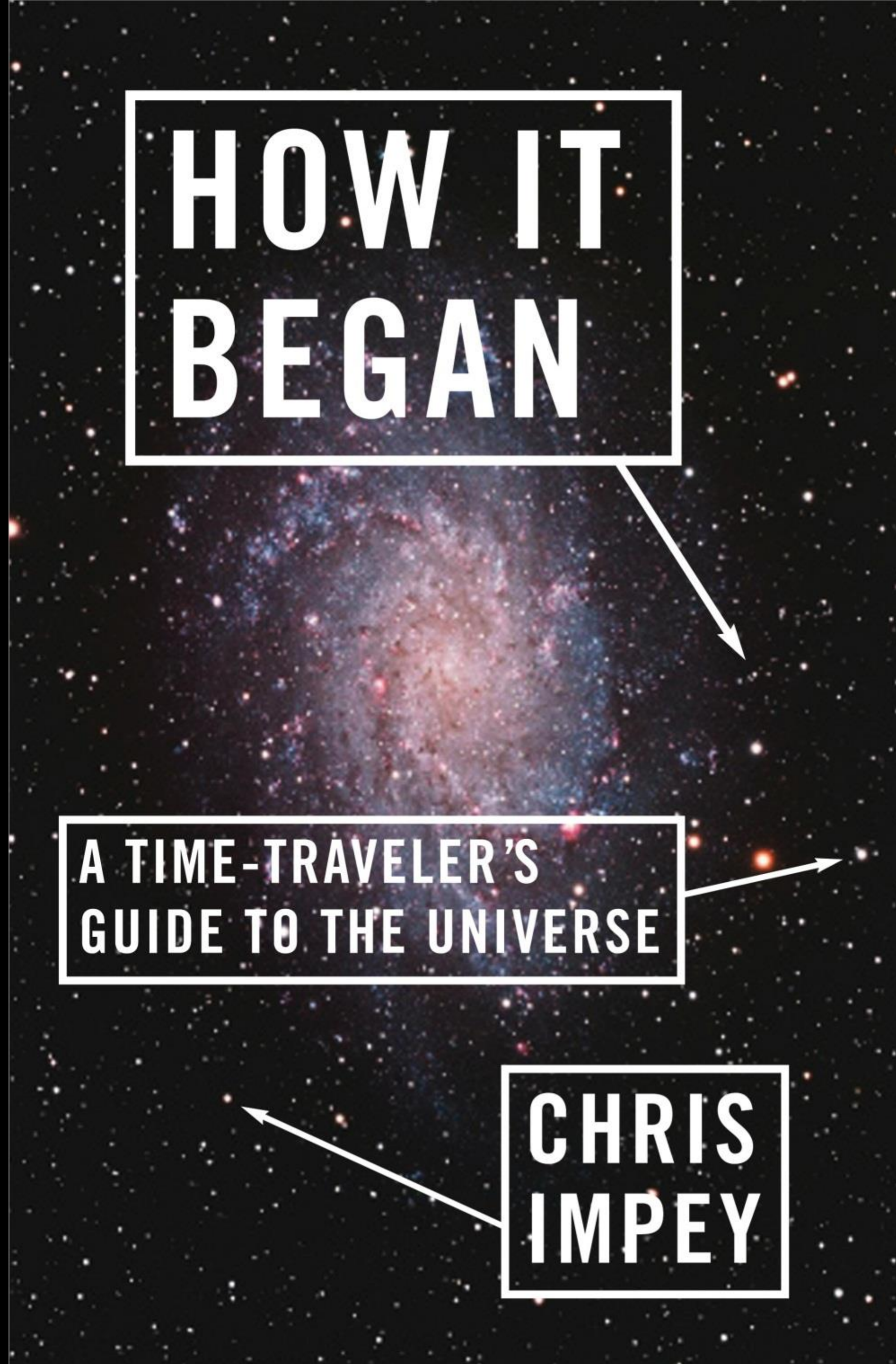
How It Began


HOW IT BEGAN
A TIME-TRAVELER'S GUIDE TO THE UNIVERSE
CHRIS IMPEY

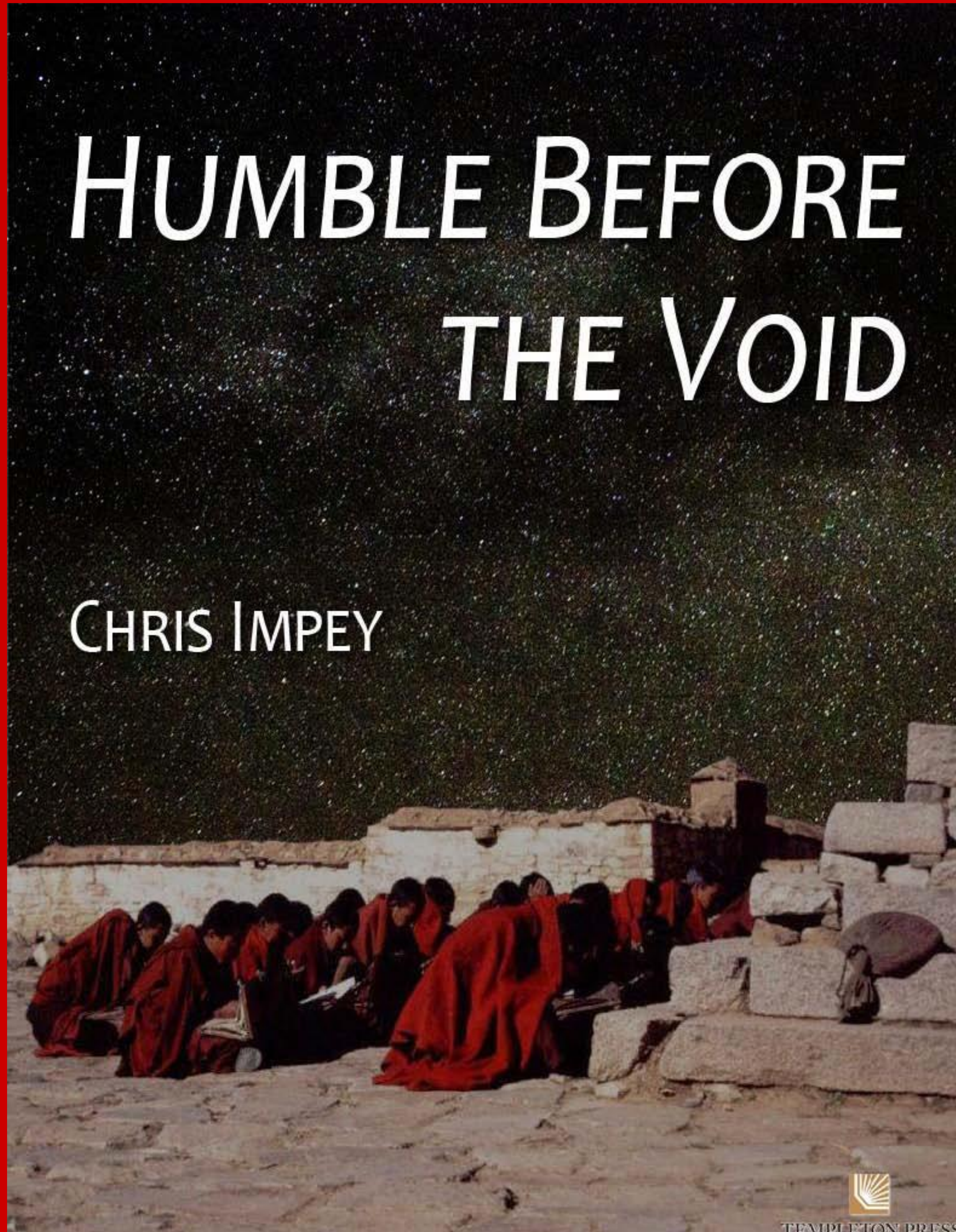
chris impey

how it ends

from you to the universe


PEOPLE FALL ILL, GROW OLD, AND DIE. NO MATTER WHAT MAGNIFICENT DAWN ILLUMINATES YOUR LIFE, YOU WILL, IN THE END, BE NAILED UP IN A COFFIN AND THROWN INTO A PIT.
REALLY EDWIN. IT'S ONLY OUR FIRST DATE!
LYNDA BARRY ©1984


Dreams of
Other Worlds
Chris Impey and Holly Henry

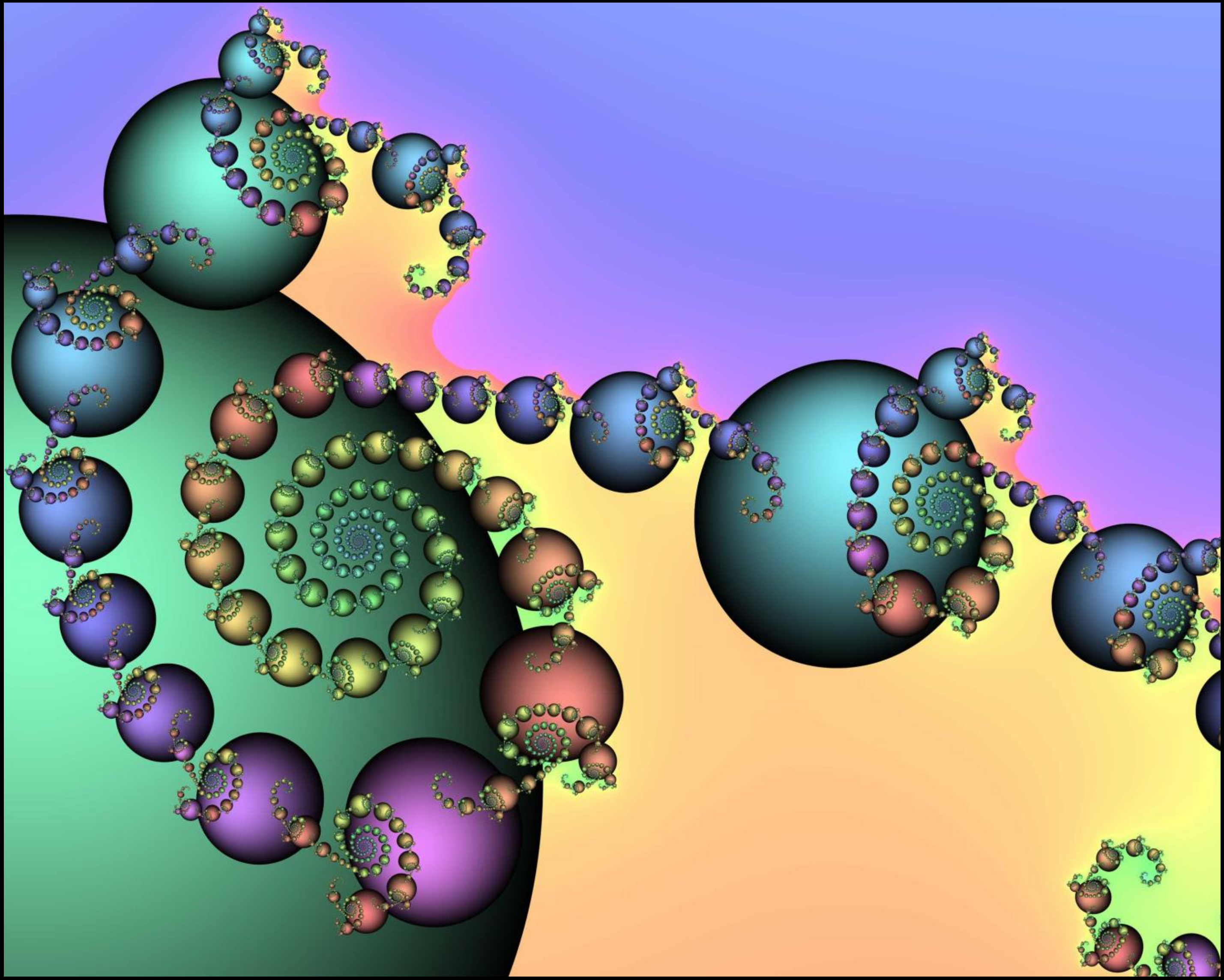

HUMBLE BEFORE
THE VOID
CHRIS IMPEY
TEMPLETON PRESS

A Little History

Finite or Infinite

What if the universe is endless and eternal?

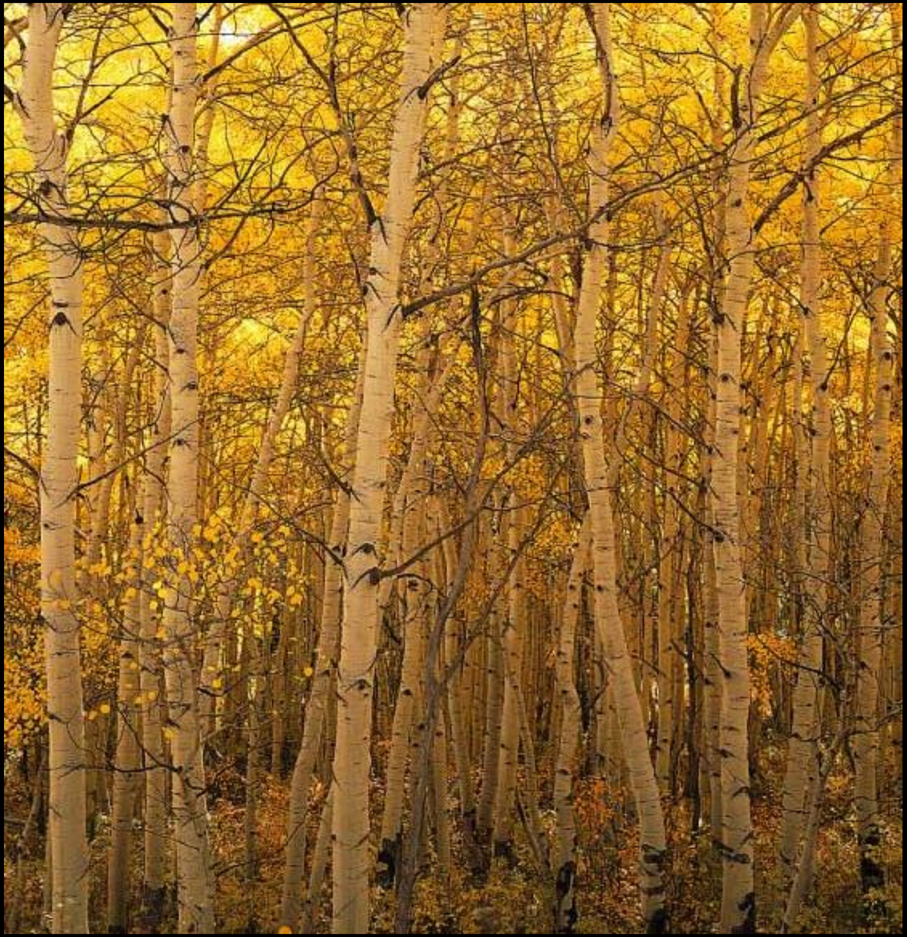
Does the universe go on forever…

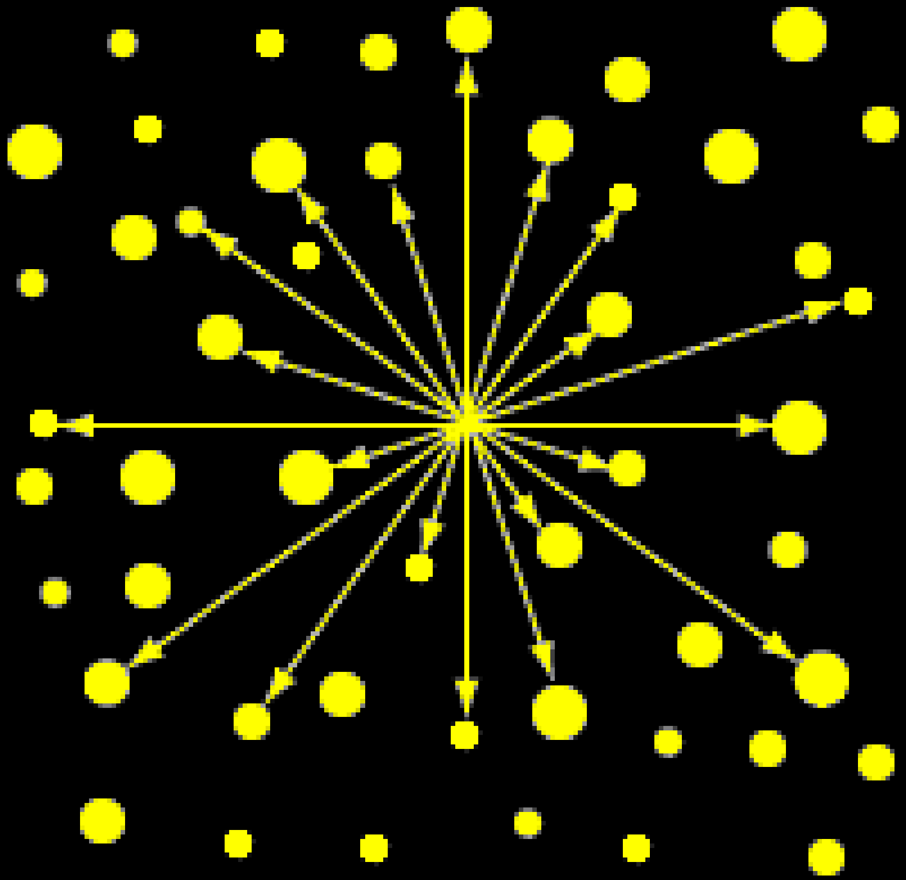


…or is it bounded in space and time?

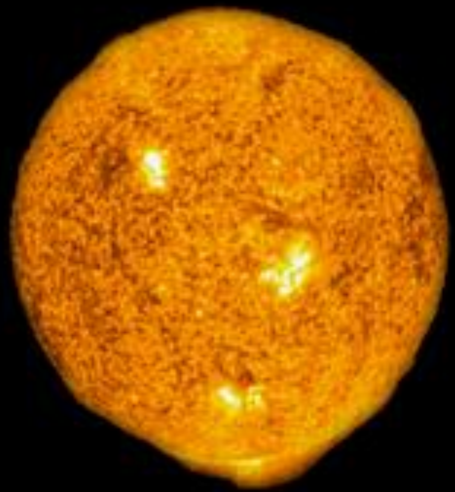
Newton's universe: eternal and infinite

Because a finite universe is unstable…



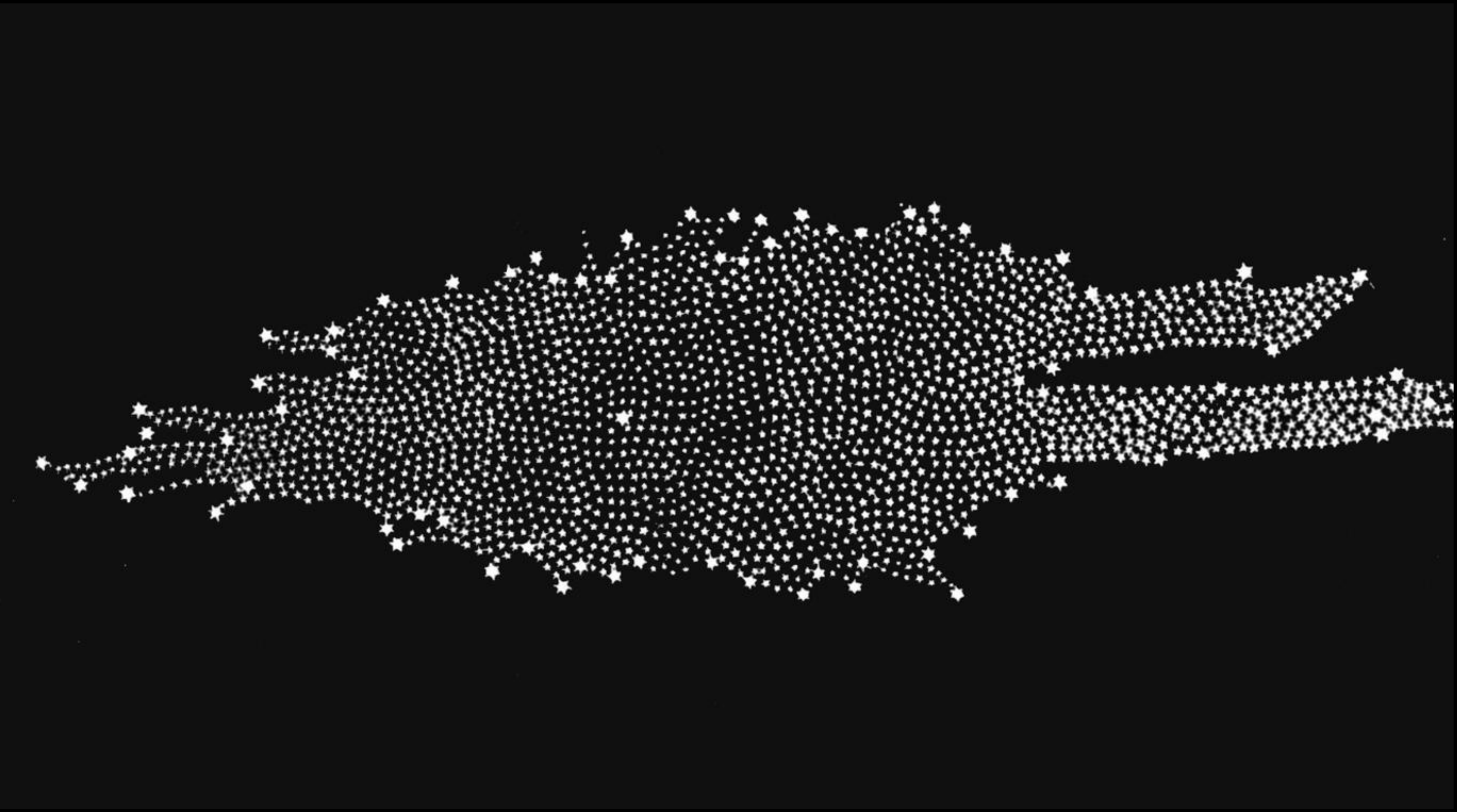


..but an finite universe has problems

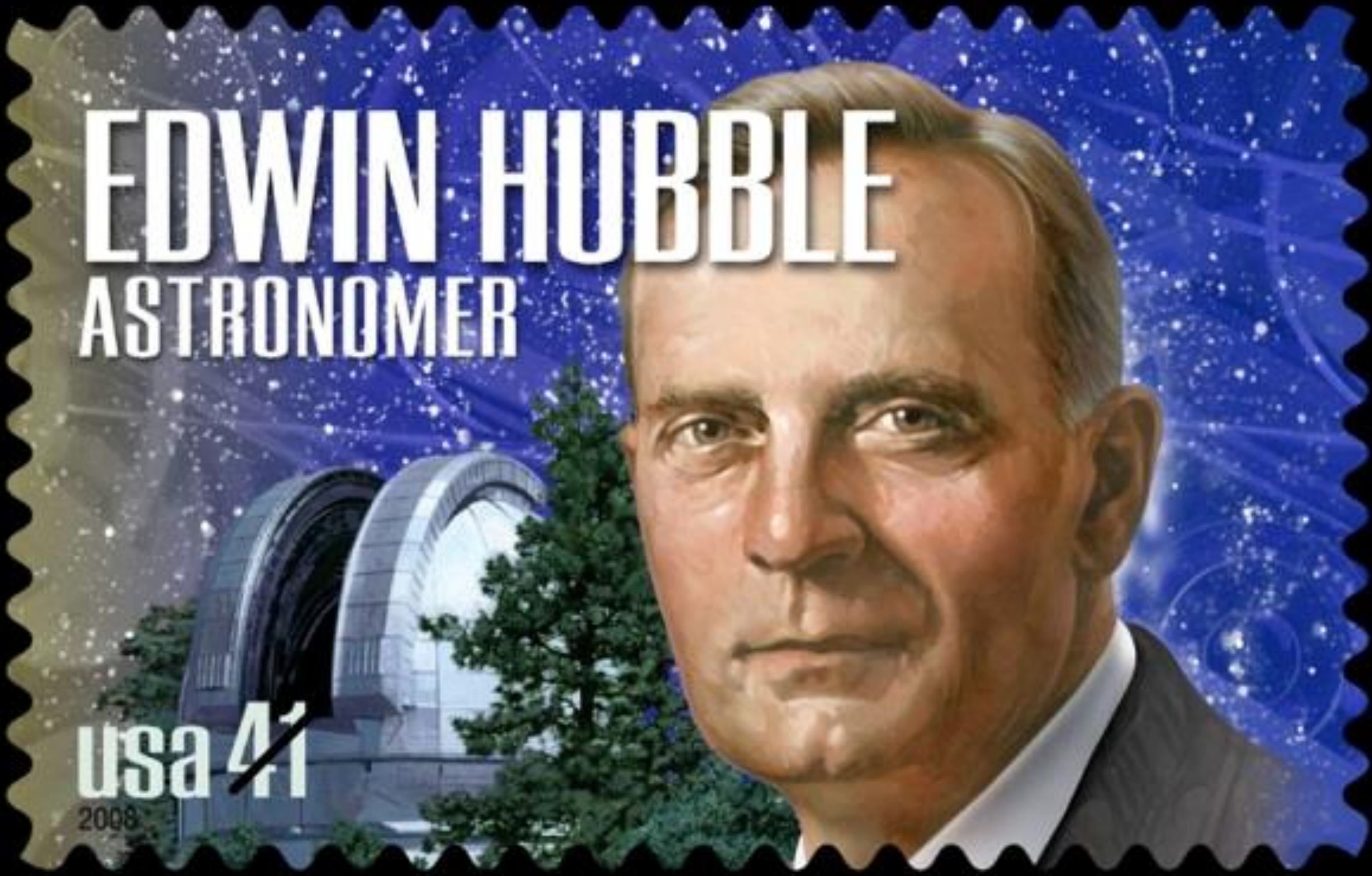


Island Universe

Herschel mapped the Milky Way

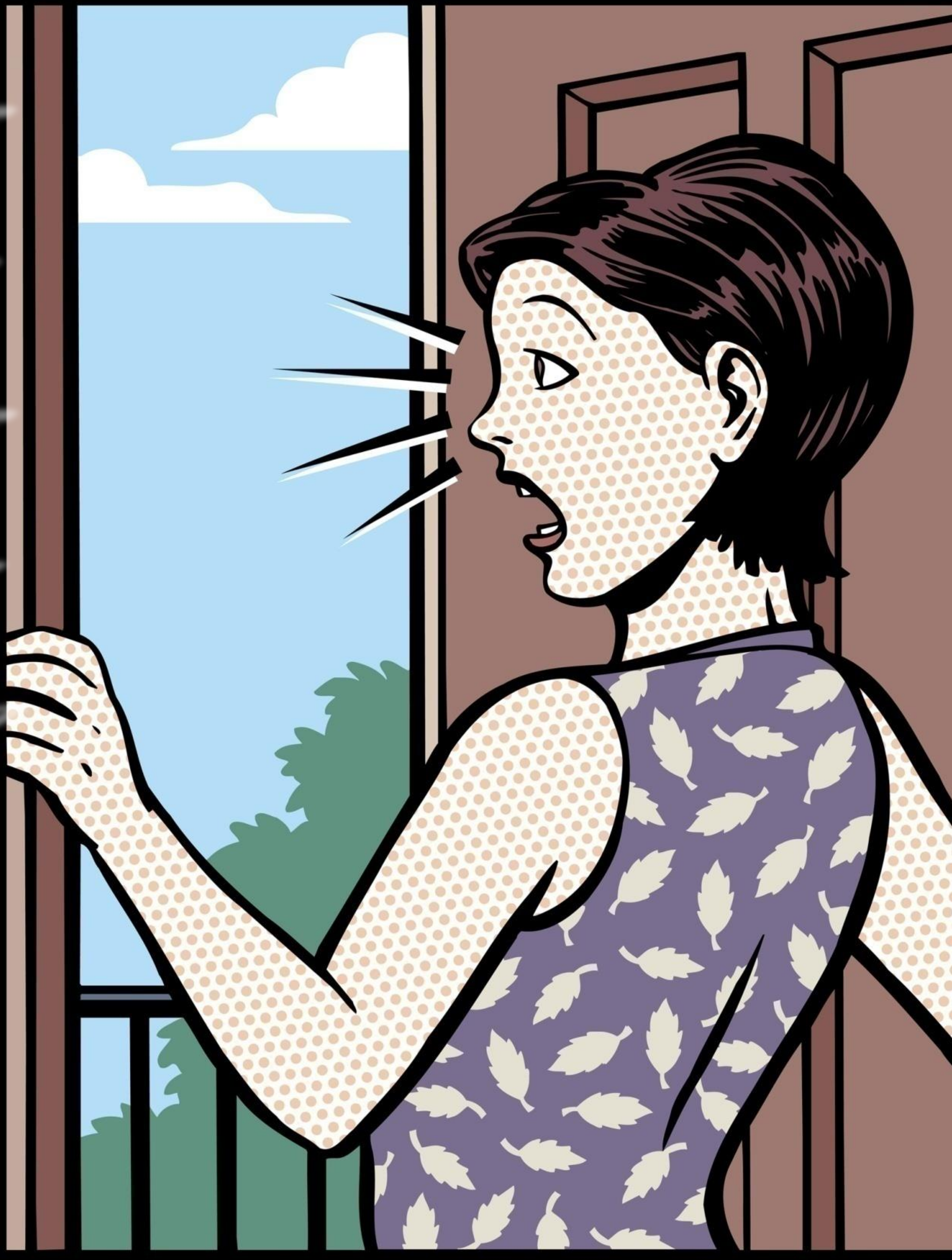


Then Hubble made a breakthrough…



…by measuring the distance to M31

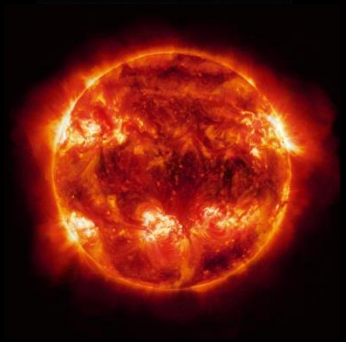
Edwin Hubble expanded the bounds of the universe by a factor of 1000



Ancient Light

Distant light is old light…

We see the Moon as it was a second ago.

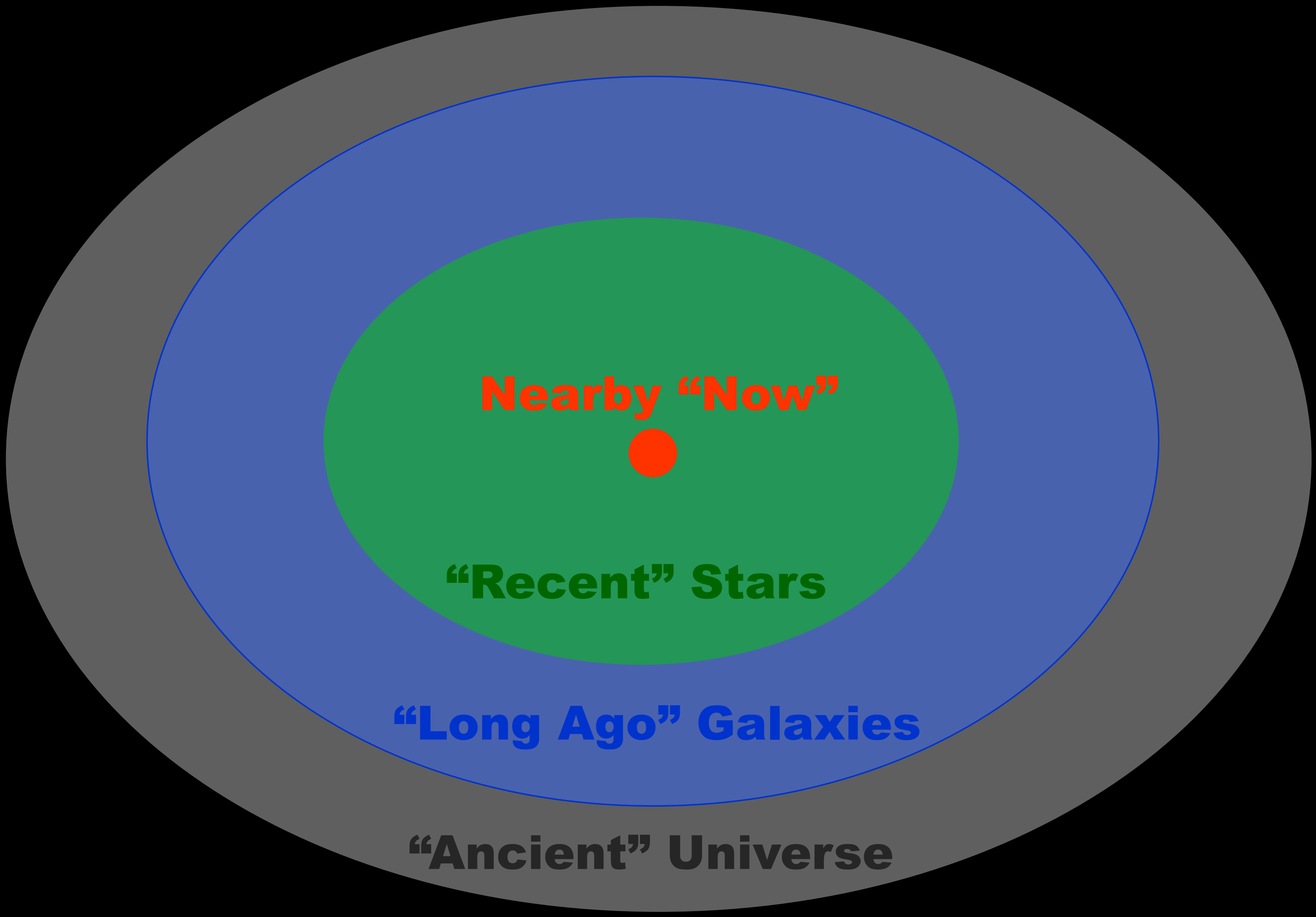


We see the Sun as it was 8 minutes ago.

We see the Sirius as it was 9 years ago.

We see M31 as it was 2.5 million yrs ago.

…so big telescopes are time machines

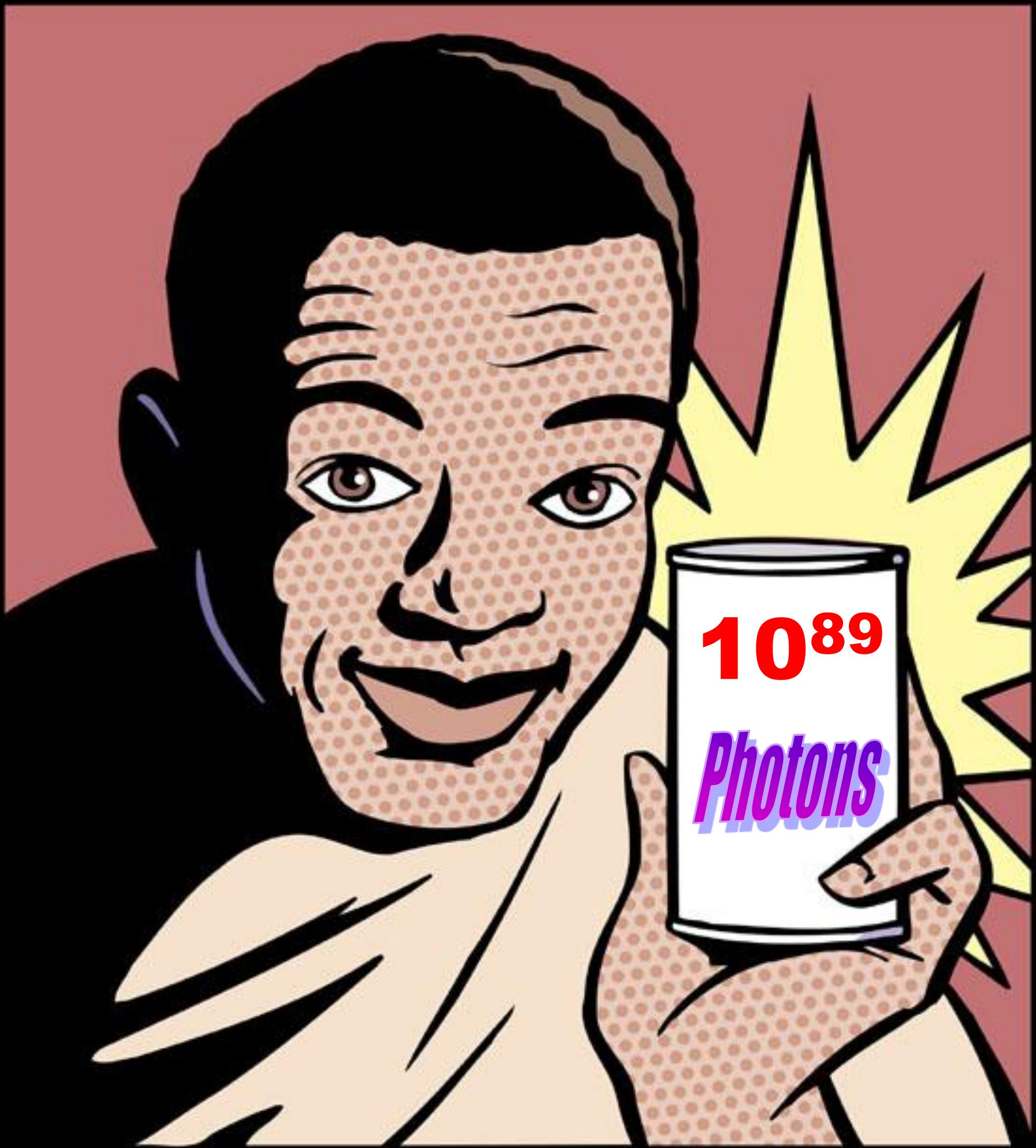

Nearby "Now"
"Recent" Stars
"Long Ago" Galaxies
"Ancient" Universe

The Contents

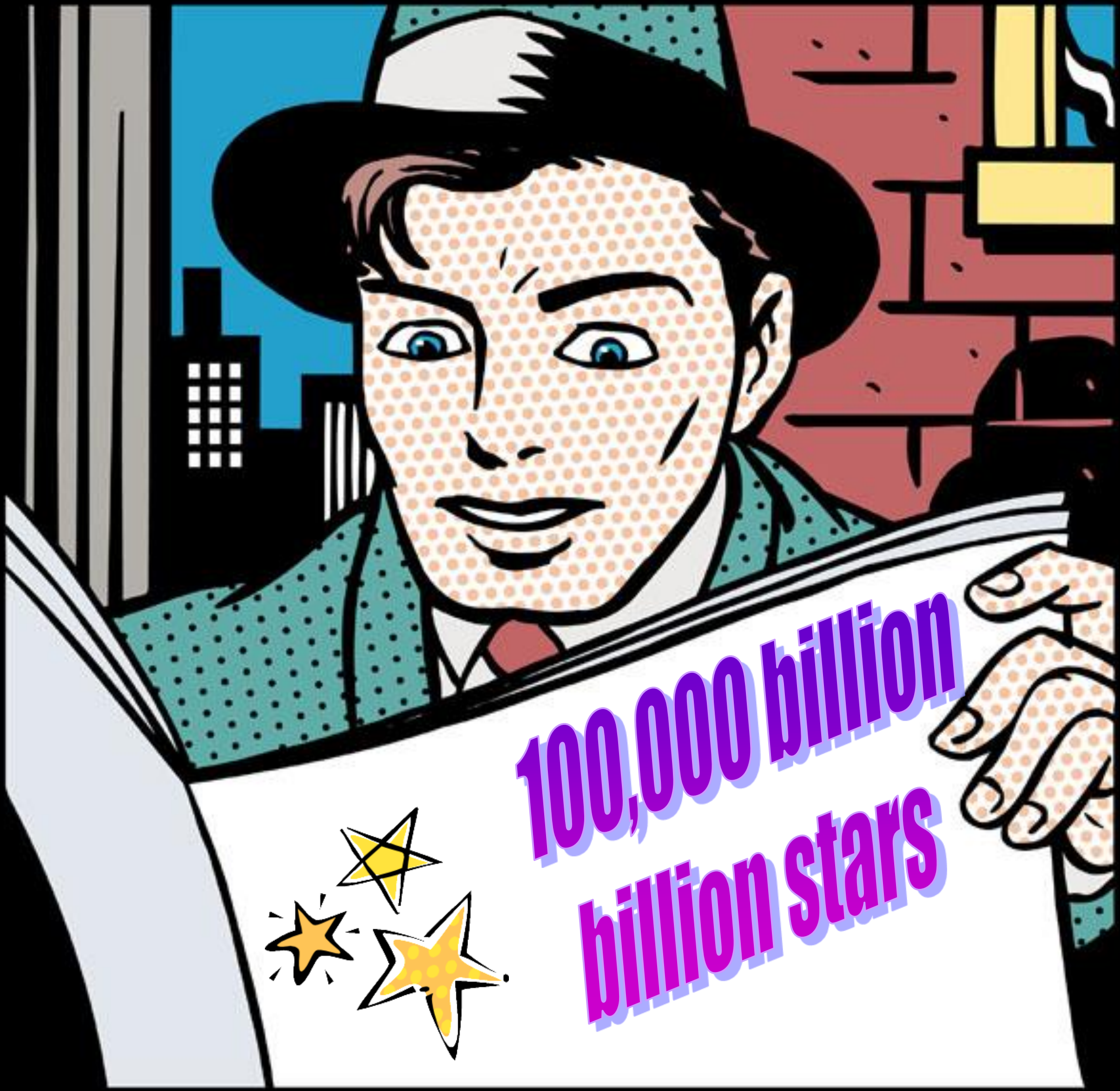
Normal Matter

More than 99.9% hydrogen and helium

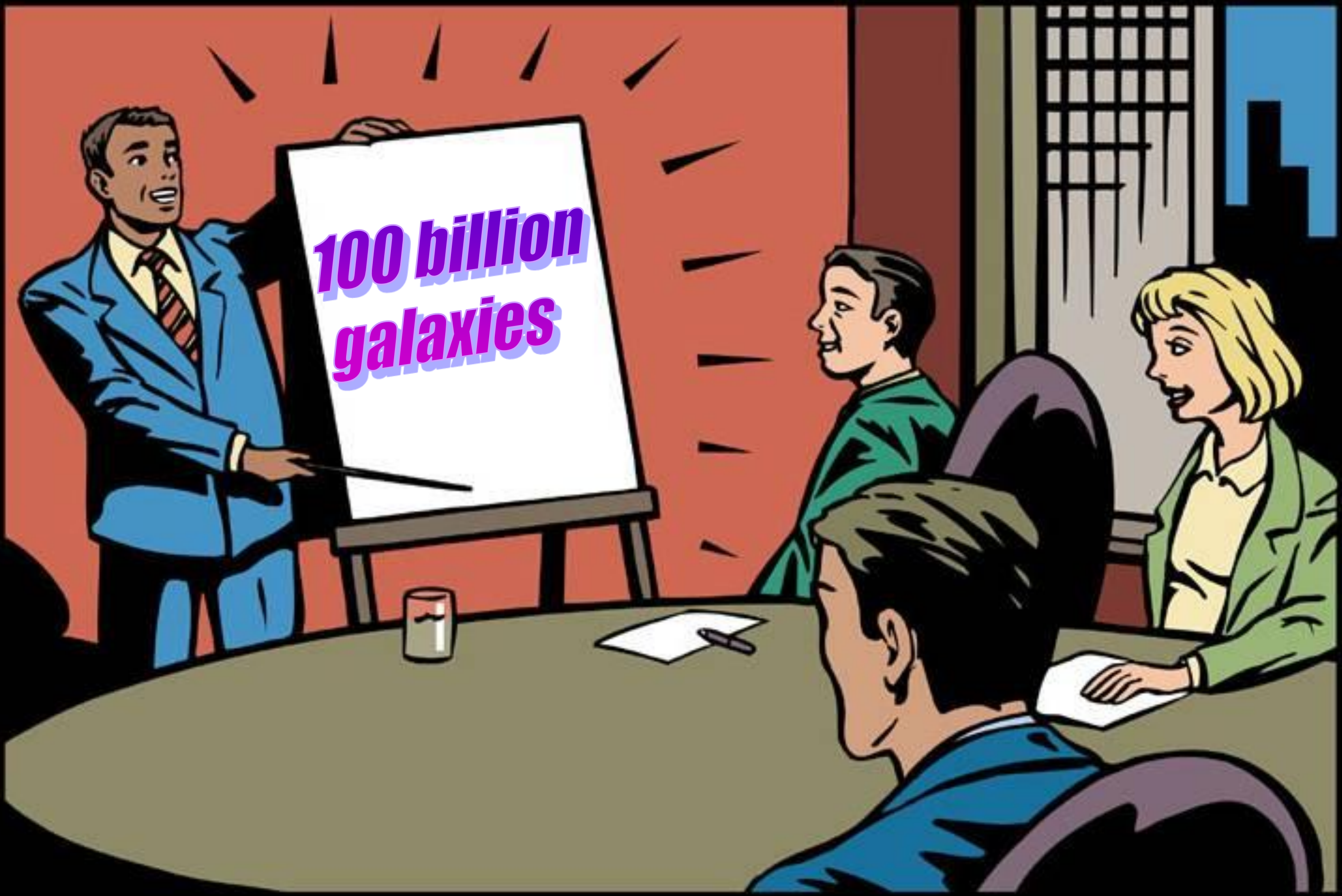
A billion photons for every particle



A typical galaxy has 100 billion stars

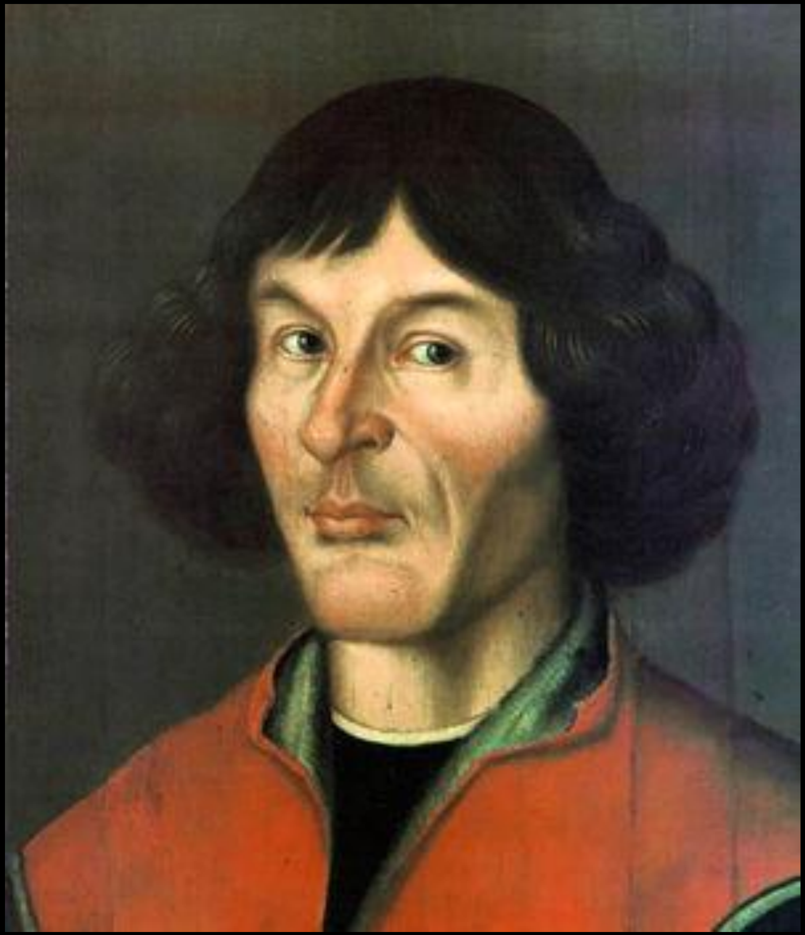


This is just in the visible universe



There are probably a billion billion Earth-like planets in the whole cosmos

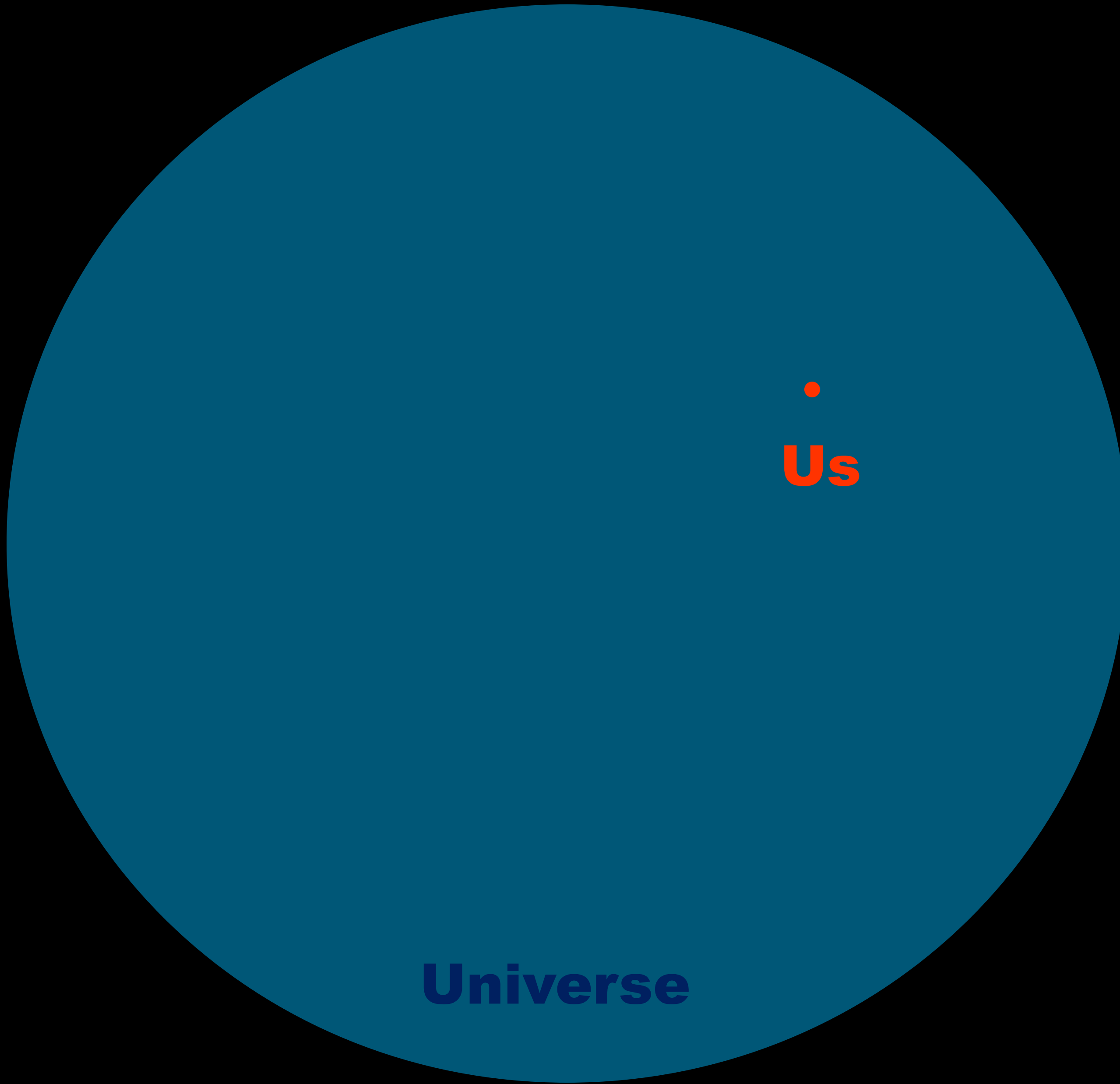
Embrace mediocrity



Copernicus

We find ourselves on an:

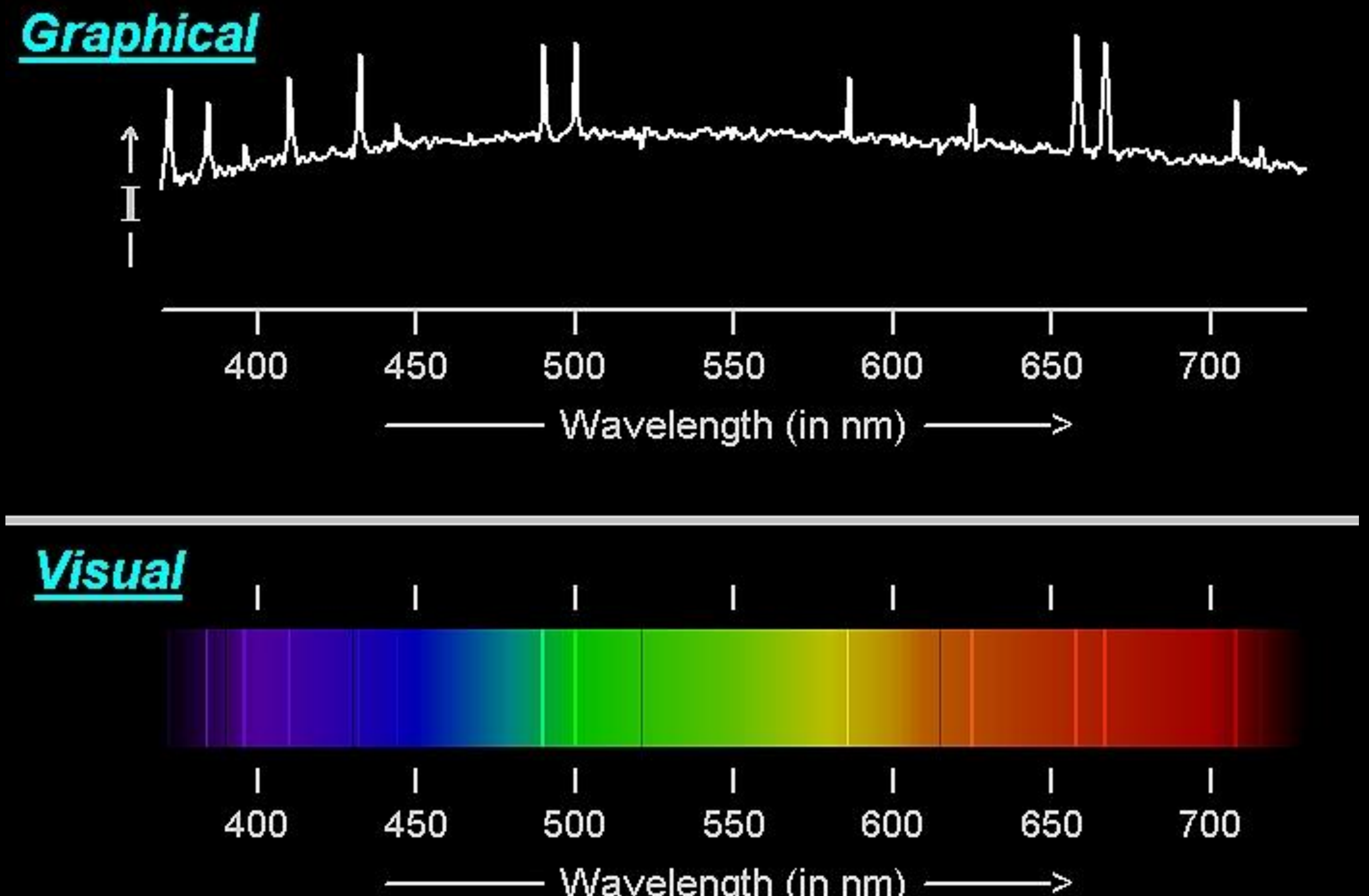
- Average planet orbiting
- An mid-sized star in an
- Average galaxy near a
- Medium-sized cluster in
- Unremarkable corner of
- A very large universe


Us
Universe

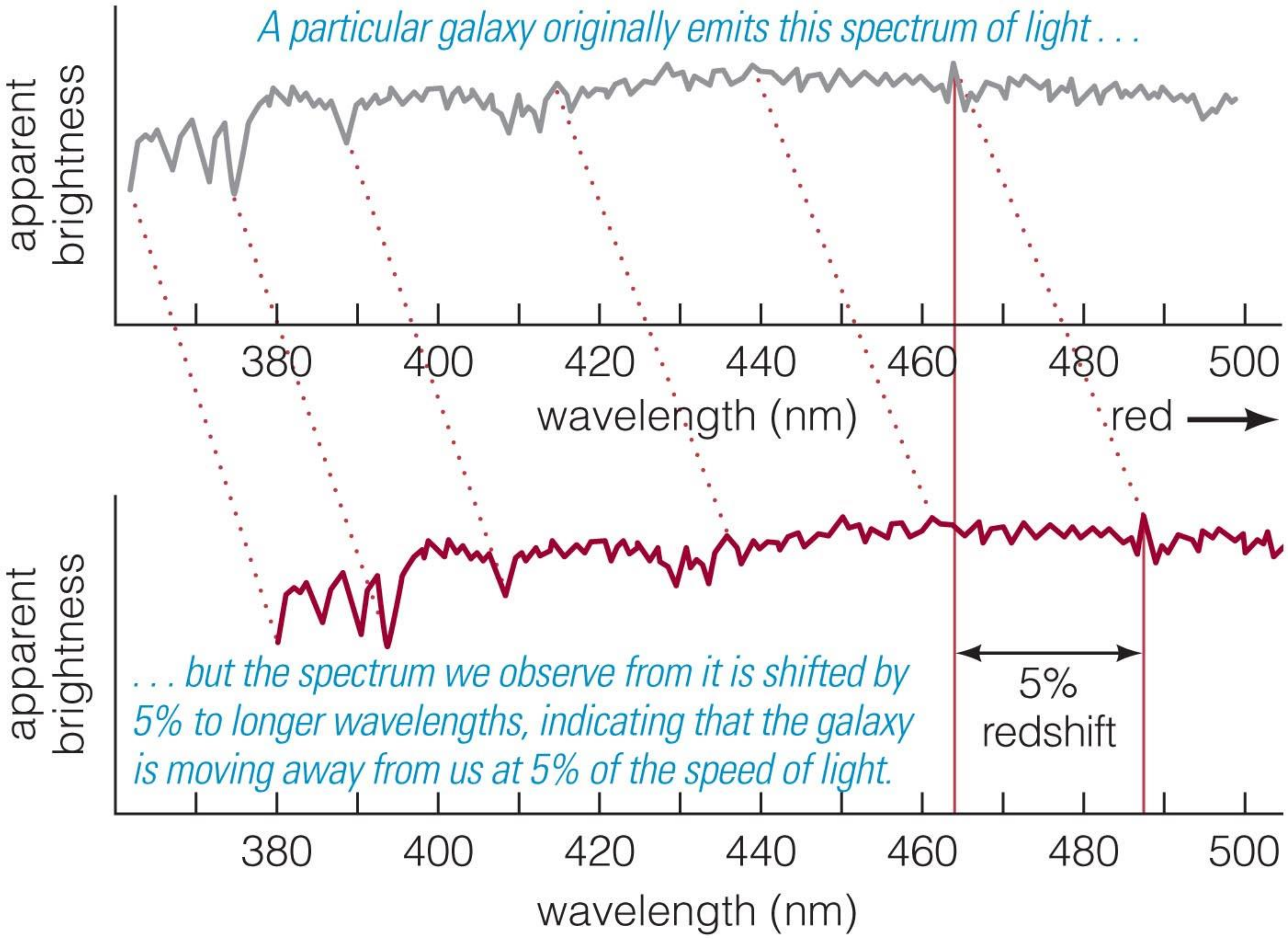
Big Bang

Cosmic Expansion

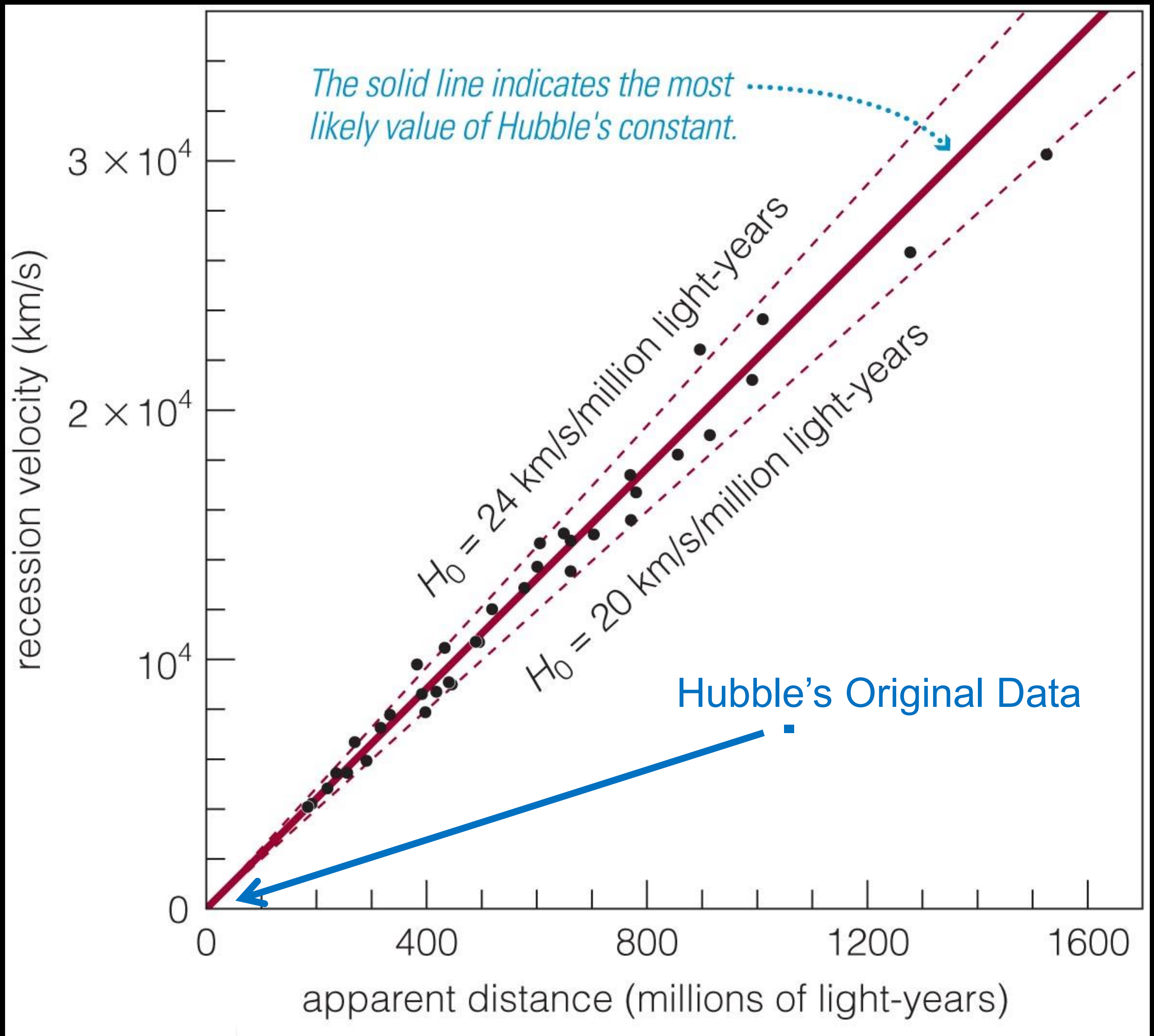
Hubble observed galaxy spectra



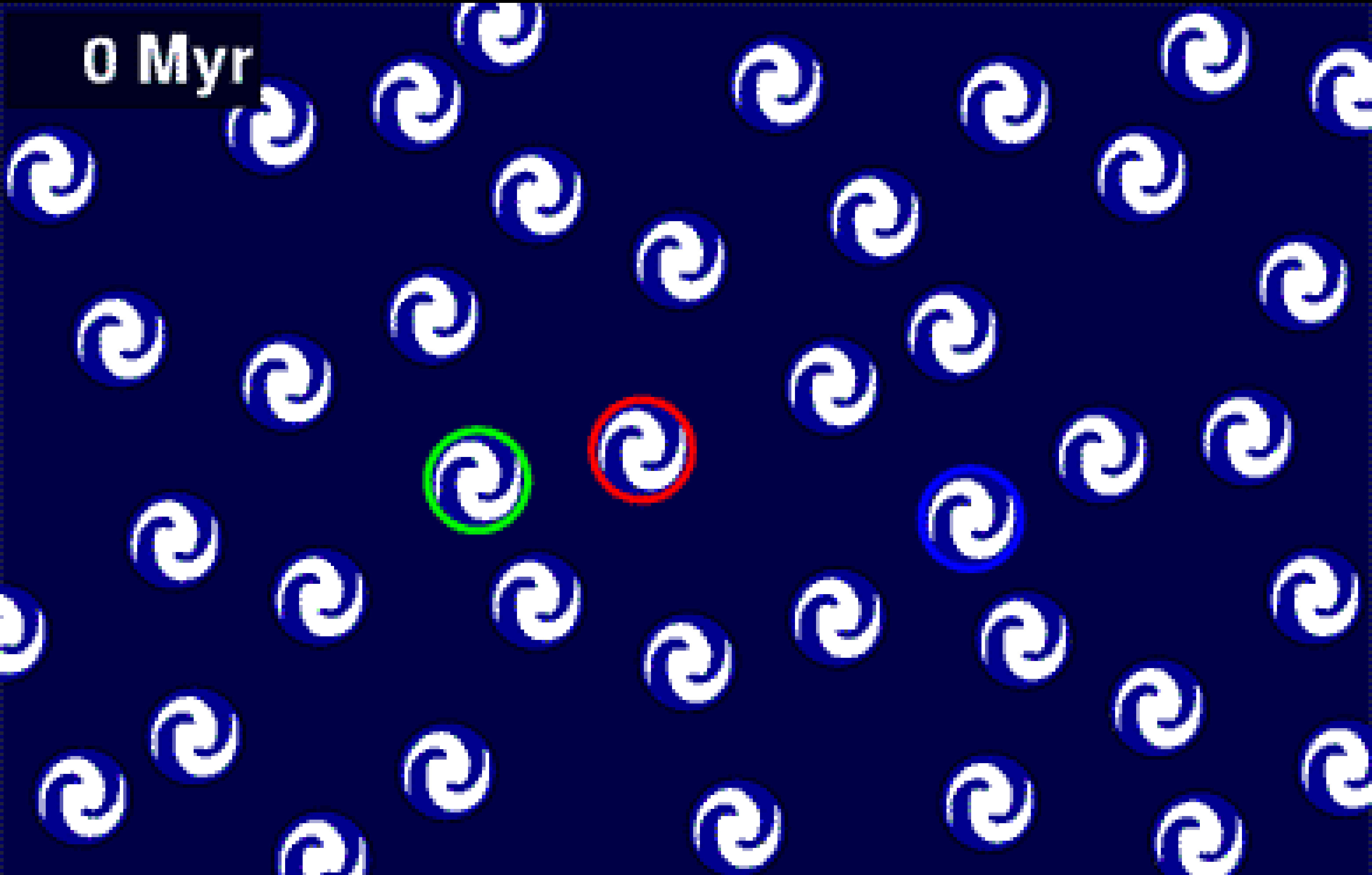
The light was almost always redshifted



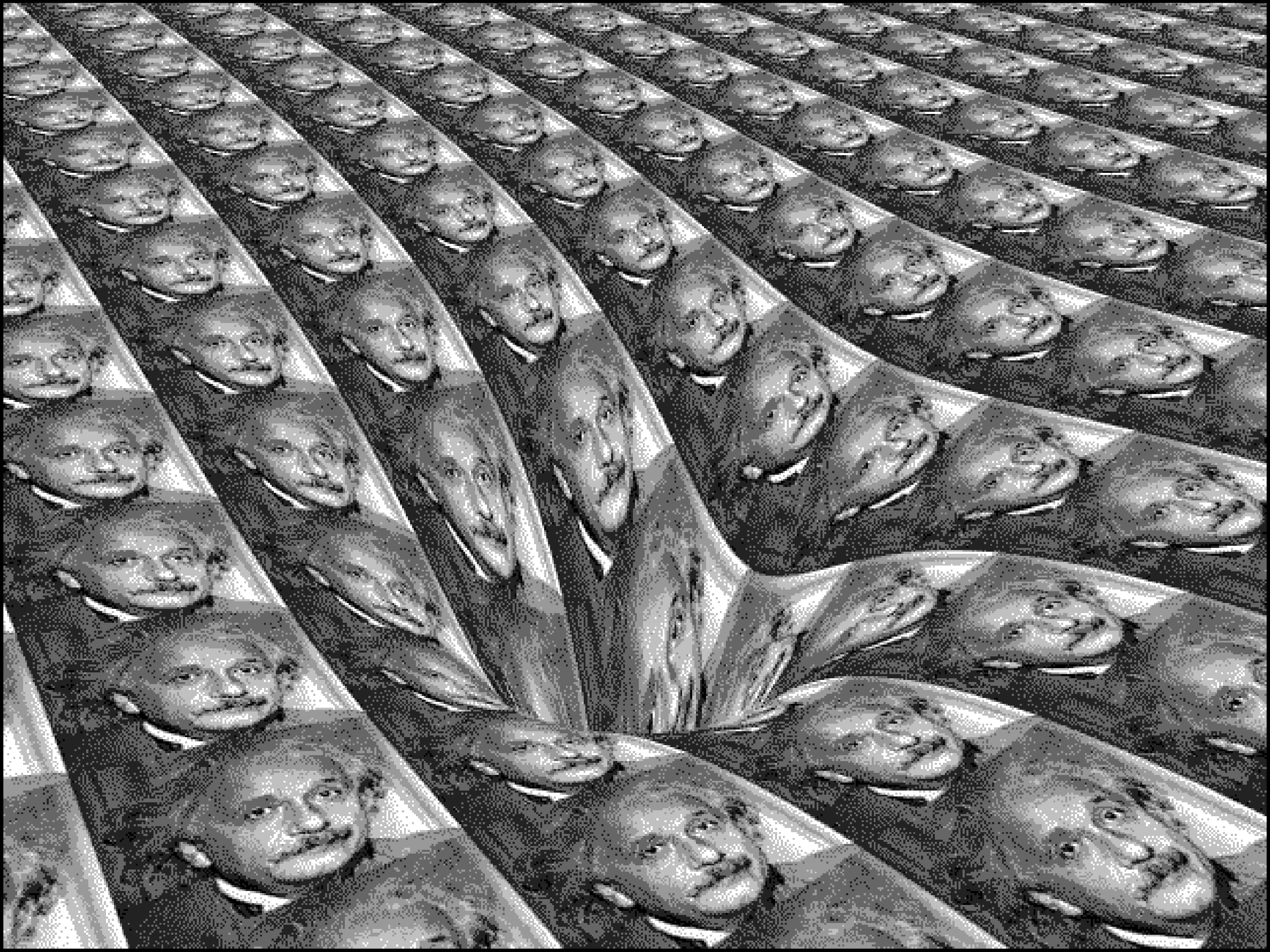
Uniform expansion to a billion light years



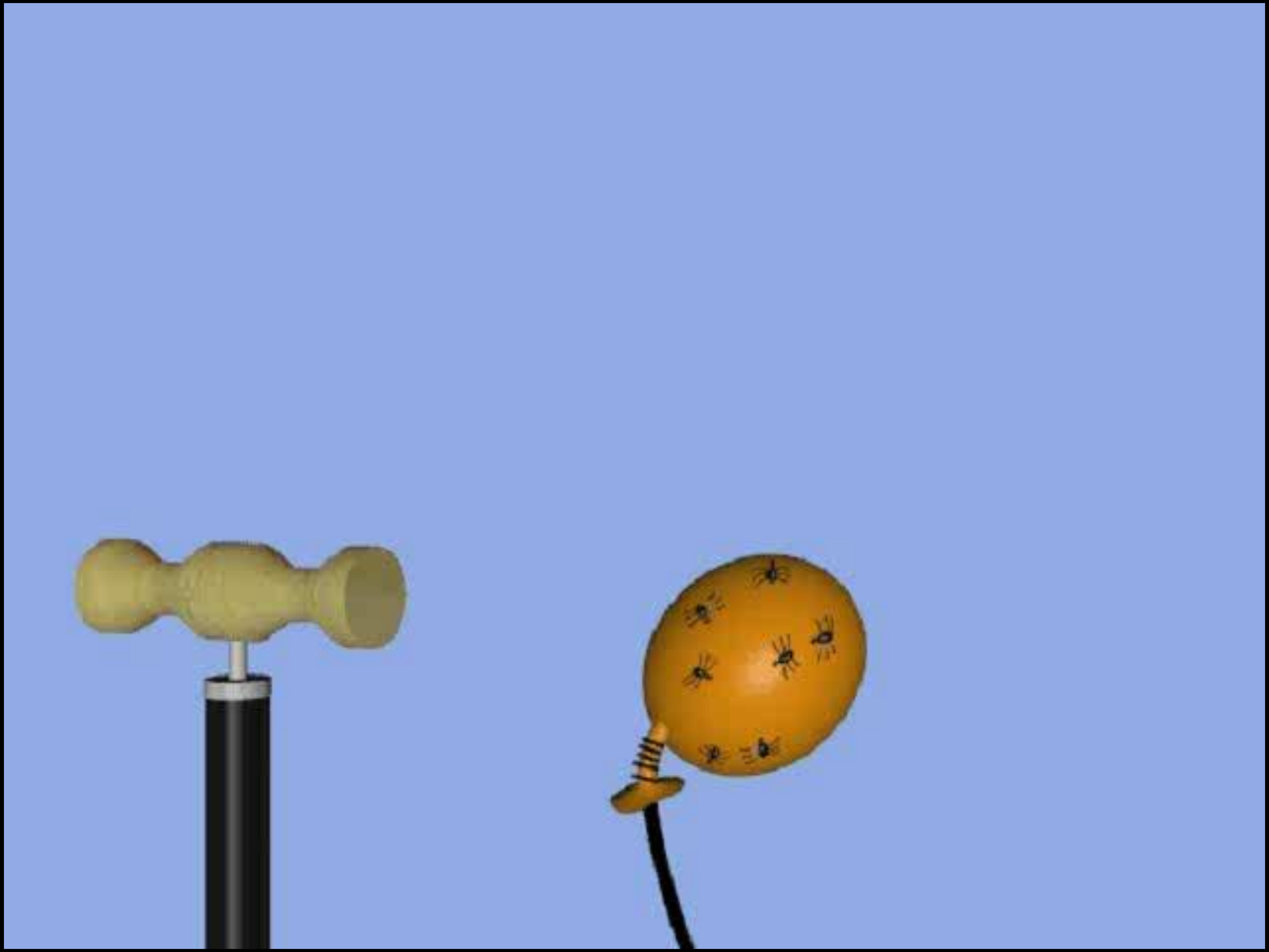
There's no center to the expansion



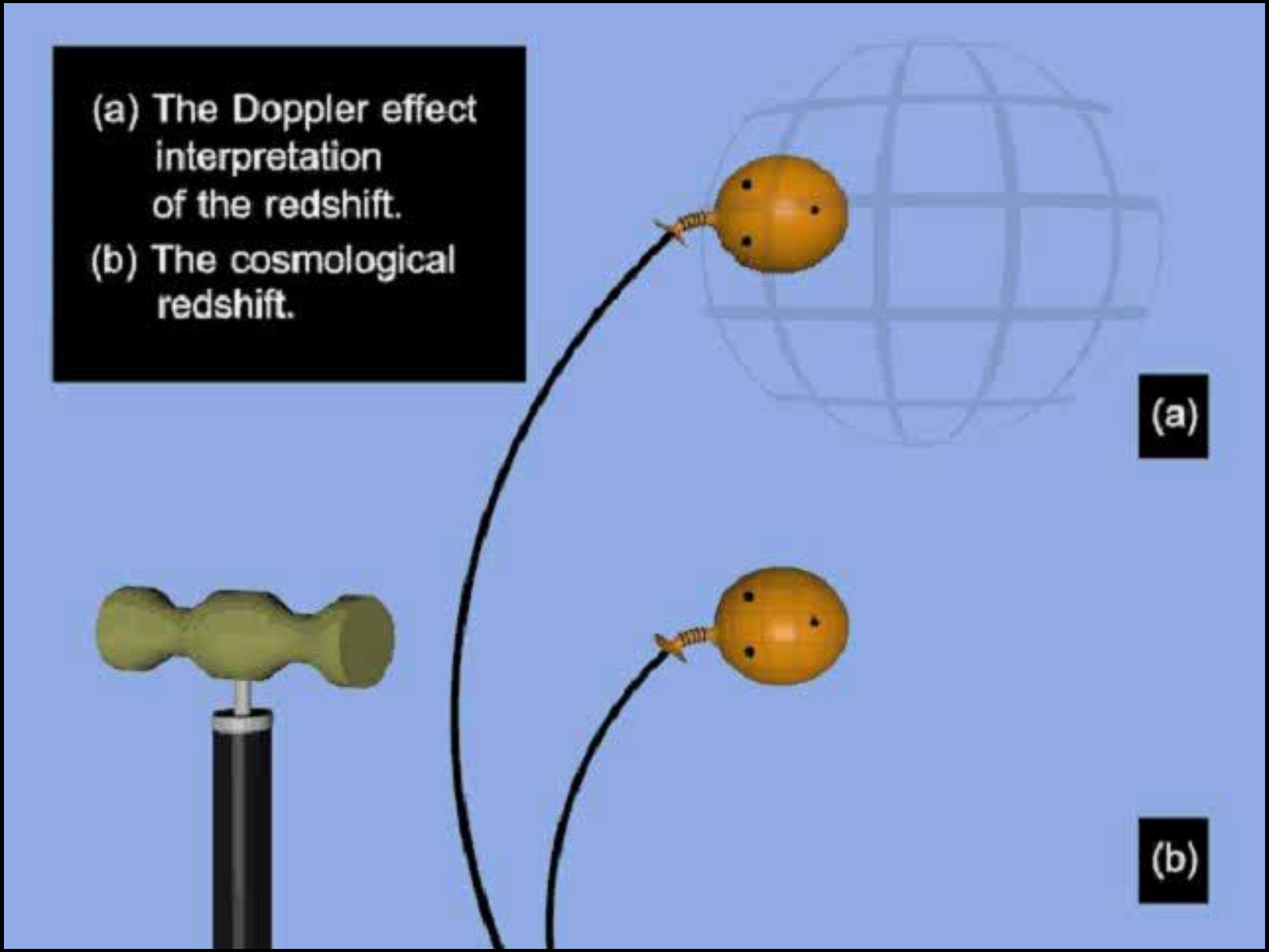
The expansion is described by relativity



Hubble Expansion



Expanding Space-Time

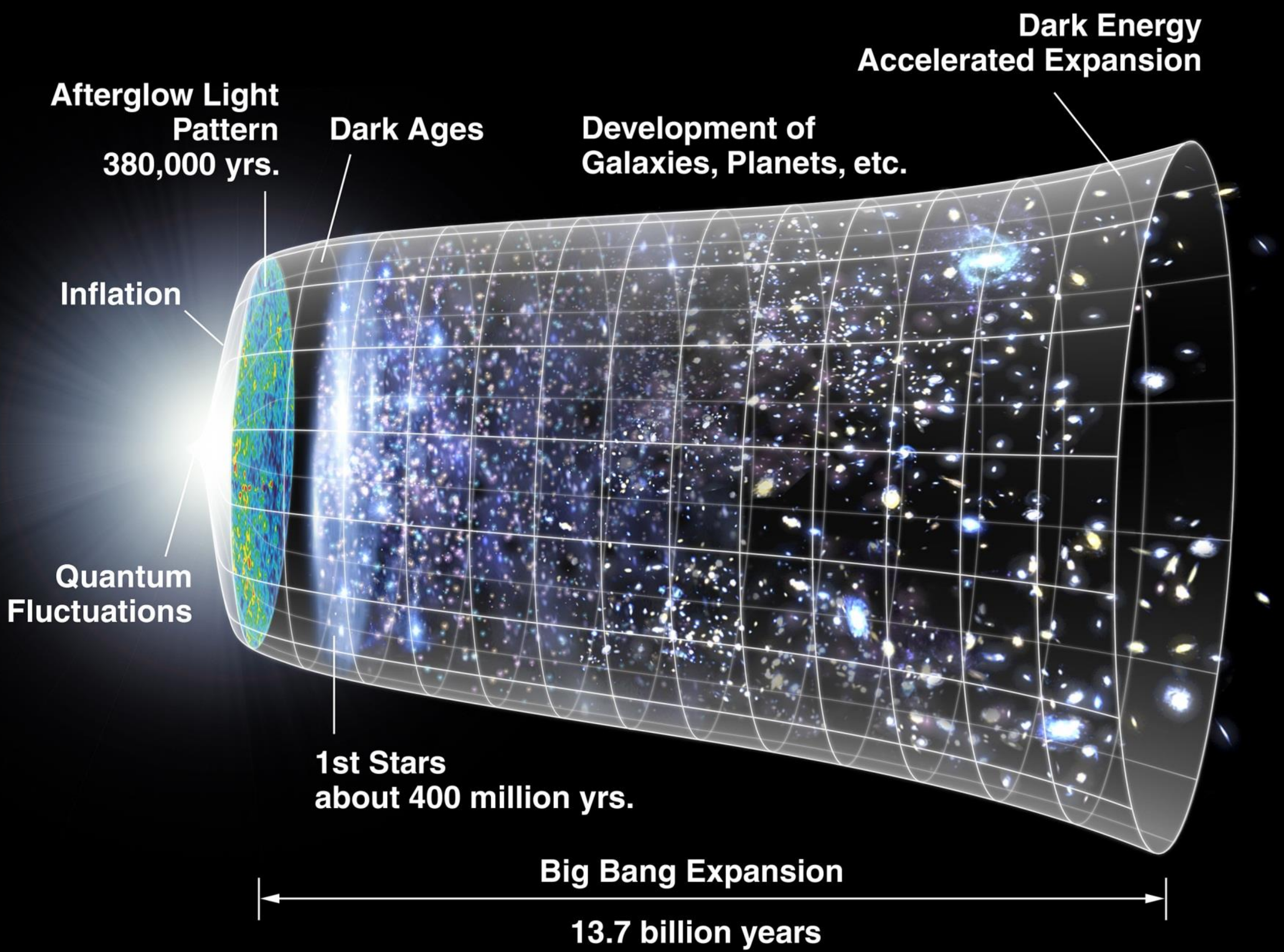


The universe only has a boundary in time not space

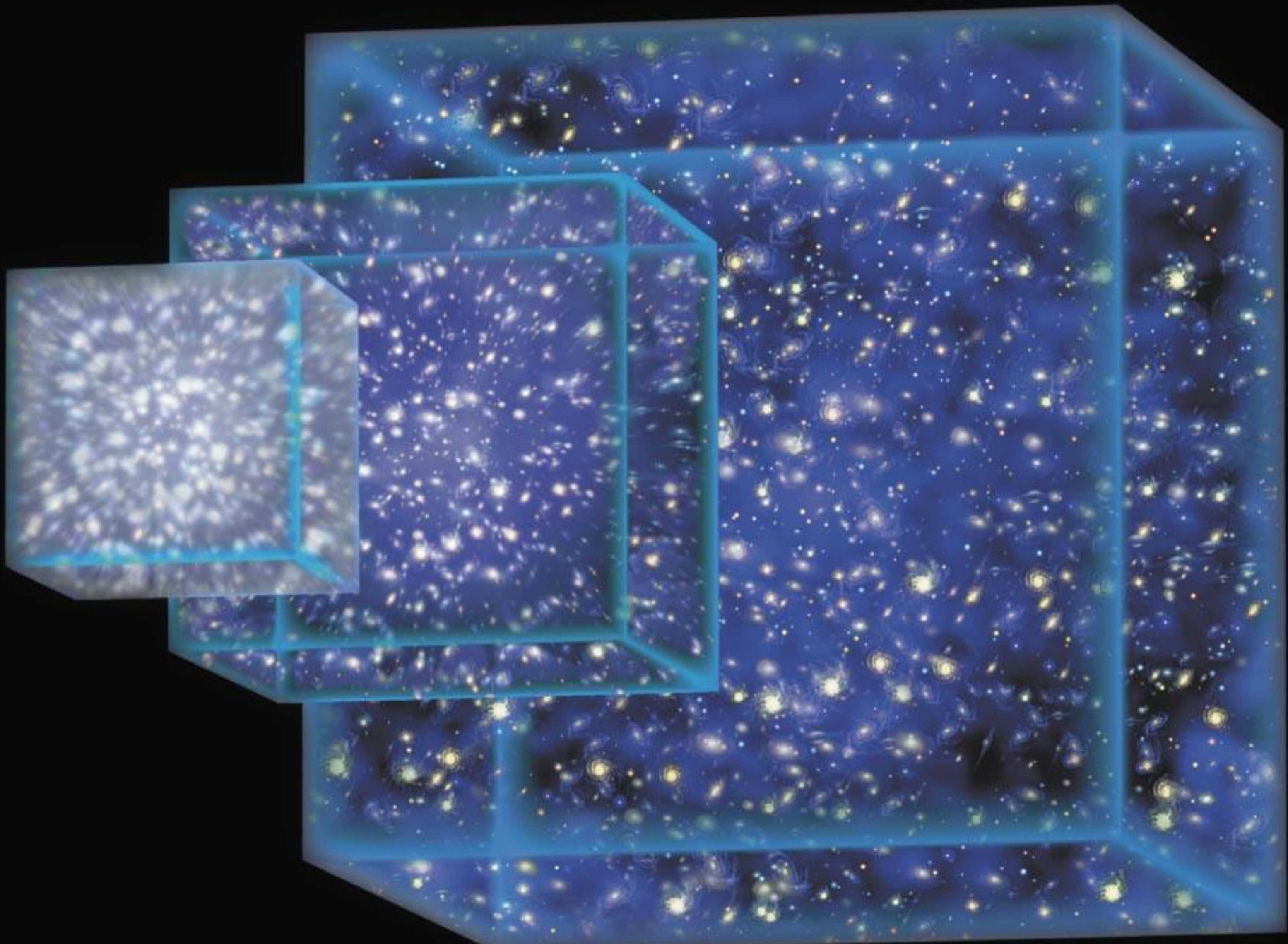
The universe has no center and isn't expanding into anything

Looking Back

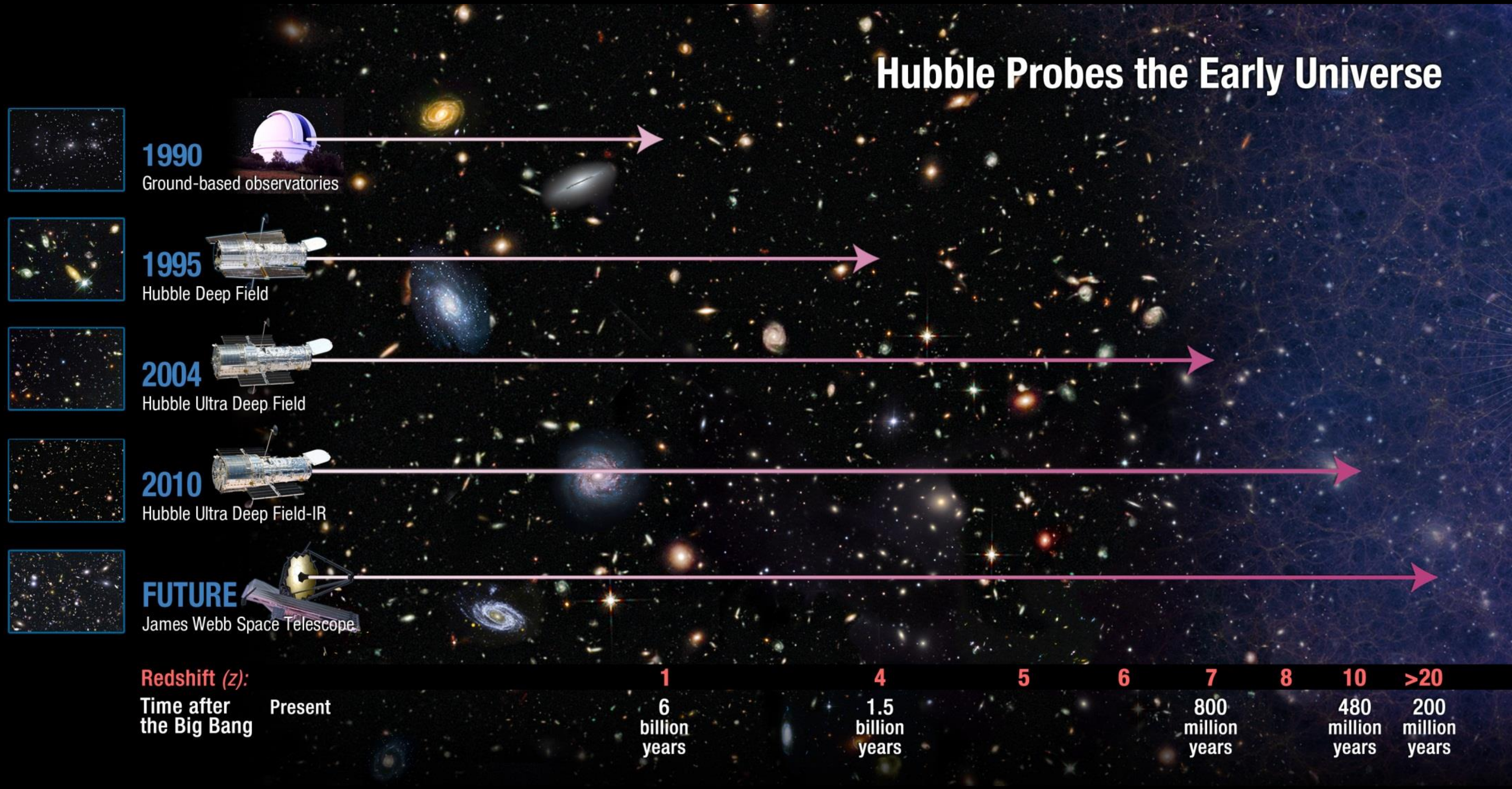
Towards First Light



Birth of the Universe: The expansion of the universe began with the hot and dense Big Bang. The cubes show how one region of the universe has expanded with time. The universe continues to expand, but on smaller scales gravity has pulled matter together to make galaxies.

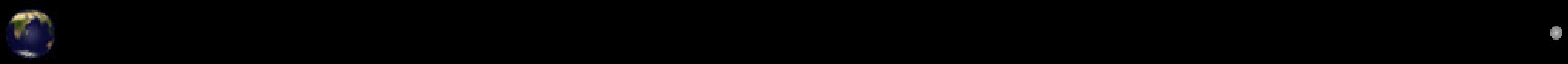


Ten billion times fainter than the eye



Faster than light

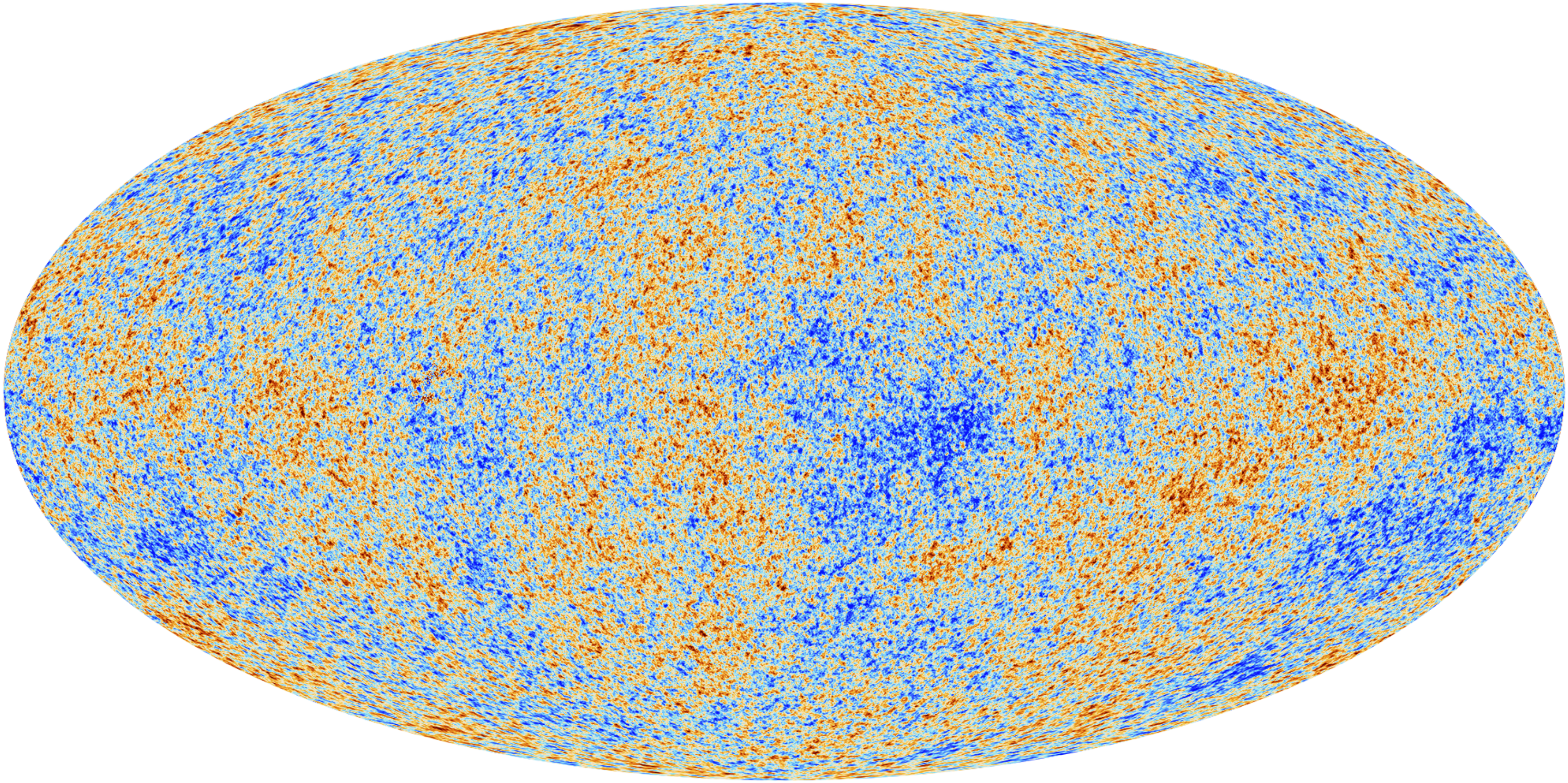
Light travels simply and directly in the local universe.

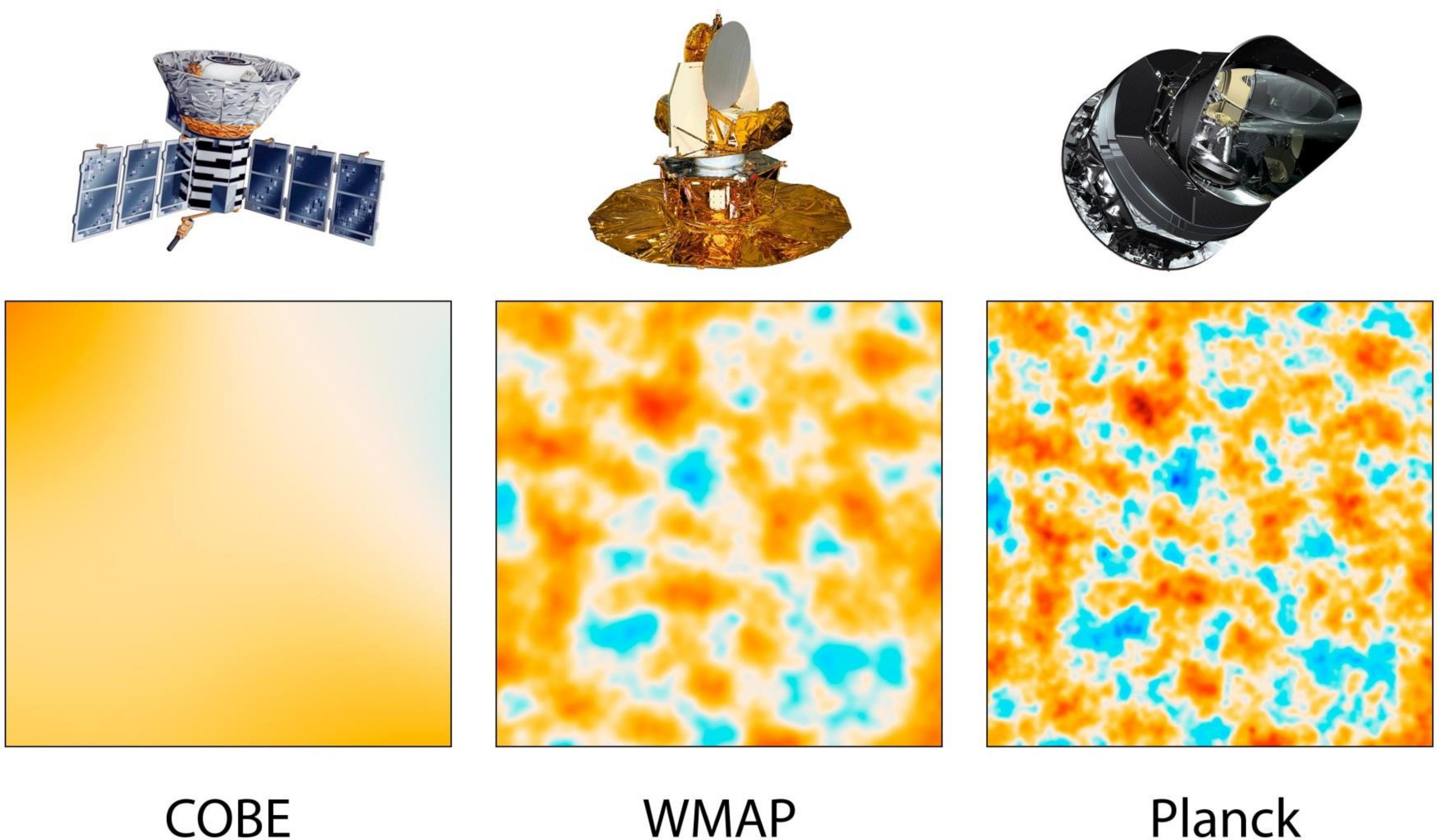


But early expansion of the universe carried any two points away from each other faster than light speed. Distant galaxies are only just becoming visible now.

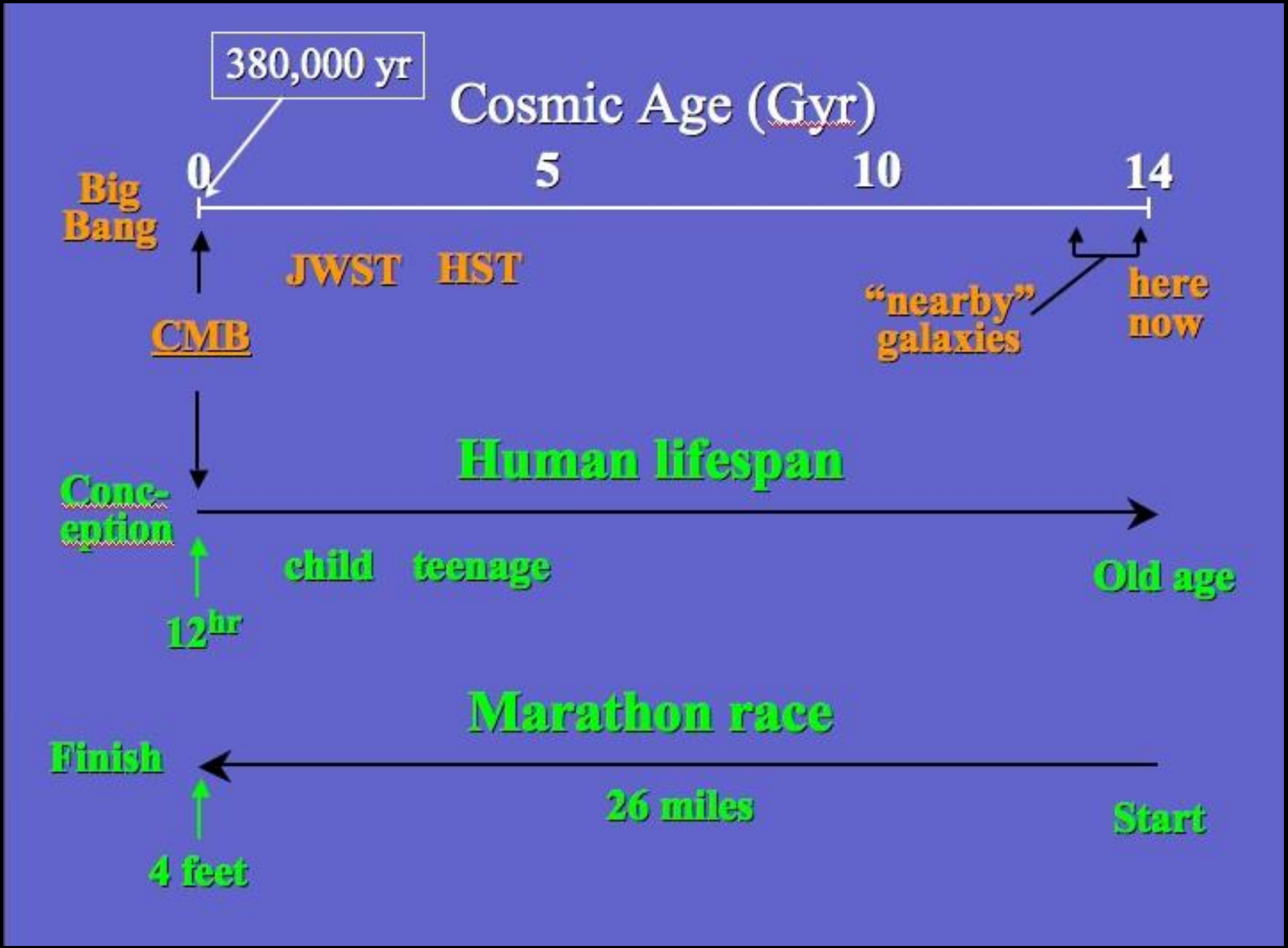
The physical universe is much larger than the visible universe

Microwave Background

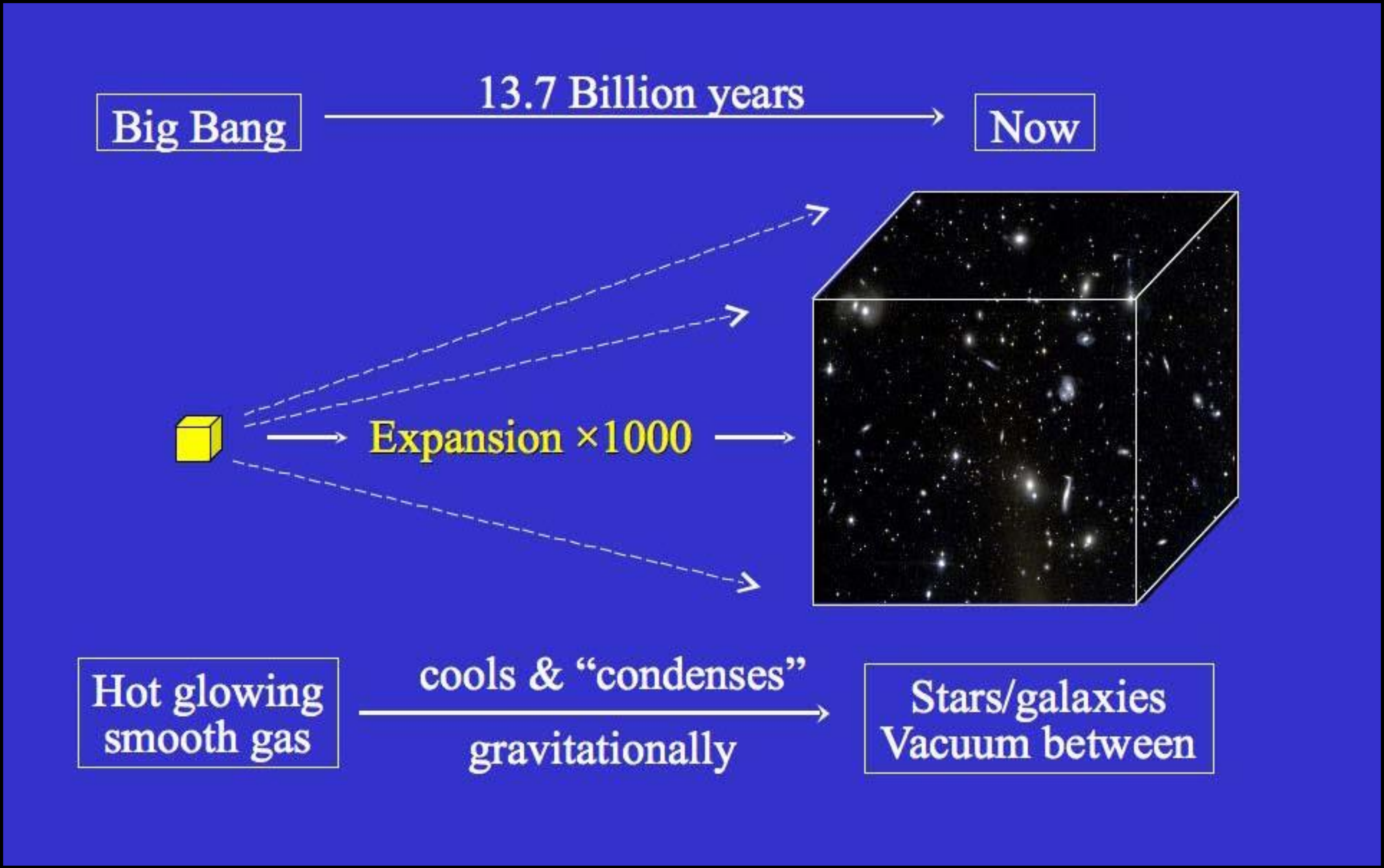



COBE
WMAP
Planck

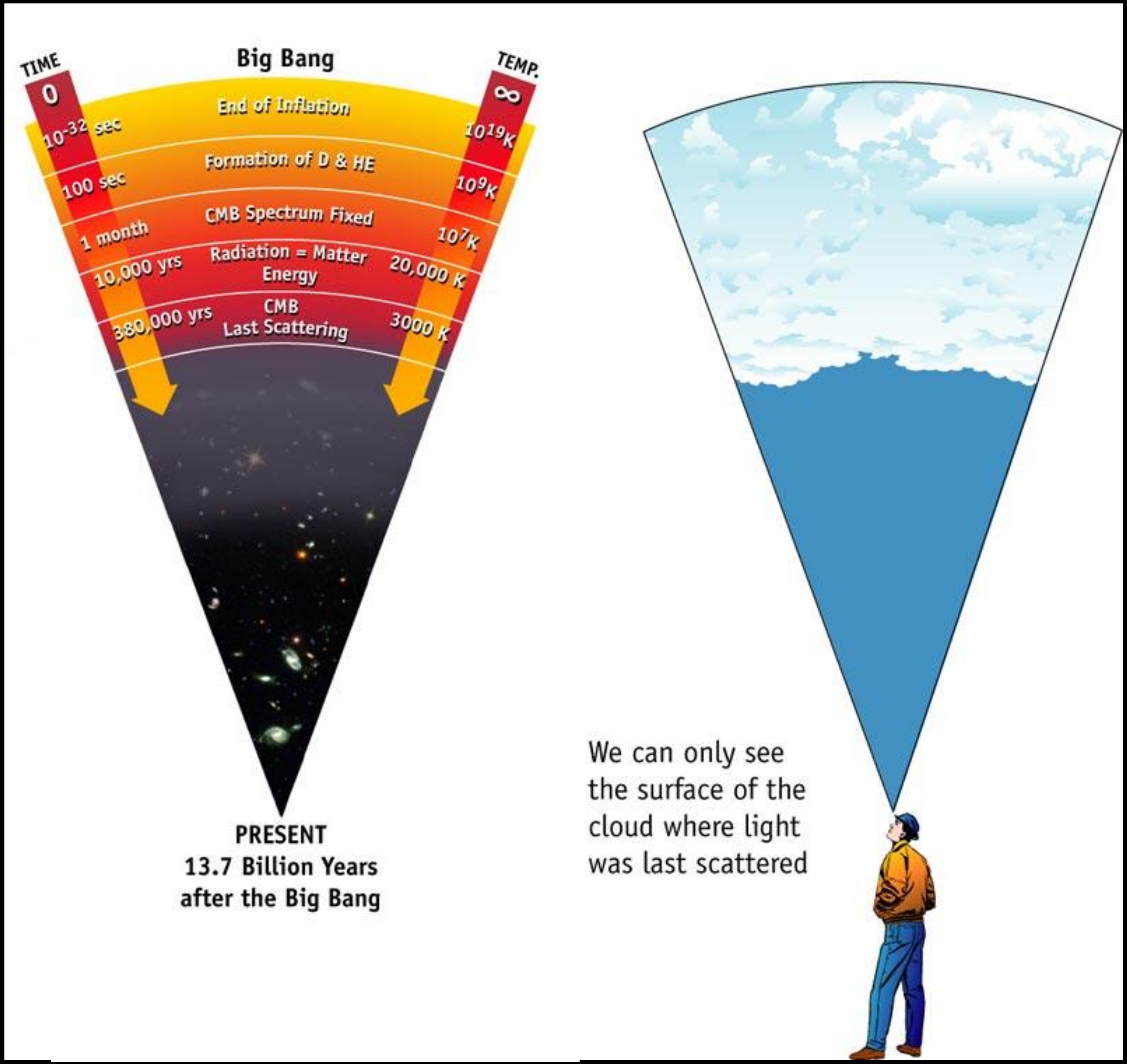
A baby picture of the universe…



…when it was 1000 times smaller.



This was the time when the "fog" lifted

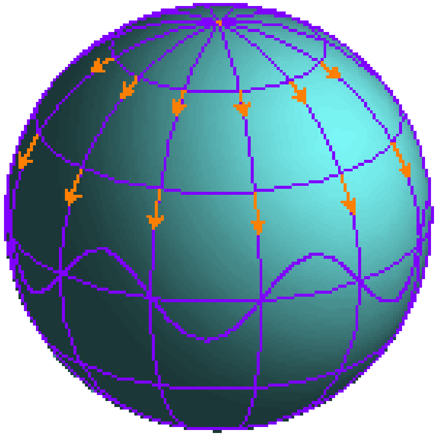


Small variations of 0.001% represent the "seeds" for the formation of stars and galaxies.

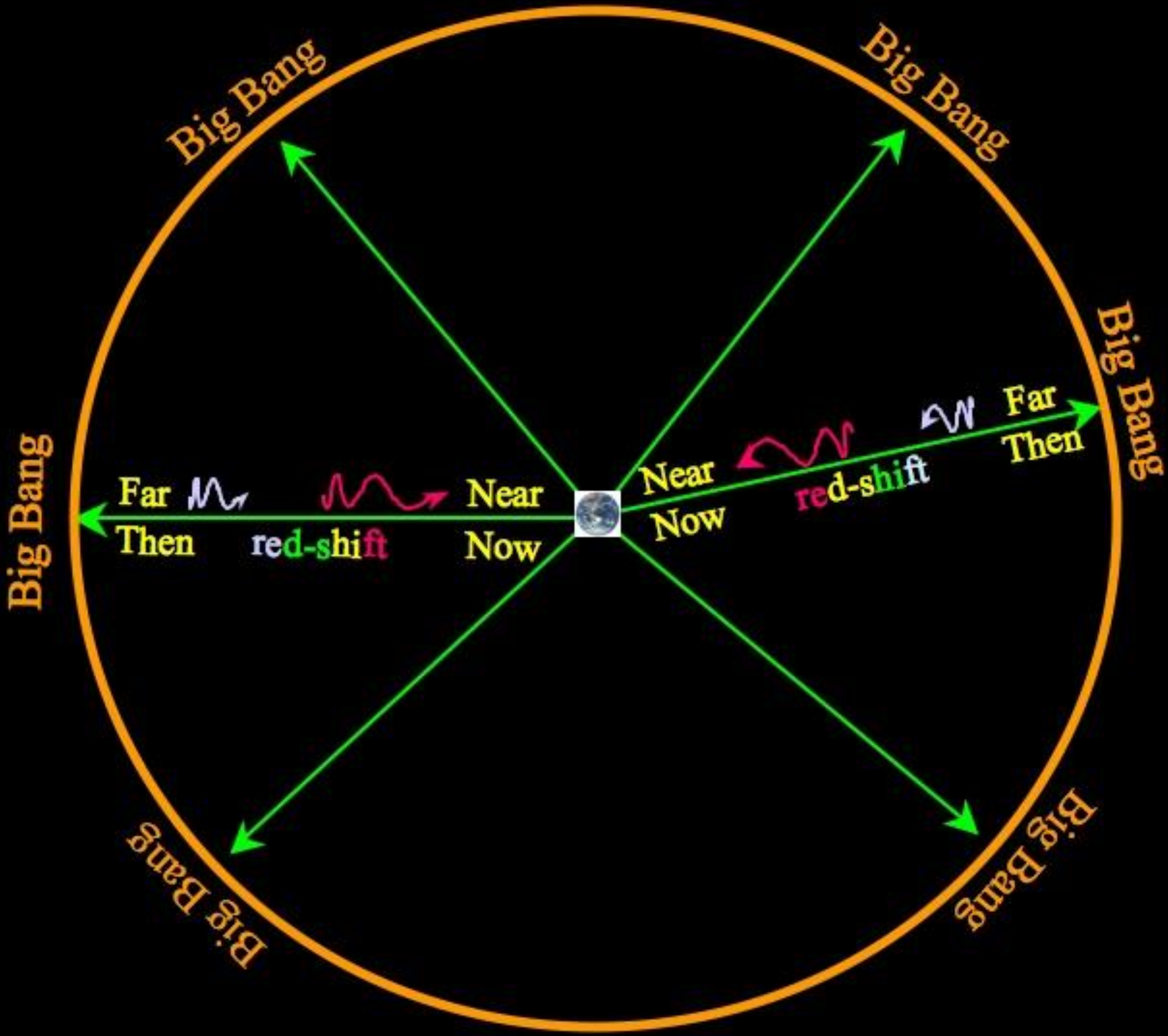
The radiation has been measured at very high precision and is a dramatic confirmation of the big bang model.

The universe was opaque before this.

Stretched 1000-fold by the expansion…



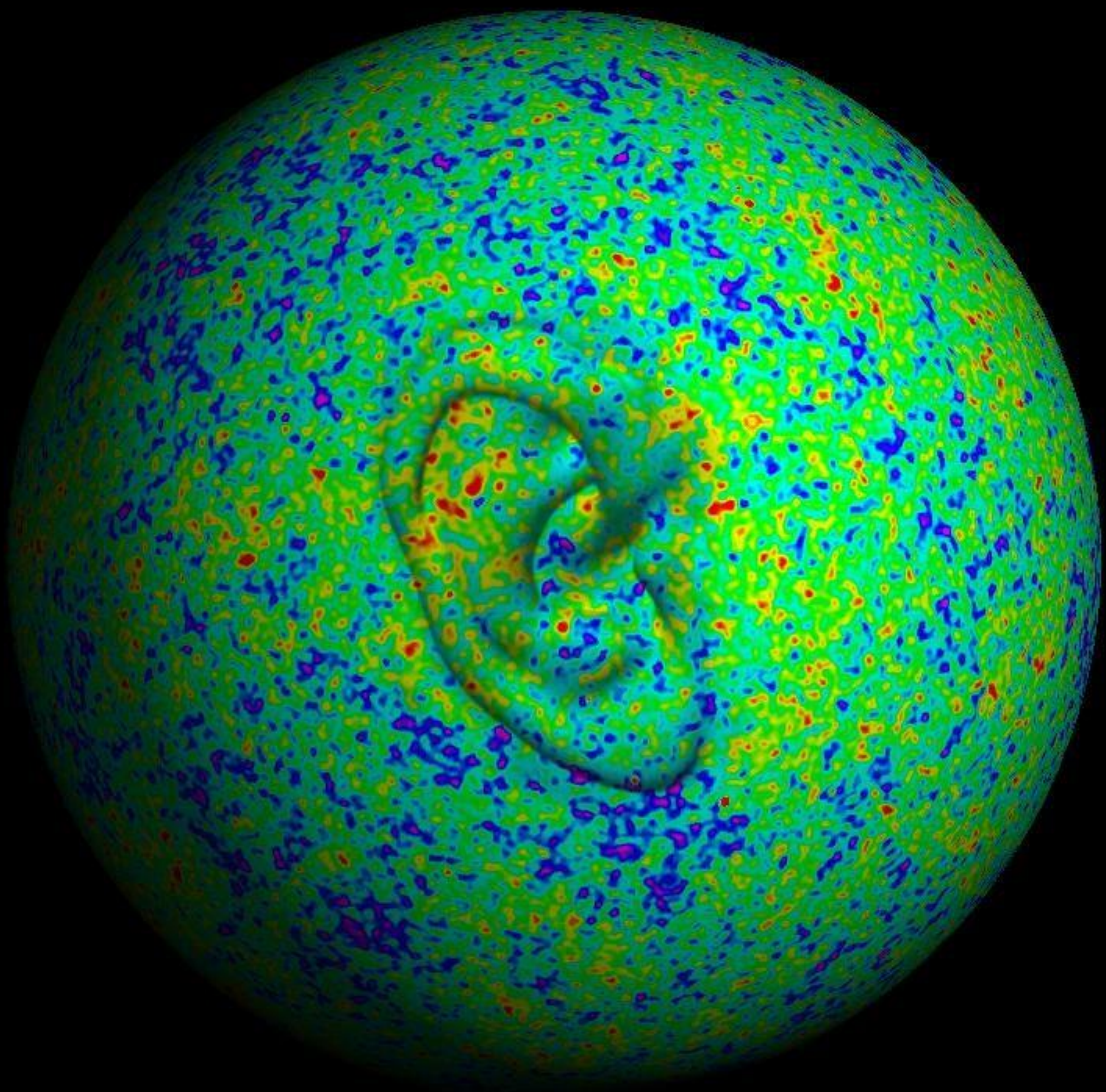
…these microwaves are all around us




The big bang was a time not a place. It was no place and every place.

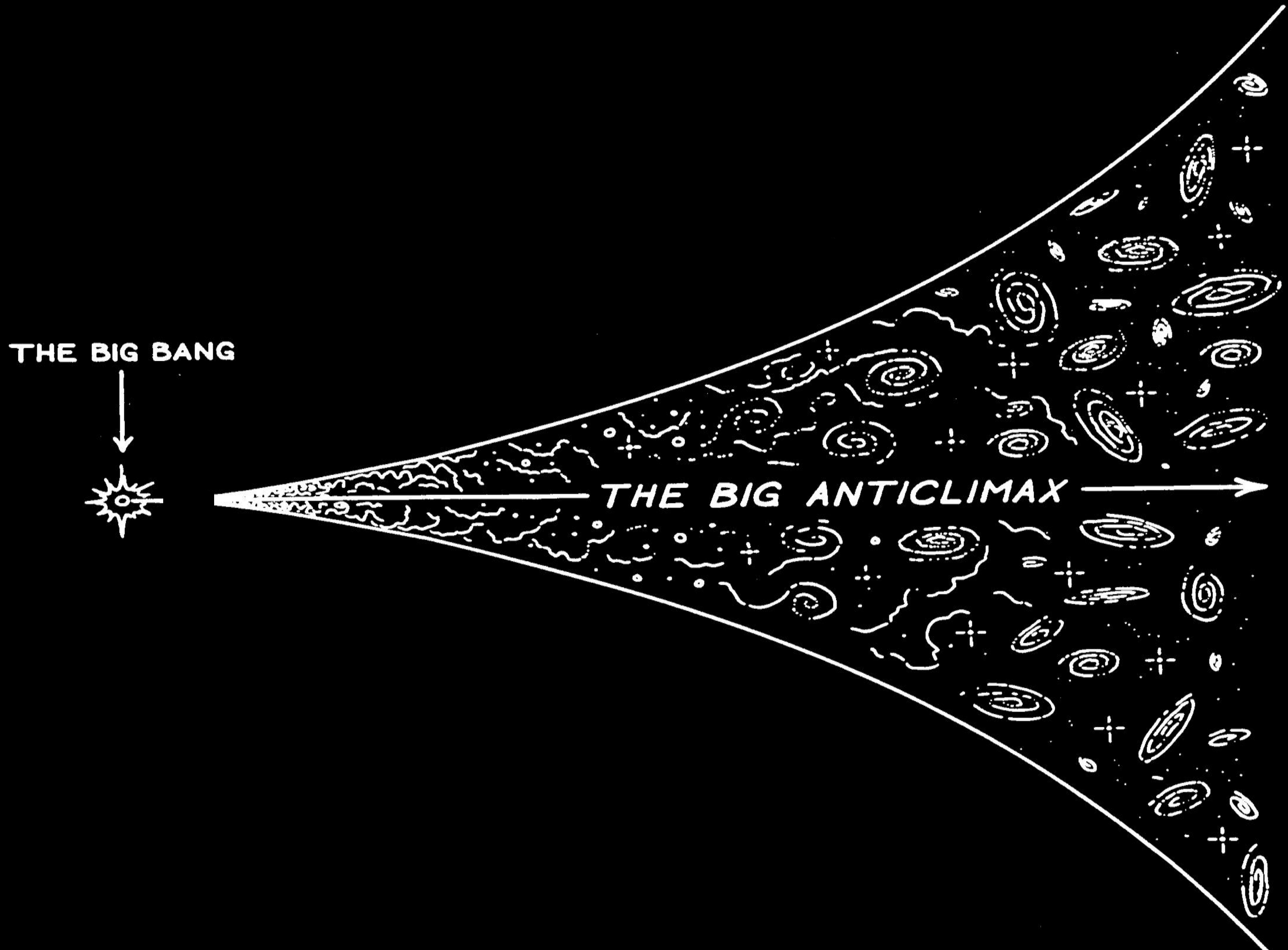
Watching the Big Bang

The First Ten Million Years

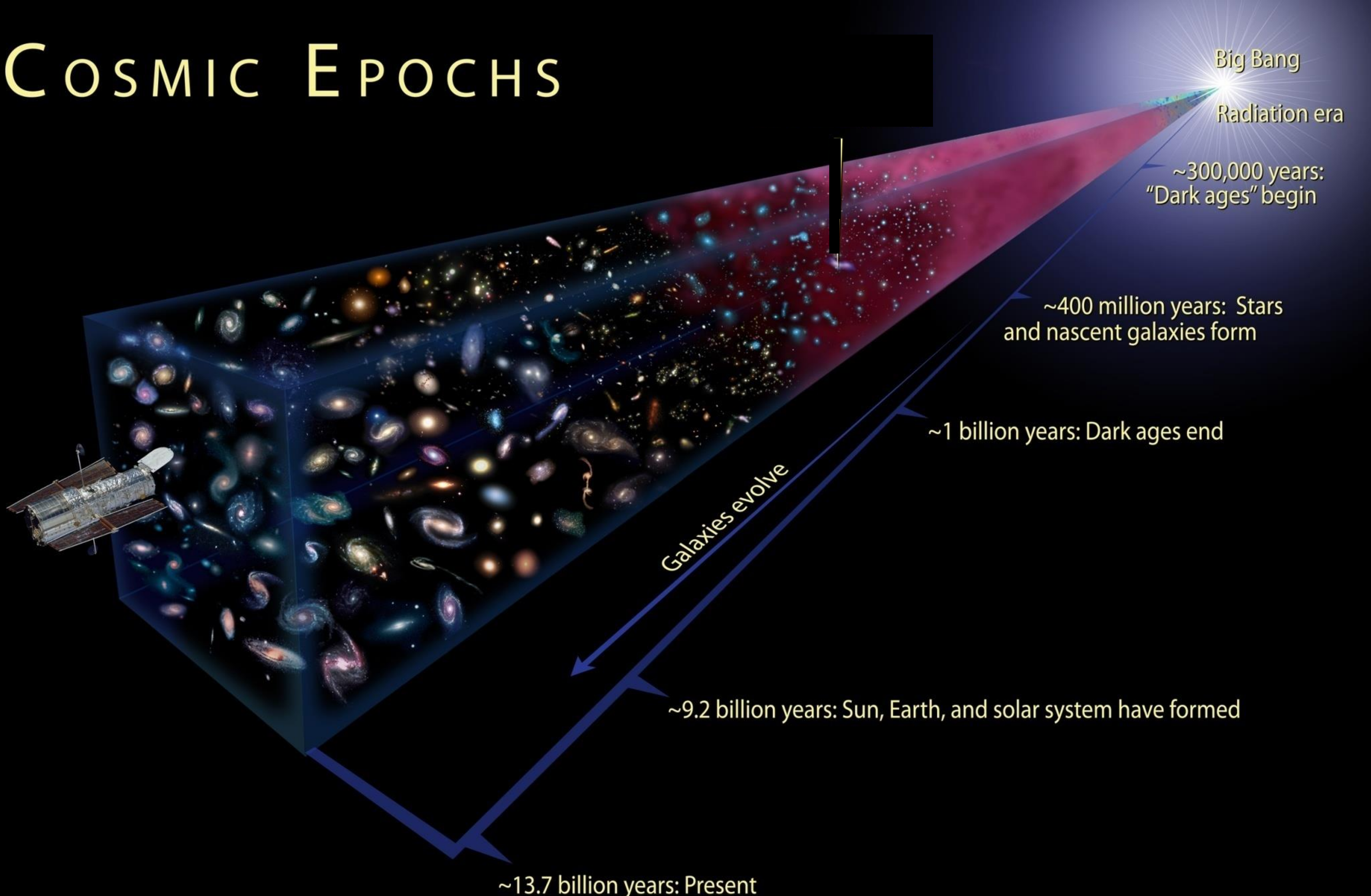


Early Universe

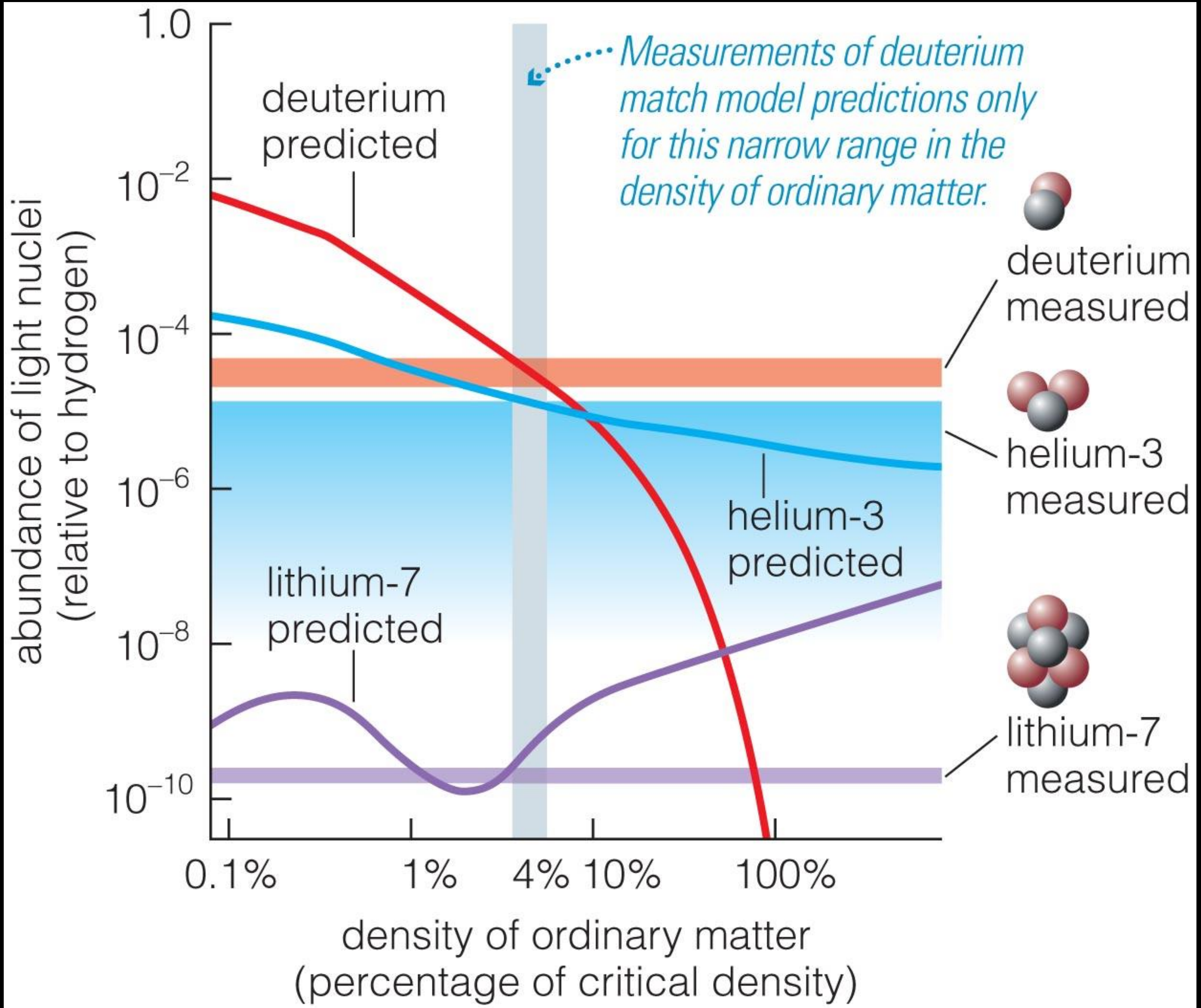
It's all gone downhill since the big bang



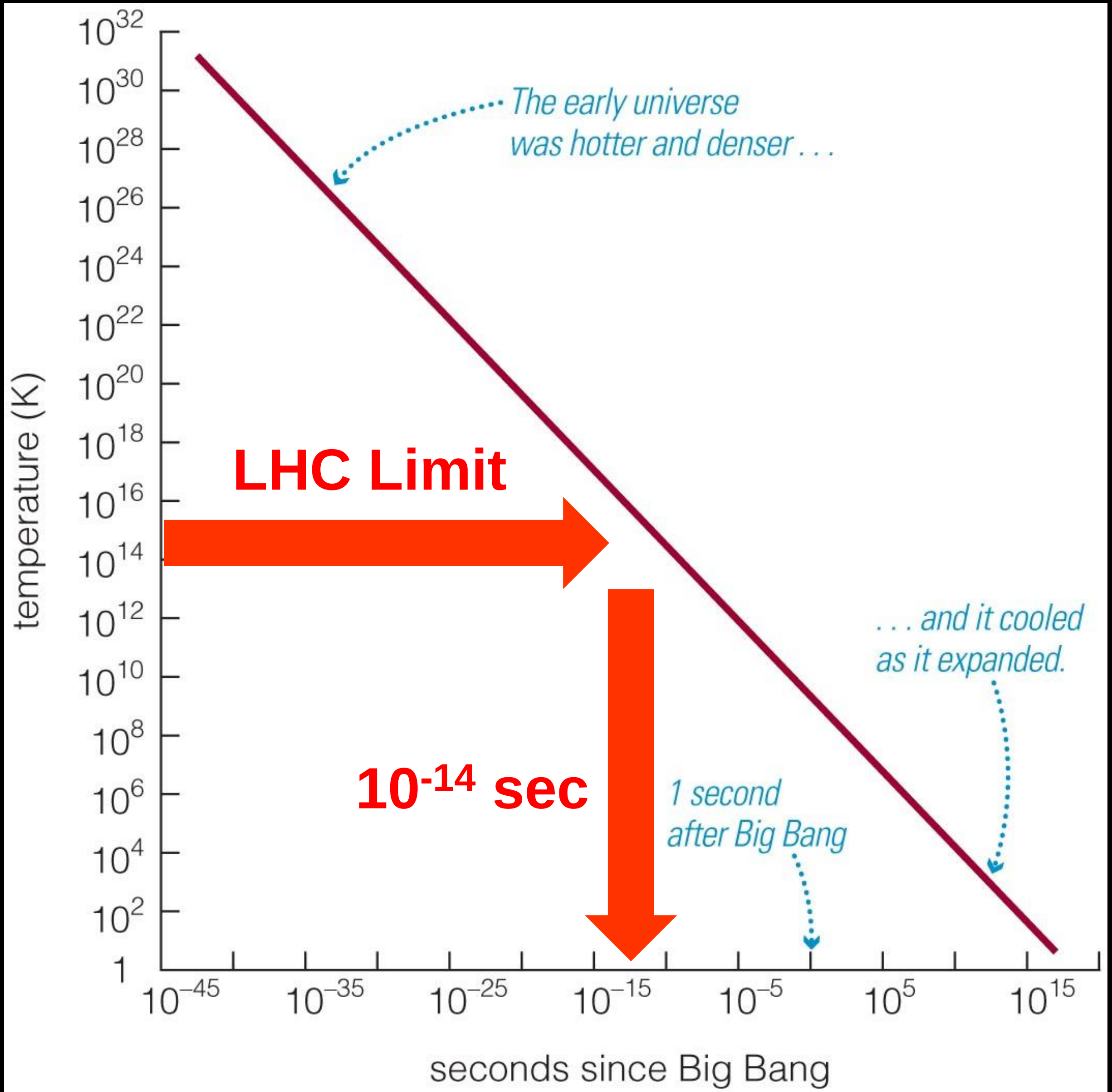
Cosmic Epochs



Light elements created within 3 minutes



The first fraction of a second

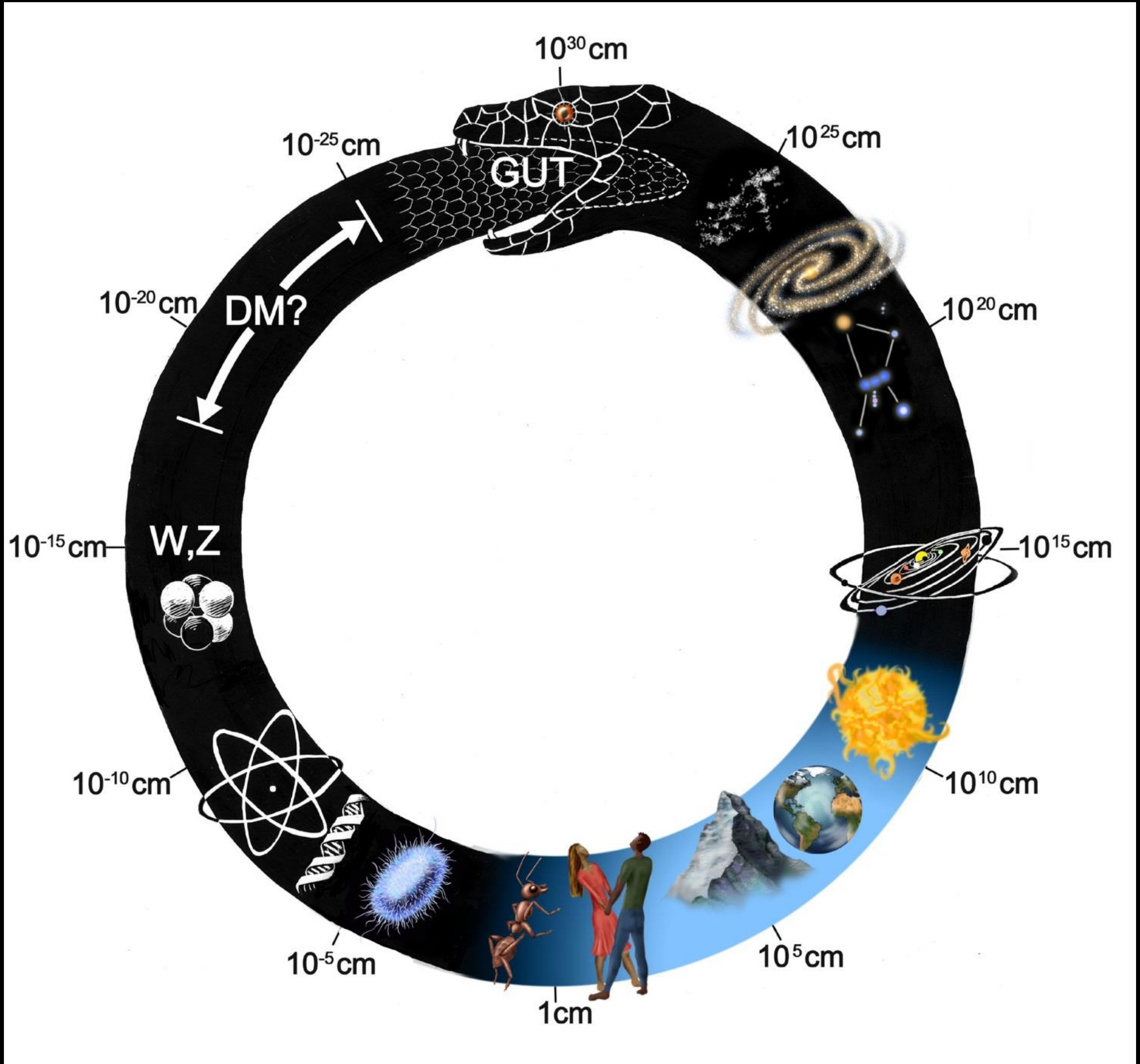


Comprehending the Singularity

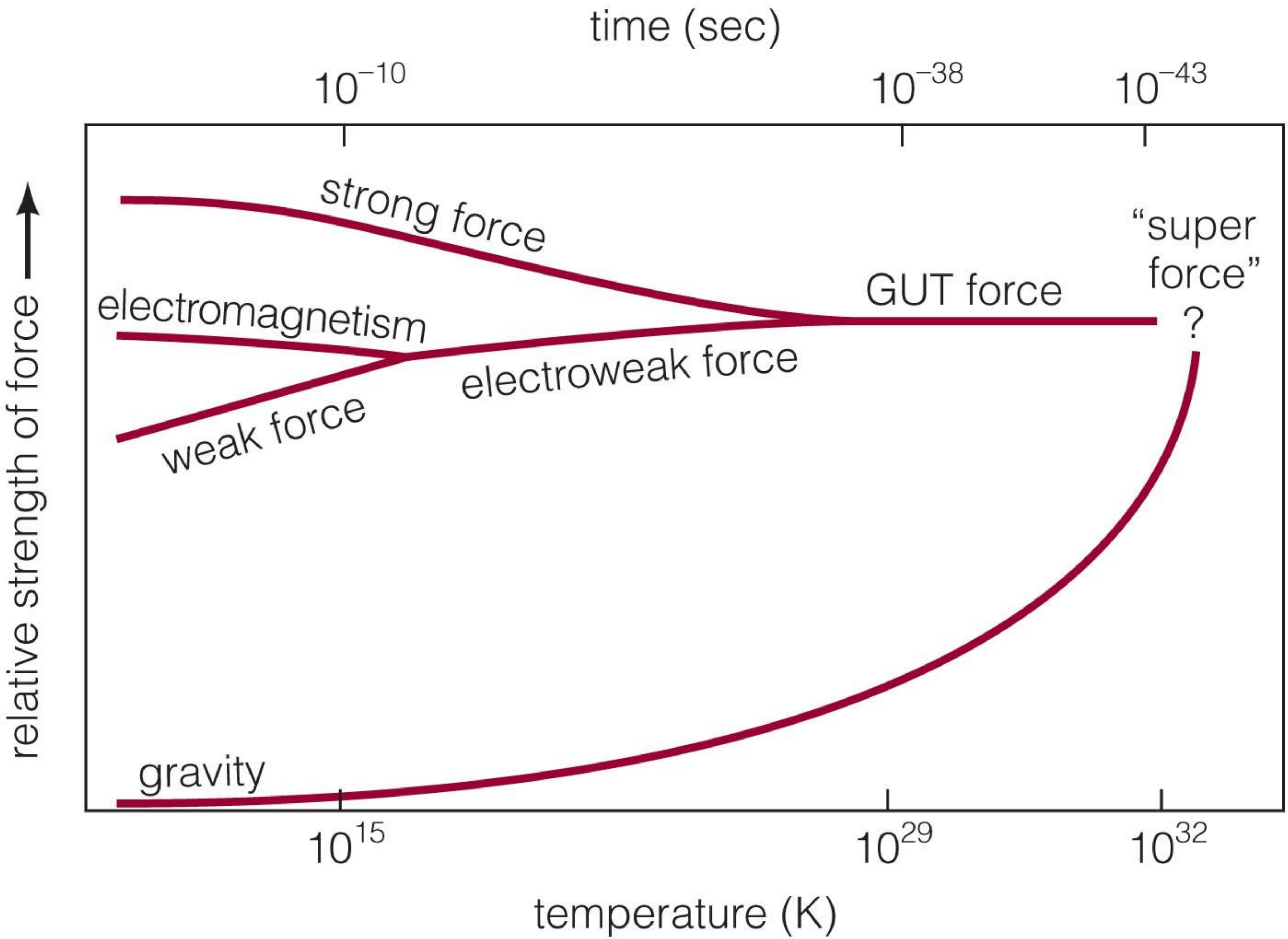
Frontiers

Unity in Nature

The ouroboros



The universe was once smaller than an atom

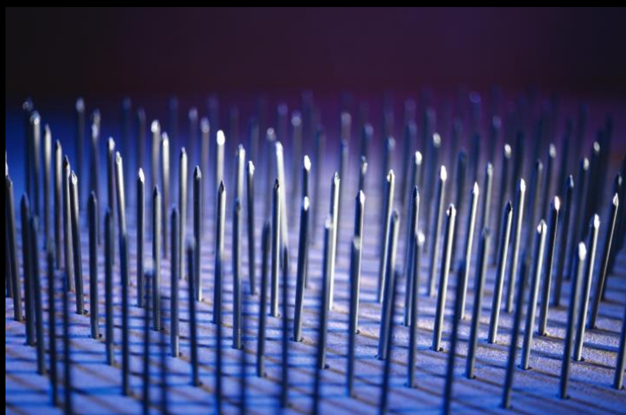


time (sec)
10^{-10}
10^{-38}
10^{-43}
relative strength of force
strong force
"super force"
GUT force
?
electromagnetism
electroweak force
weak force
gravity
10^{15}
10^{29}
10^{32}
temperature (K)


Superforce

Broken symmetry

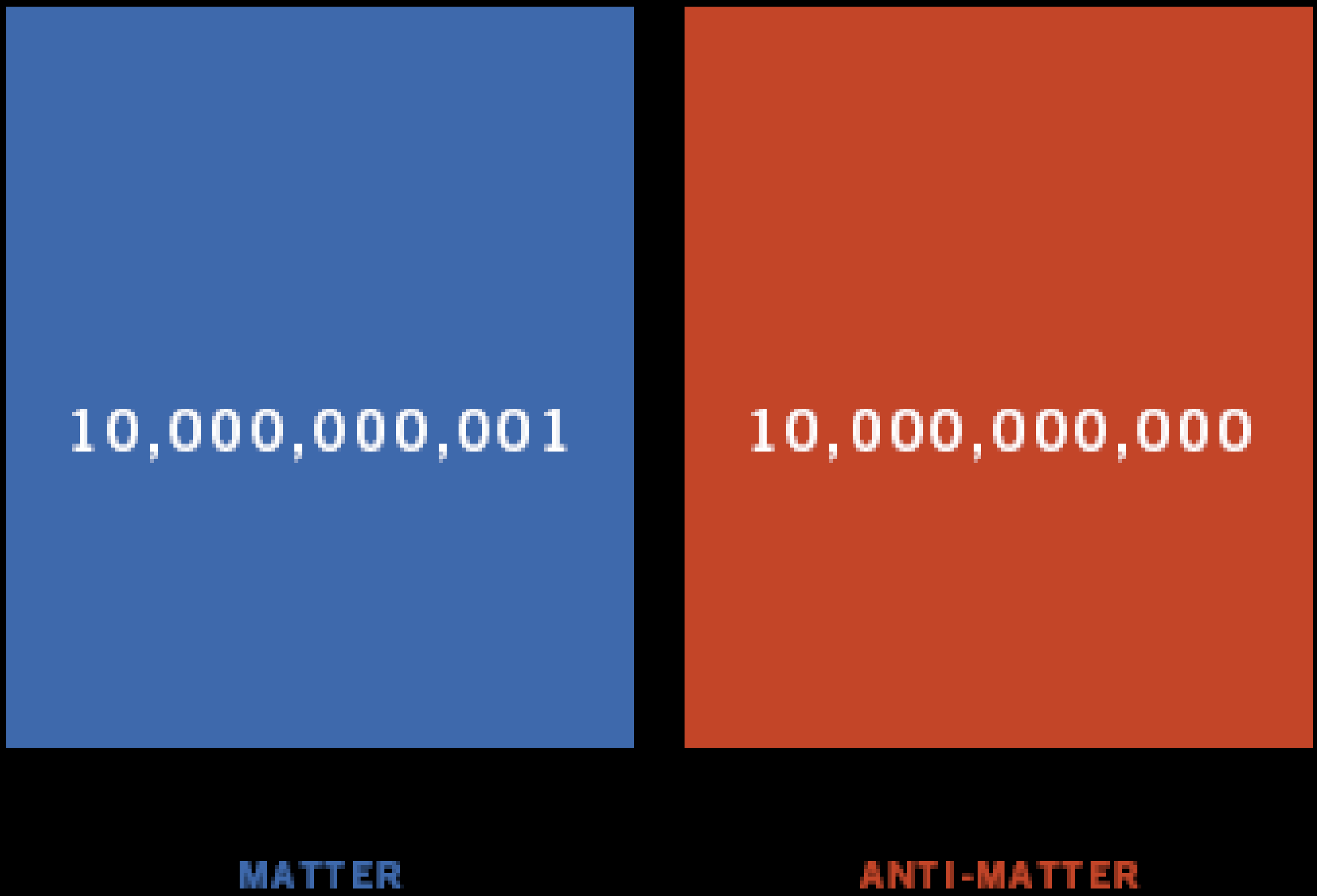
High Temp/Energy | Low Temp/Energy



The breaking of the symmetry in theories of high energy particles is a mechanism for imbalance in antimatter and matter, and for creating particle candidates for the dark matter

At lower energy, the system takes a more specific arrangement, breaking symmetry

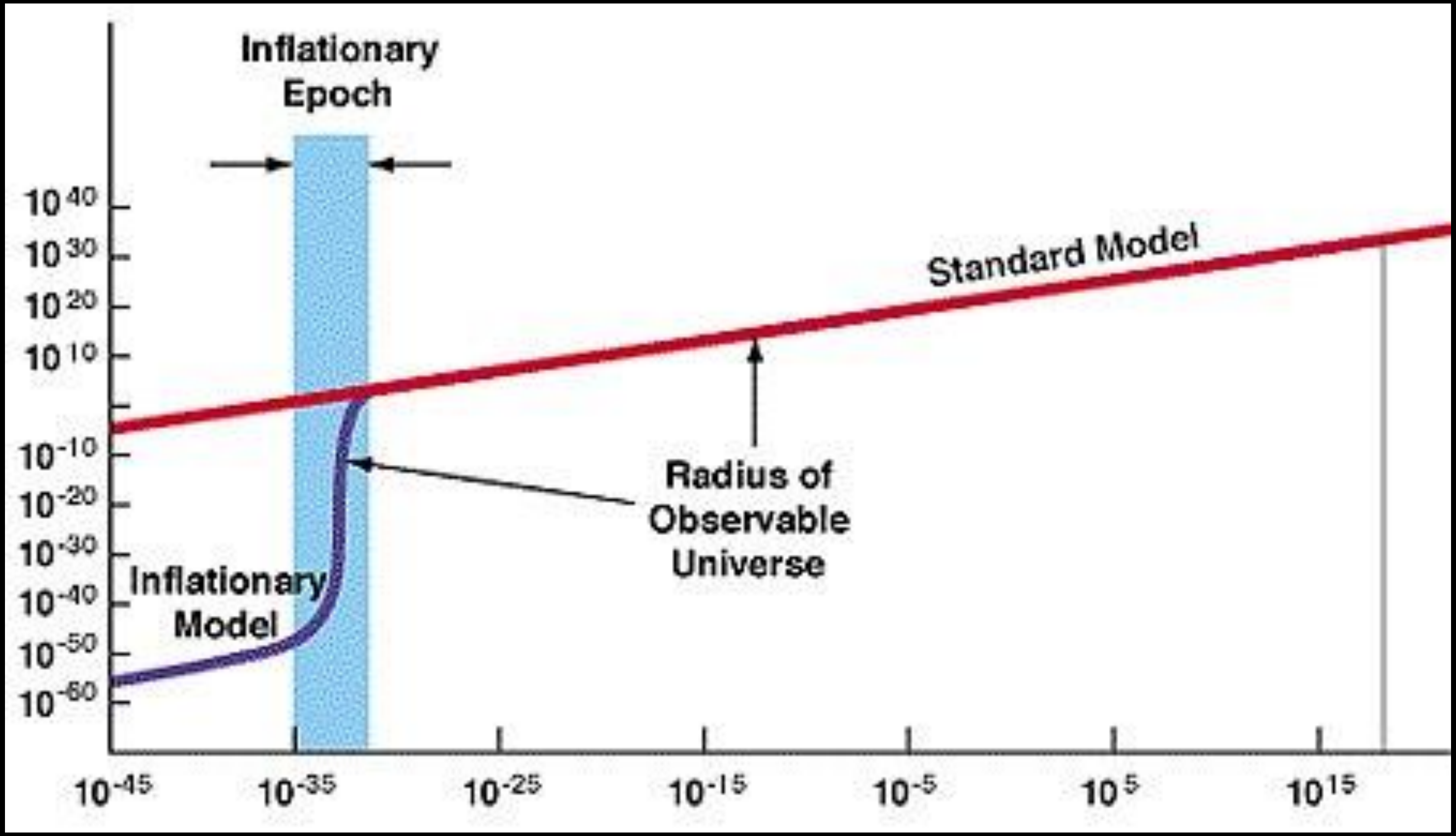
Force separation gave a slight imbalance



The demise of anti-matter

Particle annihilated with anti-particles, yielding a billion photons for every one residual particle in the universe.

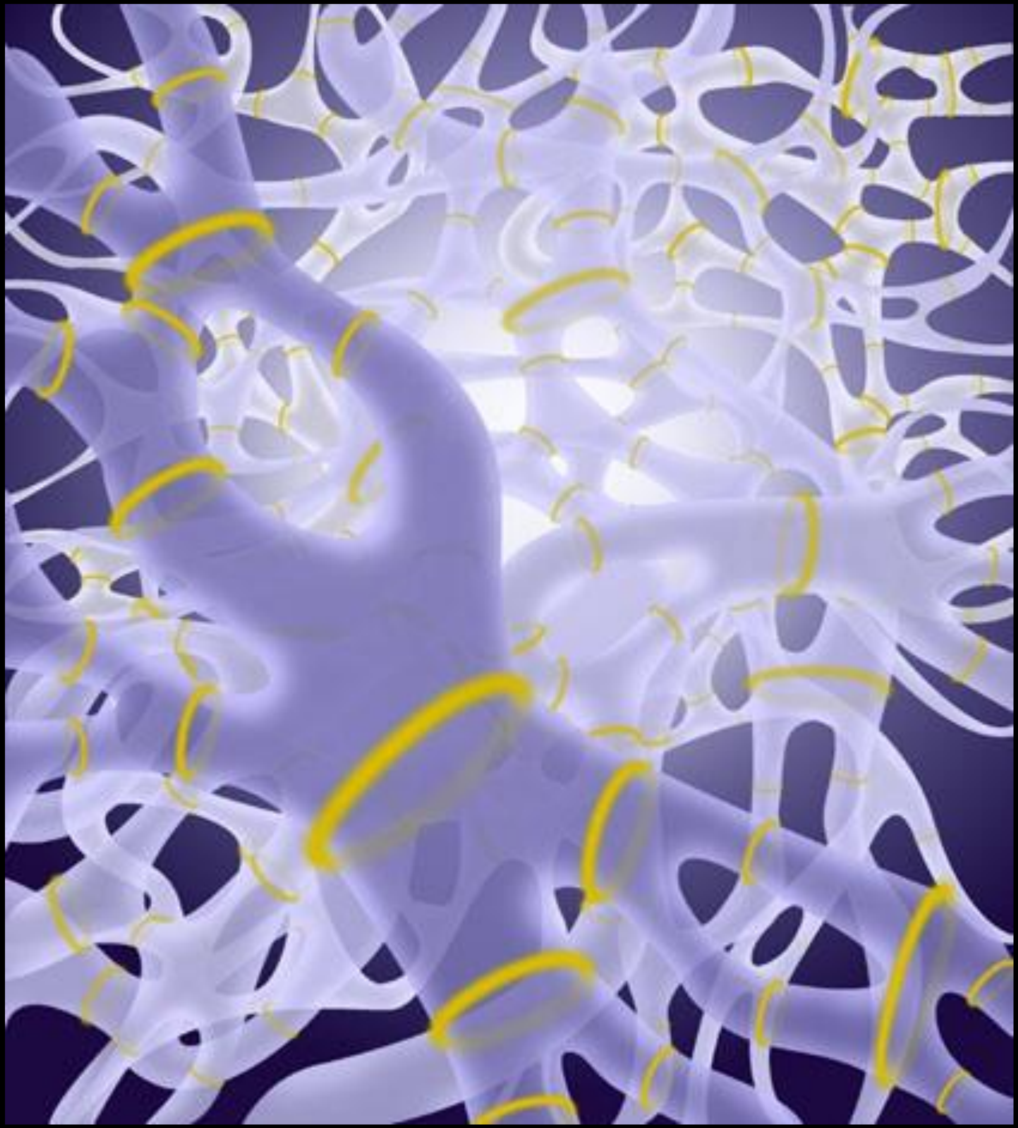
The inflationary big bang



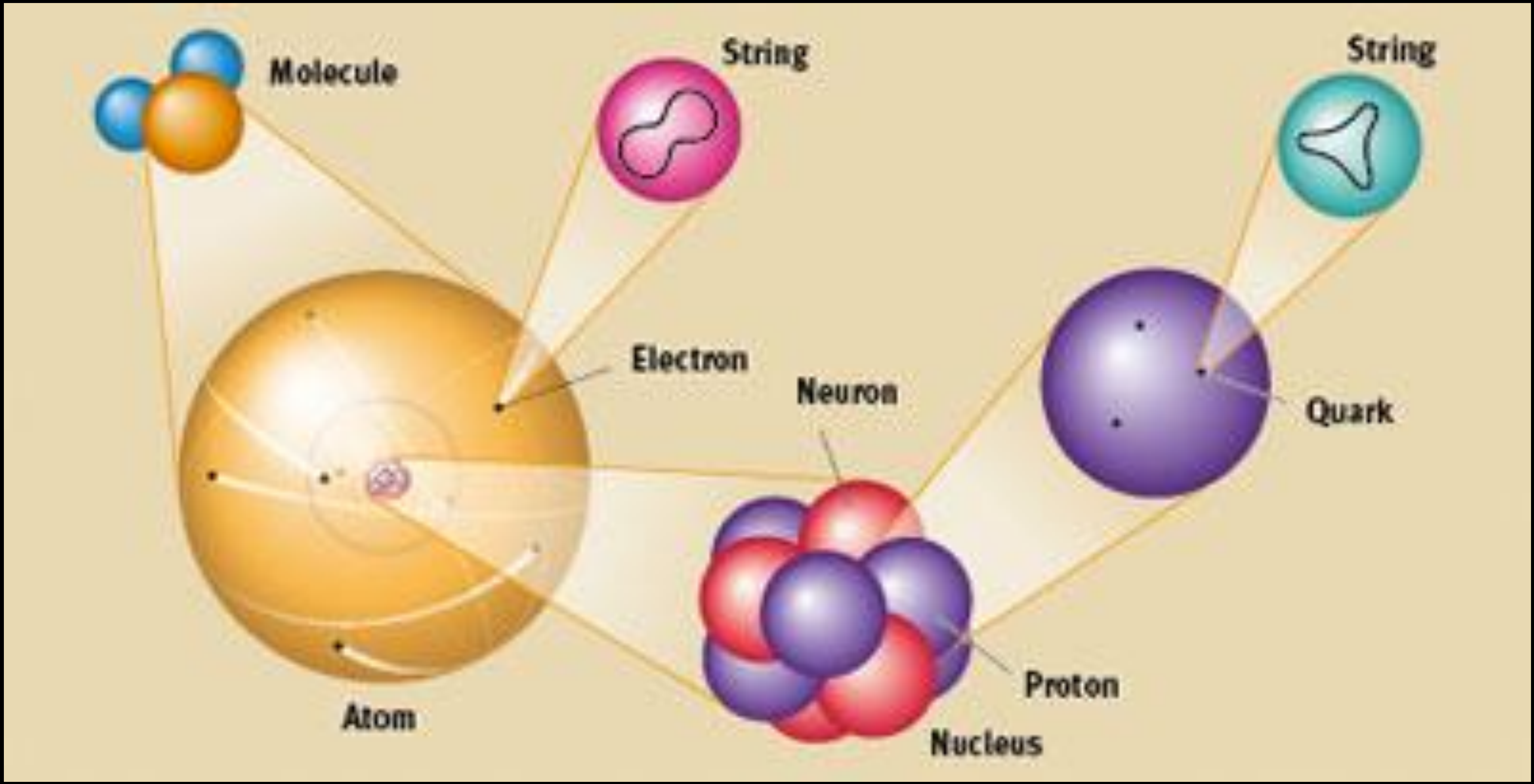
The standard big bang can't why the universe is smooth and flat, leading to the idea of an epoch of extremely rapid inflation 10^{-35} s after the big bang. The mechanism emerges from the frontier theories that seek to unite all the forces except gravity.

We need a Theory of Everything

String Theory

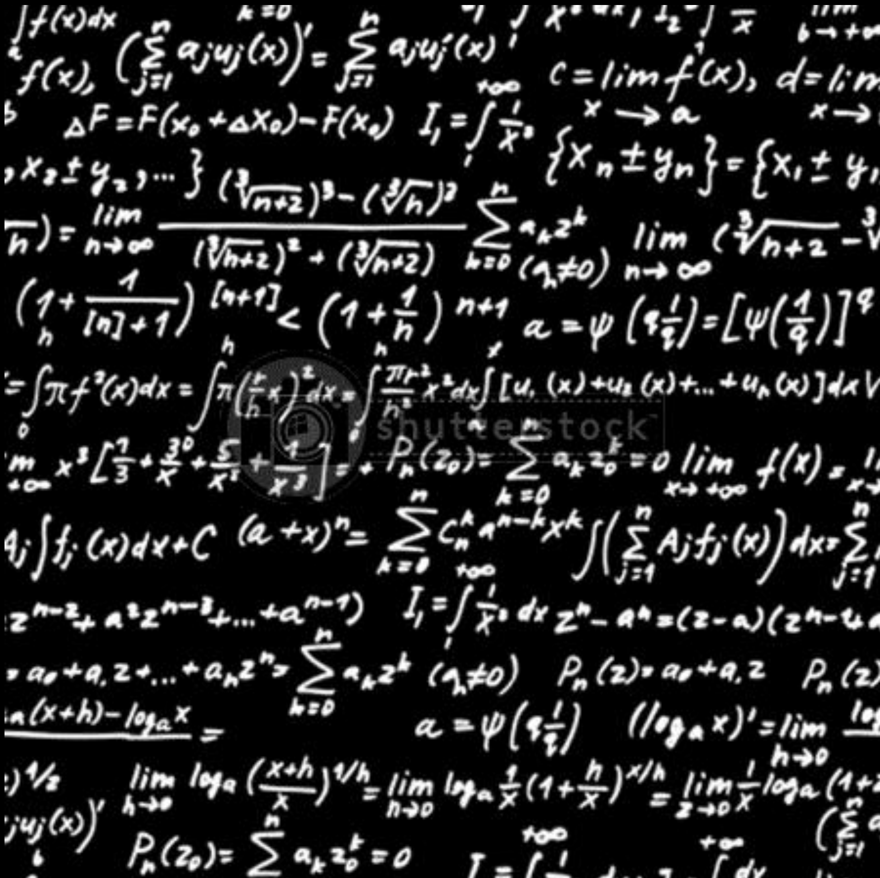


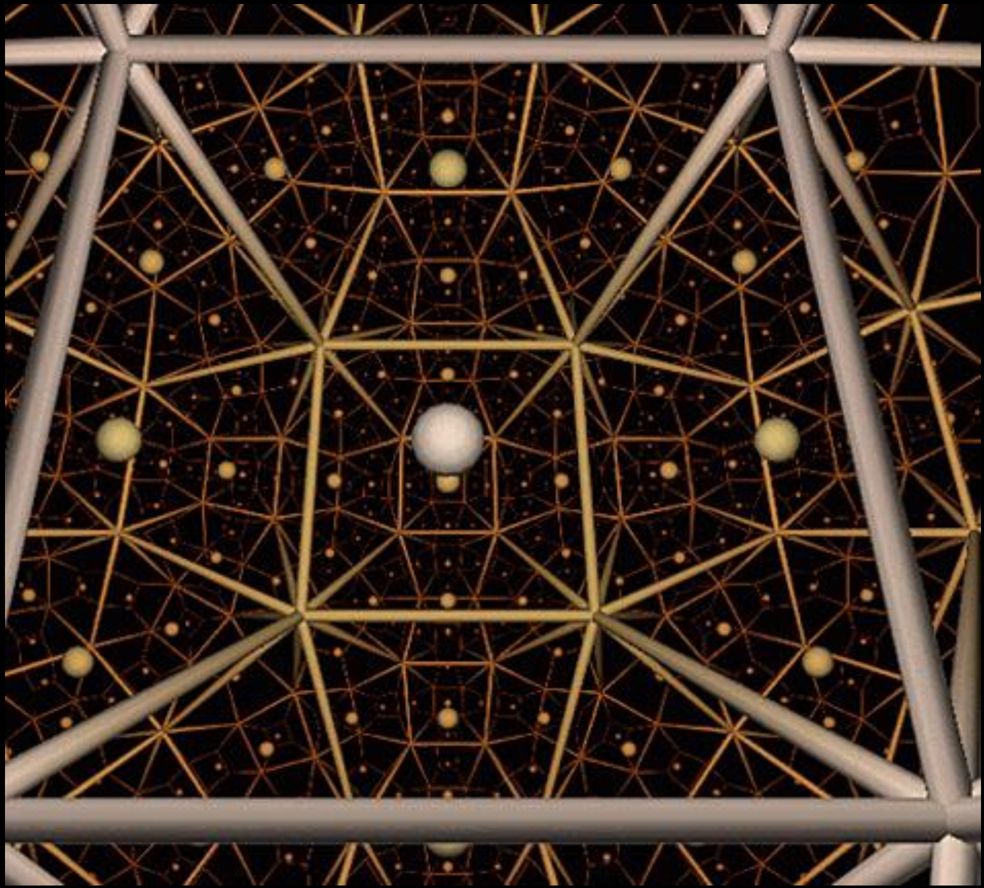
A deeper level of structure…



String theory postulates dynamic 1-dimensional entities that are only noticeable on scales of 10^{-43} meters, which is 33 orders of magnitude smaller than atomic scales!

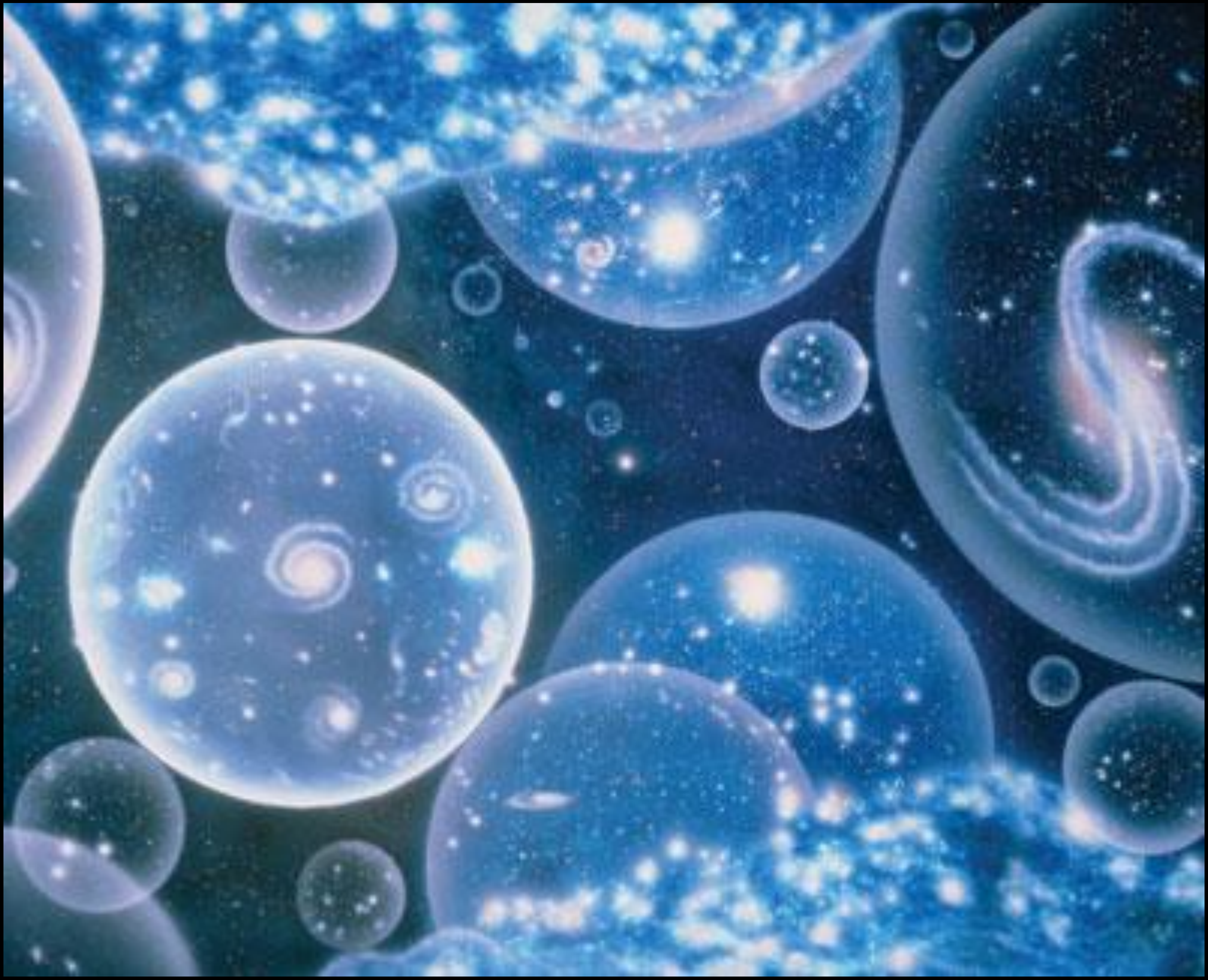
...based complex but elegant math

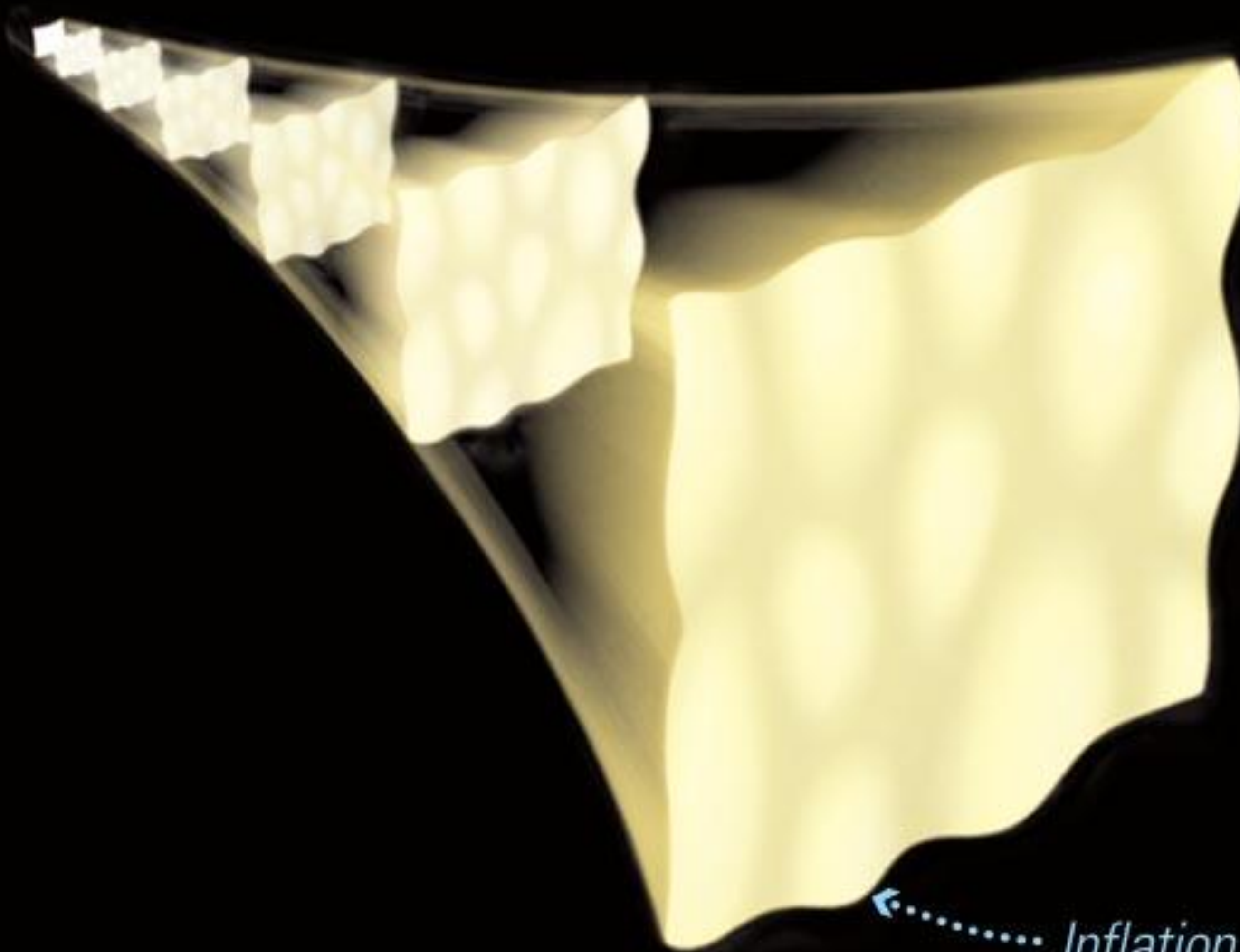




String theory is based on beautiful but very difficult mathematics. The 10-dimensional space-time that the theory is based on has never been observed

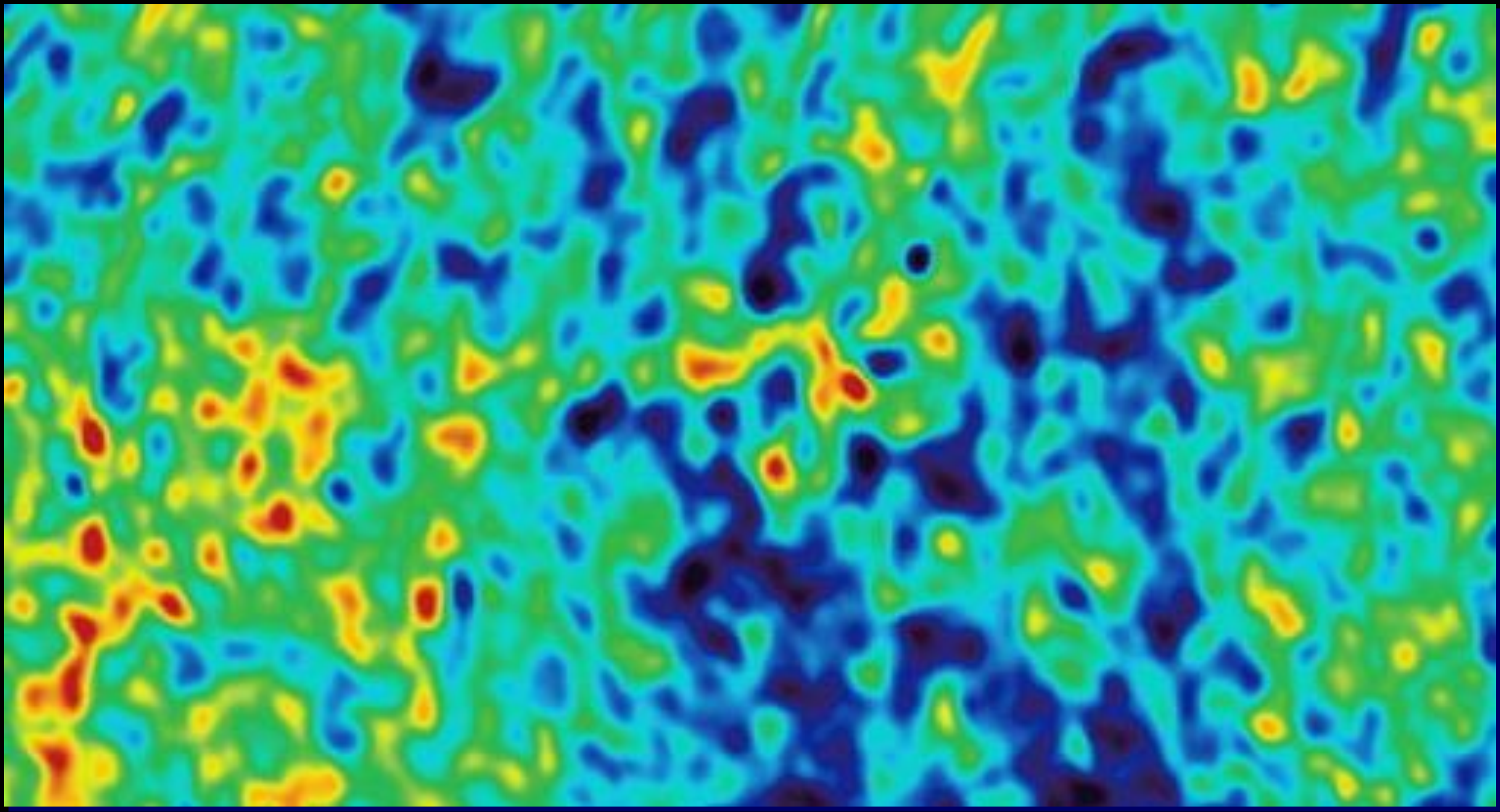
The Multiverse





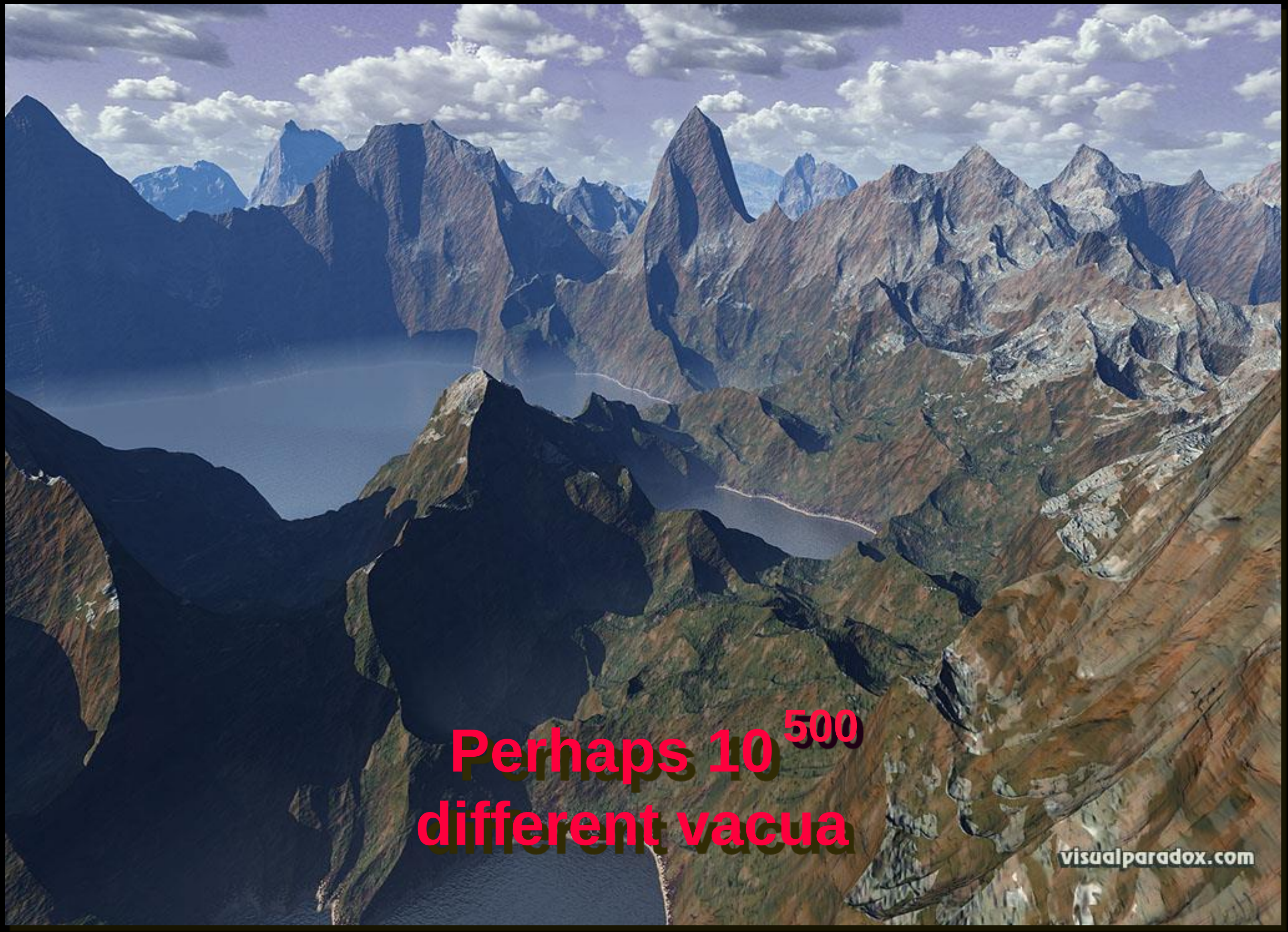
Inflation may have stretched tiny quantum fluctuations into large-scale ripples.

The basis for parallel universes



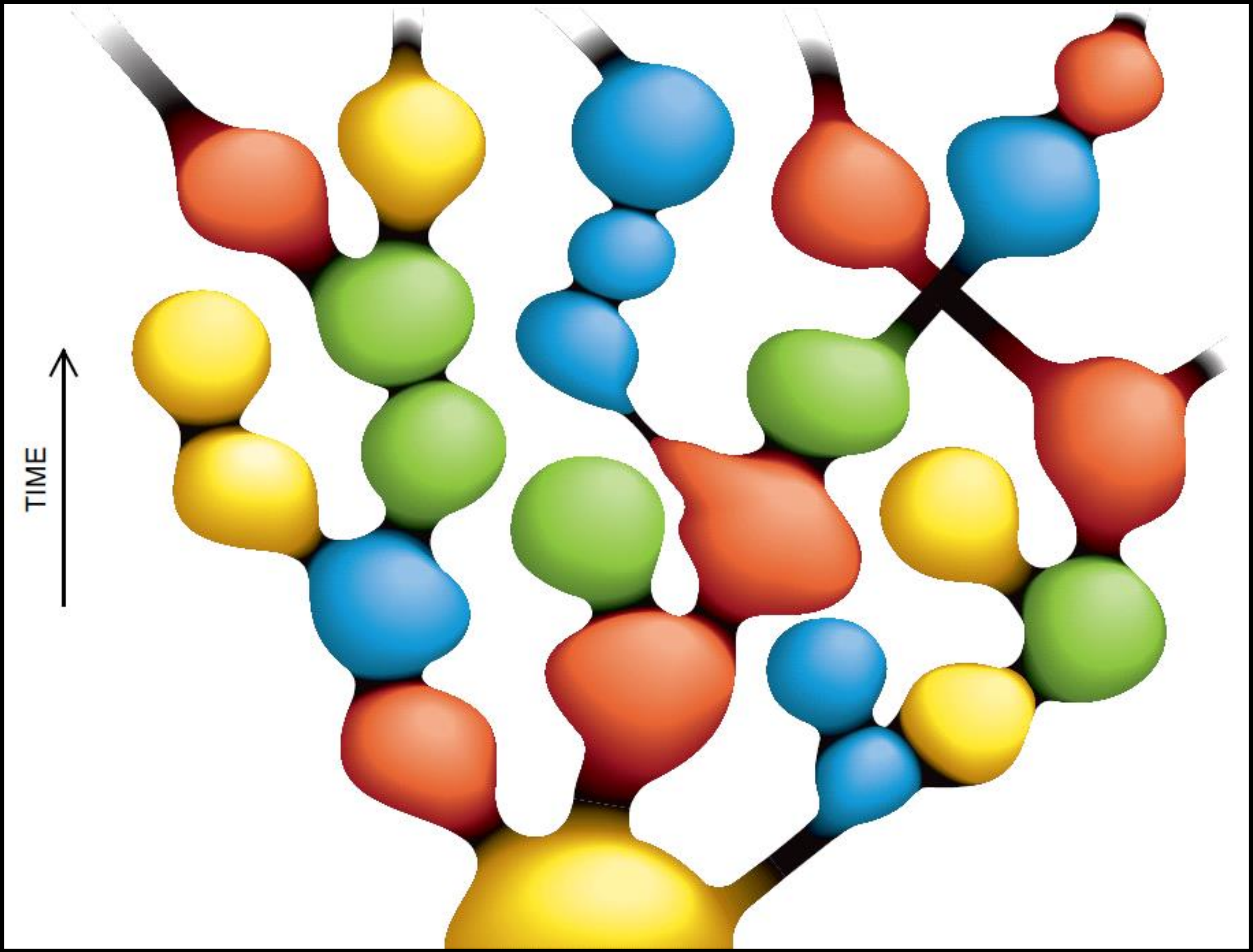
Quantum fluctuations are a mechanism for multiple realizations of the universe

String theory "landscape"



Vacua create quantum fluctuations and provide initial conditions for inflation. String theory provides a context for the "multiverse."

Self-reproducing universe



The multiverse spawns space-times with randomly different laws of physics, very few of which are hospitable universes.

Scenario for an eternal universe


Curved space contains...


...galaxies, which contain...


…stars, which are orbited by…

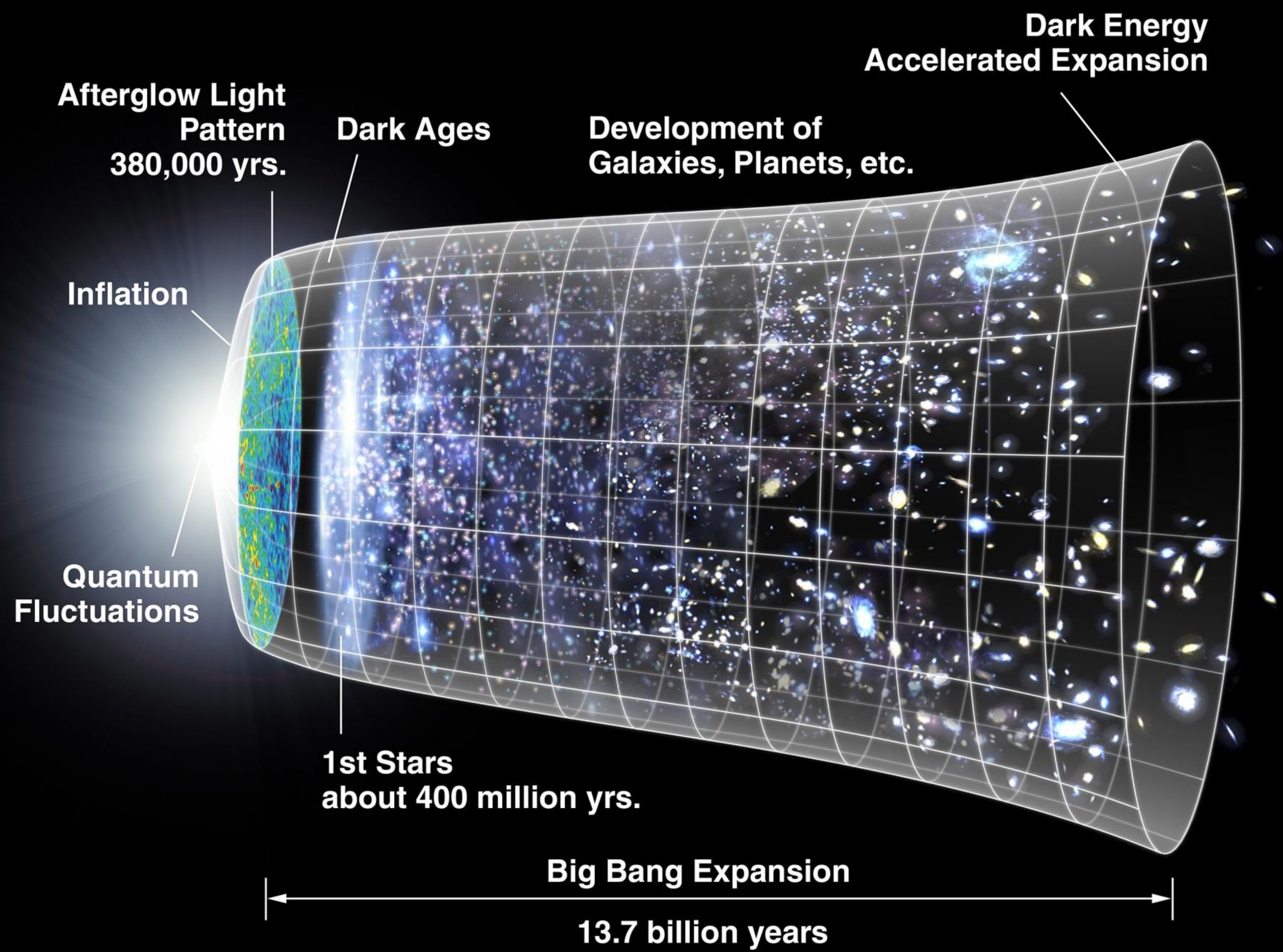

…brains and…


...stuff, which is made of...

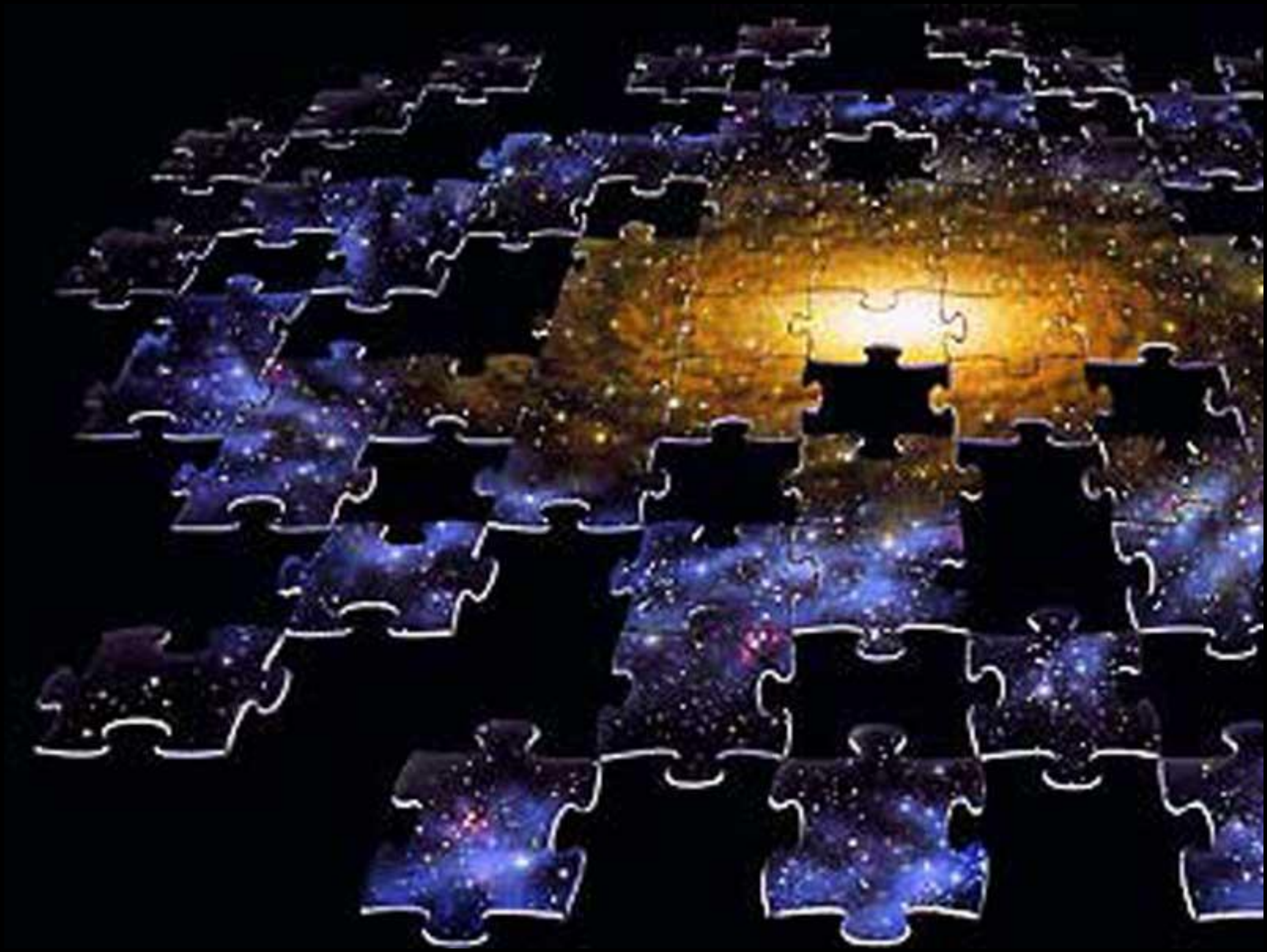

...atoms, which are made of...


. . . .strings.

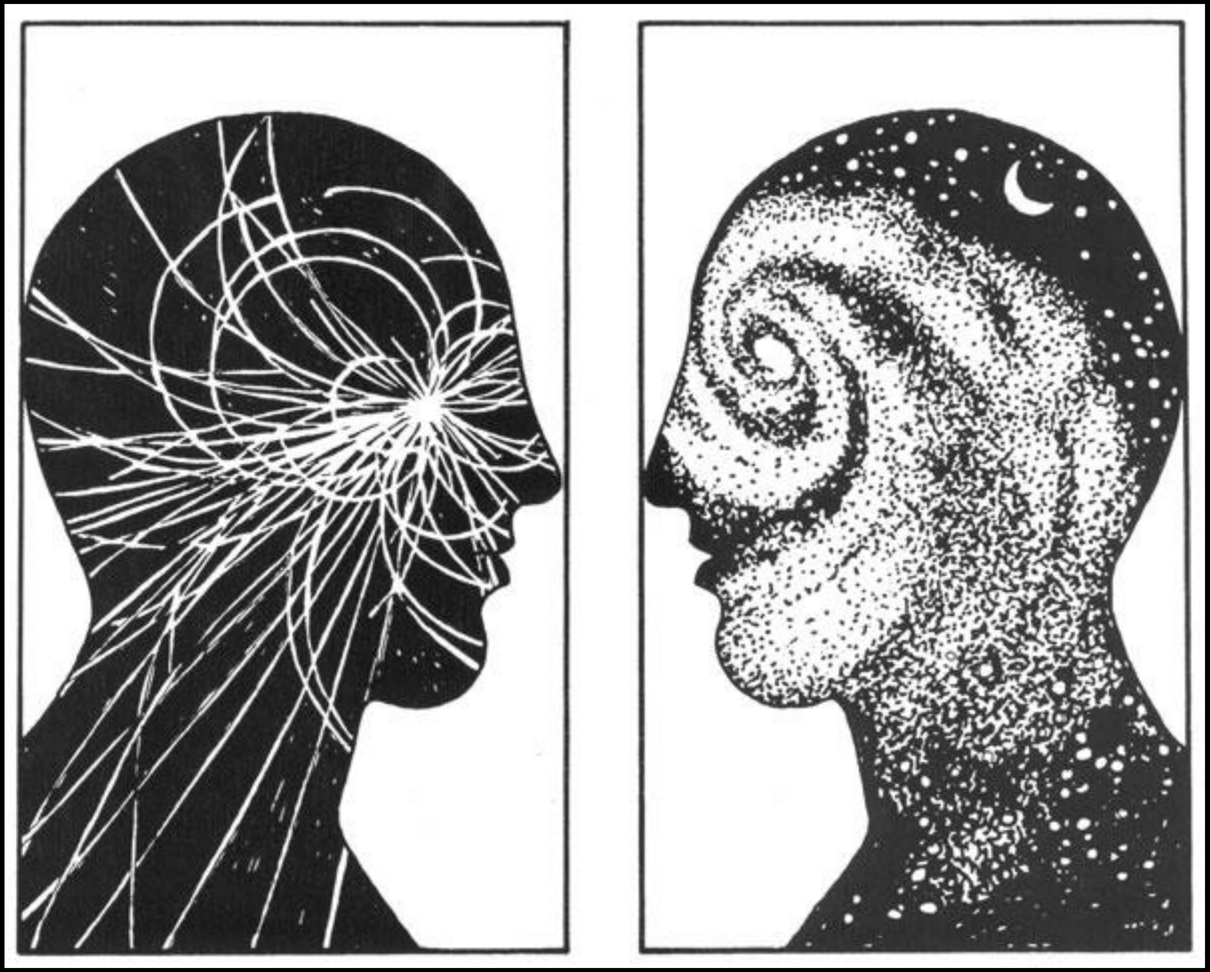
All this from an iota of space-time



Profound mysteries remain but…



...cosmology is one of our greatest triumphs



We are made of tiny particles, and we are part of a vast universe, yet we keep both within our heads.

UNIVERSAL STUDIOS
HOLLYWOOD