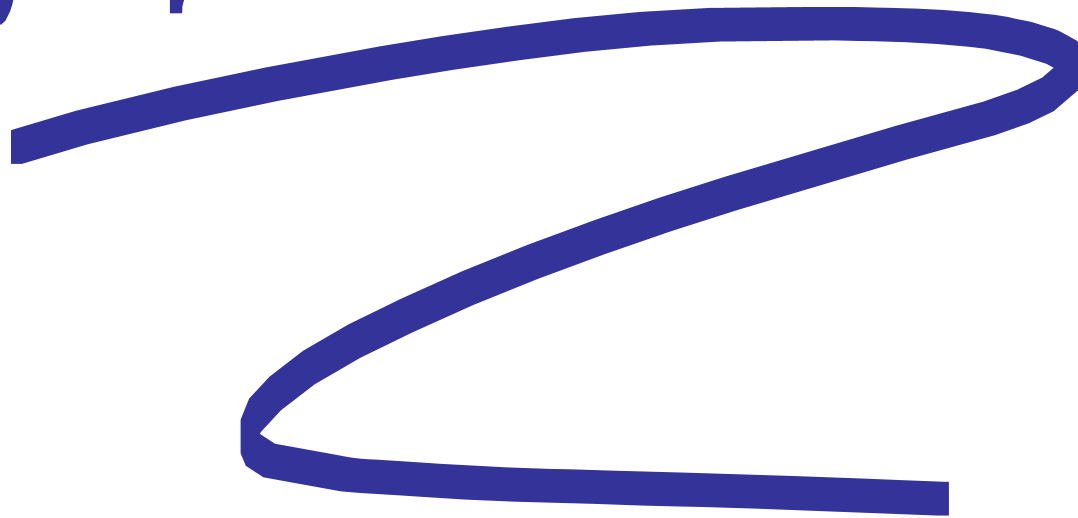
STScI

95% of the universe is unknown!

Figure from E. Linde
LDC

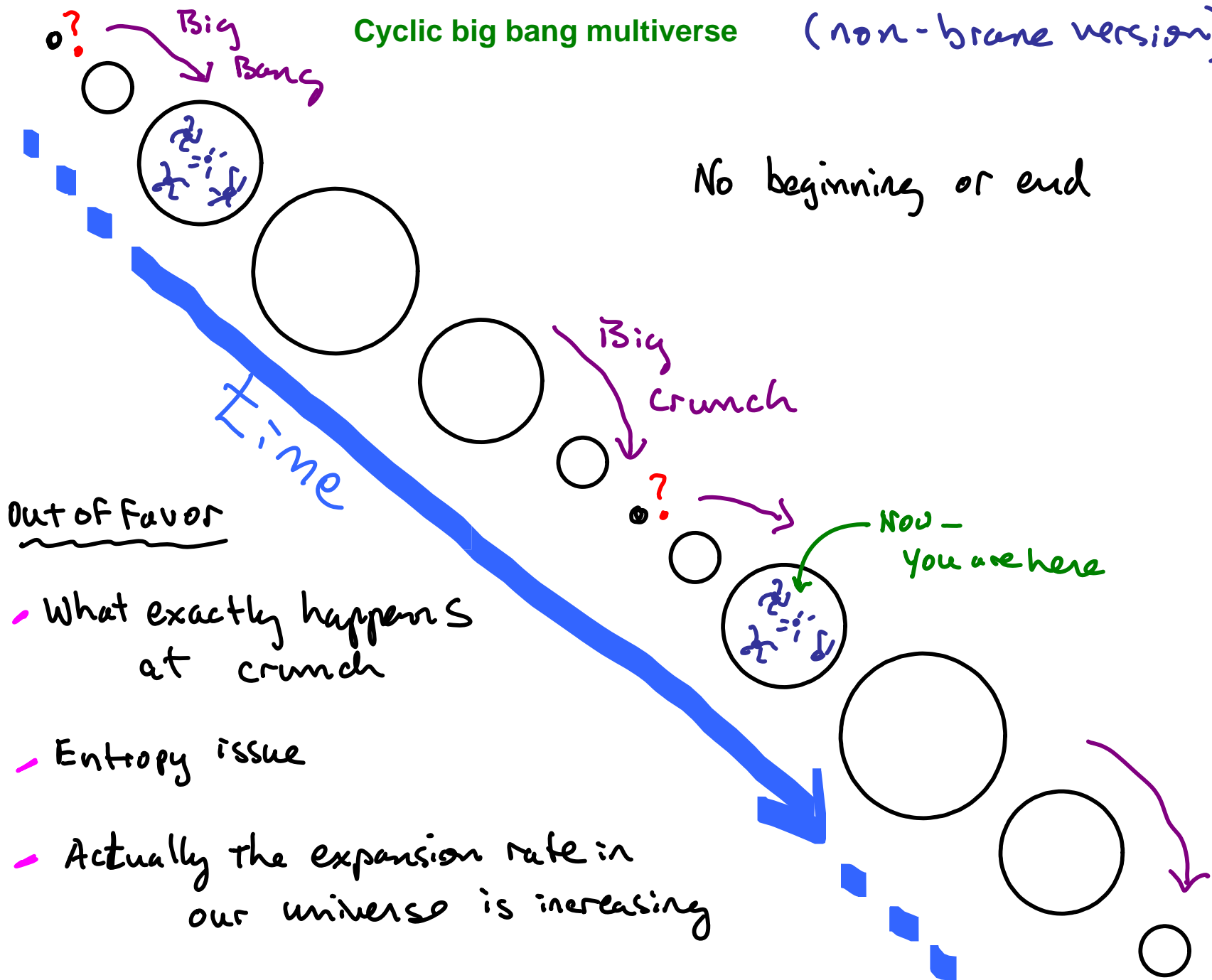
Cosmological

Multiverse



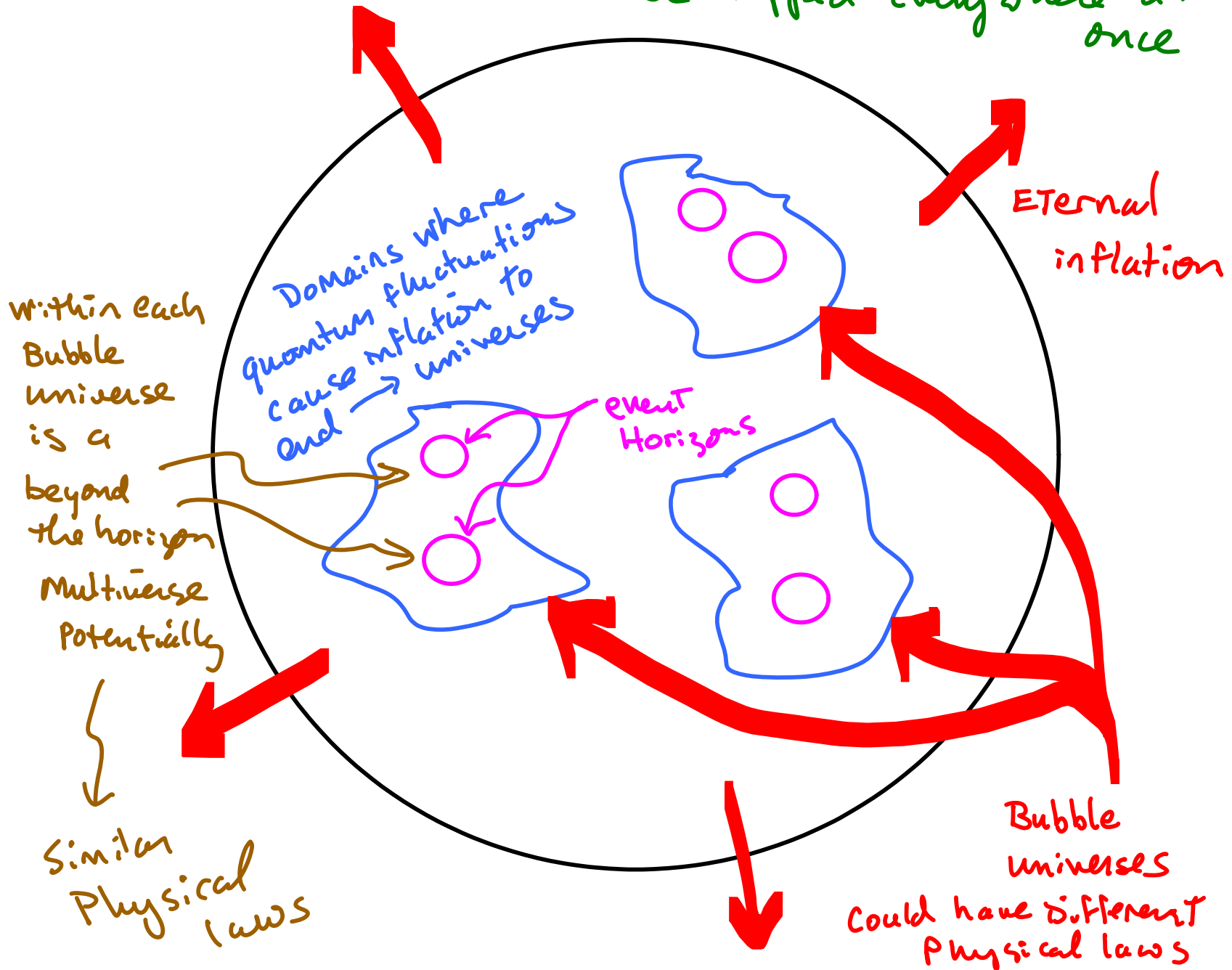
Cyclic big bang multiverse (non-brane version)

No beginning or end

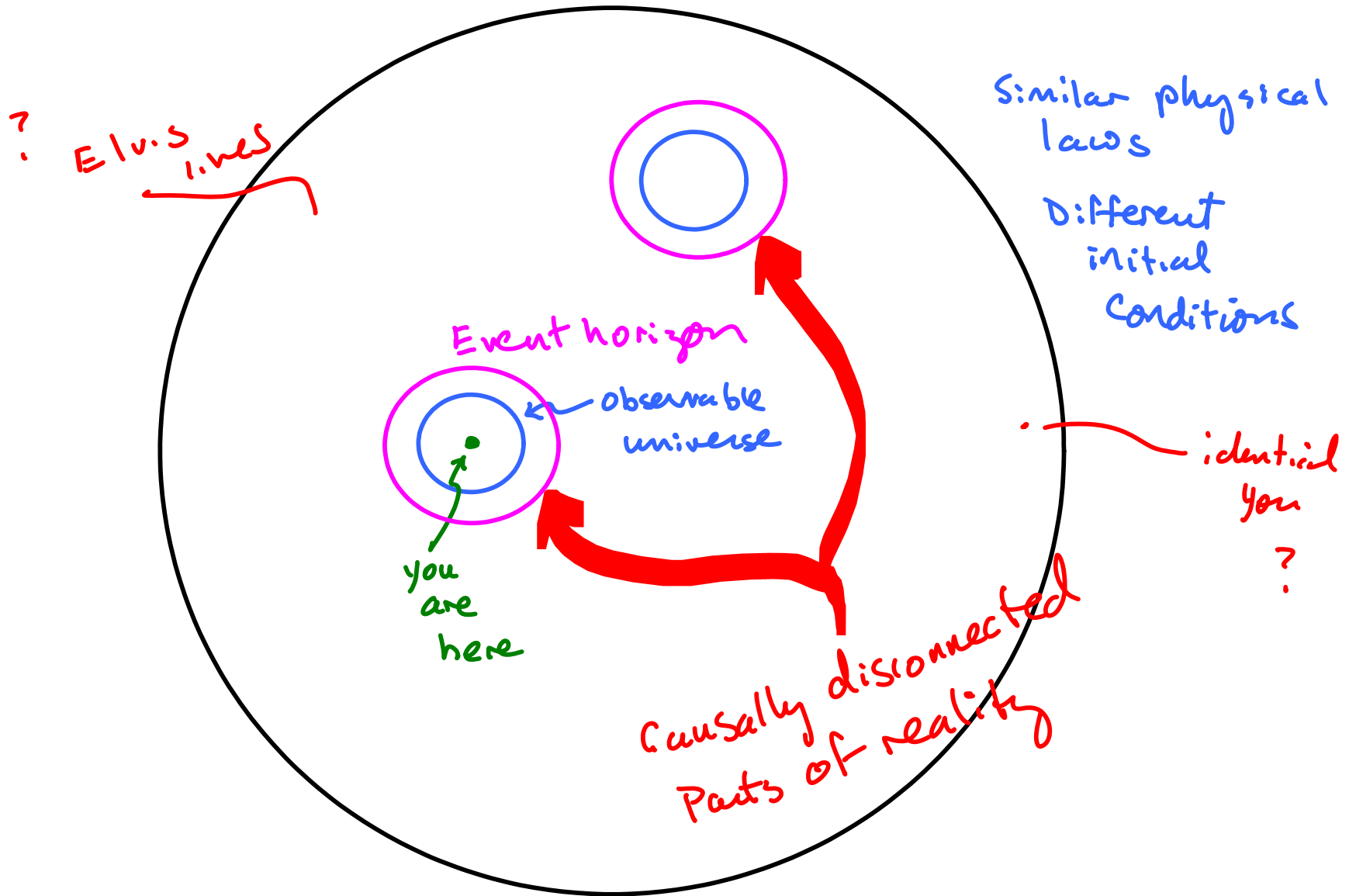


The bubble multiverse

inflation - once started cannot be stopped everywhere at once



Beyond the horizon multiverse



Inflation → countless # of such regions

Got Inflation?

See Paul Steinhardt's
Article in your
reading this week.

I know what you're thinking...