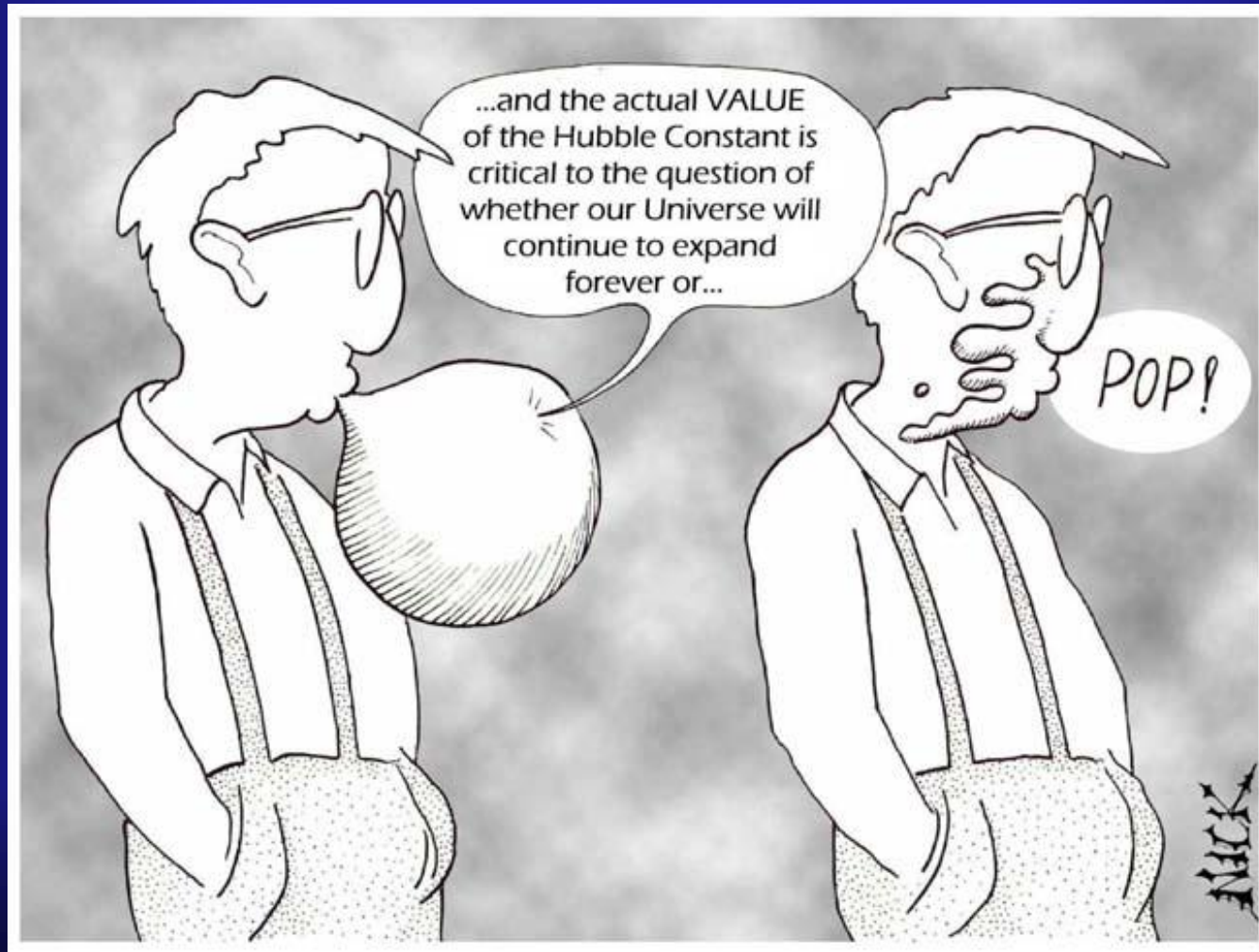


The History and the Fate of the Universe



Overview

A. The Expanding Universe

- 1. What was Einstein's view of the Universe?**
- 2. What observation shattered his view?**
- 3. What is the explanation for Hubble's observation?**
- 4. How do we measure Hubble's Constant?**
- 5. What information do we get from it?**

Overview

B. The History of the Universe- Big Bang to Present Day.

- 1. Before 10^{-43} seconds.**
- 2. Why does the early Universe have no particles?**
- 3. What is the Quark Soup**
- 4. Why is the universe 25% helium?**
- 5. Why were the Dark Ages “dark”?**
- 6. What is the CMB?**
- 7. What information do we get from it?**

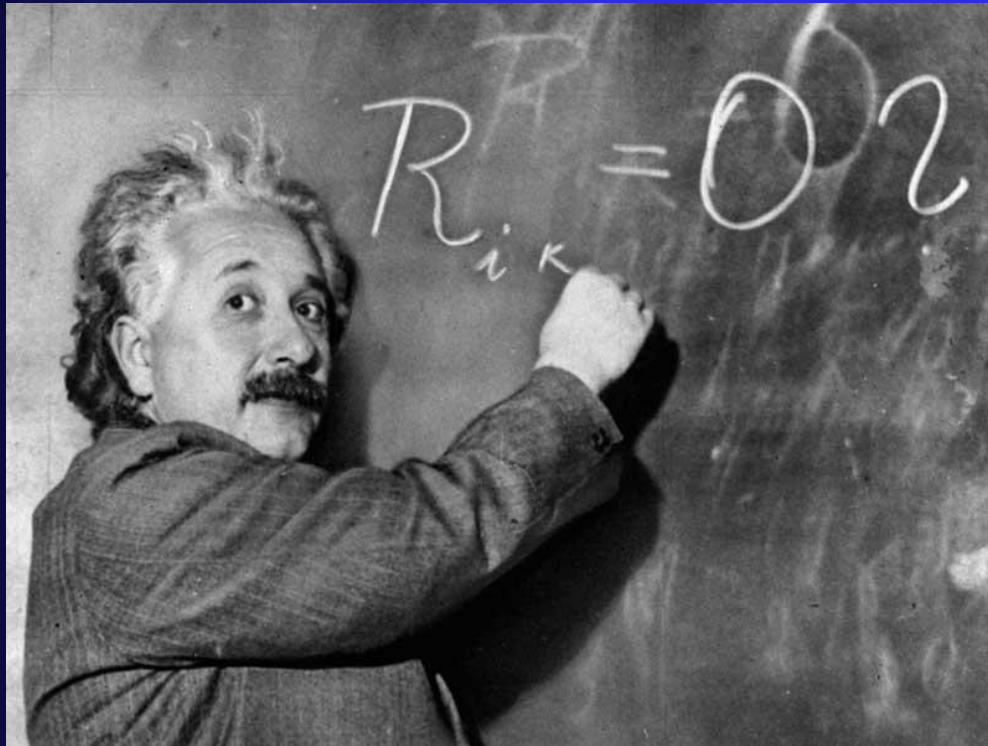
Overview

C. Dark Matter

- 1. What is the evidence?**
- 2. What are three possible explanations?**
- 3. What's the most plausible (currently)**

The Repulsive Force

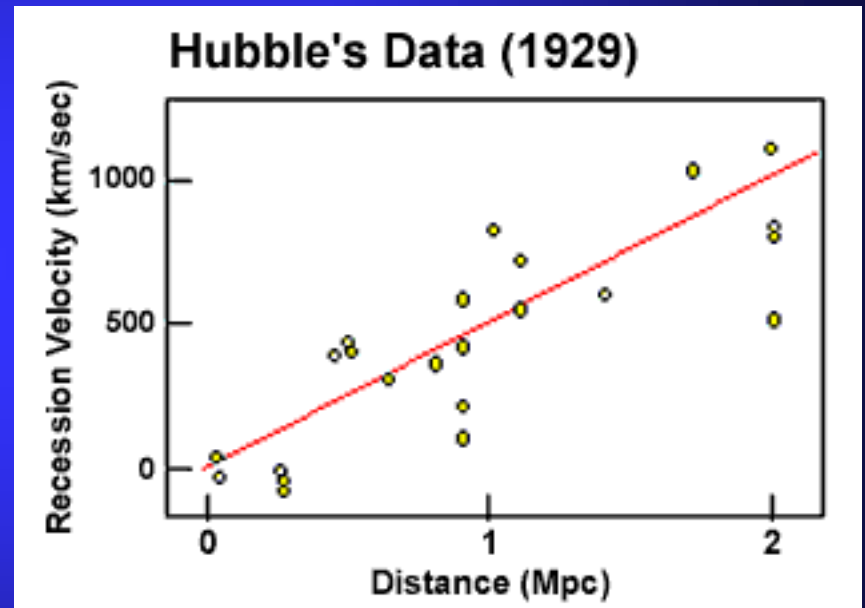
The Universe is static, you see.



A repulsive force is introduced to halt gravitational collapse

Galactic Red Shift

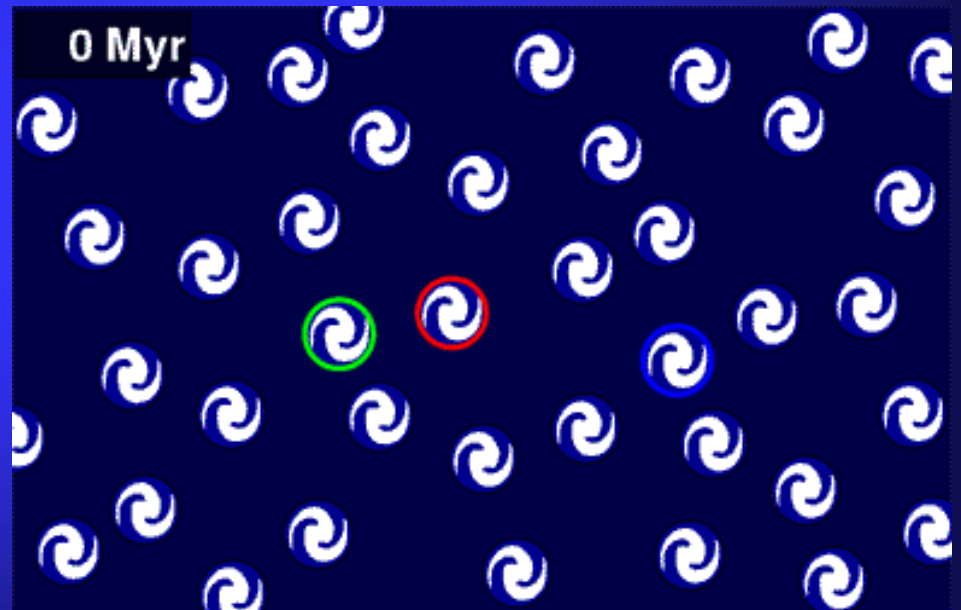
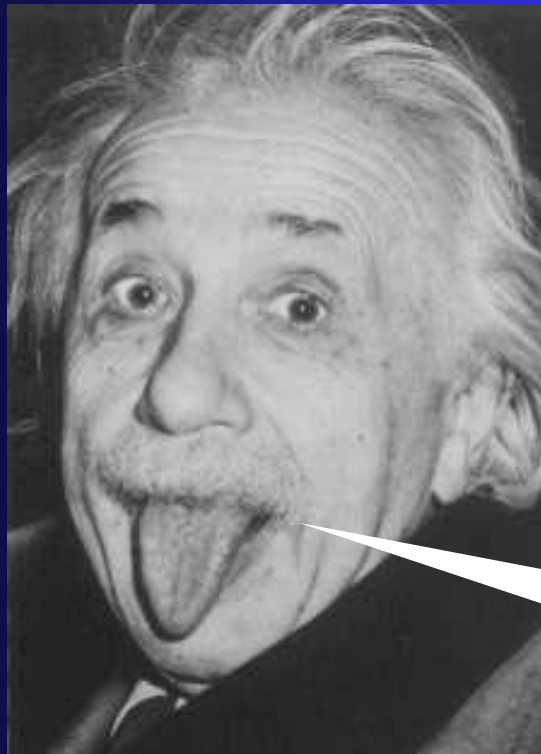
Everything is moving away!



$$V = H_0 D$$

The Universe is Expanding

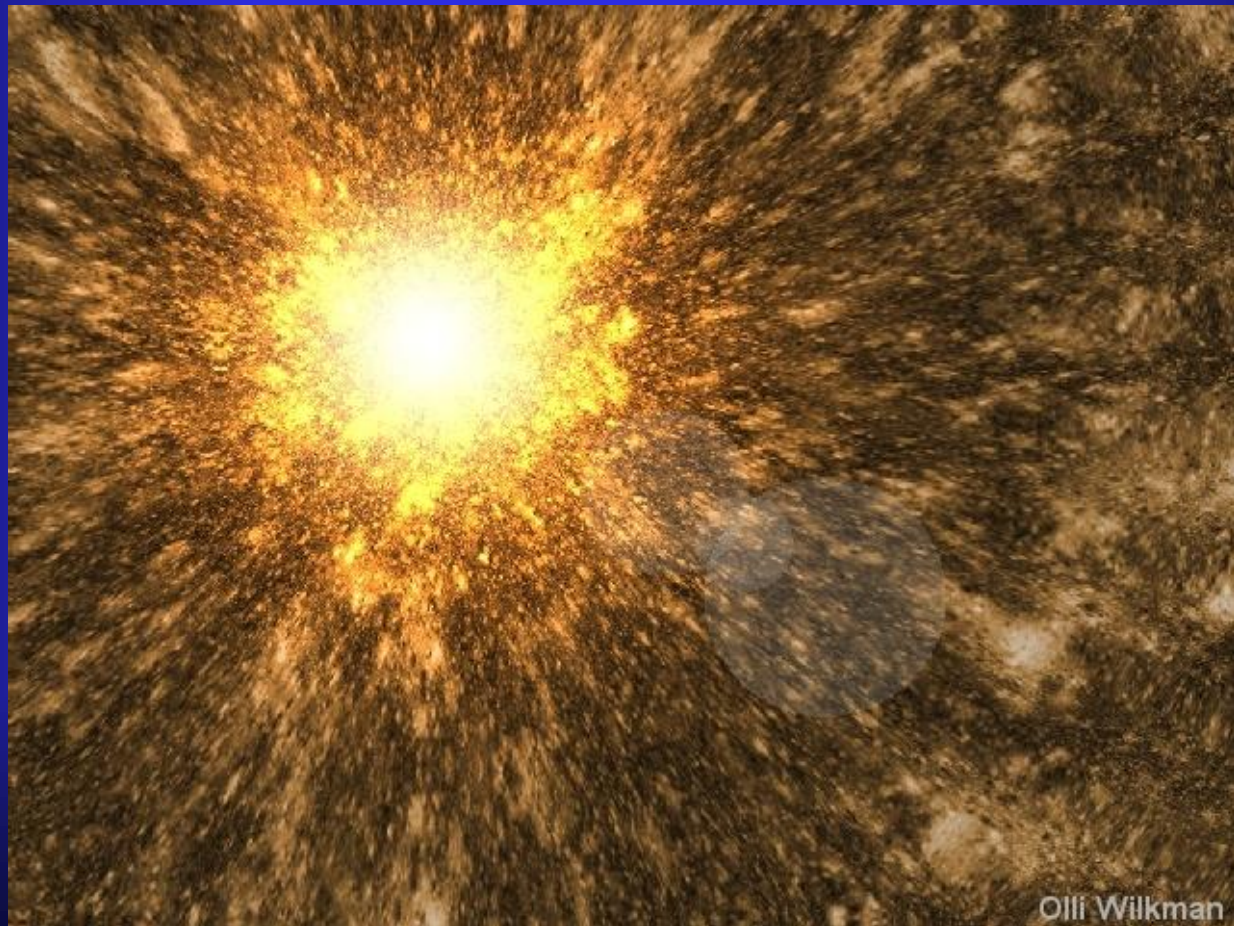
The space between galaxies
must be increasing



Oops!

Measuring H_0

Measure lots of supernova at lots of distances



Olli Wilkman

The Age of the Universe



Everything is moving apart.

In the past, things were closer together.

A long time ago, they must have all been in the same place!

The ENTIRE universe occupied a single point

Bang!

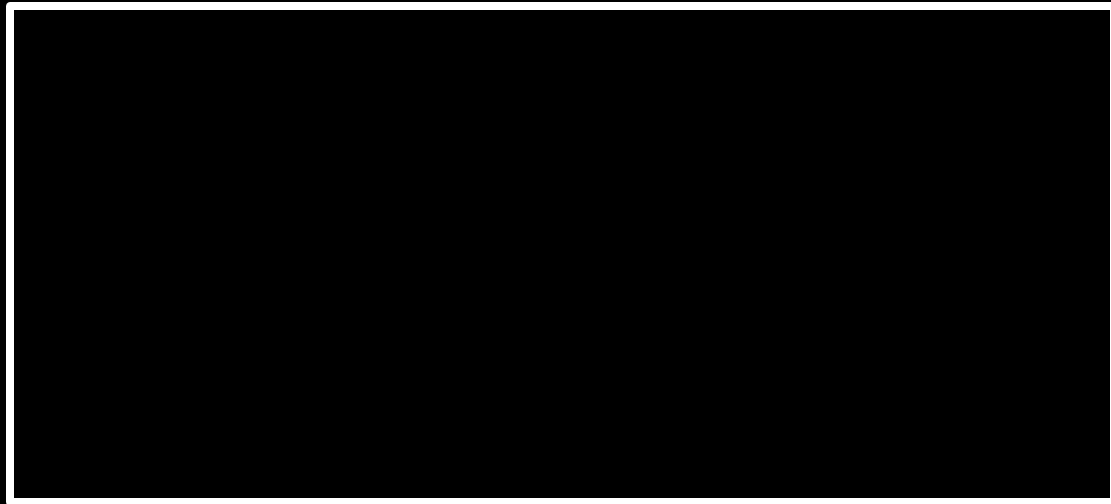
The moment of creation

It makes no sense to ask what
happened before the Big Bang
There is no before

It makes no sense to ask what is
outside the Universe
There is no outside

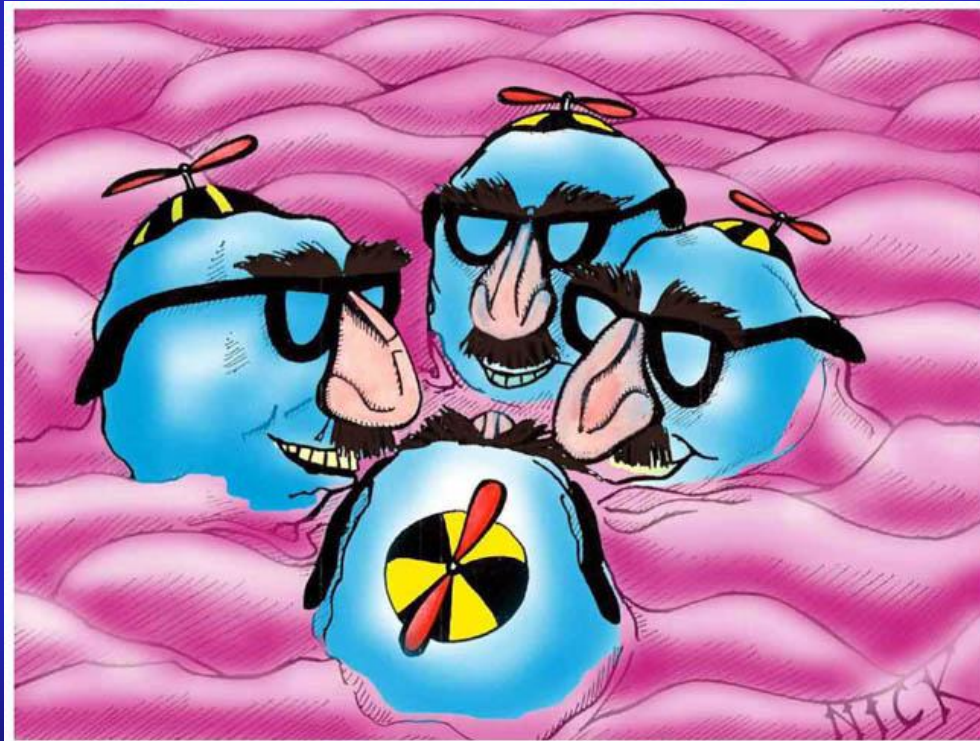
Space and Time came into
existence at the Big Bang

Everything that we know
before 10^{-43} seconds.



Quantum Fluctuations

The very early universe is ruled by quantum effects

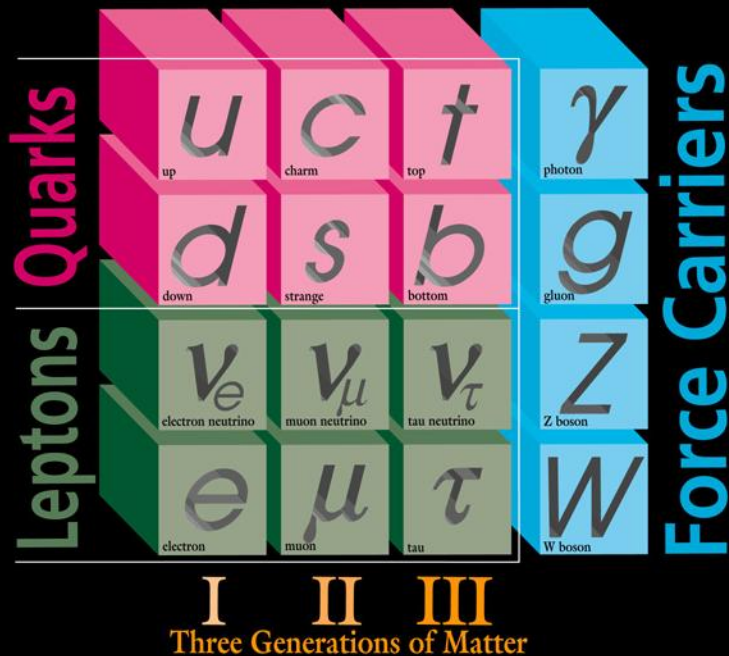


At a resolution of 10^{-24} metres, isolated clumps of Strange Matter pop briefly out of the quantum foam to debate the possible existence of Particle Physicists.

Particles at Last

The energy density drops so that particles can form

ELEMENTARY PARTICLES

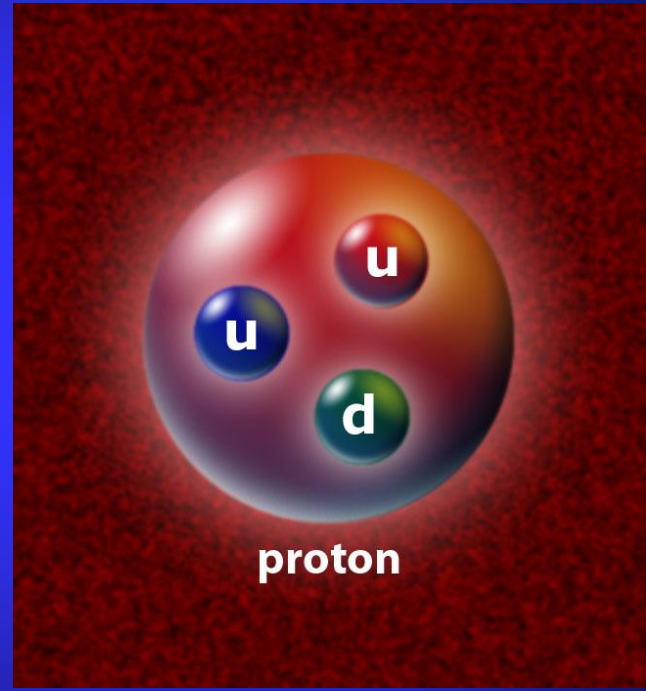
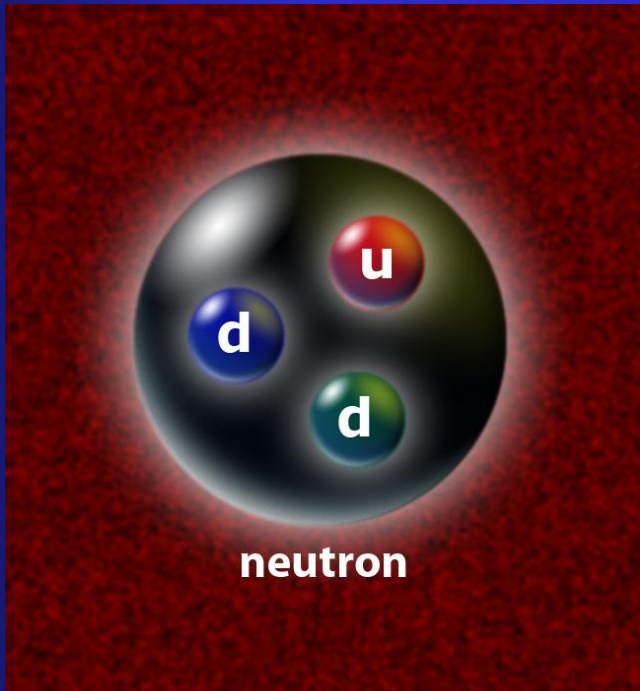


The era of particle physics begins at 10^{-10} seconds

This is the **quark soup** era

Nucleosynthesis

The Universe is about 1 second old



Quarks combine to form
protons and neutrons

Distance

After Nucleosynthesis, the Universe was “dark” because

- A) Fusion stopped so no light was being produced
- B) The universe was too dense to produce light
- C) There was plenty of light, it just couldn't get very far

The Dark Ages

The Universe is opaque for a long time.



Densities are too high for photons to go
very far

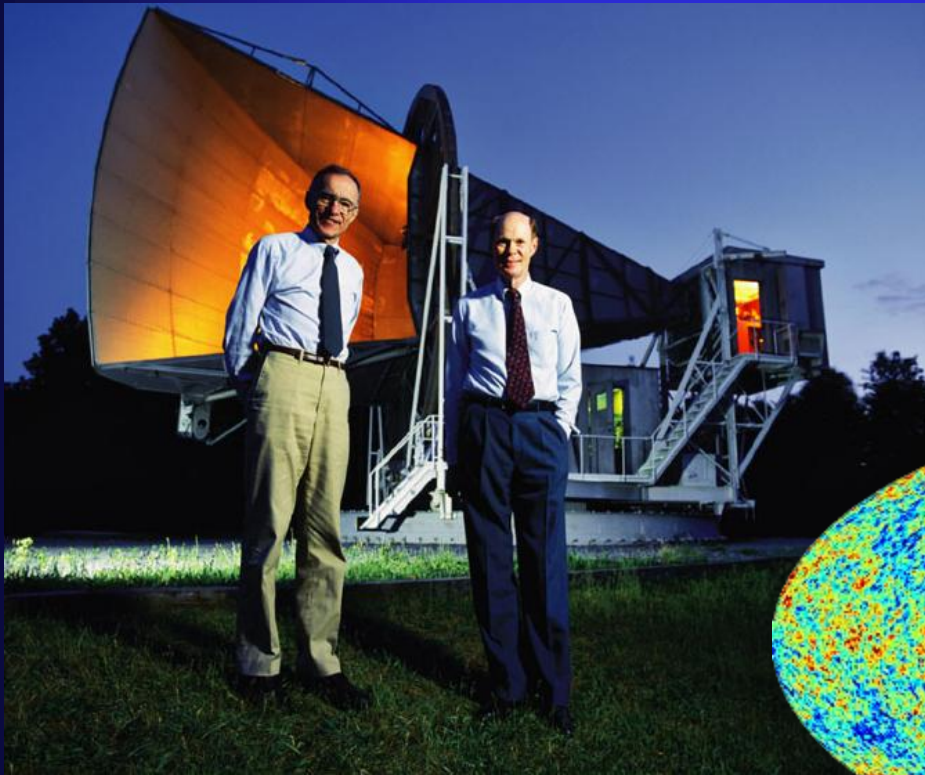
The Fog Lifts

After 380,000 years, the photons are free

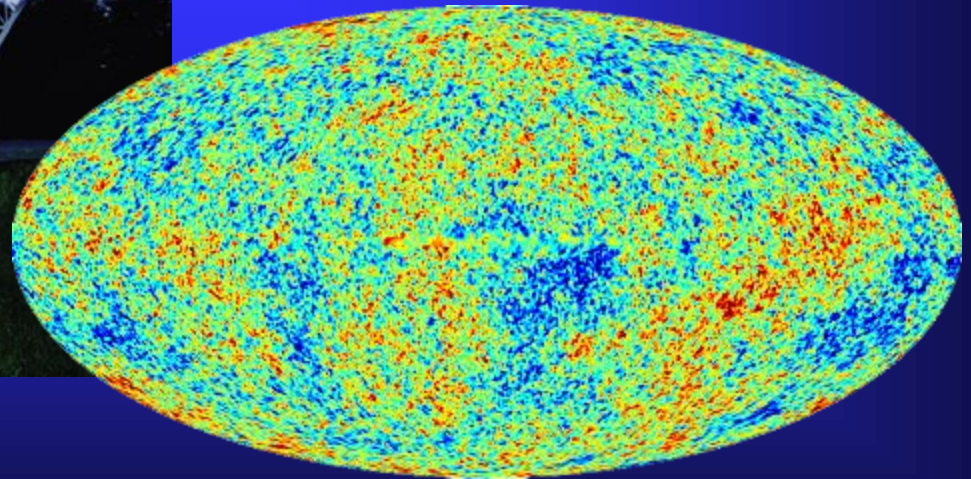


Evidence

Where are the first free photons?

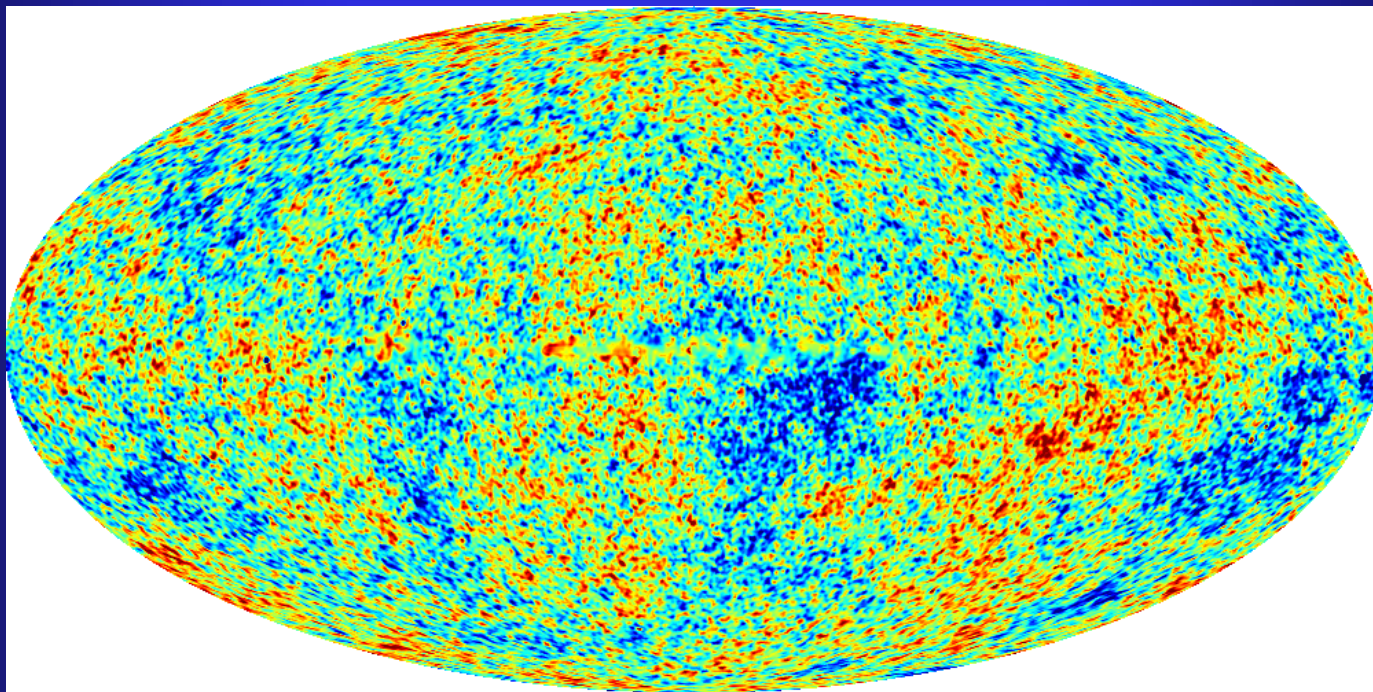


Cosmic
Microwave
Background



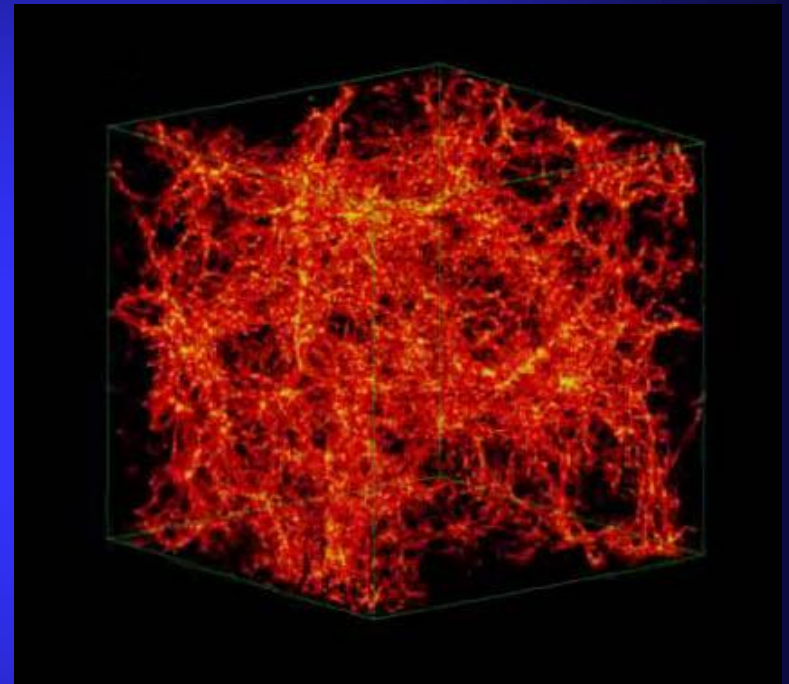
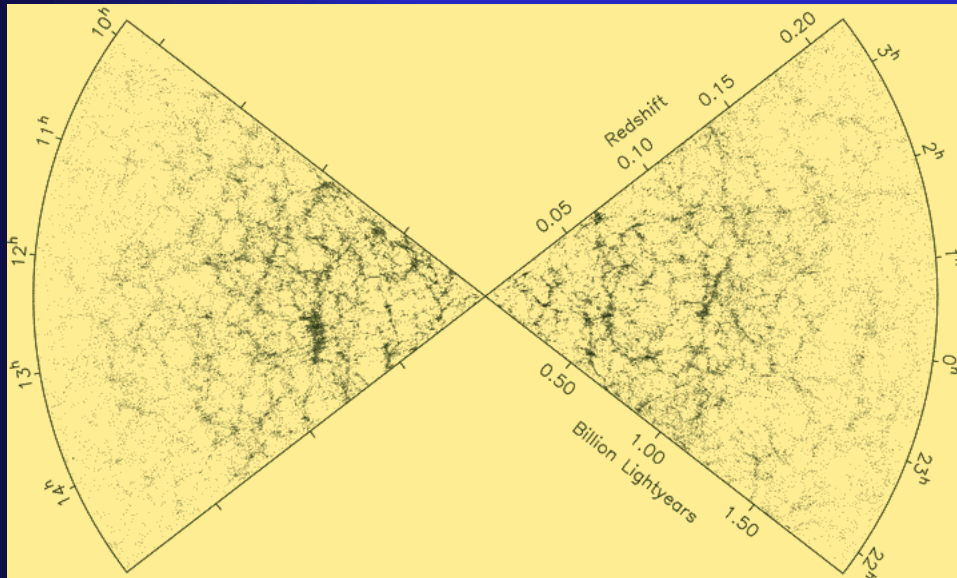
The Seeds of Structure

A period of rapid inflation magnified the early quantum fluctuations



On large scales, the Universe is quite uniform

How to Build a Universe

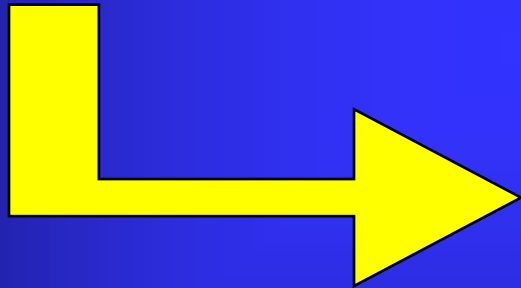


The original over densities
eventually grew into galaxies

Dark Matter

Kepler

$$p^2 = a^3$$



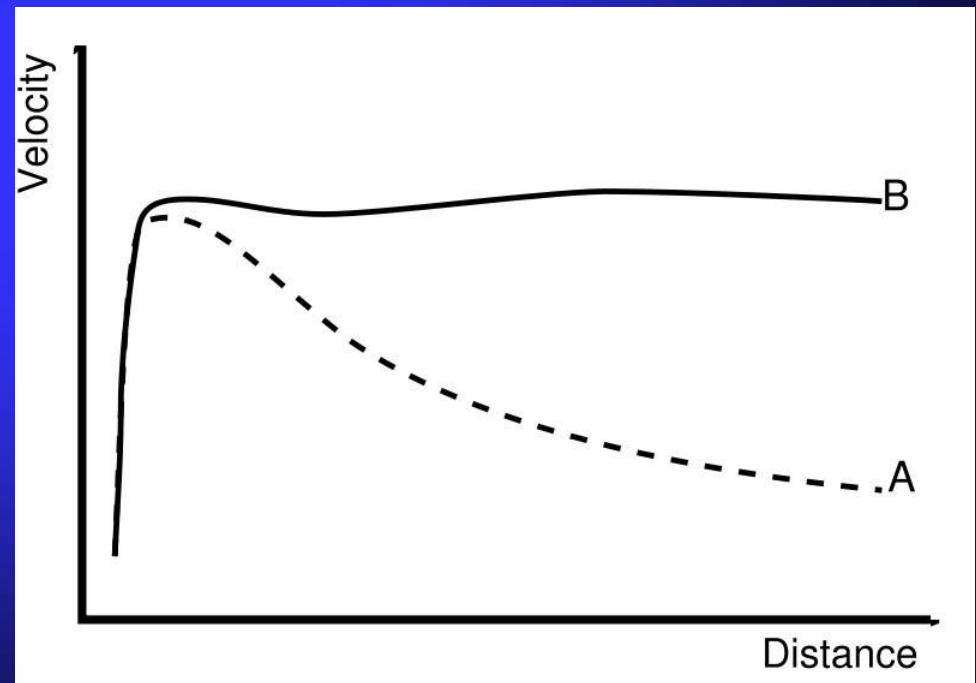
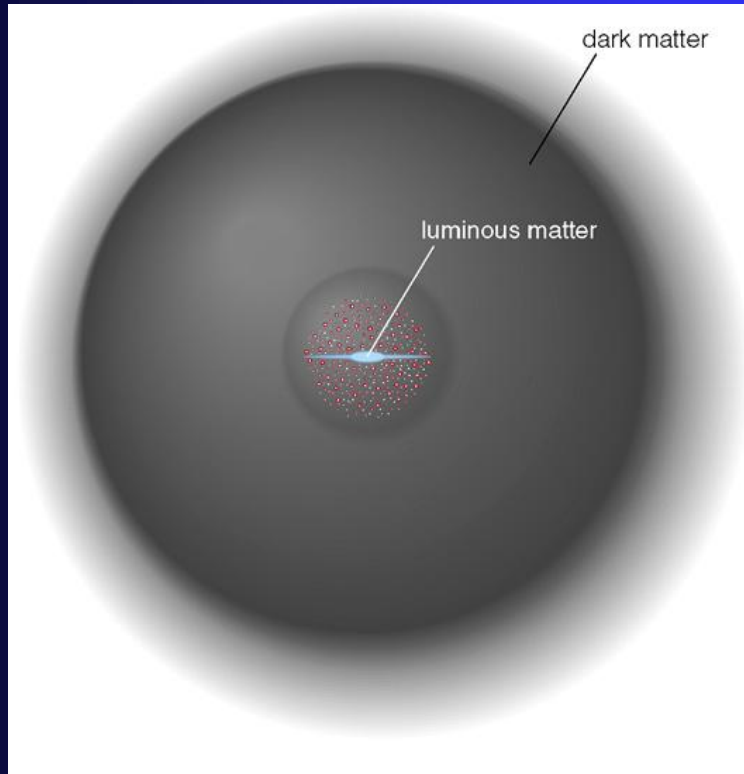
Newton

$$p^2 = \frac{4\pi^2}{G(M_1 + M_2)} a^3$$

Orbital period depends on
BOTH masses

Galactic Rotation Curve

We can't see all of the Milky Way's mass

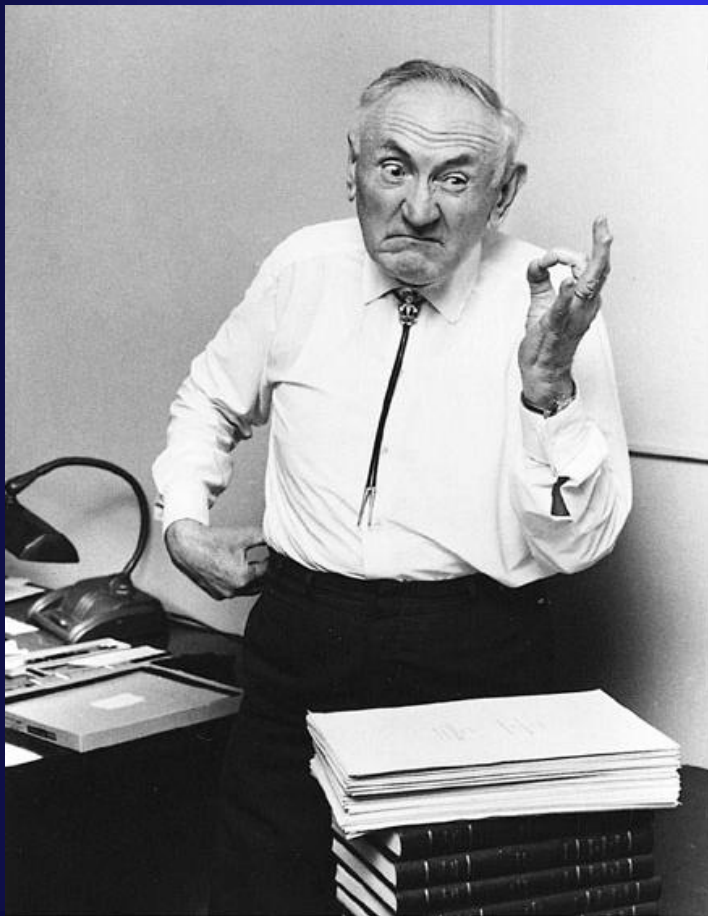


Galaxy Clusters

Orbital velocities in clusters of galaxies
are strange too

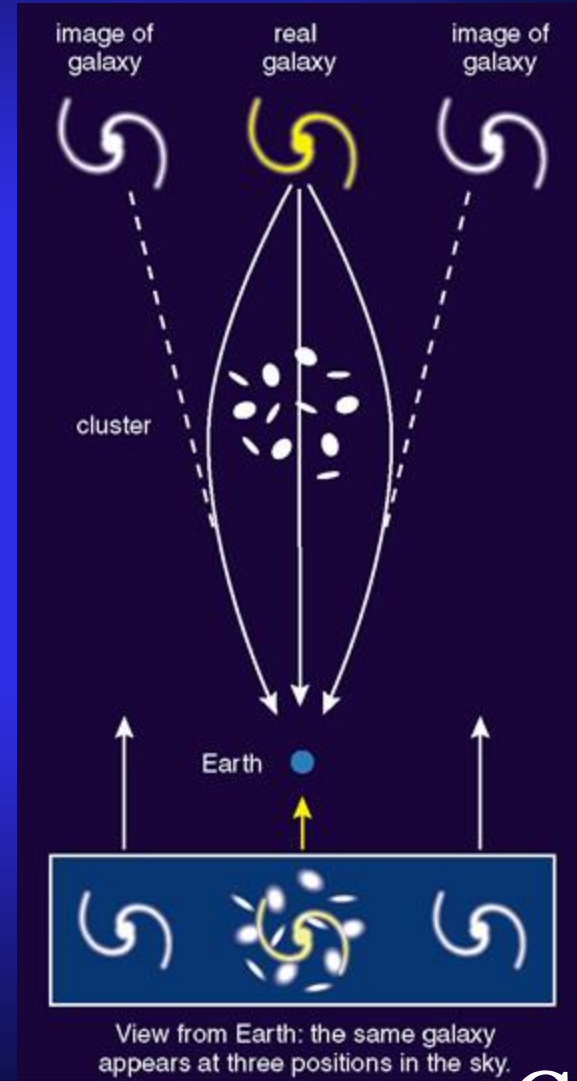
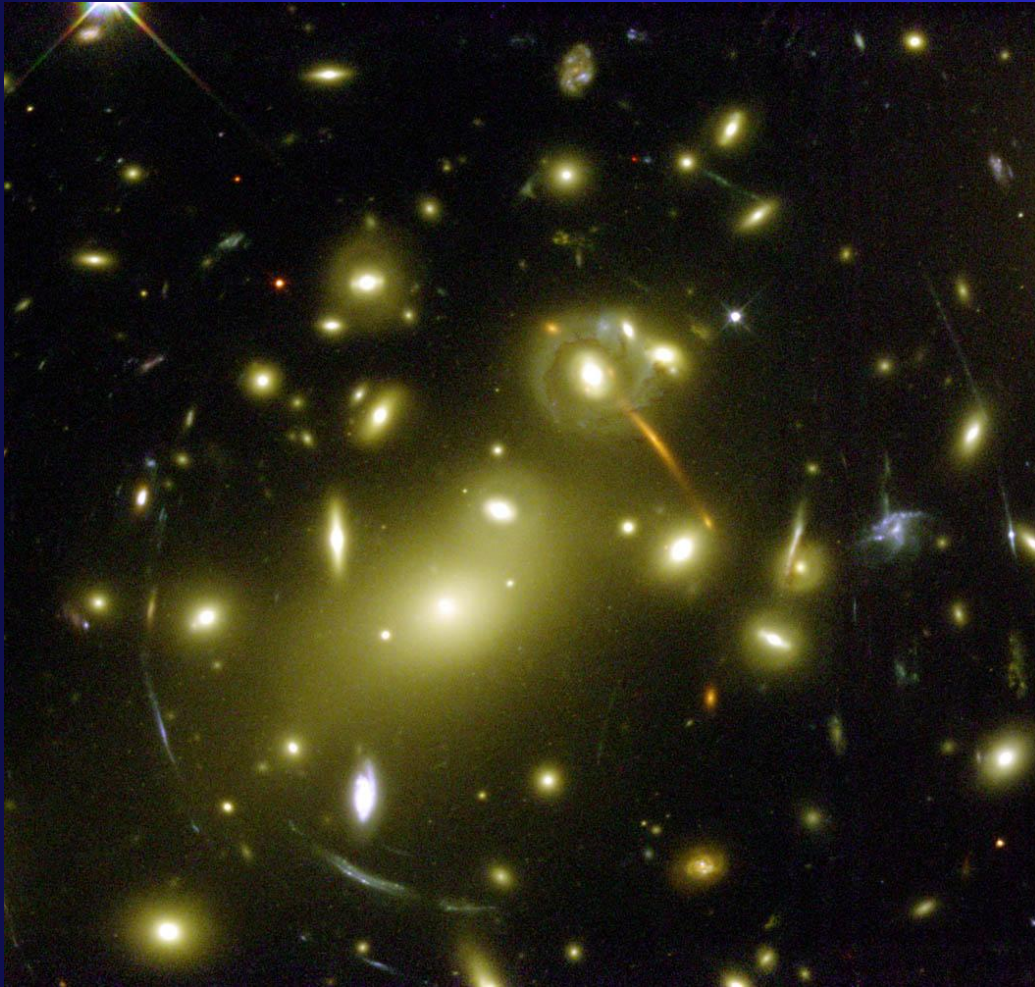
We can 'weigh' the
cluster by measuring
velocities of the galaxies

Once again, there isn't
enough mass.



Gravitational Lensing

Abel Cluster



What is it?

Could it be ordinary matter?



MACHO's
Massive Compact
Halo Objects

Surveys detect a few,
but not enough

WIMP's

Or is it extraordinary matter?



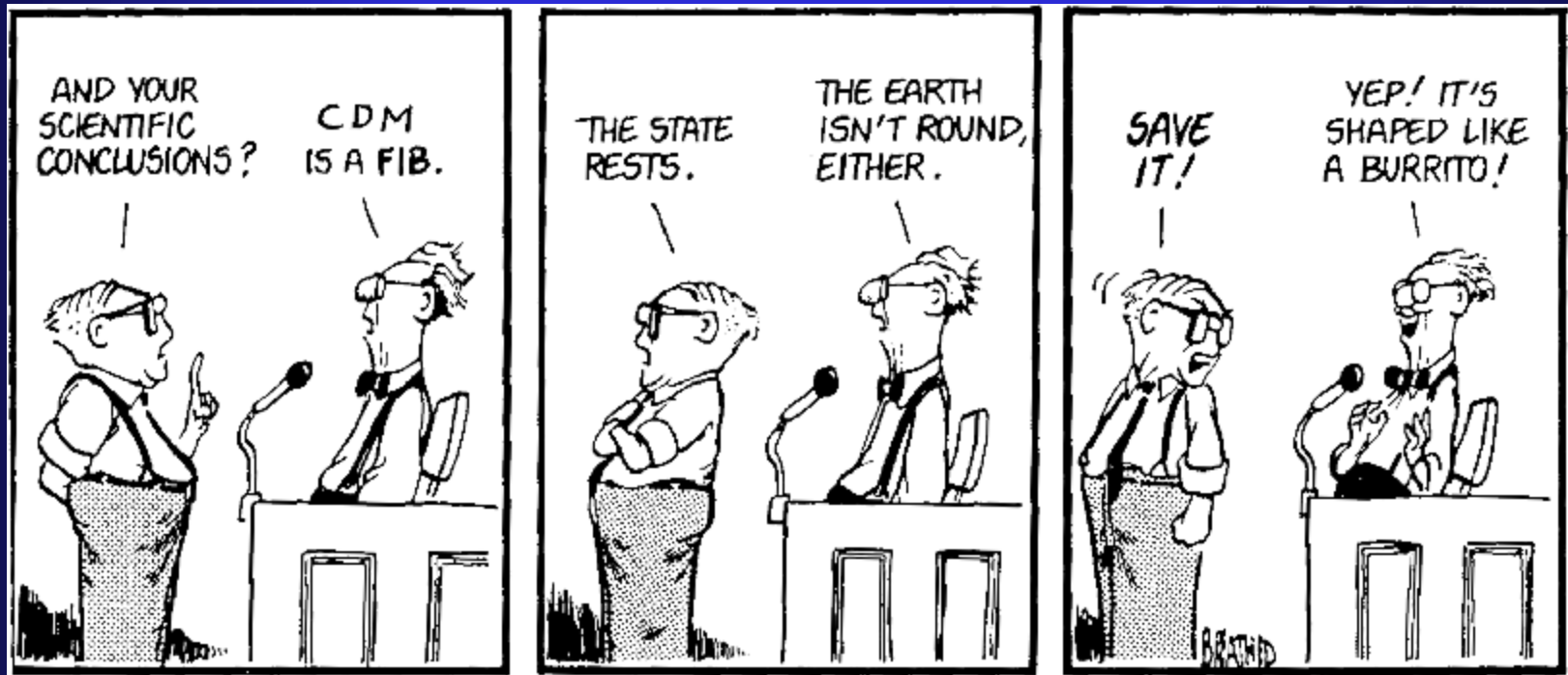
Weakly
Interacting
Massive
Particles

They Interact
gravitationally only

CMD = Cold Dark Matter

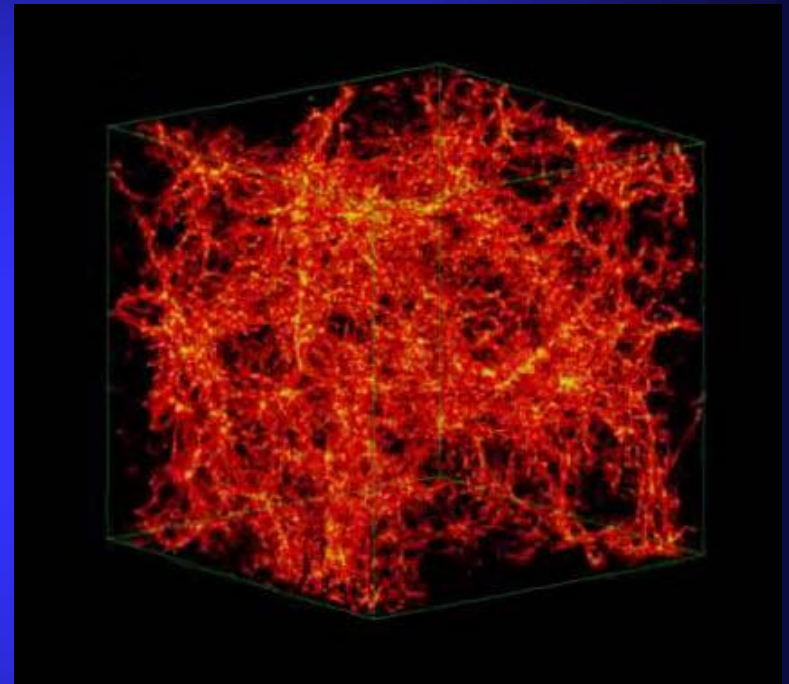
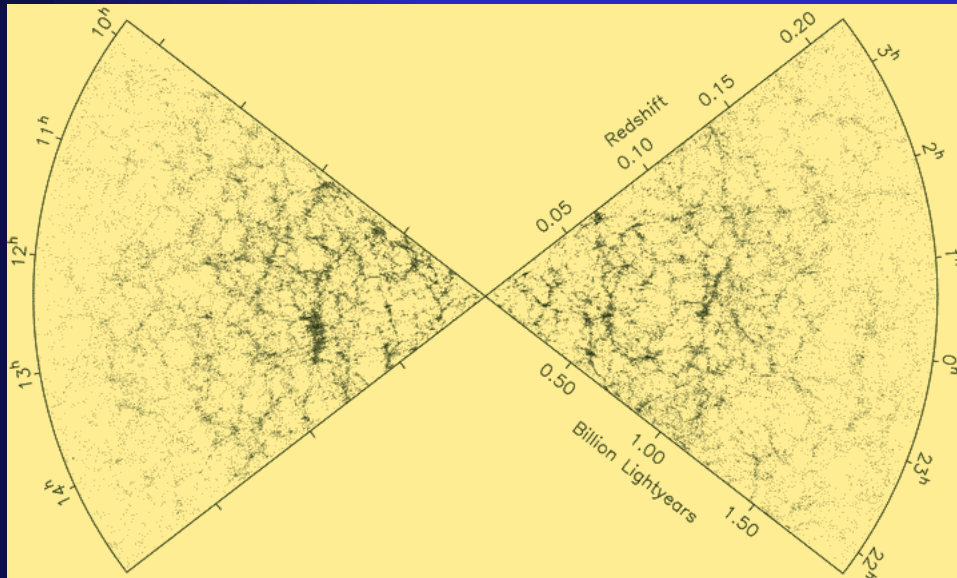
MoND

Modified Newtonian Dynamics



It hasn't come close to working yet

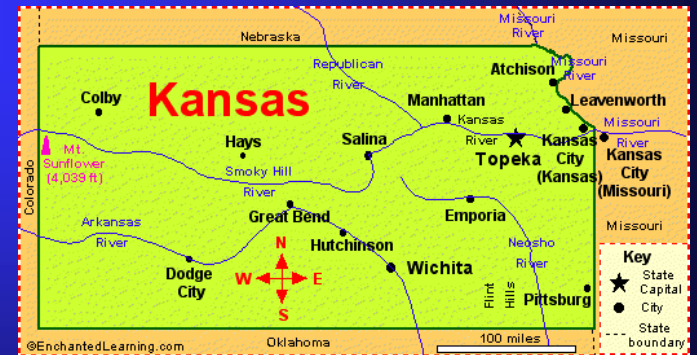
How to Build a Universe



The original over densities eventually grew into galaxies

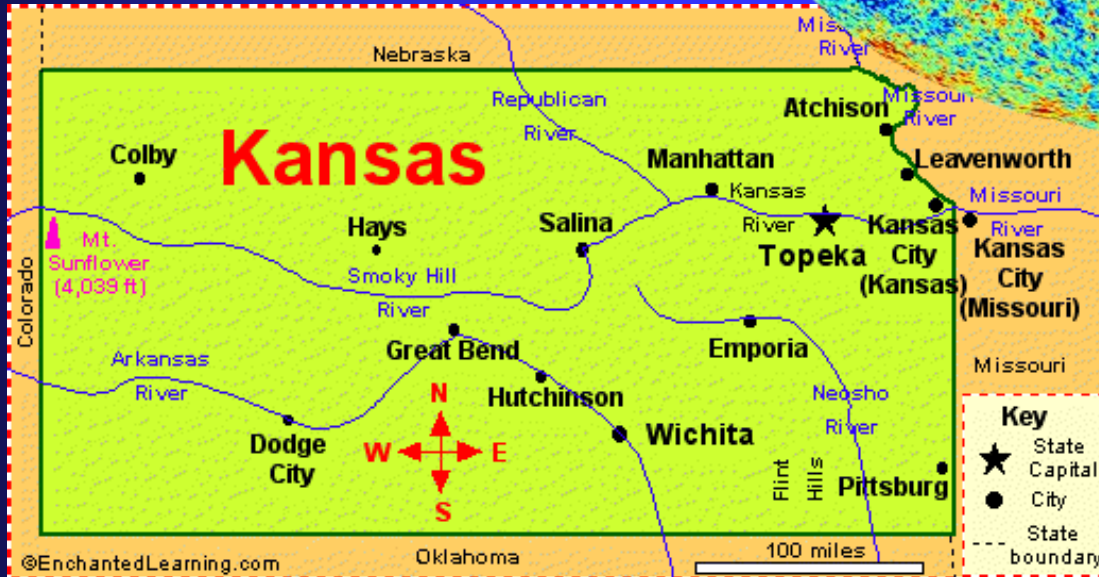
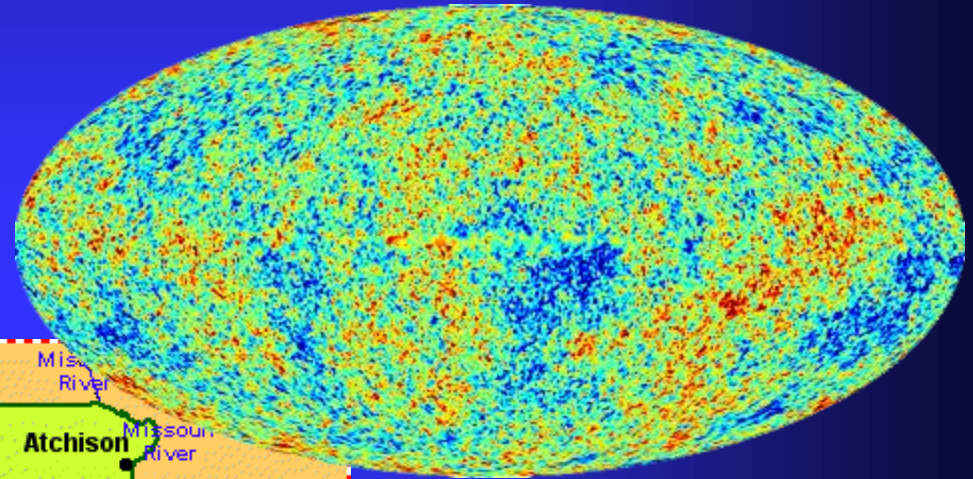
What Shape is the Universe?

Since gravity warps space... what is the overall shape of the Universe?



Looks Pretty Flat

At least overall.



The Fate of the Universe

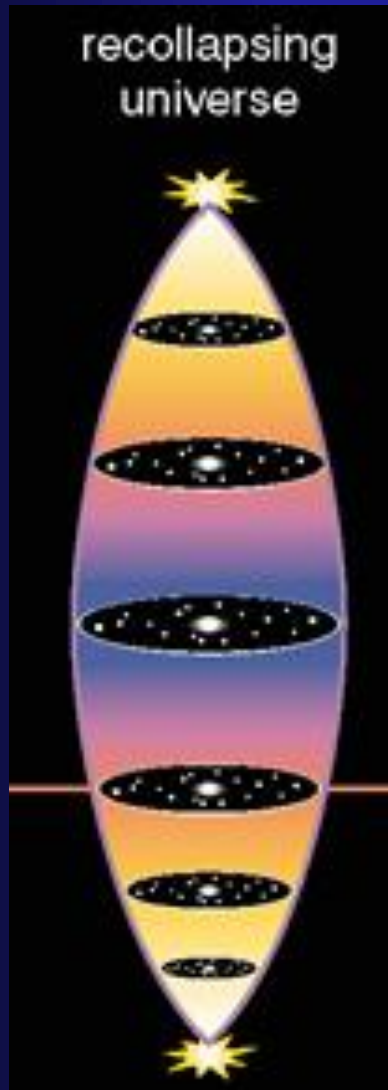
An escape velocity question
on a grand scale



If the Universe has
Critical Density it
will re-collapse

If it doesn't, it won't

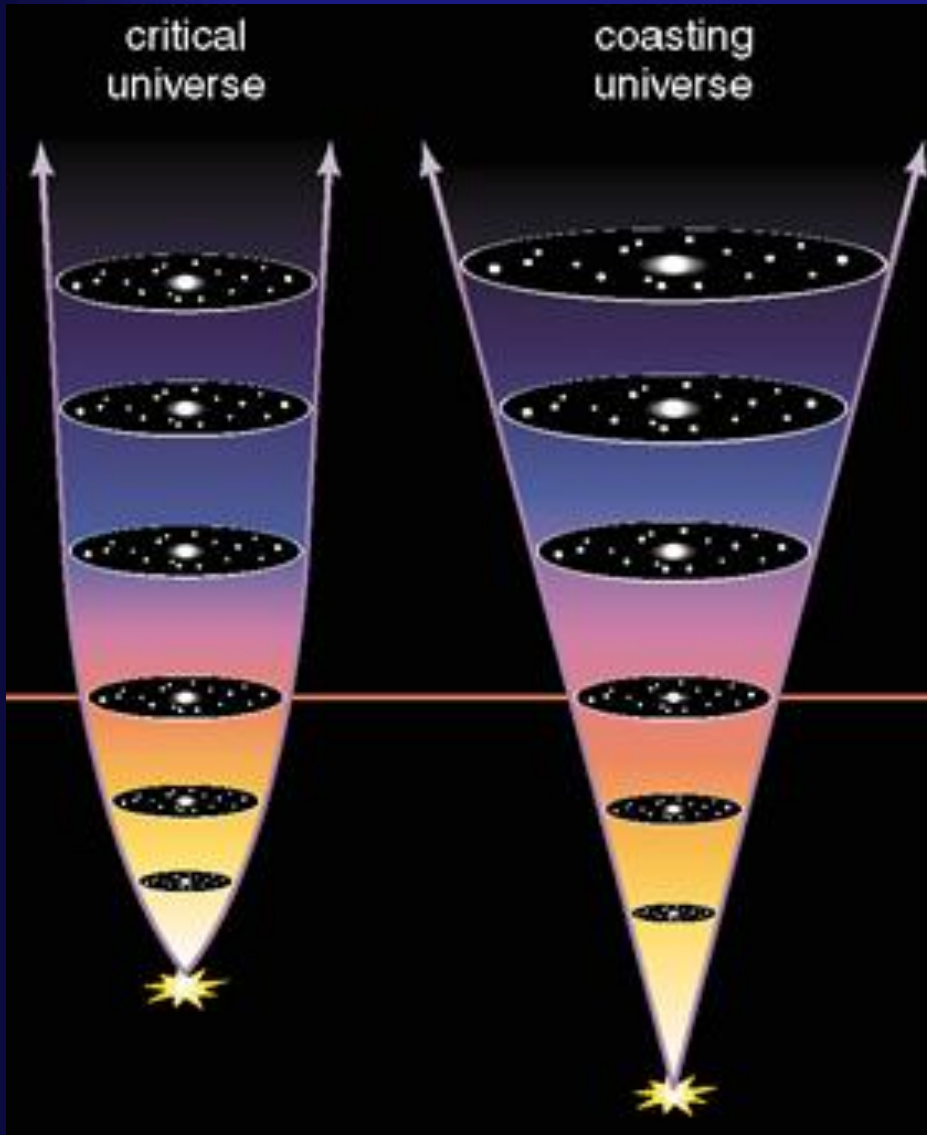
The Big Crunch



The density of the Universe is greater than critical density and the Universe recollapses

Perhaps there is another Big Bang and the whole thing just keeps happening over and over

Heat Death



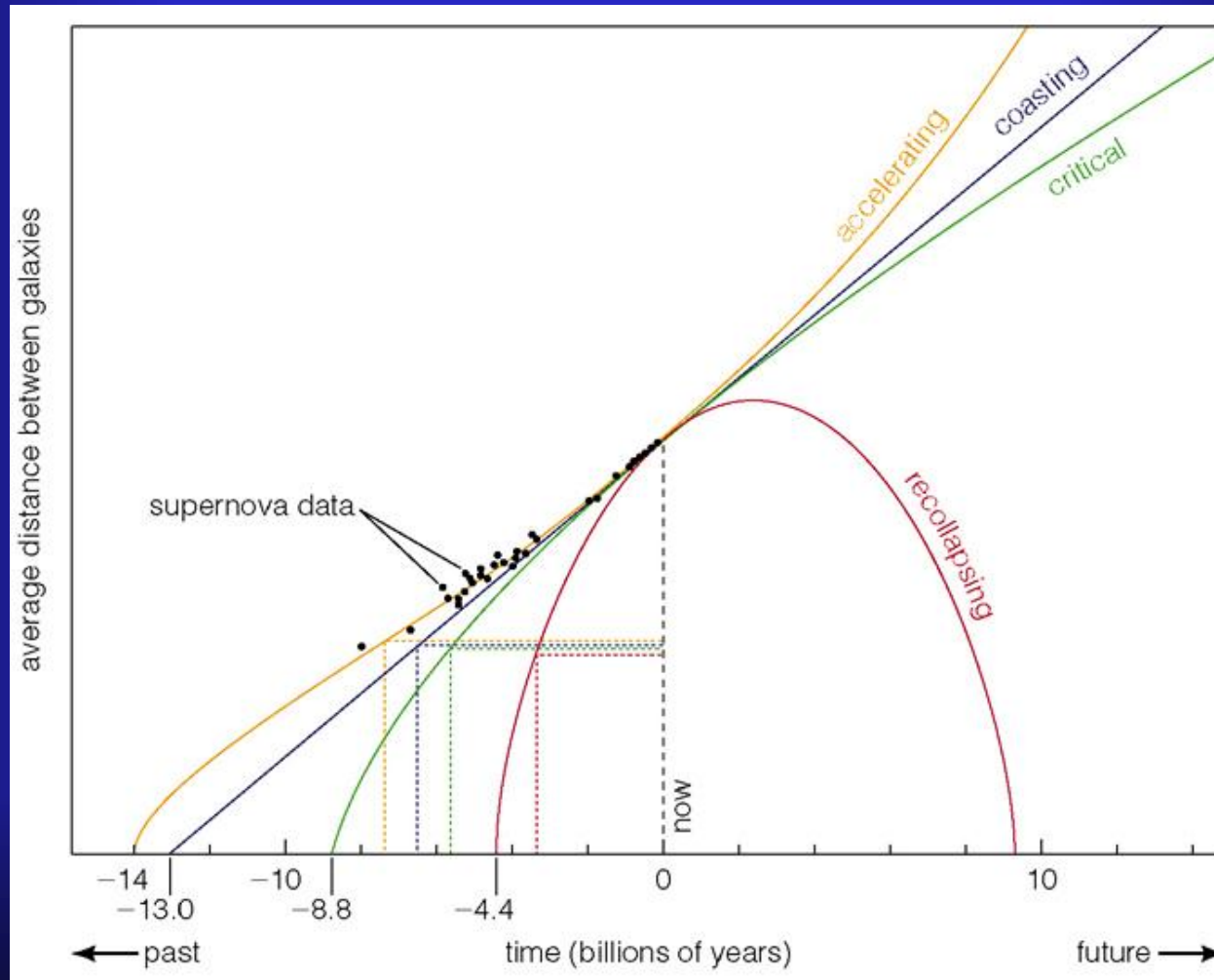
The density of the Universe is at or below critical density

It will expand forever

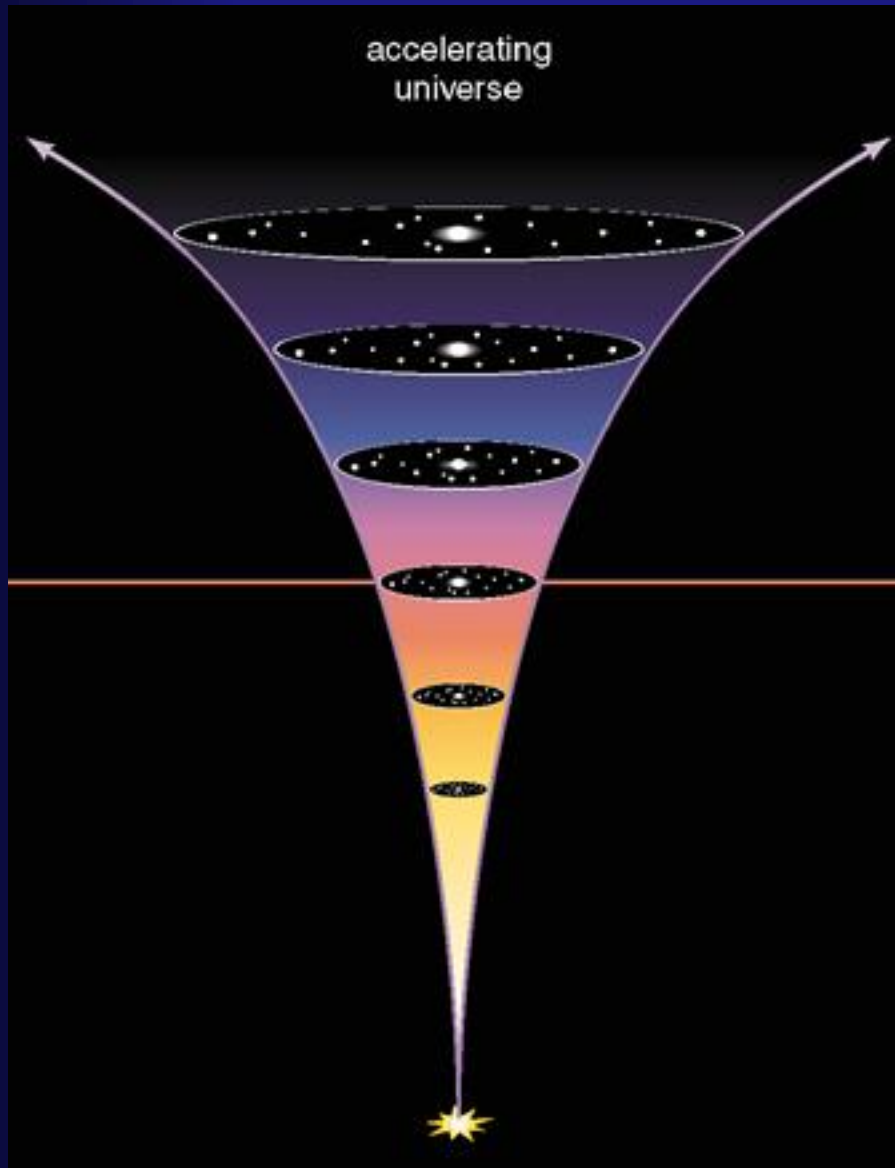
Eventually all of the stars will burn out

Some Things Never Die

The expansion appears to be accelerating



The Big Rip



Eventually the expansion will be so fast that gravity won't hold it together

Eventually **NOTHING** will hold it together!

The End?

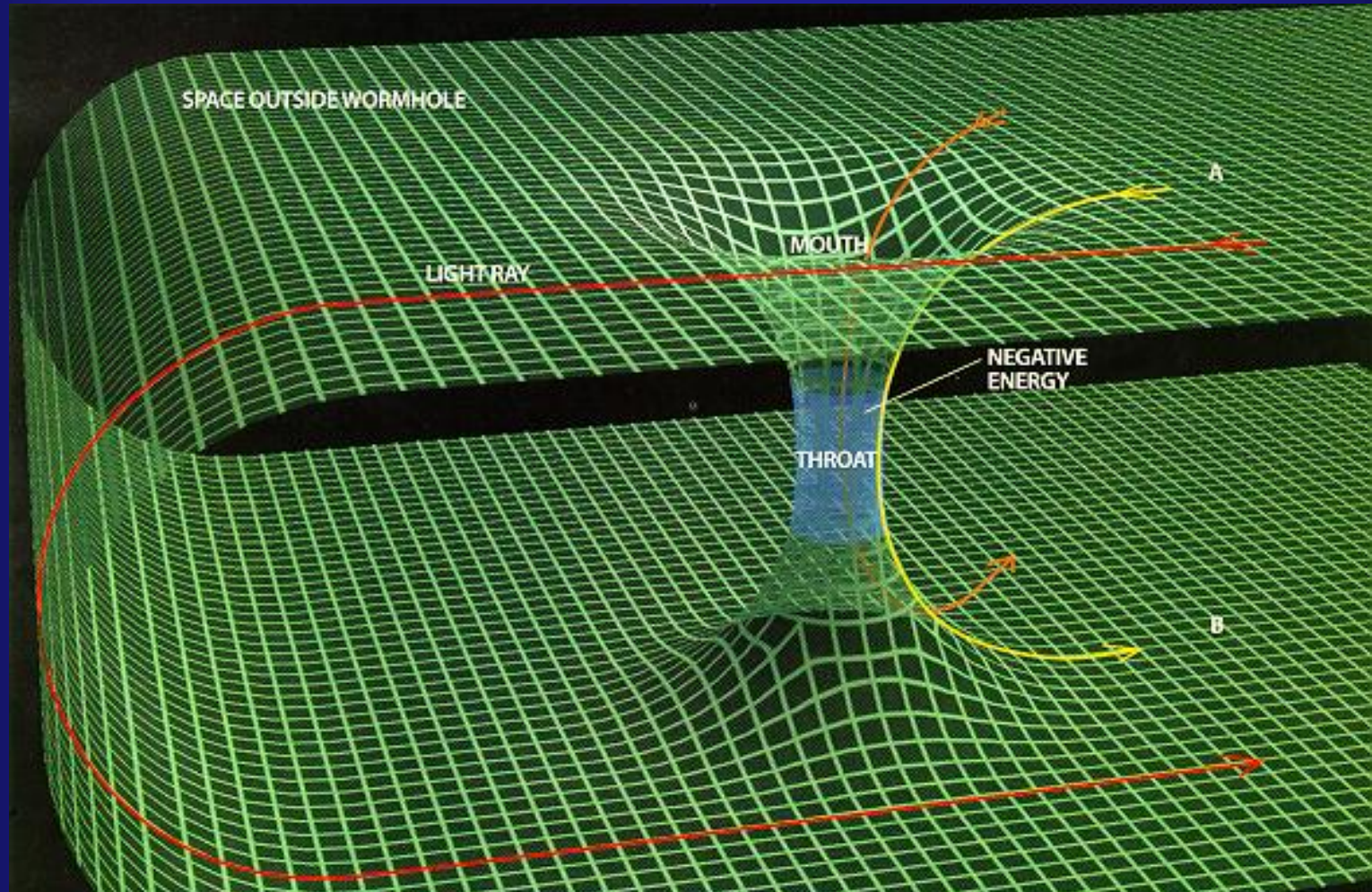
Current models

30 percent matter
70 percent dark energy

The super nova data remains
controversial

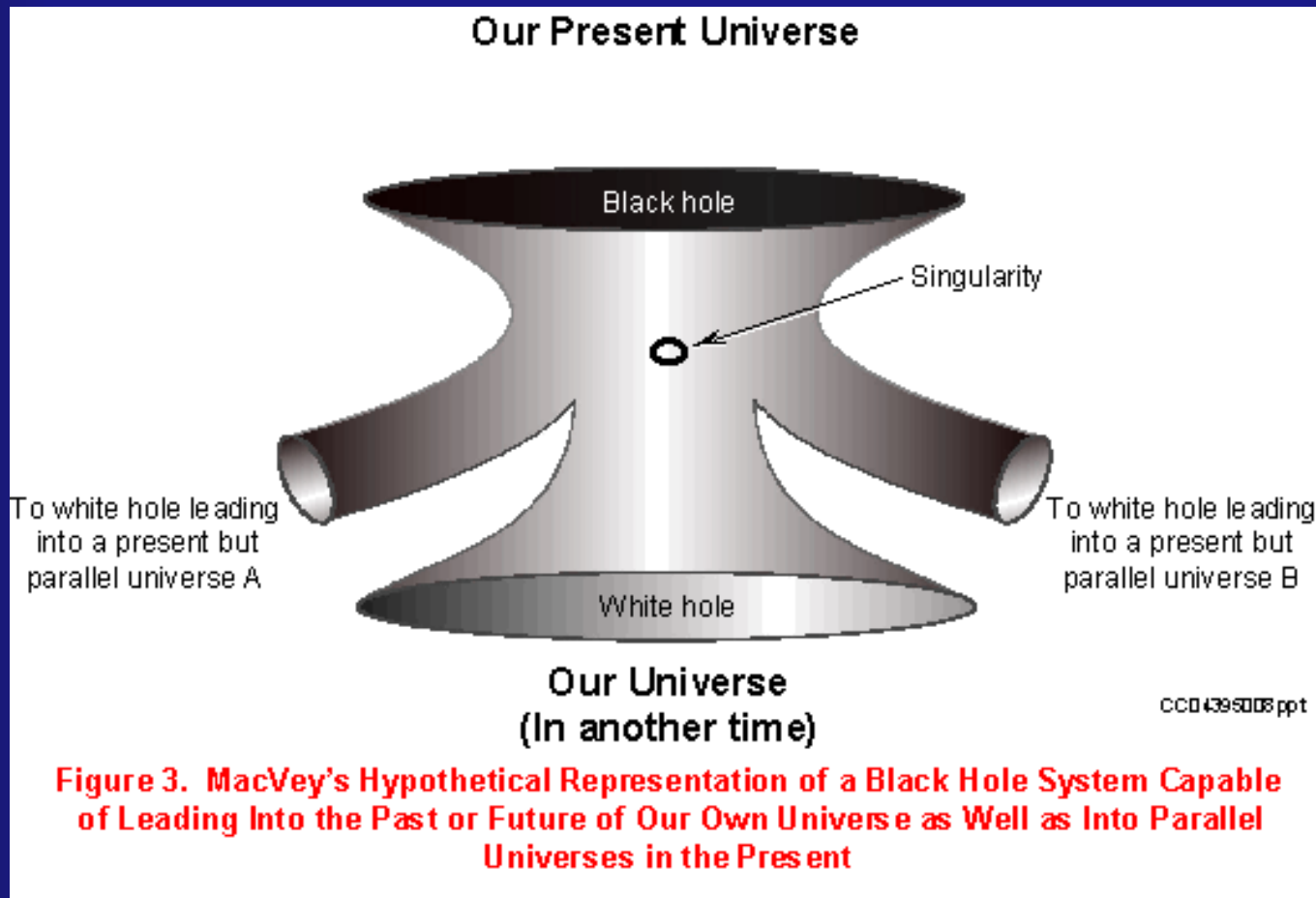
Remember the Ether!

Wormholes



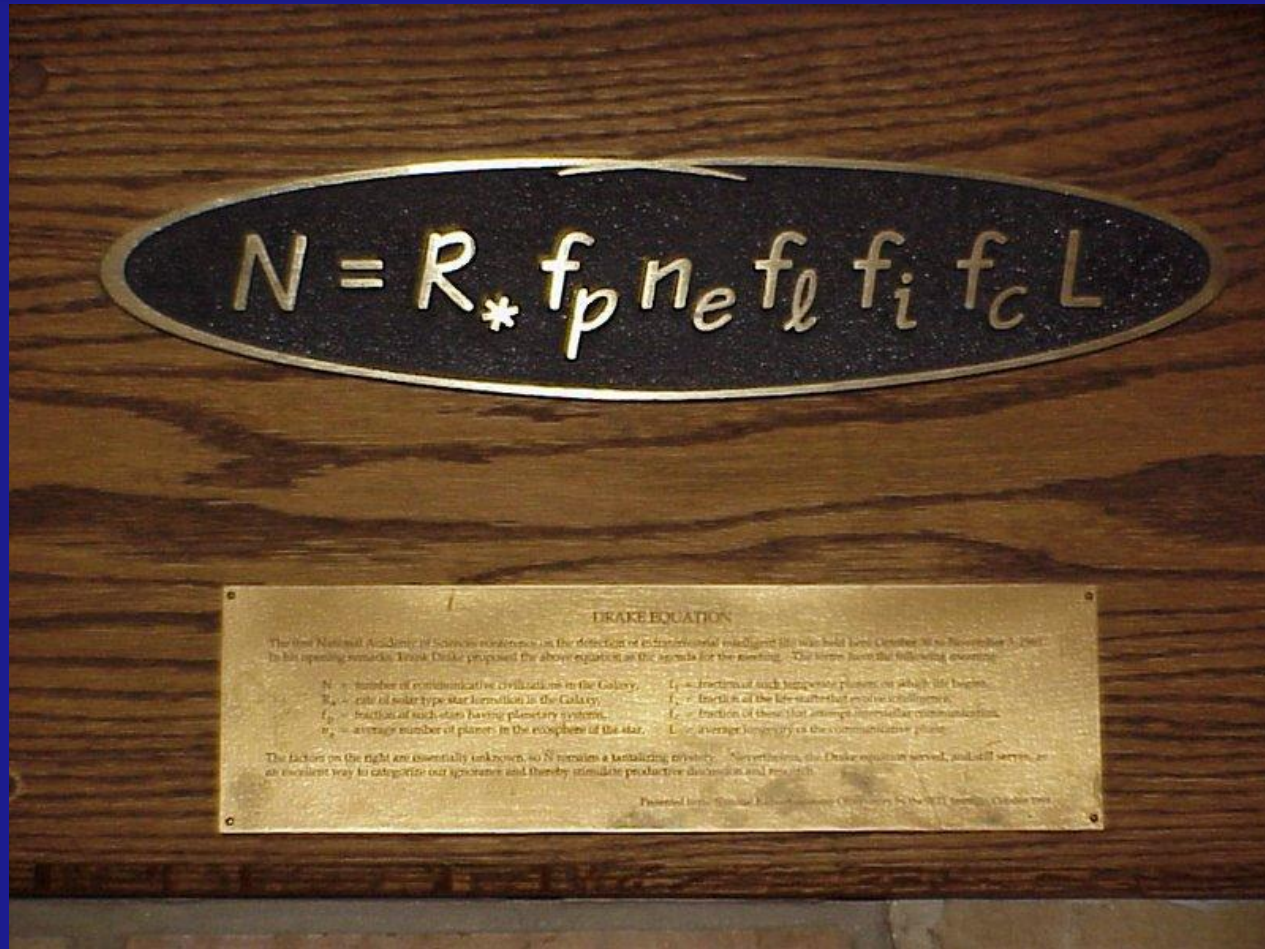
Connecting Distant Points

Black, White, Worm...



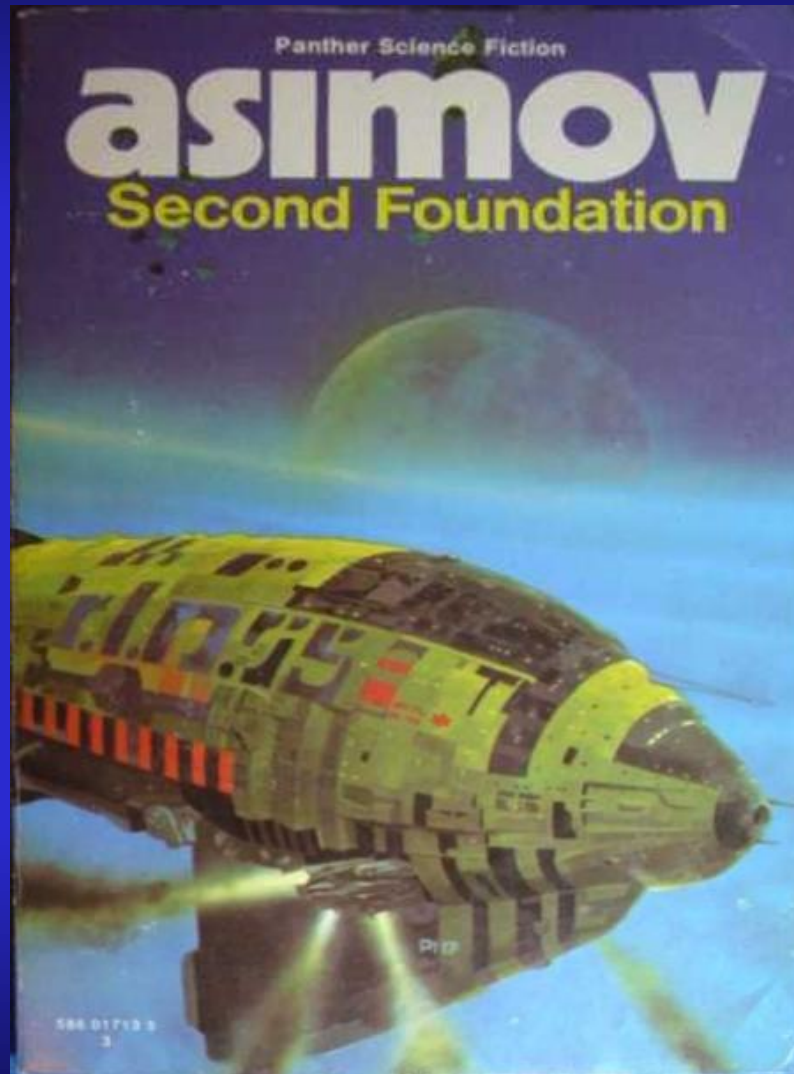
Connecting Distant Points
In space AND time

Life?



According to Drake, $N = 10,000$

Galactic Colonization!



How long would it take to colonize the galaxy?

Where are they?

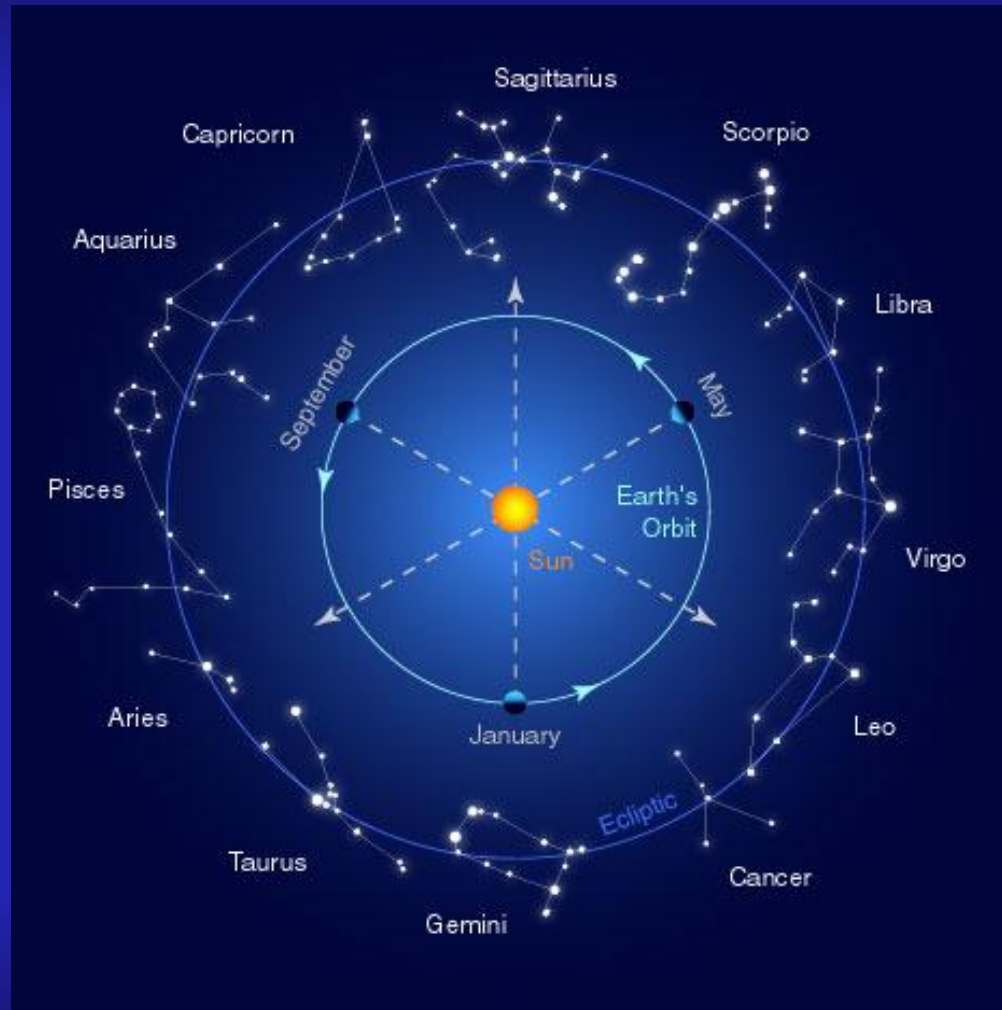
They're Here!

They've come and gone... Not interested

How long does it take to develop intelligence?

How long do intelligent civilizations persist?

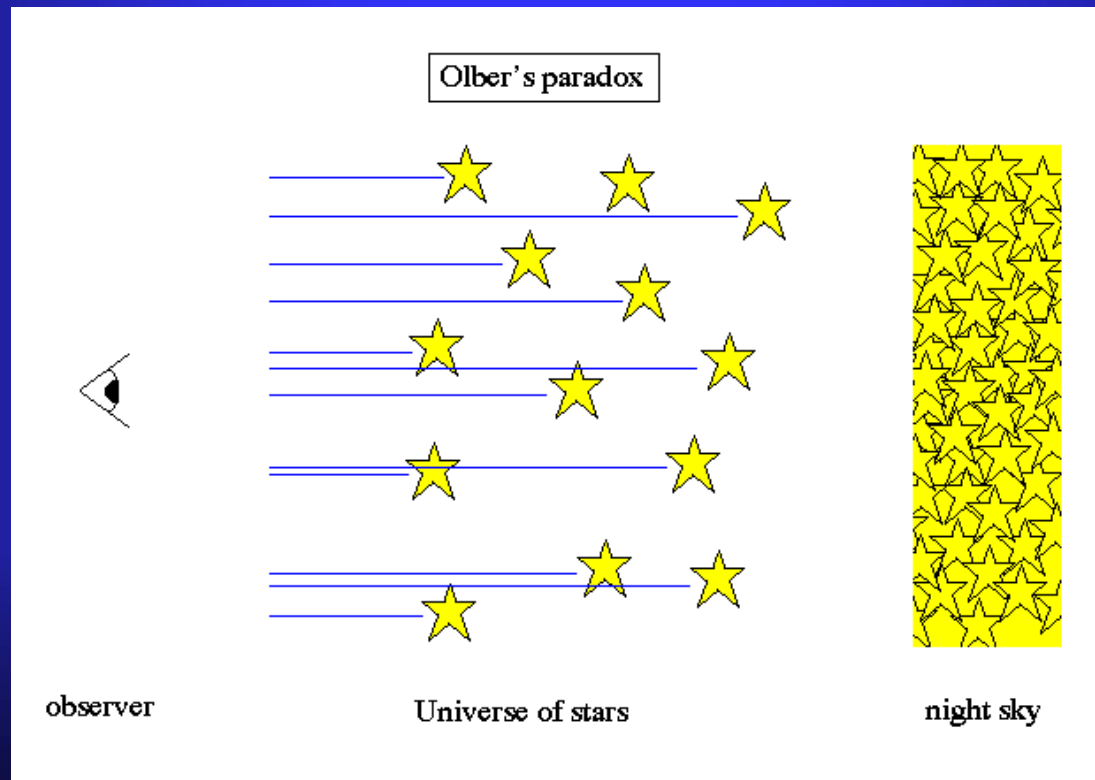
Astrology



A testable hypothesis?

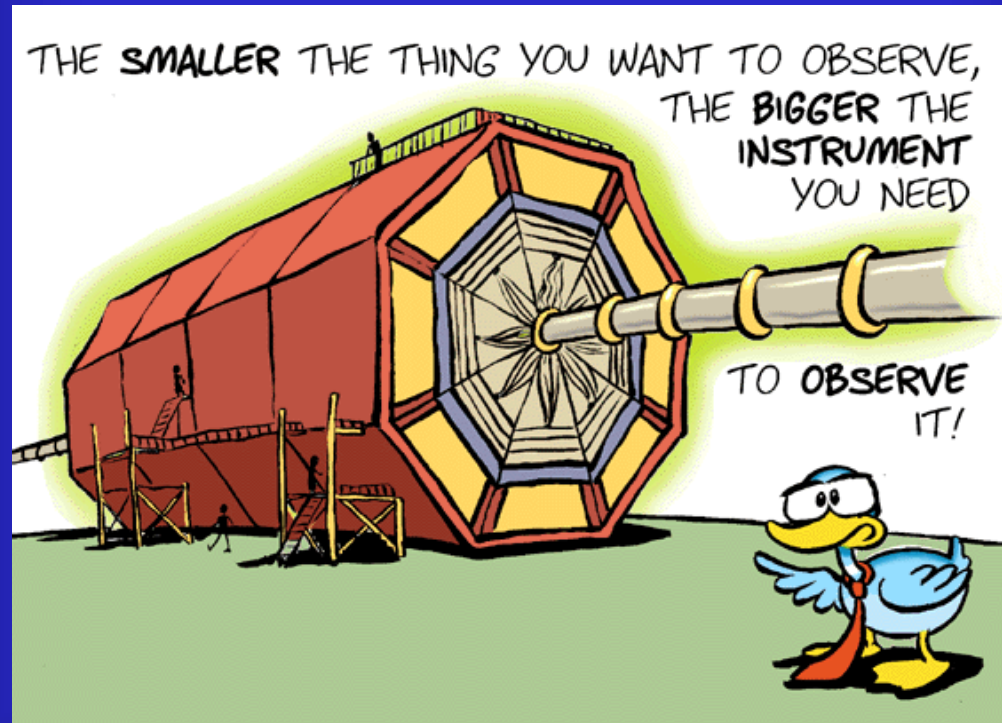
Olber's Paradox

The Universe is definitely much different today than it was in the past



A Brief History

At first, there was no matter



We use particle accelerators to
study the very beginning