Cosmology & Culture

Lecture 6

Wednesday May 6, 2009

The Cosmic Las Vegas

UCSC Physics 80C

Midterm Exam in Class May 13

The Midterm Exam will be next week, after the break.

The exam covers everything in the lectures and in *The View from the Center of the Universe* through chapter 8. There will also be some simple problems involving powers of ten.

Remember that your Astronomy Journals are to be handed in at the May 27 class, and returned at the last class.

Note: I will be speaking at a conference on Thursday, so I will not be available for Office Hours then. I could meet after 2 pm this Friday, by appointment.

The Age of the Universe

In the mid-1990s there was a crisis in cosmology, because the age of the old Globular Cluster stars in the Milky Way, then estimated to be 16±3 Gyr, was higher than the expansion age of the universe, which for a critical density ($\Omega_m = 1$) universe is 9±2 Gyr (with the Hubble parameter h=0.72±0.07). But when the data from the Hipparcos astrometric satellite became available in 1997, it showed that the distance to the Globular Clusters had been underestimated, which implied that their ages are 12±3 Gyr.

Several lines of evidence now show that the universe does not have $\Omega_m = 1$ but rather $\Omega_{tot} = \Omega_m + \Omega_\Lambda = 1.0$ with $\Omega_m \approx 0.3$, which gives an expansion age of about 14 Gyr. High-redshift supernova data alone give an expansion age of 14.2±1.7 Gyr. The WMAP cosmic background data alone give an expansion age of 13.4±0.3 Gyr, which becomes **13.7±0.2 Gyr** with the WMAP running power spectrum index model.

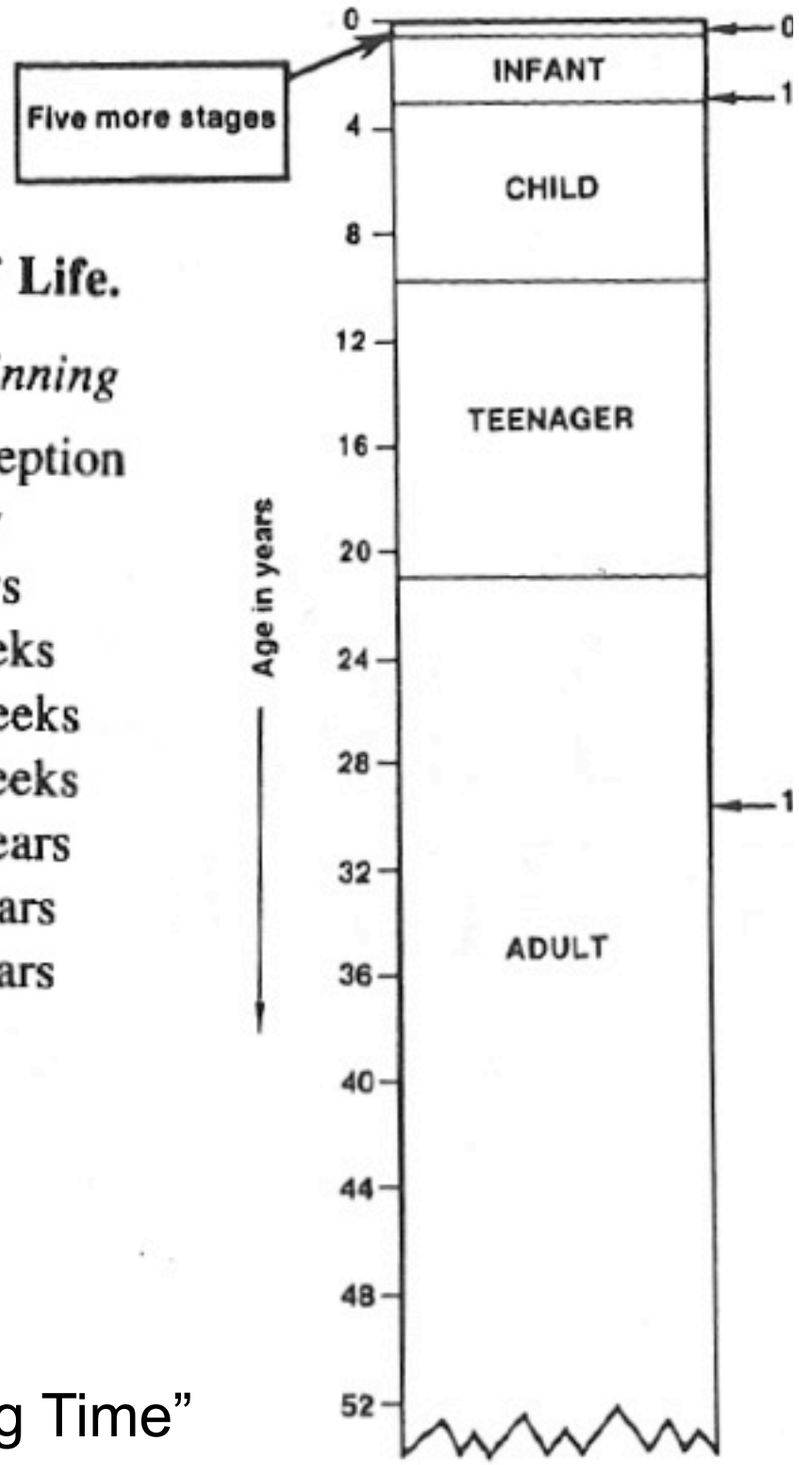
A new type of age measurement based on radioactive decay of Thorium-232 (half-life 14.1 Gyr) measured in a number of stars gives a completely independent age of 14±3 Gyr. A similar measurement, based on the first detection in a star of Uranium-238 (half-life 4.47 Gyr), gives 12.5±3 Gyr.

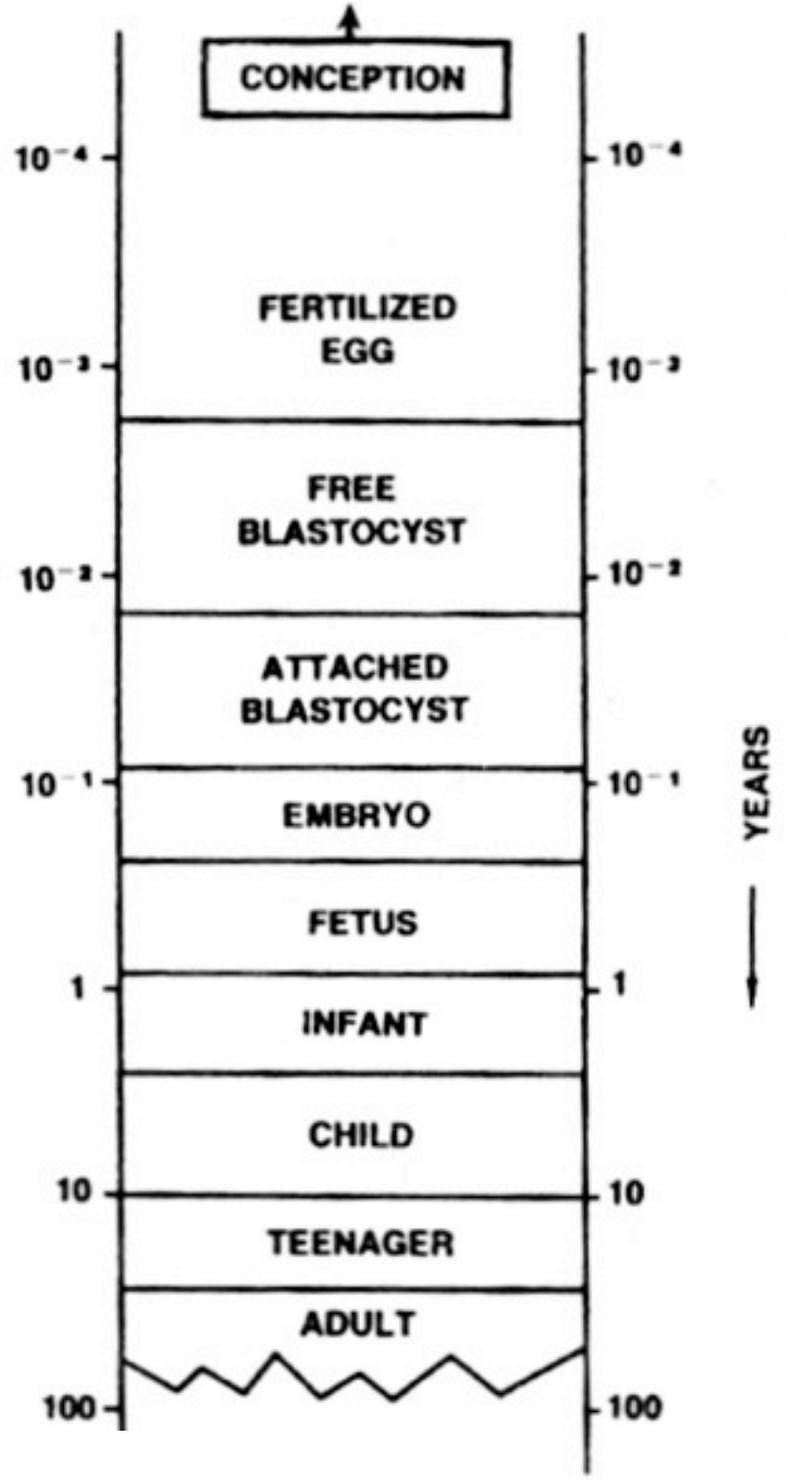
All the recent measurements of the age of the universe are thus in excellent agreement. **It is reassuring that three completely different clocks – stellar evolution, expansion of the universe, and radioactive decay – agree so well.**

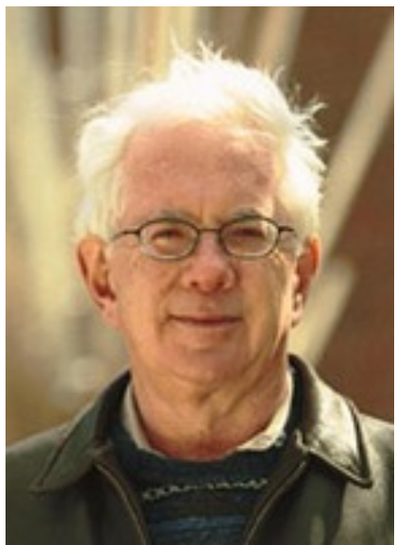
Stages of Life on Linear Time vs. Log Time

TABLE 1. The Nine Stages of Life.

Stage of Life	*Beginning*
1. Fertilized egg	Conception
2. Free blastocyst	1 day
3. Attached blastocyst	6 days
4. Embryo	4 weeks
5. Fetus	12 weeks
6. Infant	38 weeks
7. Child	2.5 years
8. Teenager	10 years
9. Adult	21 years



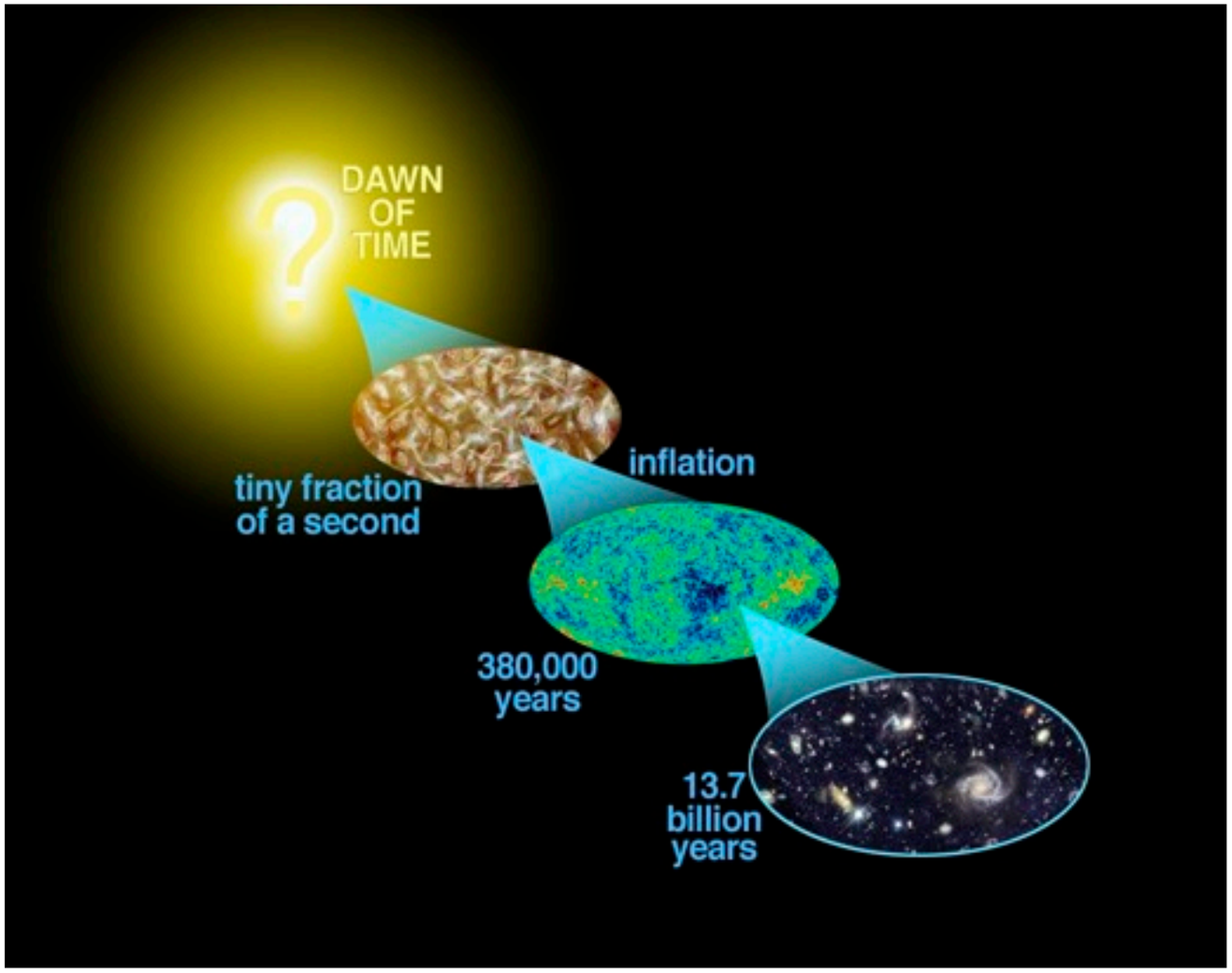


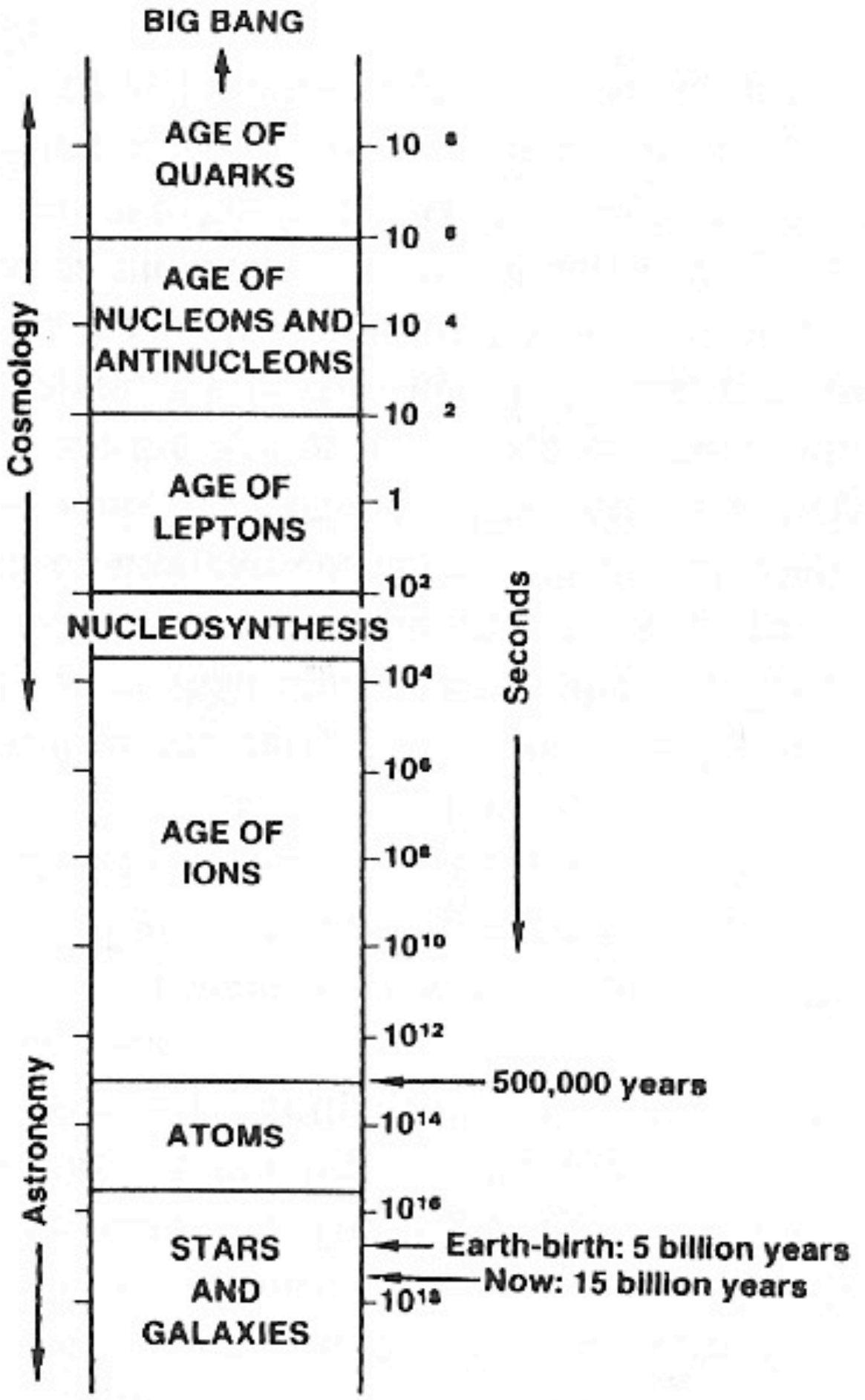


"Life on Log Time"

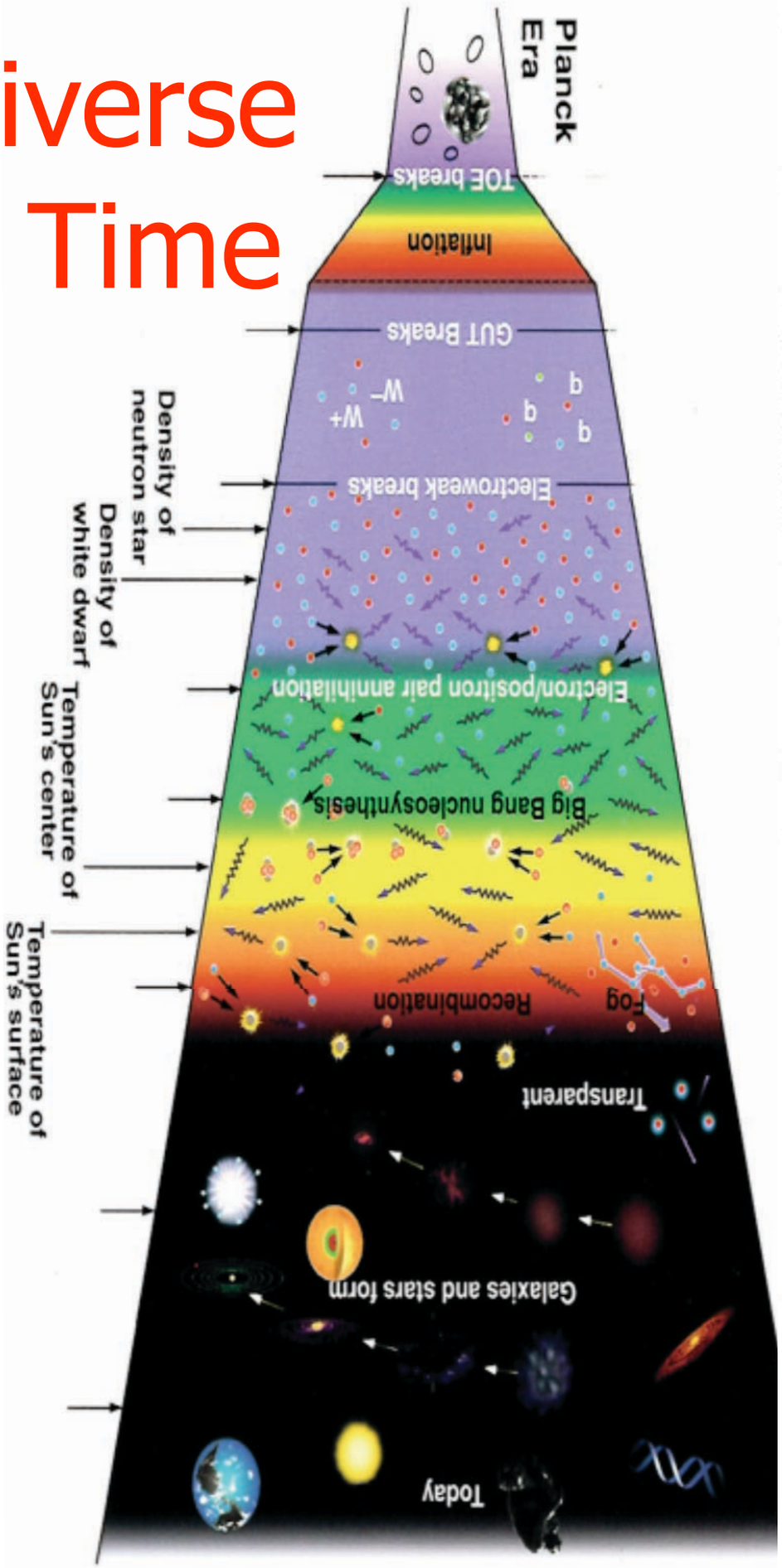
Sheldon Glashow
Harvard Nobel Laureate

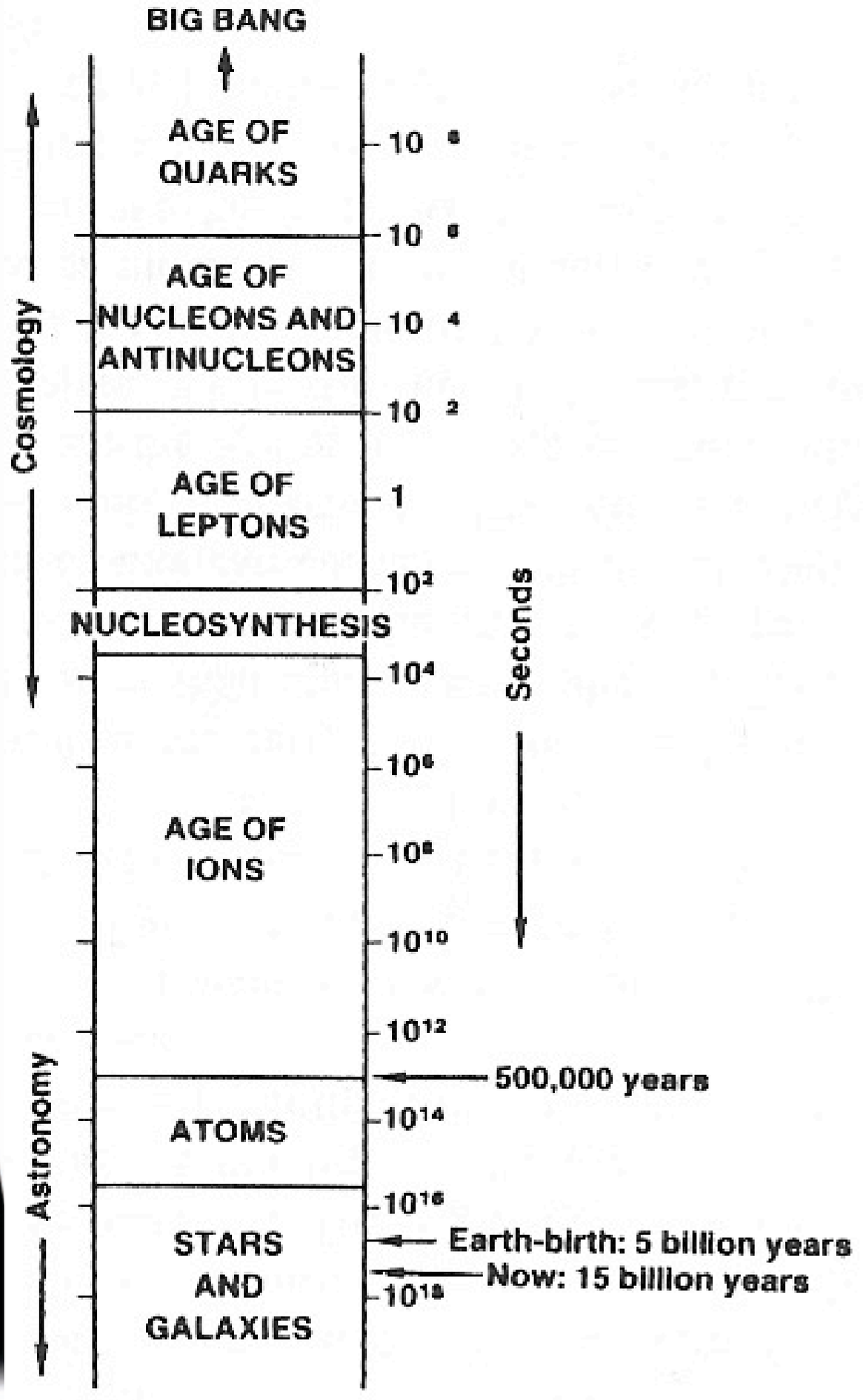
The Universe on Log Time



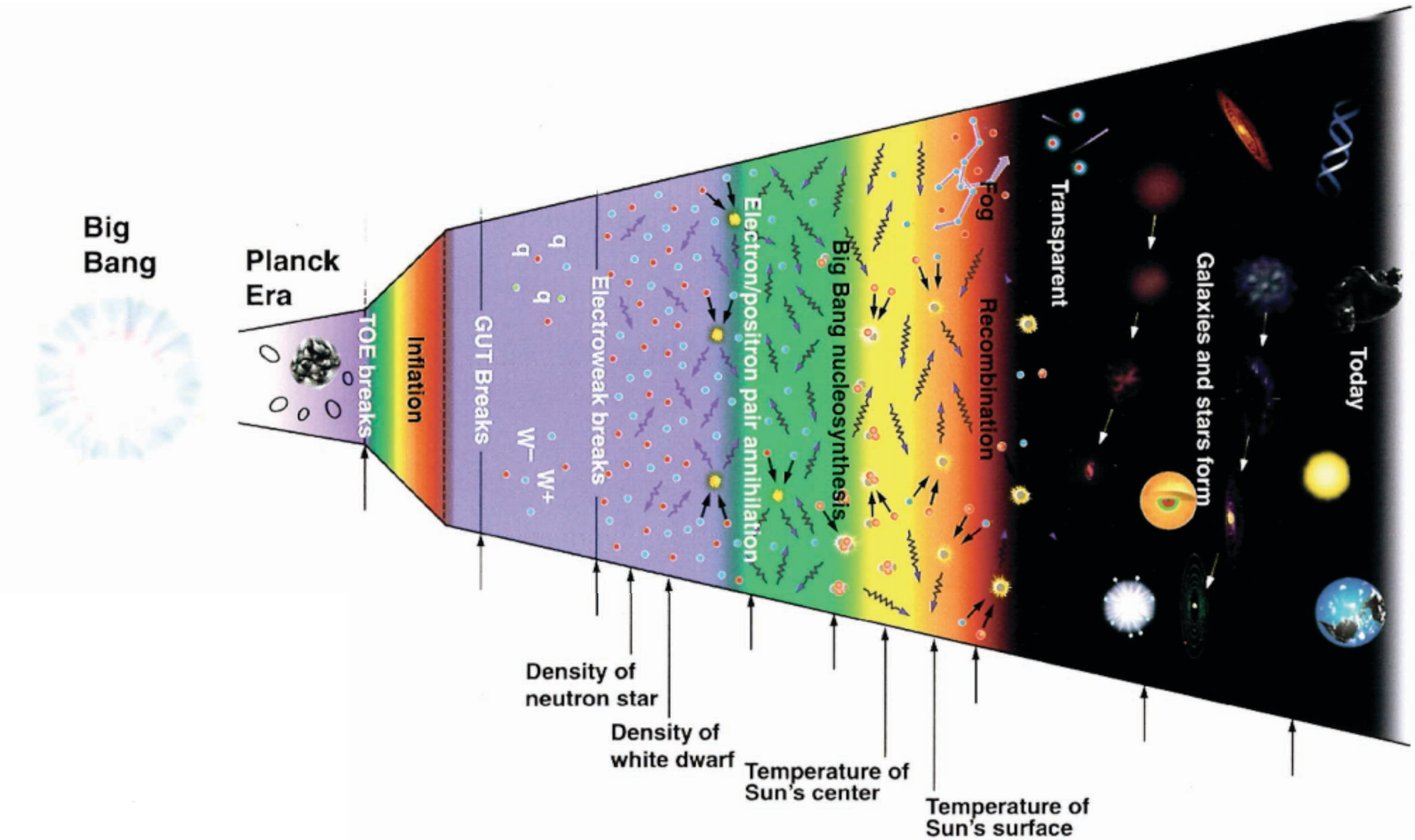


The Universe on Log Time



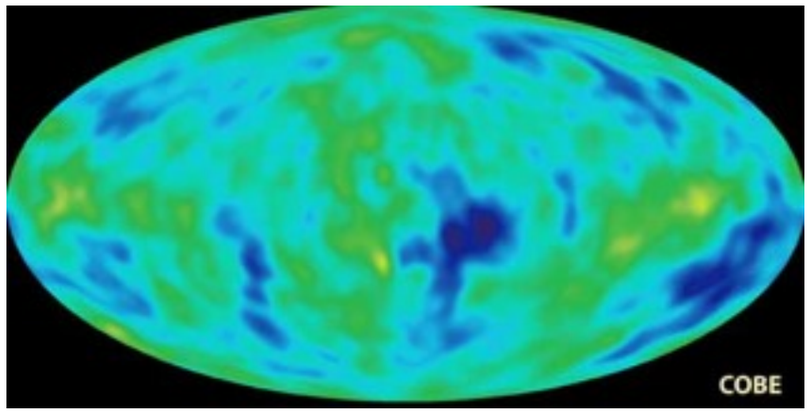


Brief History of the Universe



Brief History of the Universe

- Cosmic Inflation generates density fluctuations
- Symmetry breaking: more matter than antimatter
- All antimatter annihilates with almost all the matter (1s)
- Big Bang Nucleosynthesis makes light nuclei (10 min)
- Electrons and light nuclei combine to form atoms, and the cosmic background radiation fills the newly transparent universe (380,000 y)

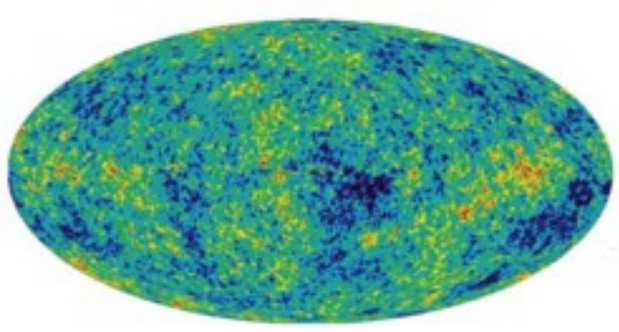


- Galaxies and larger structures form (~1 billion y)
- Carbon, oxygen, iron, ... are made in stars
- Earth-like planets form around 2nd generation stars
- Life somehow starts (~4 billion y ago) and evolves on earth

GRAVITY – The Ultimate Scrooge Principle

It Always Rewards the "Rich" and Punishes the "Poor"

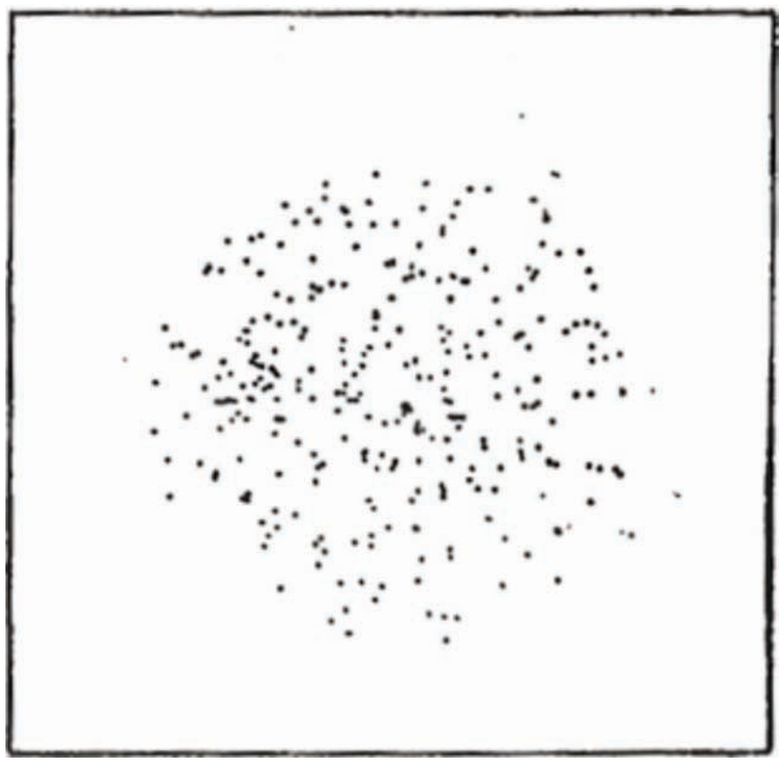
Astronomers say that a region of the universe with more matter is "richer." Gravity magnifies differences—if one region is slightly denser than average, it will expand slightly more slowly and grow relatively denser than its surroundings, while regions with less than average density will become increasingly less dense. The rich always get richer, and the poor poorer.



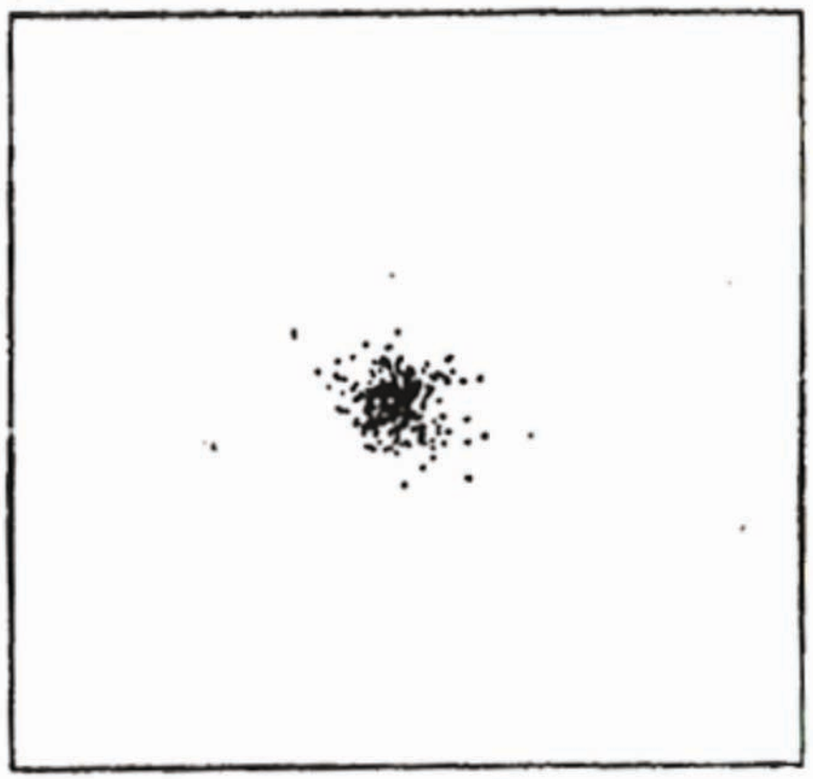
Temperature map at 380,000 years after the Big Bang. Blue (cooler) regions are slightly denser.

The early universe expands ***almost*** perfectly uniformly. But there are small differences in density from place to place (about 30 parts per million). Because of gravity, denser regions expand more slowly, less dense regions more rapidly. Thus gravity amplifies the contrast between them, until…

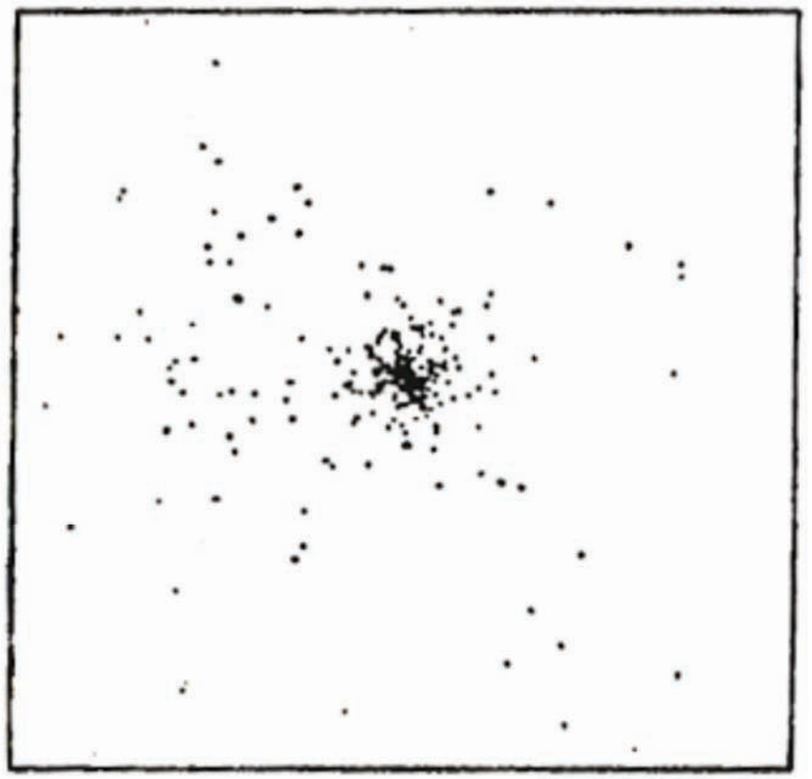
Structure Formation by Gravitational Collapse



When any region becomes about twice as dense as typical regions its size, it reaches a maximum radius, ***stops expanding***,



and starts falling together. The forces between the subregions generate velocities which ***prevent*** the material from ***all falling toward the center***.



Through Violent Relaxation the dark matter quickly reaches a ***stable configuration*** that's about half the maximum radius but denser in the center.

The Ultimate Scrooge Principle

To repeat: Gravity amplifies differences—if one region is even slightly denser than average, it will expand slightly more slowly and grow relatively denser than its surroundings, and regions with less than average density will become increasingly less dense. Gravity is thus the ultimate scrooge principle: the rich always get relatively richer, and the poor poorer.

But if matter after the Big Bang were absolutely evenly distributed, gravity would have done nothing but slow down the overall expansion. Consequently, in order to make galaxies, gravity must have had some differences in density to work with from the beginning. What could have caused these initially tiny ripples in density? The only theory yet proposed is called Cosmic Inflation.

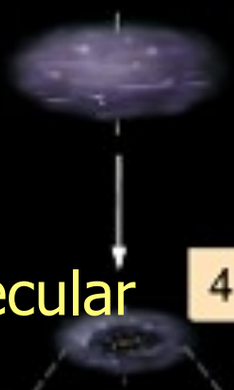
Formation of Star and Planets

Giant Molecular Cloud

1 GMC collapses

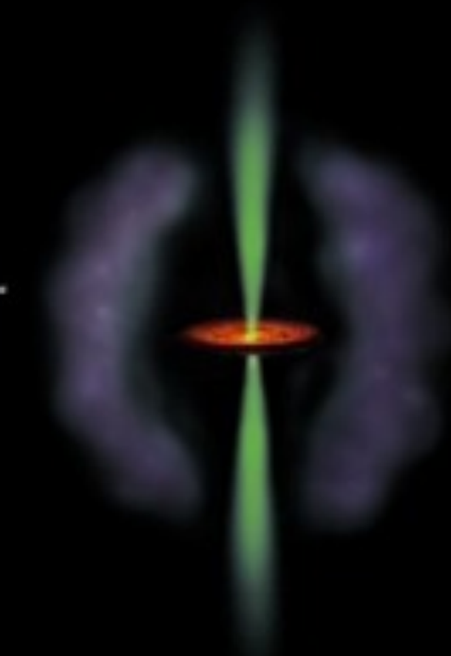
2 and fragments

3 to molecular cores



4 accretion disk forms

5 bipolar jets from protostar form Herbig-Haro objects as jets hit interstellar material



6

T Tauri star and protoplanetary disk

7 H fusion starts

8 disk material forms planetary system

HST Images of Eagle Nebula

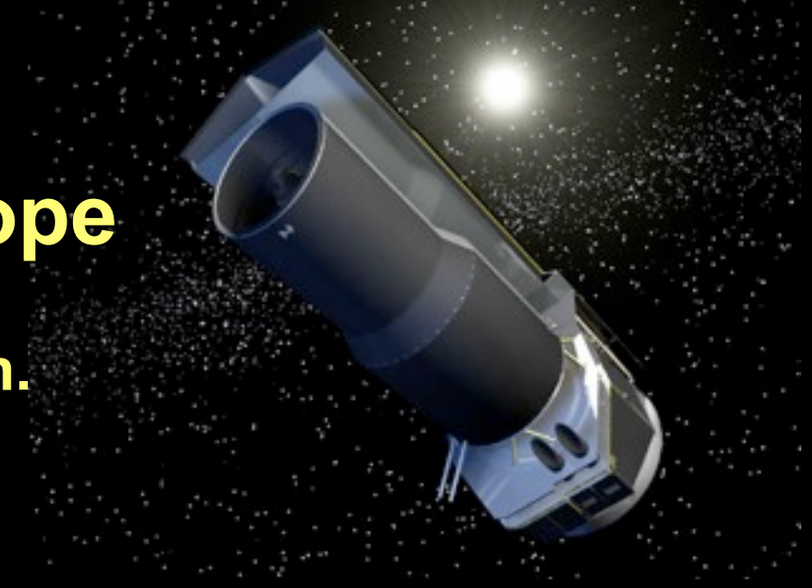
visible light image of molecular cloud

infrared light sees into dusty regions where stars and planets form

Spitzer Space Telescope

Launched Aug 25, 2003

Now in orbit around the Sun.



Tarantula Nebula in the Large Magellanic Cloud

Pink: visual light Multicolor: infrared

(Spitzer Space Telescope)

Dark Globule in IC 1396

Pink: visual light Multicolor: infrared

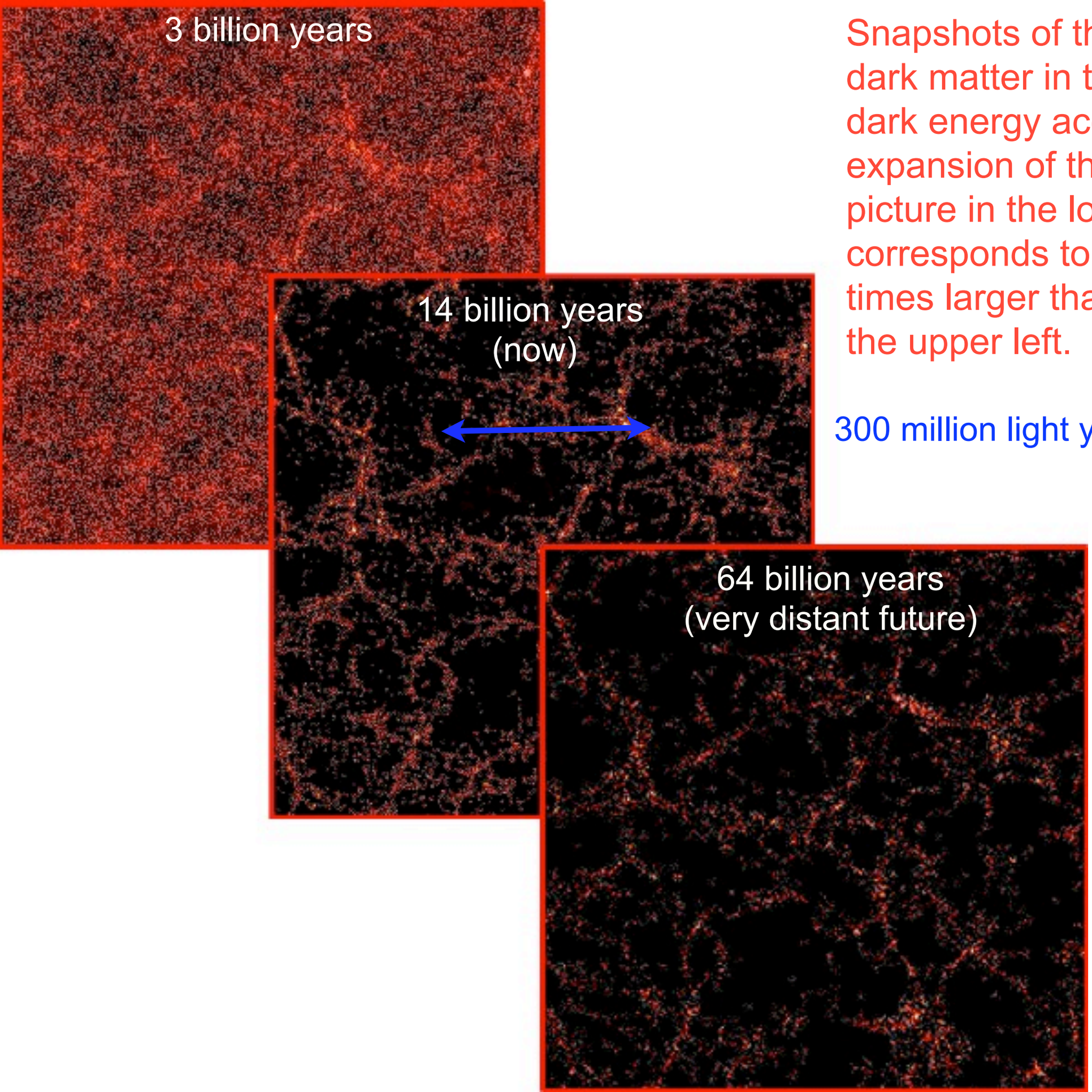
(Spitzer Space Telescope)

What the Big Bang Doesn't Explain

- What happened before the Big Bang to make the early universe so uniform, but with tiny ripples? **Inflation**?
- What is the **dark matter** that enabled the tiny ripples in density to grow into galaxies, clusters, and voids?

  Cold Dark Matter WIMPs?
- How did galaxies form and evolve?
- What is the **dark energy** that is making the expansion of the universe accelerate?

Nevertheless, the ΛCDM cosmological standard model is doing very well!



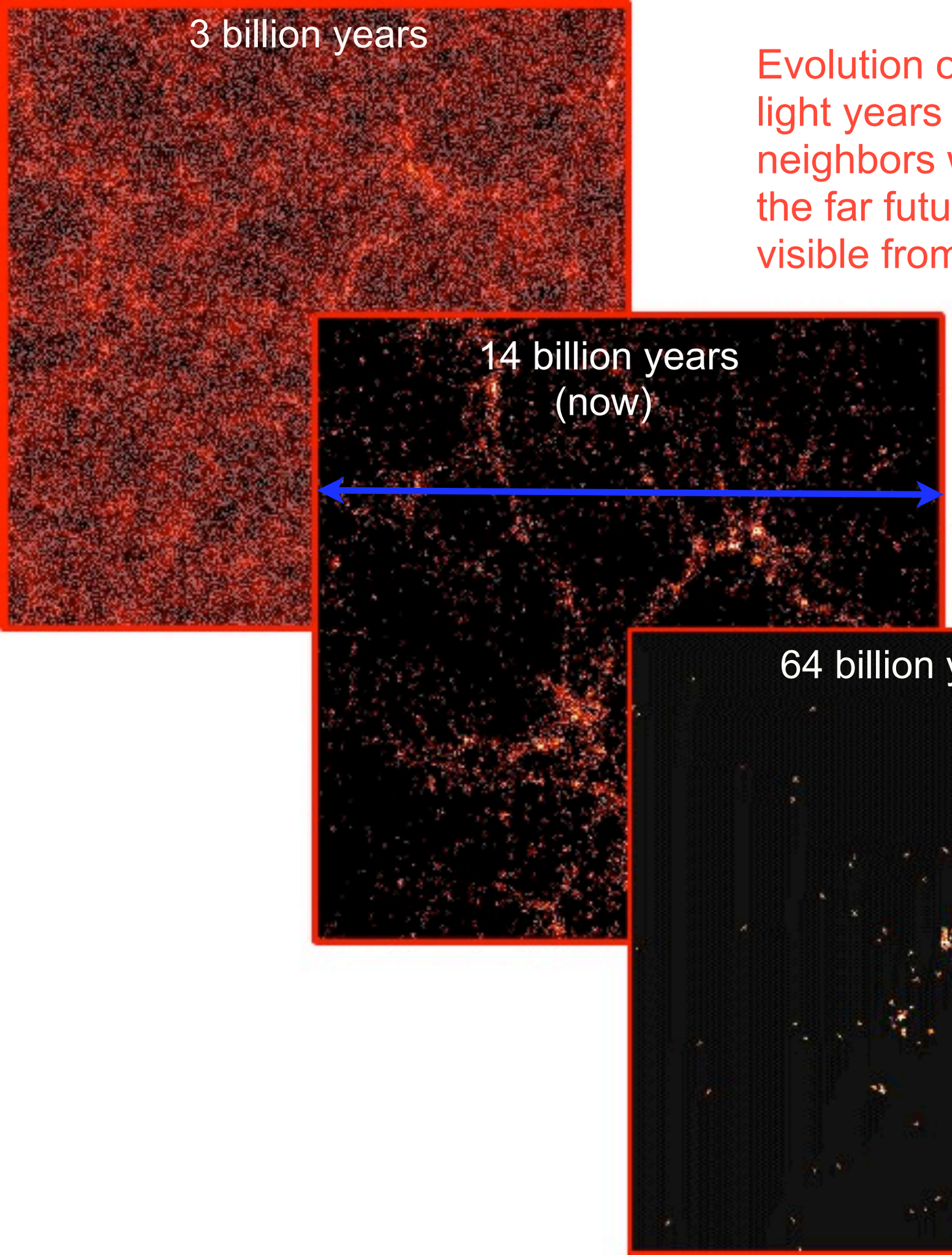
Snapshots of the distribution of dark matter in the universe. The dark energy accelerates the expansion of the universe; the picture in the lower right corresponds to a region seventy times larger than the picture in the upper left.

300 million light years across

same
comoving
size

Michael Busha,
Risa Wechsler,
Fred Adams &
Gus Evrard

Evolution of a fixed physical region 300 million light years across. Only our immediate neighbors will be gravitationally bound to us in the far future; fewer and fewer objects will be visible from our Galaxy.



300 million light years across

same
physical size

FUTURE EVOLUTION OF COSMIC STRUCTURE IN AN ACCELERATING UNIVERSE

MICHAEL T. BUSHA, FRED C. ADAMS[1], RISA H. WECHSLER, AND AUGUST E. EVRARD[1]
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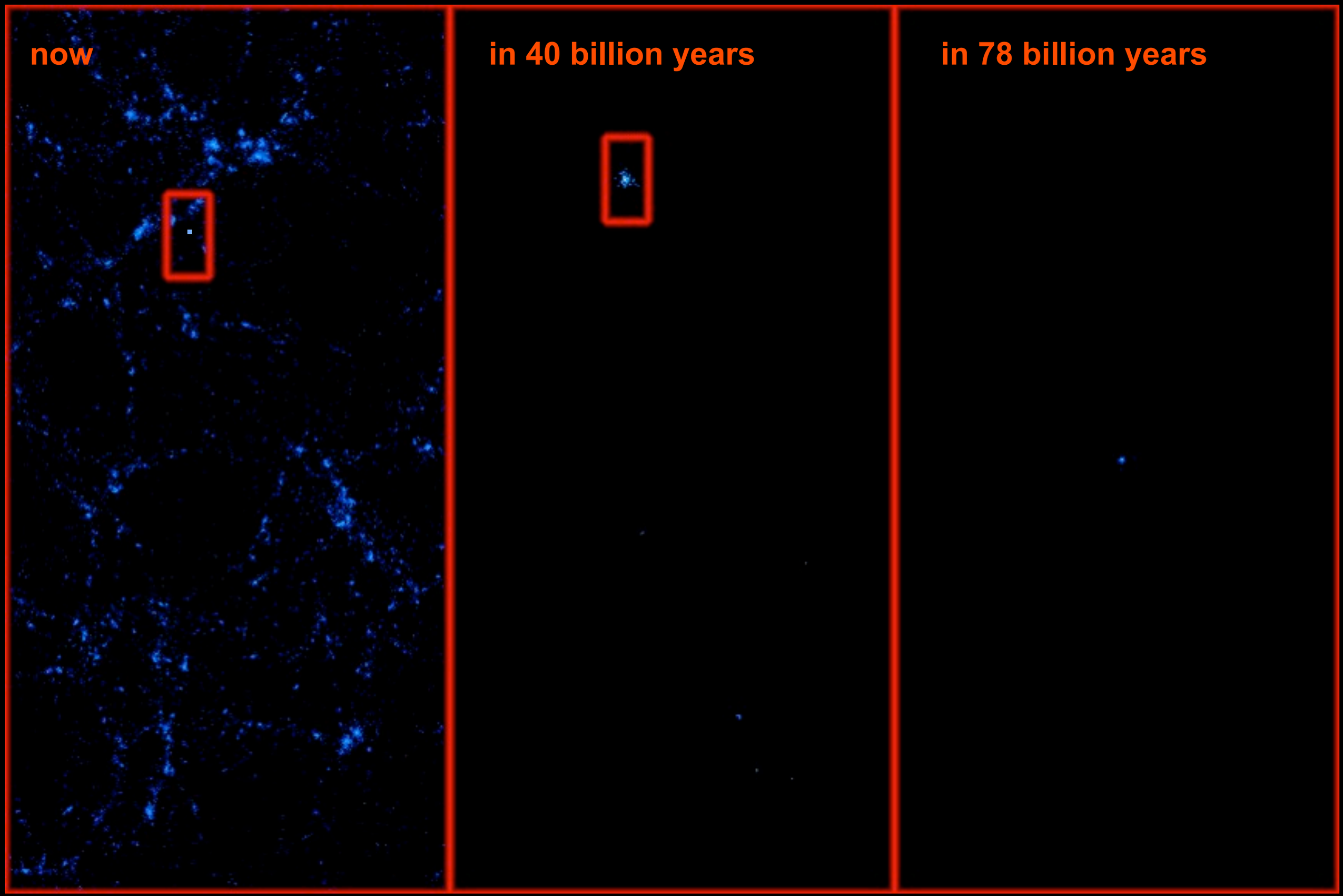
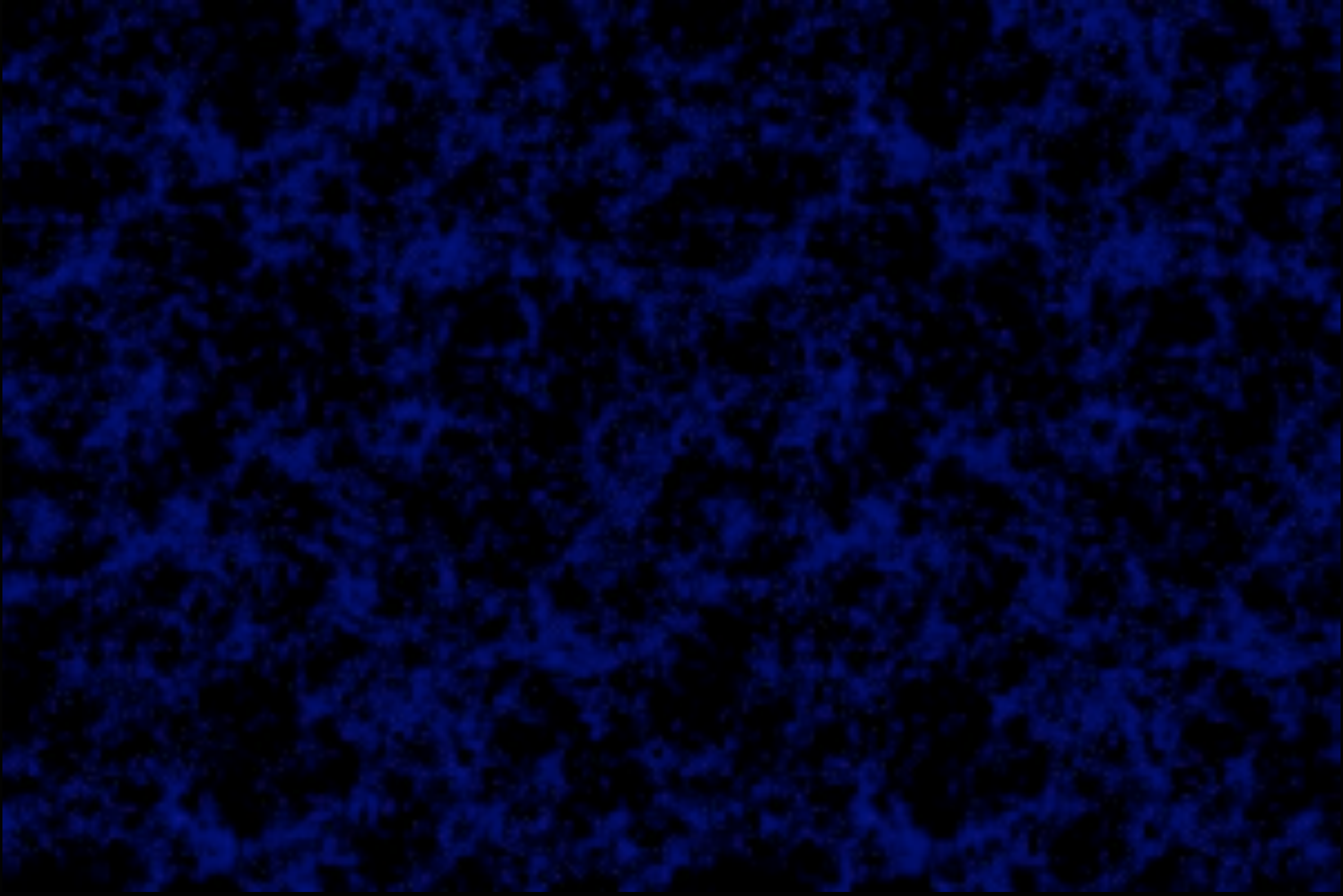
TIME SCALES AND SCALE FACTORS

Event	*Time* τ (Gyr)	$a(\tau)$
Time scale for scale factor to approach exponential form	5.6	–
Inverse Hubble constant H_0^{-1}	14	–
e-folding time of the future universe $(H_0\sqrt{\Omega_{\rm v,0}})^{-1}$	17	–
Current age of the universe	13.7	1
Virgo Cluster leaves our horizon	132	1000
The Local Group grows isolated	180	2×10^4
Exiled stars become isolated	336	2×10^8
Individual particles grow isolated	1060	6×10^{26}
CBR photons stretch beyond the horizon	1120	2×10^{28}
Optical photons stretch beyond the horizon	1260	10^{32}
Lifetime of longest-lived stars	17,000	10^{434}
End of the Stelliferous Era	100,000	10^{2554}

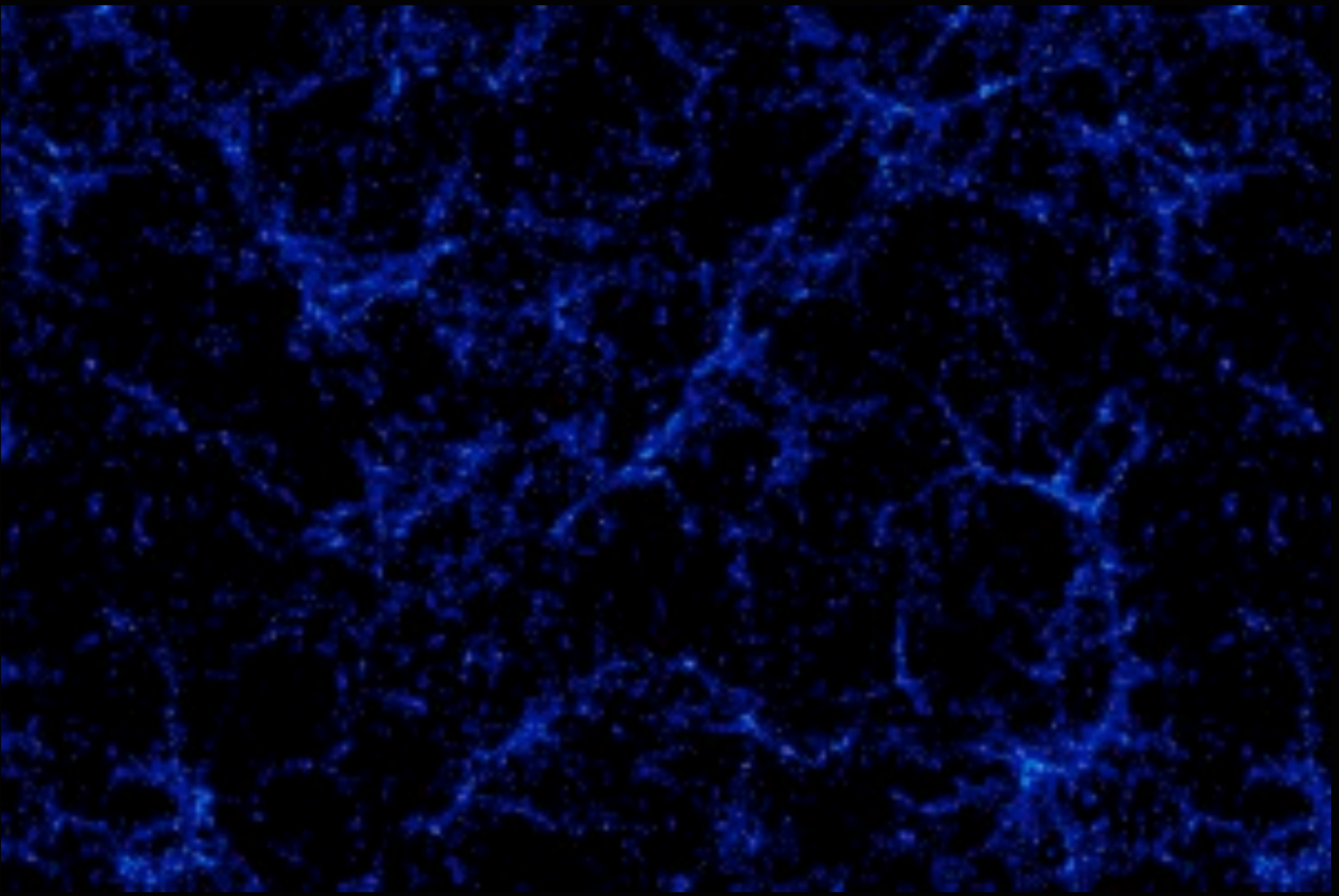
Doubling Time = 12 Gyr (1 Gyr = 1 billion years)

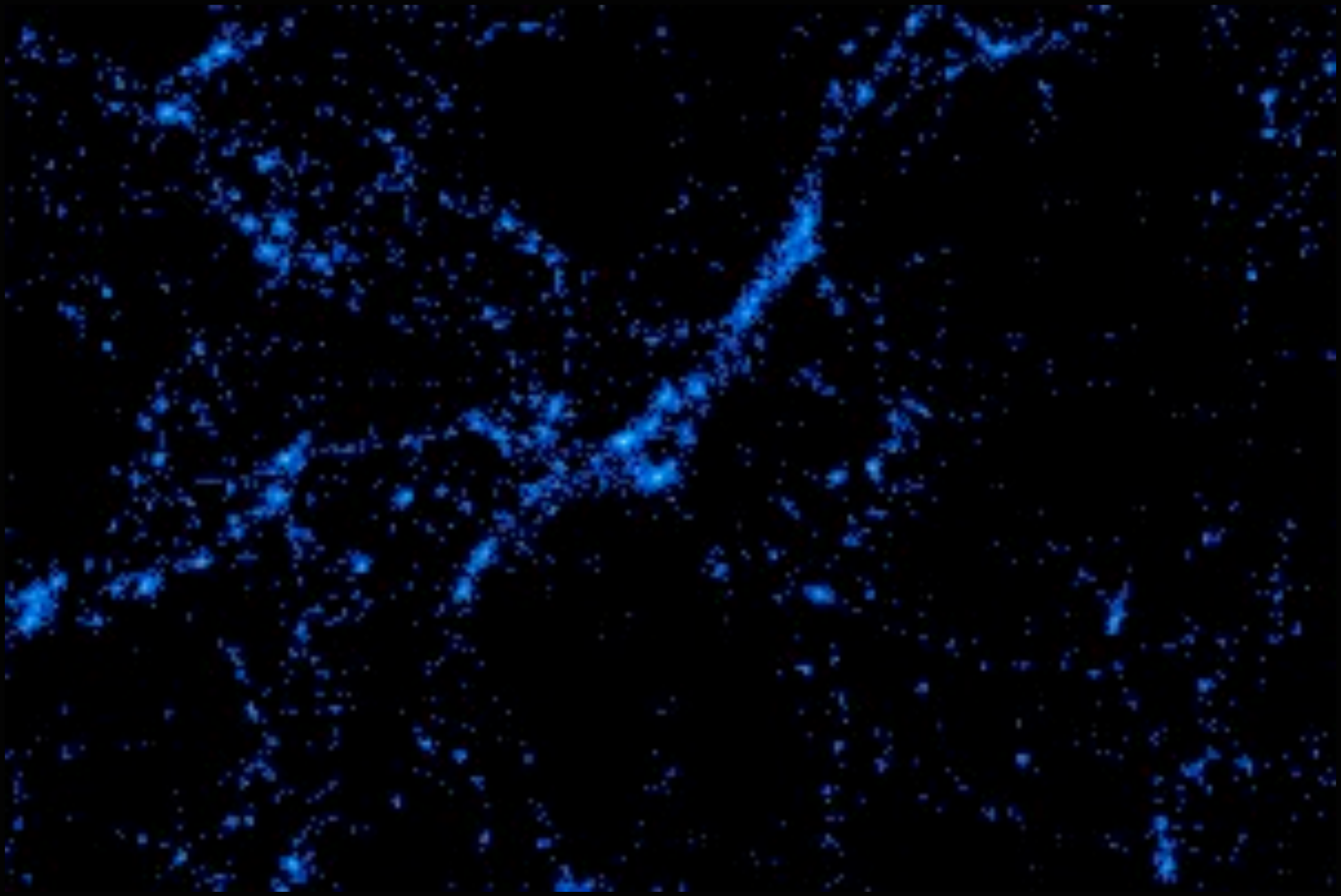
The Double Dark Future of the Universe



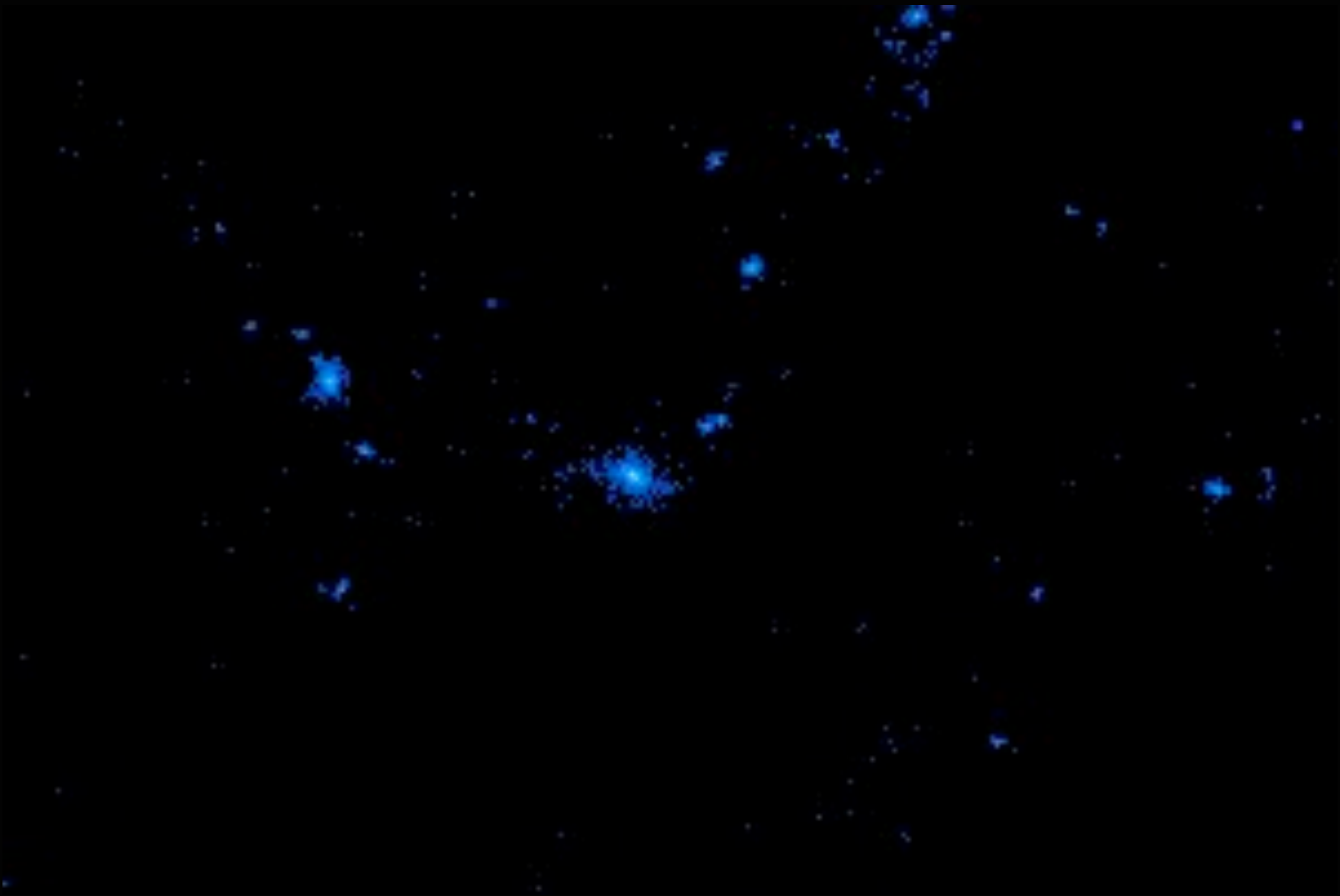


3 Gyr





14 Gyr
(now)

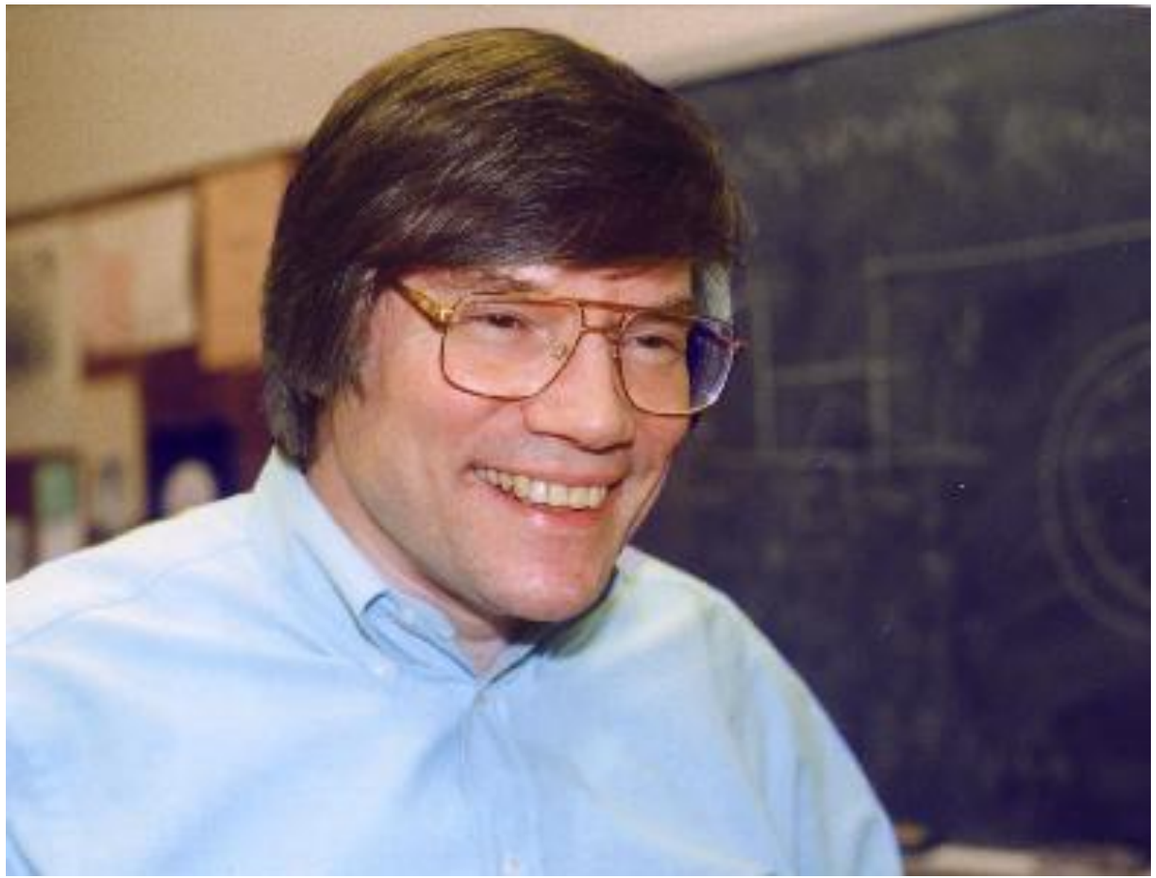


64 Gyr

Cosmic Inflation

If matter after the Big Bang were absolutely evenly distributed, gravity would have done nothing but slow down the overall expansion. Gravity magnifies differences—that is, if one region is ever so slightly denser than average, it will expand slightly more slowly and grow relatively denser than its surroundings, while regions with less than average density will become increasingly less dense. Consequently, in order to make galaxies in some places and voids in others, gravity must have had some differences in density to work with from the beginning.

What could have caused these differences in density? The theory of **Cosmic Inflation** was proposed in the early 1980s by Alan Guth and others to answer this question.



Cosmic Inflation

says that for an extremely small fraction of a second before the Big Bang—much less time than it would take light to cross the nucleus of an atom—the universe expanded exponentially, inflating countless random quantum events in the process. The density differences in the universe reflect these quantum events, enormously inflated. This is the only theory cosmologists have for the origin of the needed density differences that is consistent with the cosmic background radiation data. It also is the only explanation we have for the fact that the temperature of the cosmic background radiation itself is so uniform. All the predictions of Cosmic Inflation theory that we have so far been able to test have been confirmed.

Inflation is exponential growth—the longer it goes on, the faster it gets. A story told by physicist George Gamow in his book One, Two, Three … Infinity *illustrates its blinding speed:*

An Indian King wanted to reward his Grand Vizier for inventing the game of chess. Overwhelmed with gratitude, the King asked him to choose his reward.

"You may give me one grain of wheat to place on the first square," said the Grand Vizier, "two grains on the next square, four on the next, eight on the next, and so on. That would be enough."

"Such a modest gift for so great an act?" the King exclaimed. "You shall have it today!"

But when the King tried to prepare the chessboard, he discovered that the amount of wheat needed grew faster and faster. By the sixty-fourth square, he would need about a trillion metric tons—a thousand years' worth of the modern world's production of wheat.

DOUBLING

$2^{10} = 1024 \approx 1000 = 10^3 =$ Thousand

So…

$2^{10} \approx 10^3 =$ Thousand

$2^{20} \approx 10^6 =$ Million

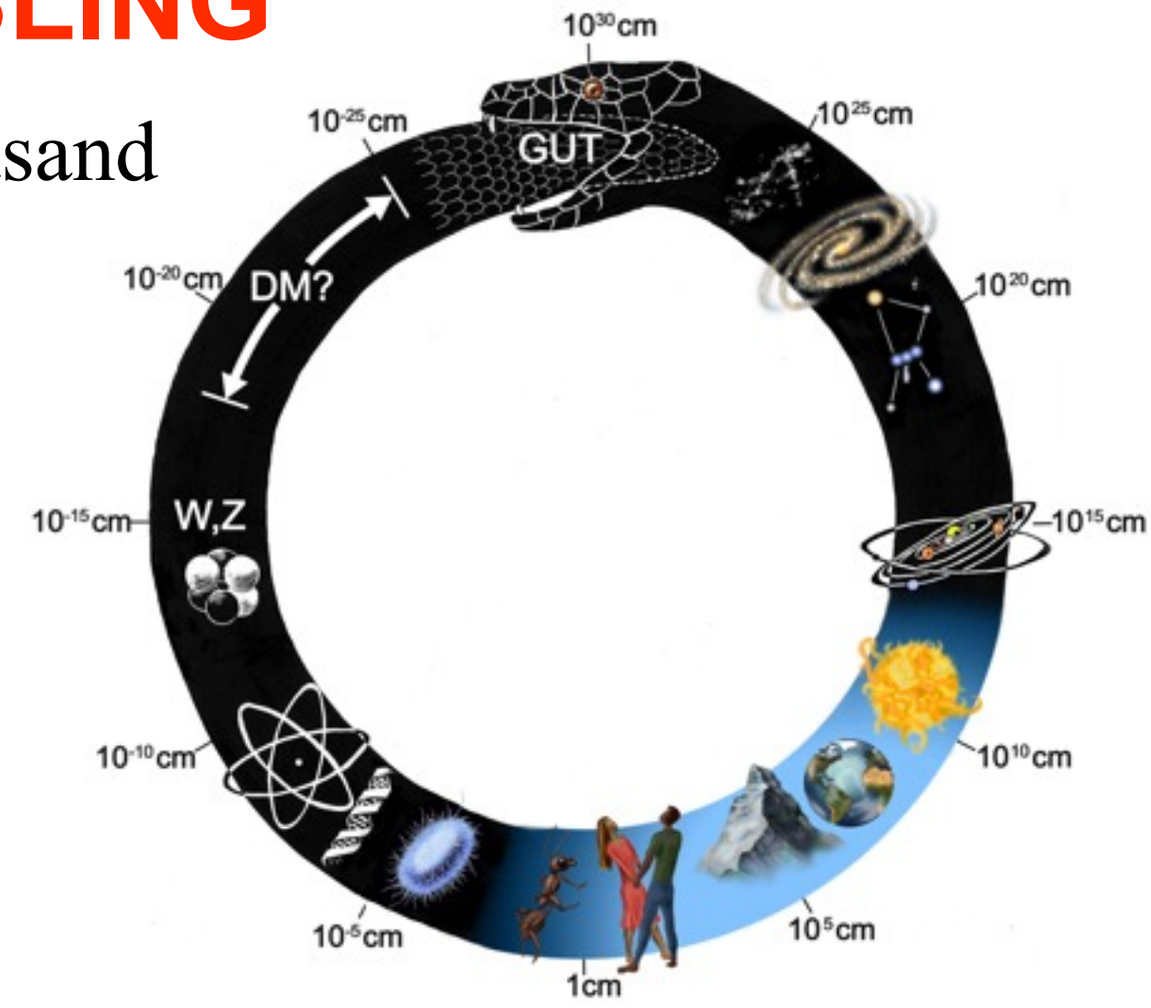
$2^{30} \approx 10^9 =$ Billion

$2^{40} \approx 10^{12} =$ Trillion

$2^{50} \approx 10^{15} =$ Quadrillion

$2^{60} \approx 10^{18} =$ Quintillion

etc.



The current population of the world is

$6 \times 10^9 = 1.5 \times 4 \times 10^9 = 1.5 \times 2^2 \times 2^{30}$

$= 1.5 \times 2^{32}$

The number of grains of wheat on the grand vizier's chessboard is

$2^{64} = 2^4 \times 2^{60} = 16 \times 10^{18} \approx 10^{19}$

Three chessboards is almost all the way around the Uroboros

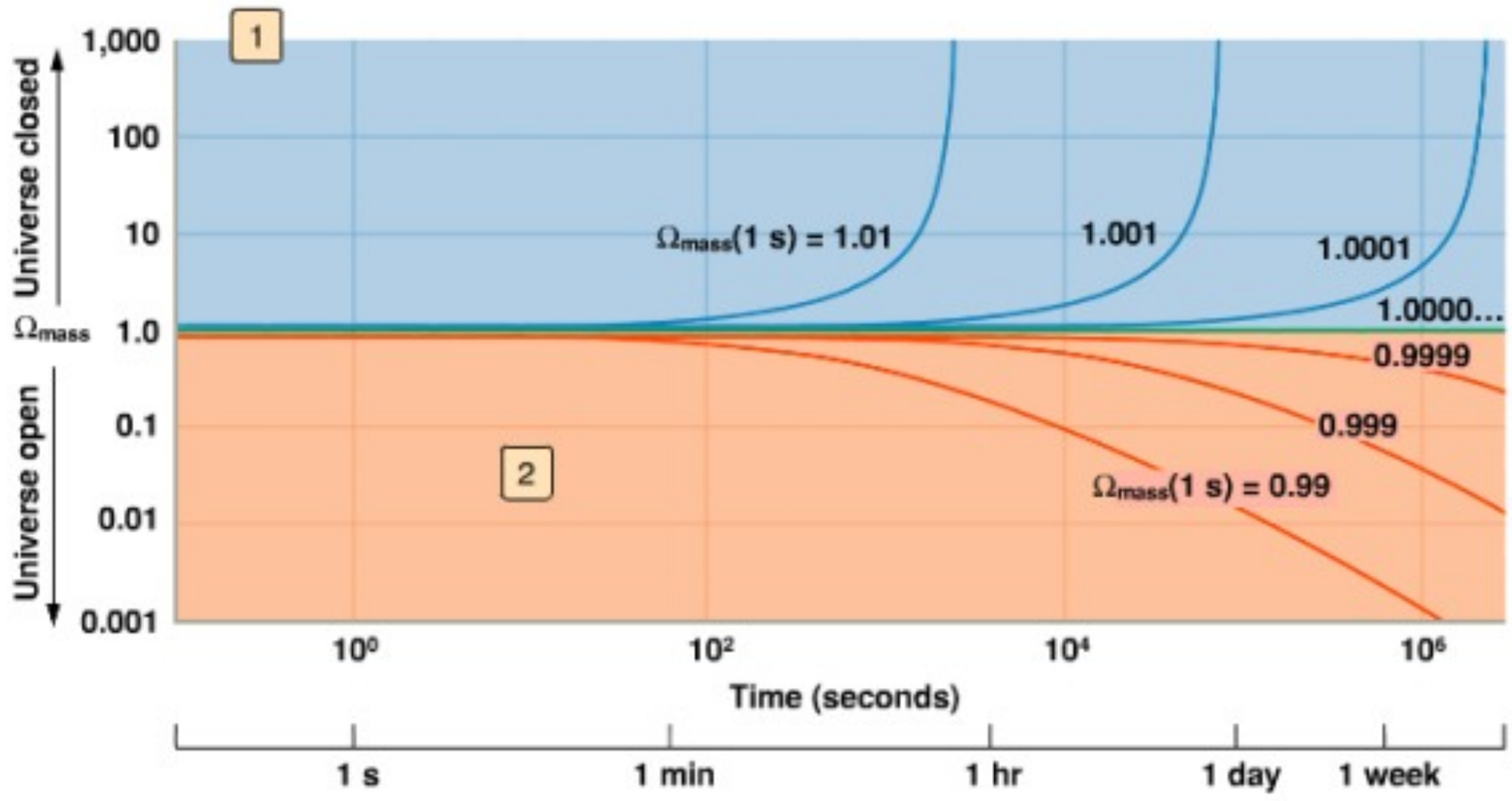
Cosmic Inflation

Cosmic Inflation is exponential expansion caused by "dark energy"

Big Bang problems that Inflation can solve:

1. Flatness: Why is $\Omega_{tot}=1$ so precisely?

If $\Omega_{tot}=1\pm\varepsilon$ at an early time (here ε means a small number), then Ω_{tot} increasingly deviates from 1



2. Horizon: why is the CMB temperature so uniform?
3. Absence of magnetic monopoles and other "dragons"?
4. Origin of fluctuations on super-horizon scales at early times?

Cosmic Inflation Summary

	Problem Solved	
1.	Horizon	Homogeneity, Isotropy, Uniform T
2.	Flatness/Age	Expansion and gravity balance
3.	"Dragons"	Monopoles, doman walls,... banished
4.	Structure	Small fluctuations to evolve into galaxies, clusters, voids

Cosmological constant $\Lambda > 0 \Rightarrow$ space repels space, so the more space the more repulsion, $\Rightarrow$ de Sitter exponential expansion $a \propto e^{\sqrt{\Lambda}t}$.

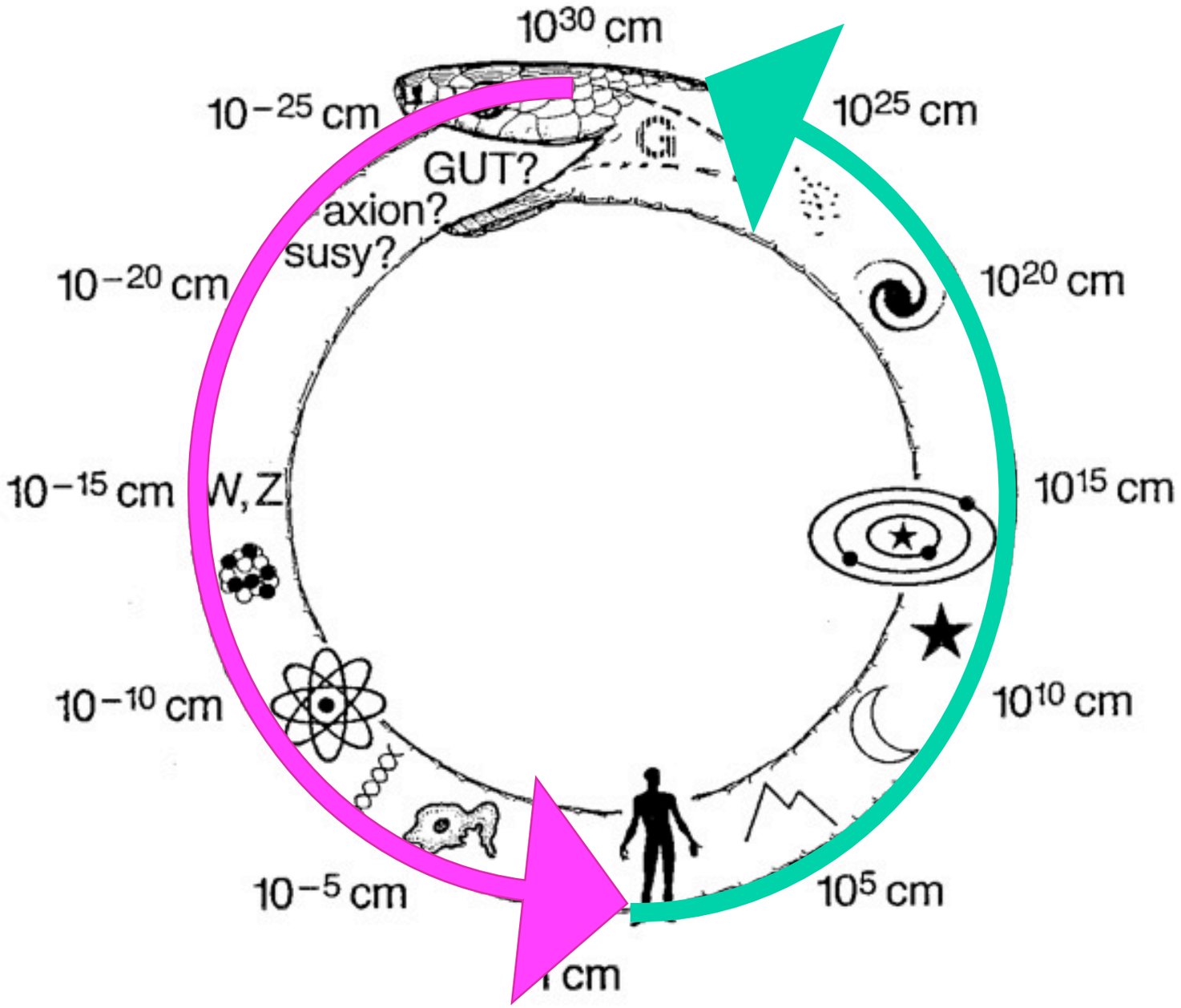
Inflation is exponentially accelerating expansion caused by effective cosmological constant ("false vacuum" energy) associated with hypothetical scalar field ("inflaton").

	Forces of Nature	**Spin**
Known	Gravity	2
Known	Strong, weak, and electromagnetic	1
Goal of LHC	Mass (Higgs Boson)	0
Early universe	Inflation (Inflaton)	0

Inflation lasting only $\sim 10^{-32}$s suffices to solve all the problems listed above. Universe must then convert to ordinary expansion through conversion of false to true vacuum ("re-"heating).

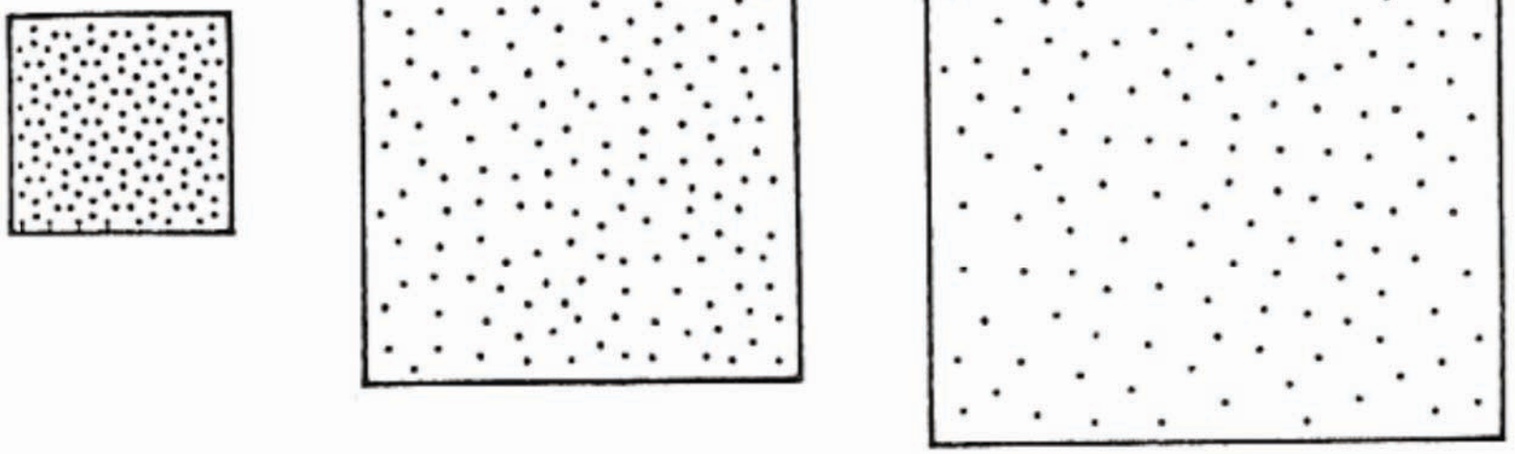
Cosmic Inflation

According to Cosmic Inflation theory, the entire visible universe was once about 10^{-30} cm in size. Its size then inflated by a factor of about 10^{30} so that when Cosmic Inflation ended (after about 10^{-32} second) it had reached the size of a baby. During its entire subsequent evolution, the size of the visible universe has increased by only about another factor of 10^{28}.



ORDINARY EXPANSION

density of matter + energy decreases



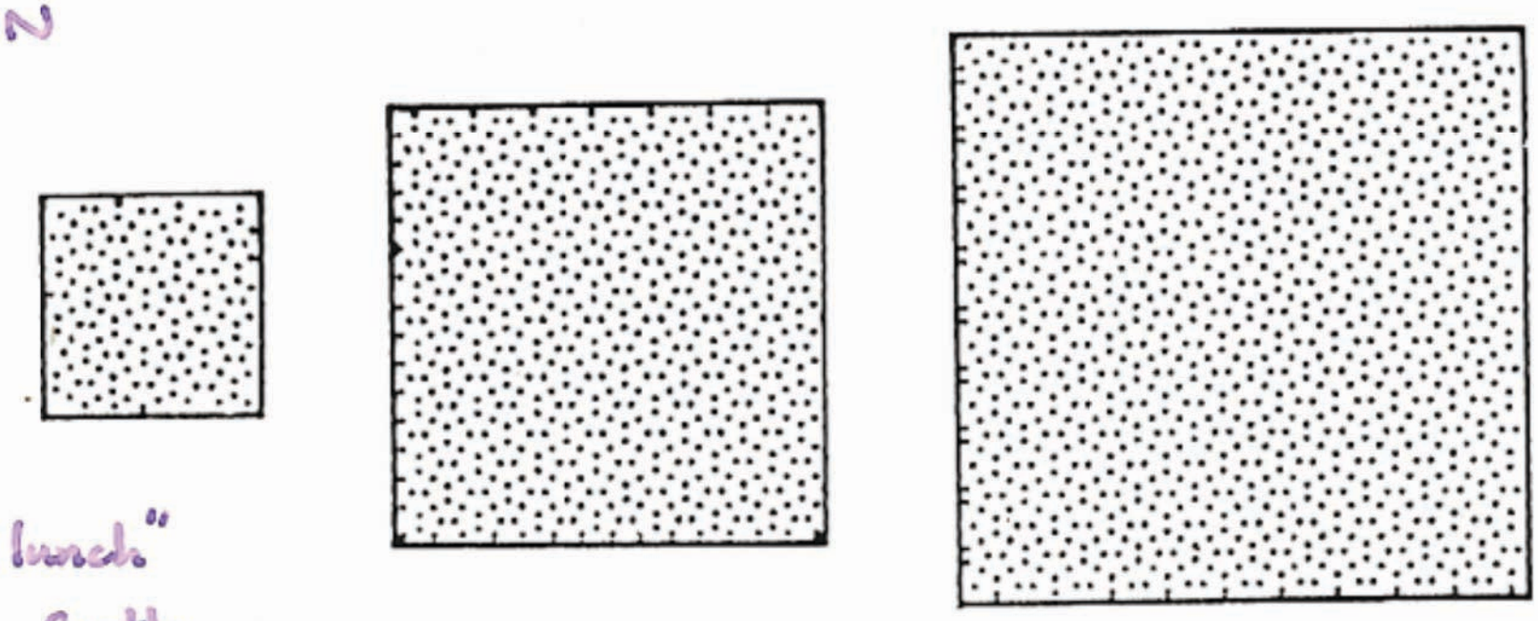
BIG BANG

INFLATION

density constant!

FAST!

"ultimate free lunch"
Guth



STEADY STATE

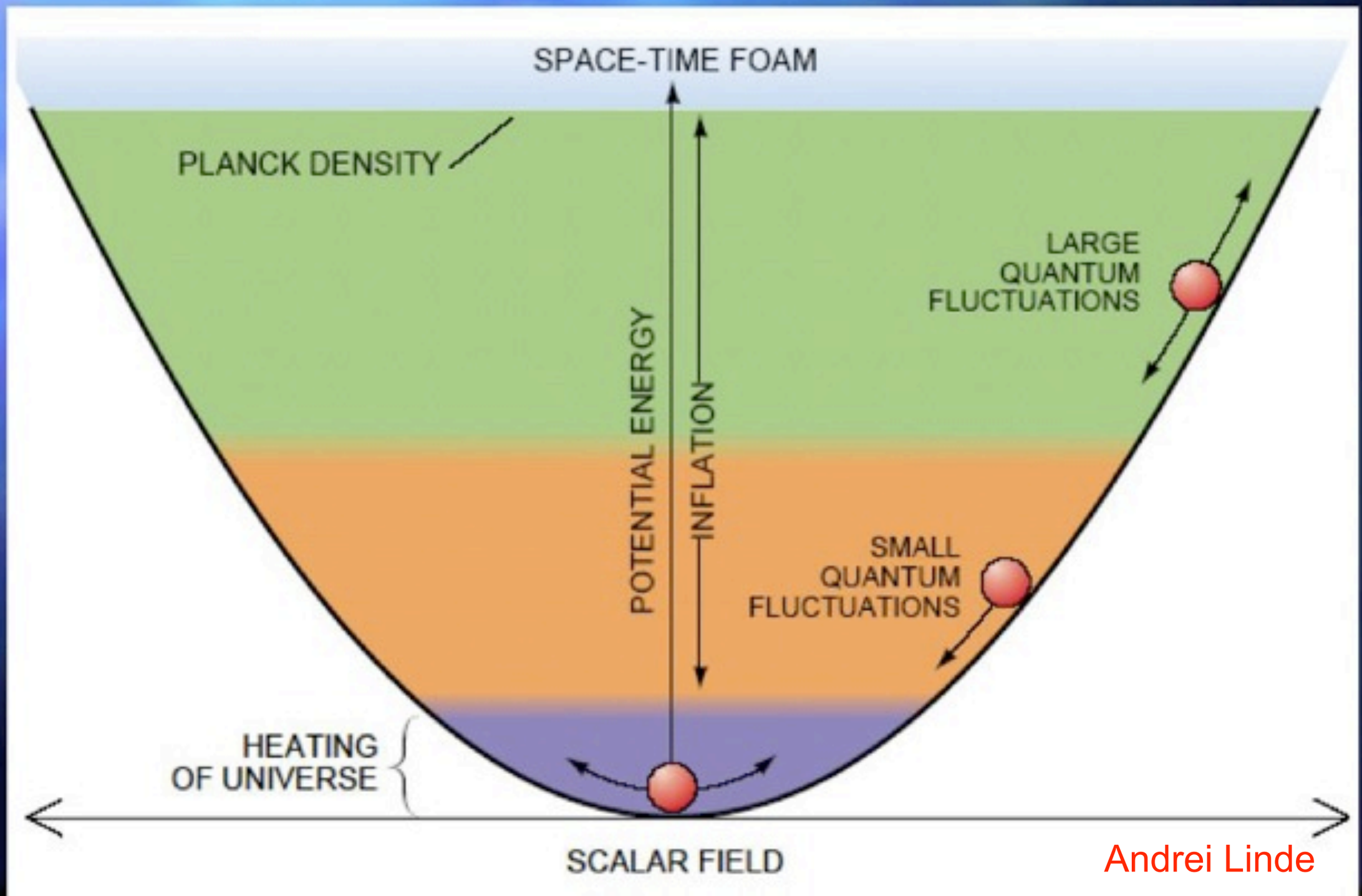
What Happened Before Cosmic Inflation?

While Cosmic Inflation provides an explanation for both the smoothness and the irregularities in the Big Bang, what about the origins of inflation itself? If we extrapolate backwards to find the origin of inflation, the most likely possibility is that in most of the superuniverse, inflation never stopped. It is a state of existence that goes on forever. The theory of **Eternal Inflation** was largely worked out

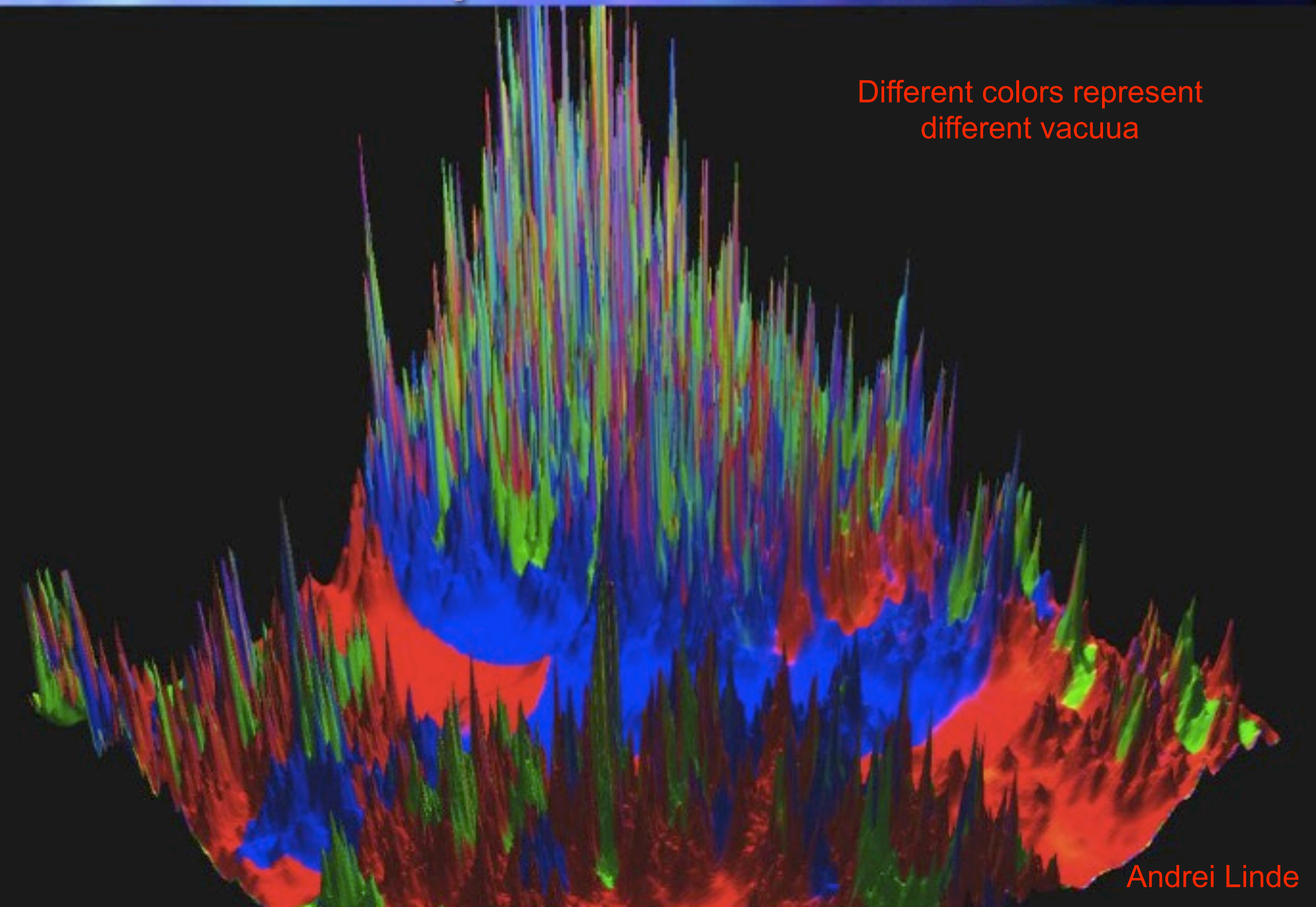
by Russian astrophysicist Andrei Linde, now at Stanford University. The theory says that inflation stopped only in the minute part of the universe we can see—within our cosmic horizon—and some unknown distance beyond that. Almost everywhere else it continues forever, eternally creating Big Bangs.

Inflation as a theory of a harmonic oscillator

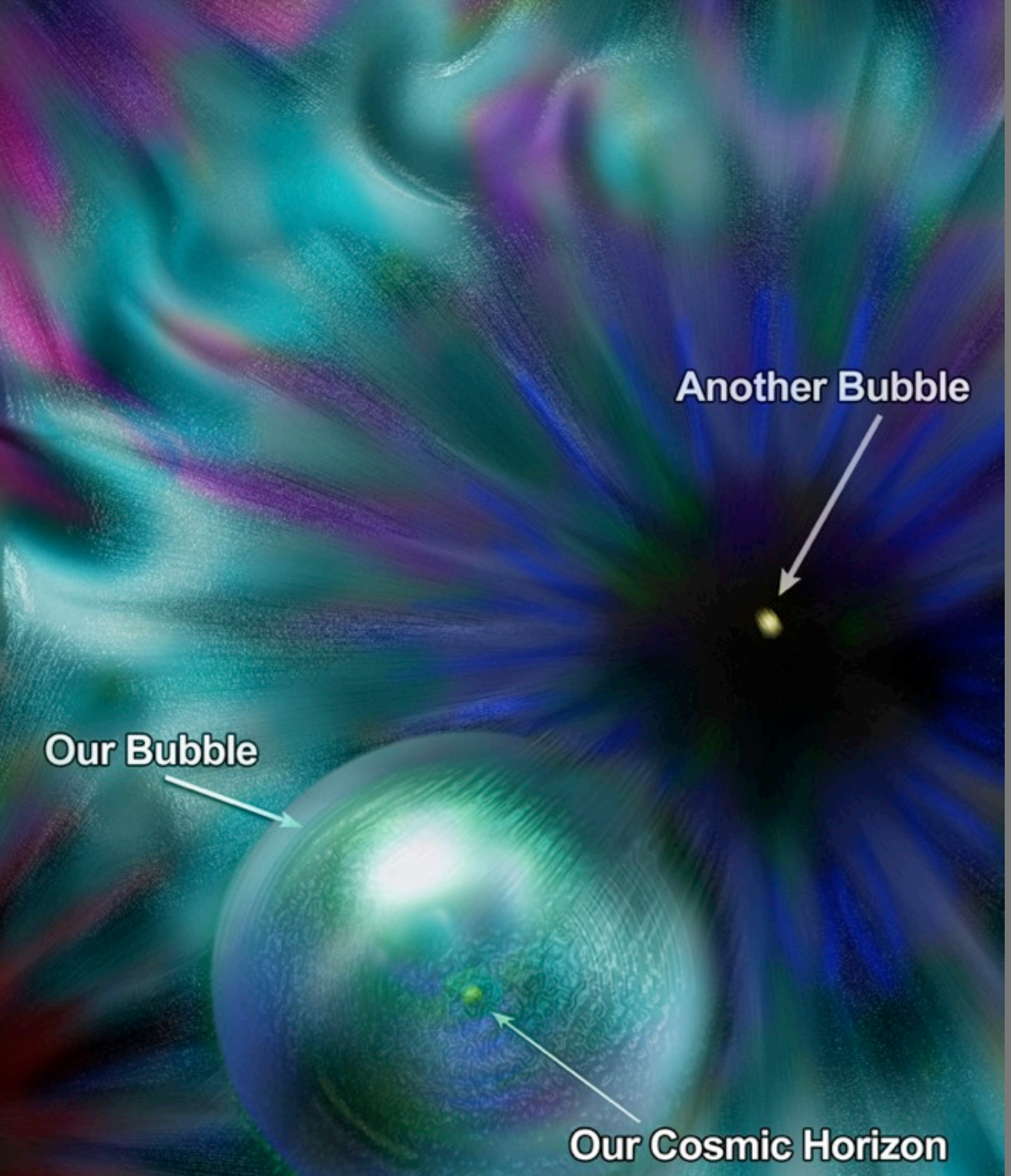
$$V(\phi) = \frac{m^2}{2}\phi^2$$



Landscape of eternal inflation



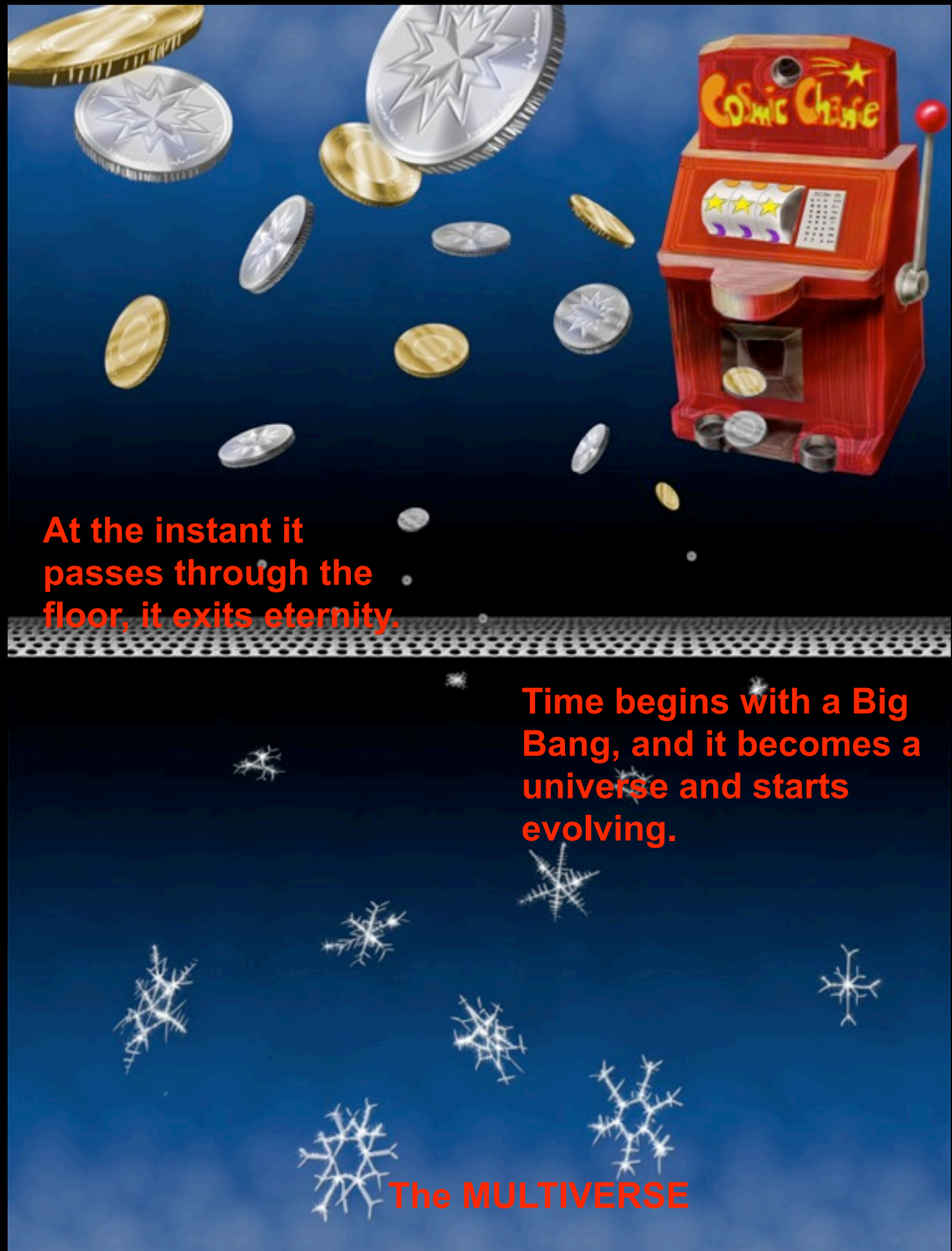
OUR COSMIC BUBBLE IN ETERNAL INFLATION



THE COSMIC LAS VEGAS

Coins constantly flip. Heads means the coin doubles in size *and* there are two of them. Tails means the coin shrinks to half its size.

Consider a coin that has a run of tails. It becomes so small it can pass through the grating on the floor.



Implications of Eternal Inflation?

The English astronomer Fred Hoyle and others proposed in the late 1940s that the universe is unchanging in time, a "Steady State" cosmology. This was ruled out when galaxies were observed to change at higher redshifts, and by the Cosmic Background Radiation. Eternal Inflation is the old Steady State cosmology on a grander scale!

Do all the "Bubbles" have the same laws of physics and the same numbers of dimensions of space? Or are there many possibilities, with intelligent life arising in only the most favorable ones? (This is sometimes called "anthropic cosmology.")

Freud said that Copernicus had shown that the earth is not the center of the universe, that Darwin had shown that we are just intelligent apes, and that he had shown that our reason is only a small part of what happens in our heads. Dark matter is another displacement of humans from the center of the universe. But maybe Eternal Inflation puts us back in a special place, since most of the superuniverse is undergoing inflation.

Anthropic Cosmological Principle

The term "anthropic principle" was first proposed in 1973 by Brandon Carter during the celebration of Copernicus's 500th birthday, as if to proclaim that humanity does hold a special place in the universe after all.

Proponents of the anthropic principle suggest that the universe appears to be "fine-tuned" to allow the existence of life as we know it, and that if any of the basic physical constants (h, c, G, e, m_e, m_p, …) were different, then life as we know it would not be possible. The universe we observe must be suitable for the development of intelligent life, for otherwise we could not be here to observe it. There are at least three possibilities:

1. There are indeed many universes with different laws of physics, and we happen to live in one of the few non-sterile ones.
2. There is only one (or perhaps a few) self-consistent laws.
3. God designed the universe so it would be right for us.

Anthropic Cosmology

Weak Anthropic Argument: The forces of nature must be about as they are for carbon based intelligent life to exist. Here are some "anthropic coincidences":

Strong force: In 1954 Fred Hoyle predicted that an excited state must exist in the nucleus of Carbon-12 in order that the short-lived isotope Beryllium-8 (10^{-17} sec half-life) can react with Helium to make Carbon-12 in stars, necessary so heavier elements (and life) can form. This was subsequently confirmed by experiment. If the strong force were slightly stronger or weaker, neither this requirement, nor the abundance of elements produced in early universe, would be right for life.

Weak force: if weaker, supernovae would not explode, since the neutrinos leaving the core would not transfer enough momentum and energy to the outer layers of the collapsing star; if stronger, the neutrinos would not get out of the core. Moreover, if the weak force (responsible for neutron decay) were weaker, most of the ordinary matter formed in the early universe would have been Helium rather than Hydrogen, stars would burn much faster, and H_20-based life probably could not exist.

Anthropic Cosmology

Electromagnetic force: Terrestrial animals cannot be much bigger than they are, or they would break when they fall because the electrical – i.e., chemical – forces would not be strong enough compared to gravity on a planet the size of earth.

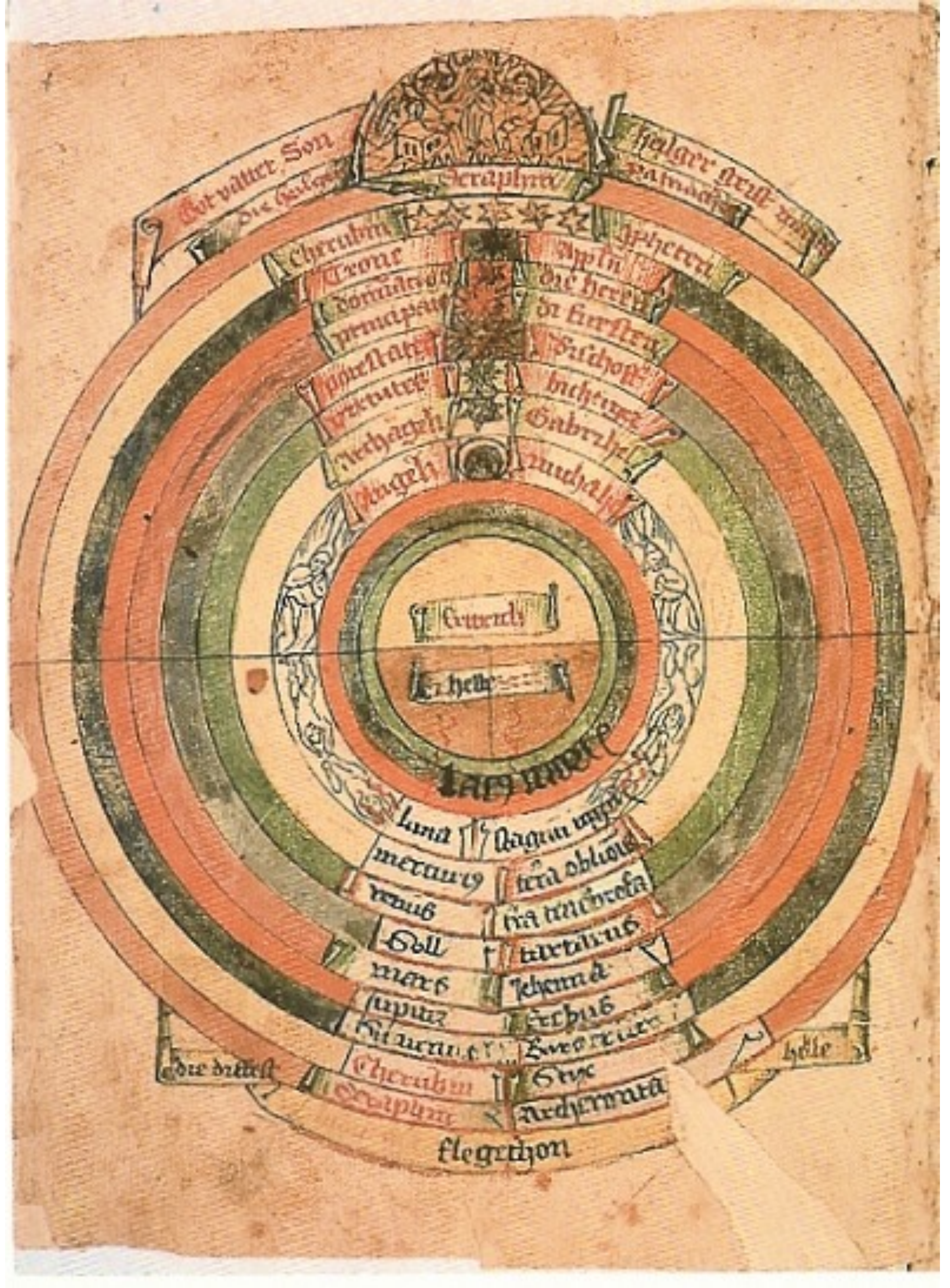
Gravity: For stars, the mass $M \propto G^{3/2}$ while the lifetime $T \propto 1/G$. So if G were 10^{10} times larger, stars would be 10^{-15} as massive (10^{-7} as massive as the moon), and would live about 1 year. They would be about 10^{-5} as bright as the sun, and could support comfortable-temperature planets $10^{-2.5}$ of earth's orbit with a year of about 20 days and the mass of a small asteroid, but creatures on such a planet could not be more massive than about 10^{-3} g (about 10^{3} bacteria) and could hardly be intelligent. Moreover, there would be no time for evolution, since stars would be so close together that near-collisions would tear such planets off in much less than a year. The horizon at the typical stellar lifetime would be only 1 light-year. Our universe is large and diffuse, and allows time for large creatures like us to evolve, because gravity is so weak.

Dimensionality d of space: Stable orbits exist for $1/R^n$ force only for $n = 2 = d-1$, i.e. only for d=3 dimensional space. (Former equality due to Newton; latter, Einstein.)

Inflation and Kabbalah

Medieval Cosmos

The geocentric pre-Copernican Universe in Christian Europe. At center, Earth is divided into Heaven (tan) and Hell (brown). The elements water (green), air (blue) and fire (red) surround the Earth. Moving outward, concentrically, are the spheres containing the seven planets, the Moon and the Sun, as well as the "Twelve Orders of the Blessed Spirits," the Cherubim and the Seraphim. German manuscript, c. 1450.



Kabbalah

"Kabbalah" means "secret tradition." It is the Medieval Jewish mystical tradition. Its origins are uncertain. Although after *Sephir Yetzirah* (3d to 6th century CE) its earliest preserved writings date from the twelfth century, from Provence and later Spain, its adherents believed it derived from the secret Torah given to Moses.

The early Medieval kabbalists were Jews living at the time when Moslem culture was transmitting the philosophy and science of Plato and Aristotle to Europe. Committed to the reality of the infinite and singular God, Jews began applying Greek reasoning to long-standing problems of their religion, especially the question of the nature of God. The kabbalists used every resource they had—not only reason and logic but also poetry, meditation, numerology and mystical experiences—to try to understand the nature of God. They believed that they could learn about God through contemplation of God's relationship to creation. For this reason, they strove to grasp the hidden reality behind the opening words of Genesis.

At that time Moses Maimonides, the Aristotle of Judaism, was teaching that God could only be truly described by negatives: unknowable, incorporeal, unlimited, unchangeable. How, the kabbalists asked, could God be beyond human description yet walk with Adam and Eve and talk with Abraham and Moses, as Torah reports? How, if God is infinite, could there have been room for anything else to be created? In answer to questions like these, the kabbalists developed a theoretical system portraying God pictorially as having ten different aspects—in Hebrew, sephirot—with complex relationships among all the aspects. Beyond the picture was Ein Sof, "Without End," the unknowable God, which emanated the light that created the aspects of God knowable to humans.

Kabbalistic Version of Medieval Cosmos

God

Surrounds

the

Created

World

Kabbalah

Origins unknown:

Legend – handed down orally to Moses with the Ten Commandments

First written source (*Sephir Yetzirah*) 3d to 6th century CE

Hebrew letters were the material from which God created world

Done by living numbers, beings like angels – Sephirot

In tradition of Pythagorean number mysticism

1280: *Zohar*, by Moses de Leon attributed to 2nd century Rabbi Shim'on bar Yohai

Describes the "emanations" of God that allowed him to create world

Big question: what is the hidden meaning of the creation stories of Genesis?

Reason: can only know God through his creation.

By describing the emanations, Kabbalists ordered the Sephirot into a system and revealed the ladder by which God had descended into human life and which humans could ascend toward God, according to Daniel Matt, who is making a new translation of *Zohar*.

Dan Matt: Kabbalah is "the revenge of myth" – reminiscent of ancient theogonies

Kabbalah Timeline

~200-600 CE *Sephir Yetzirah* (first Kabbalistic writing)

1280 *Zohar*, by Moses de Leon, but attributed to 2nd century Rabbi Shim'on bar Yohai

1492 Jews expelled from Spain
1543 Copernicus publishes De Revolutionibus; Moses Cordovero building mystical community of Safed in Palestine
1570 Cordovero teaches Isaac Luria for one year, then dies
1570-1572 Luria teaches in Safed
1571 Kepler born in Germany
1572 Luria dies at 38. His students keep his teachings secret for a generation

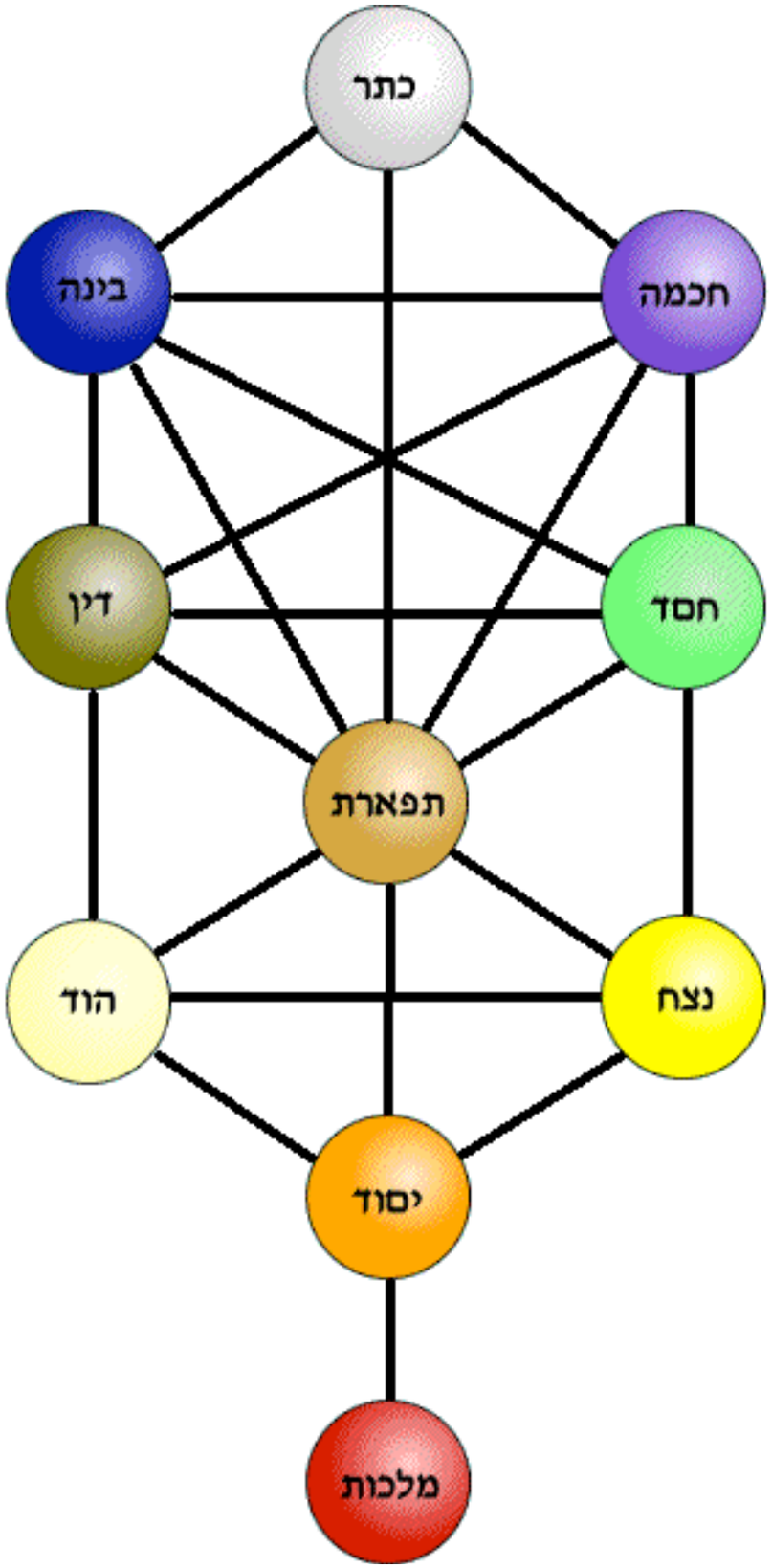
The great Kabbalist Isaac Luria asked how the process of emanation started. God filled existence, so He had to withdraw to make space for the world. By injecting concept of "space" into the story, Luria began to tie metaphorical cosmology to the physical world – as it was understood in the Middle Ages.

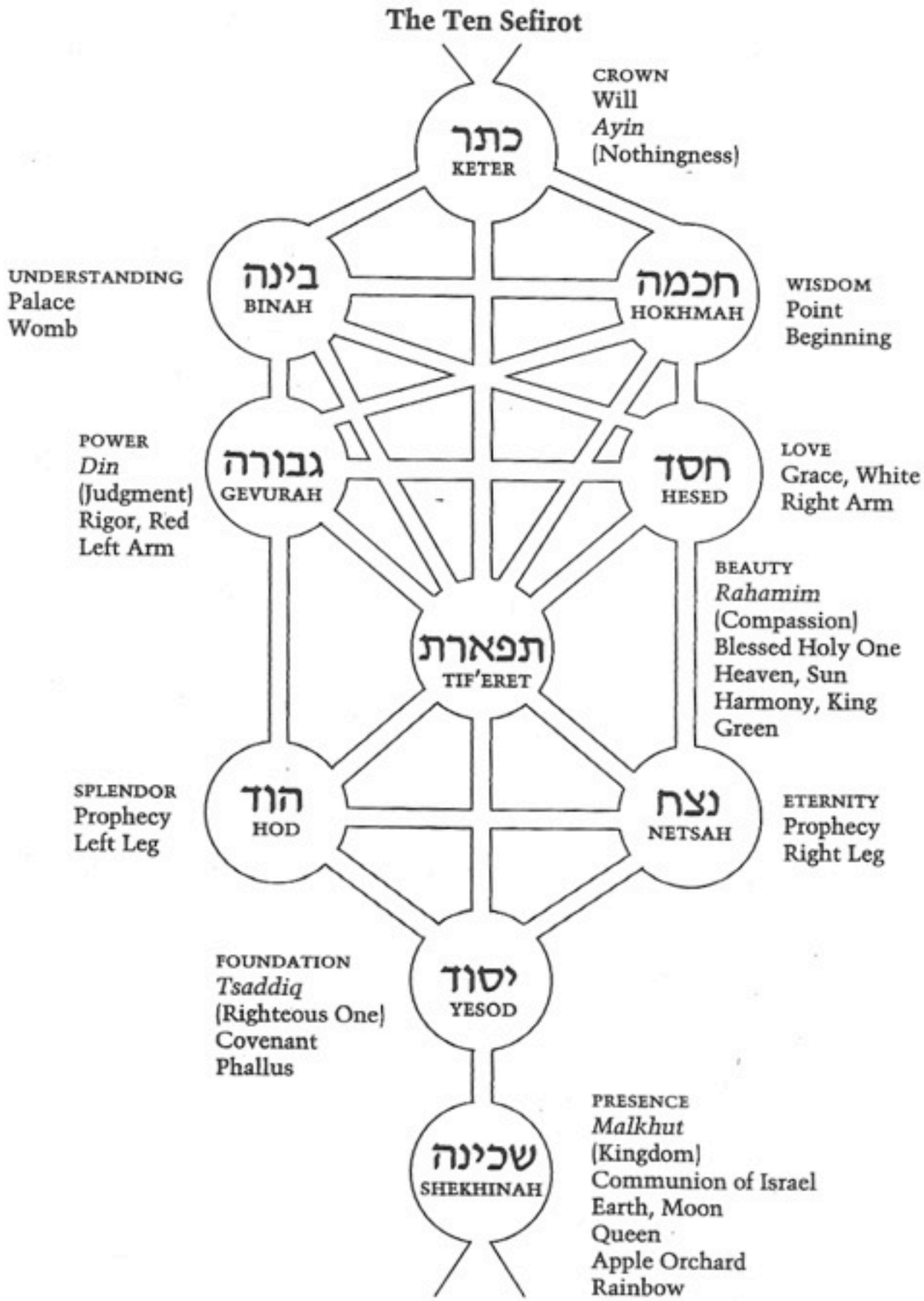
Main ideas: Tzimtzum (contraction)
Shevirah (shattering of vessels)
Tikkun Olam (repair of the world)

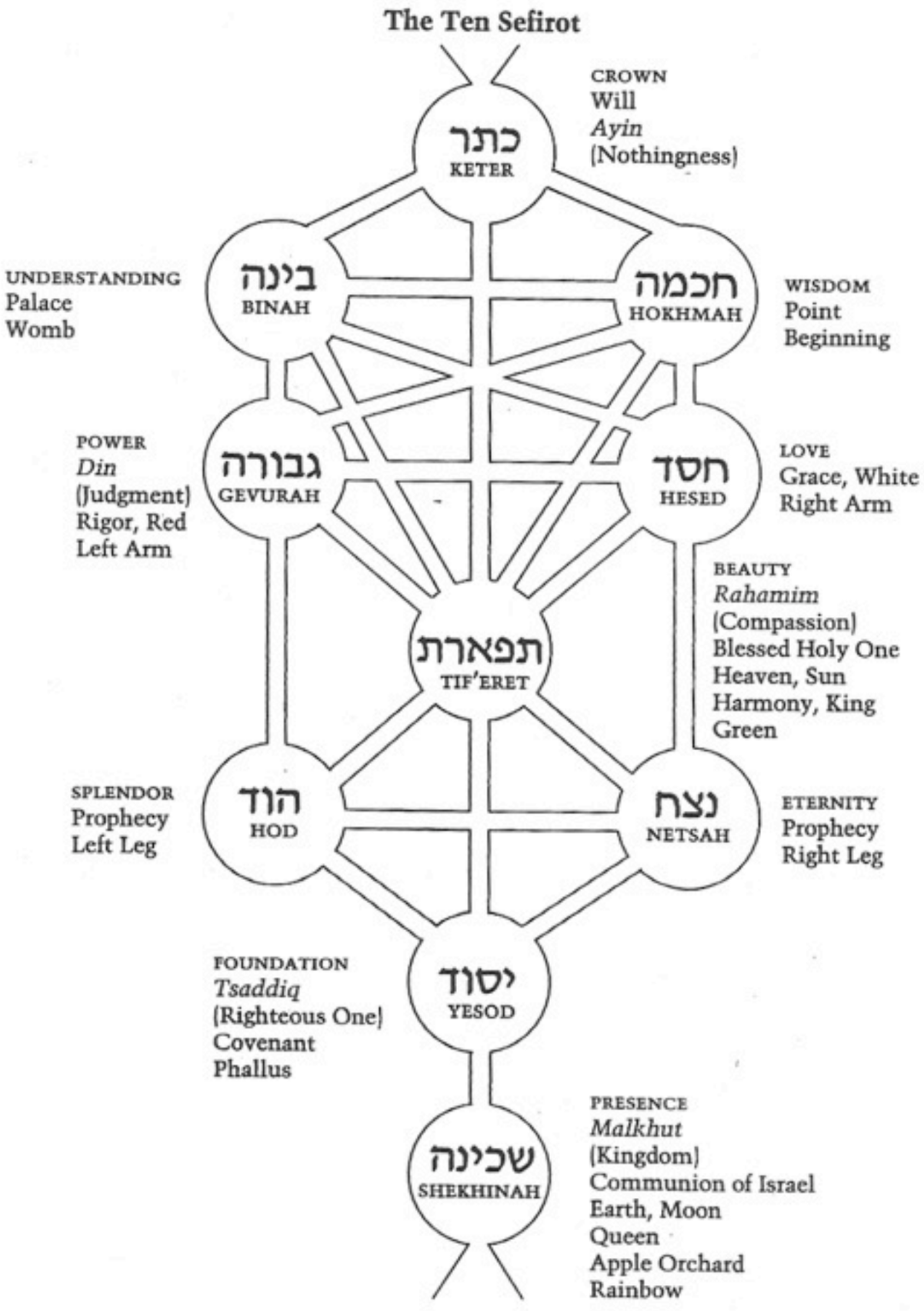
According to Gershom Scholem, the great 20th century scholar of the history of Kabbalah, the result was that cosmology was connected to Jewish culture:

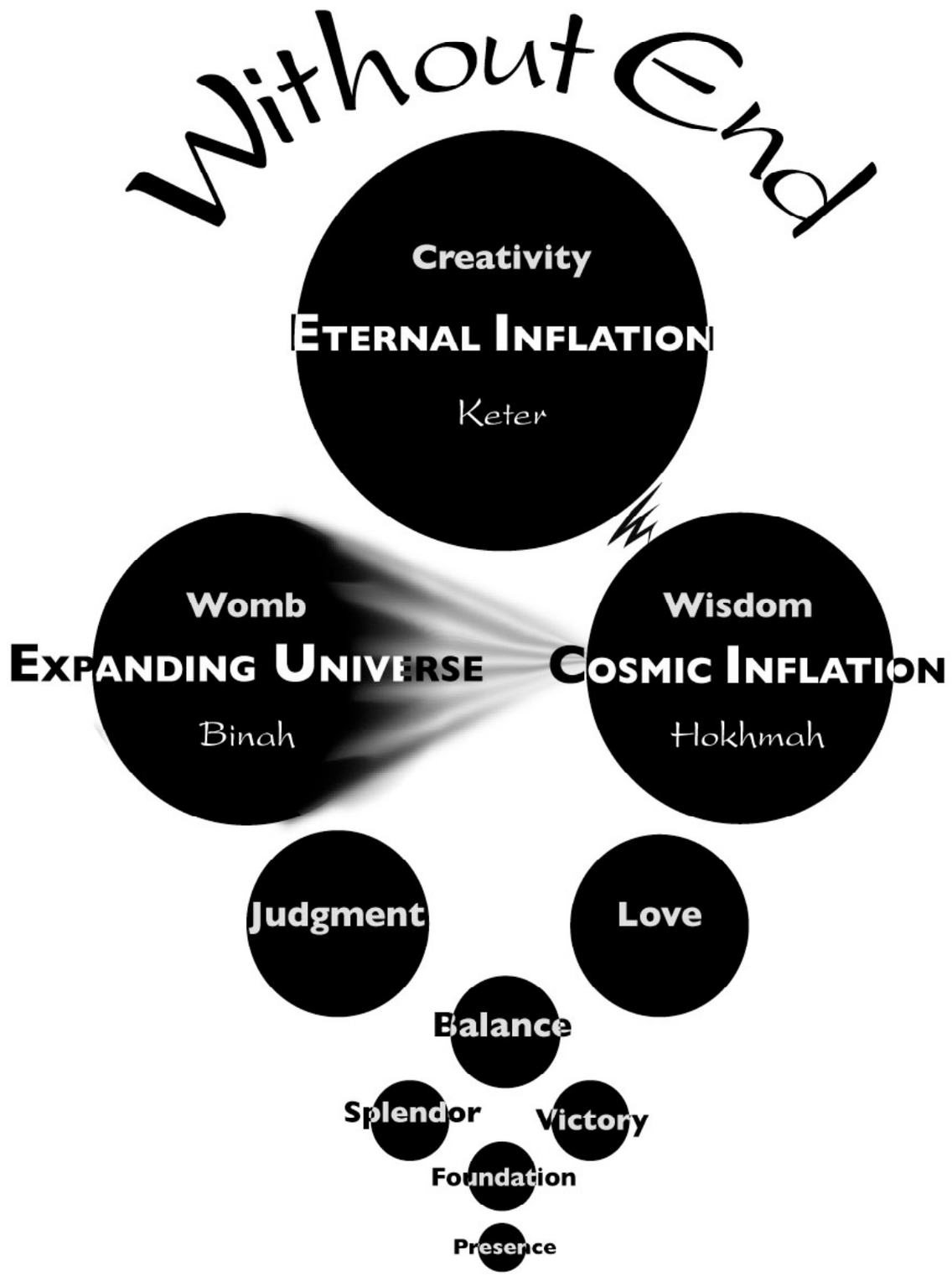
a) God was in exile, like the Jews
b) The Jews' purpose derived from cosmology: to repair the world

(Other scholars disagree with this interpretation.)

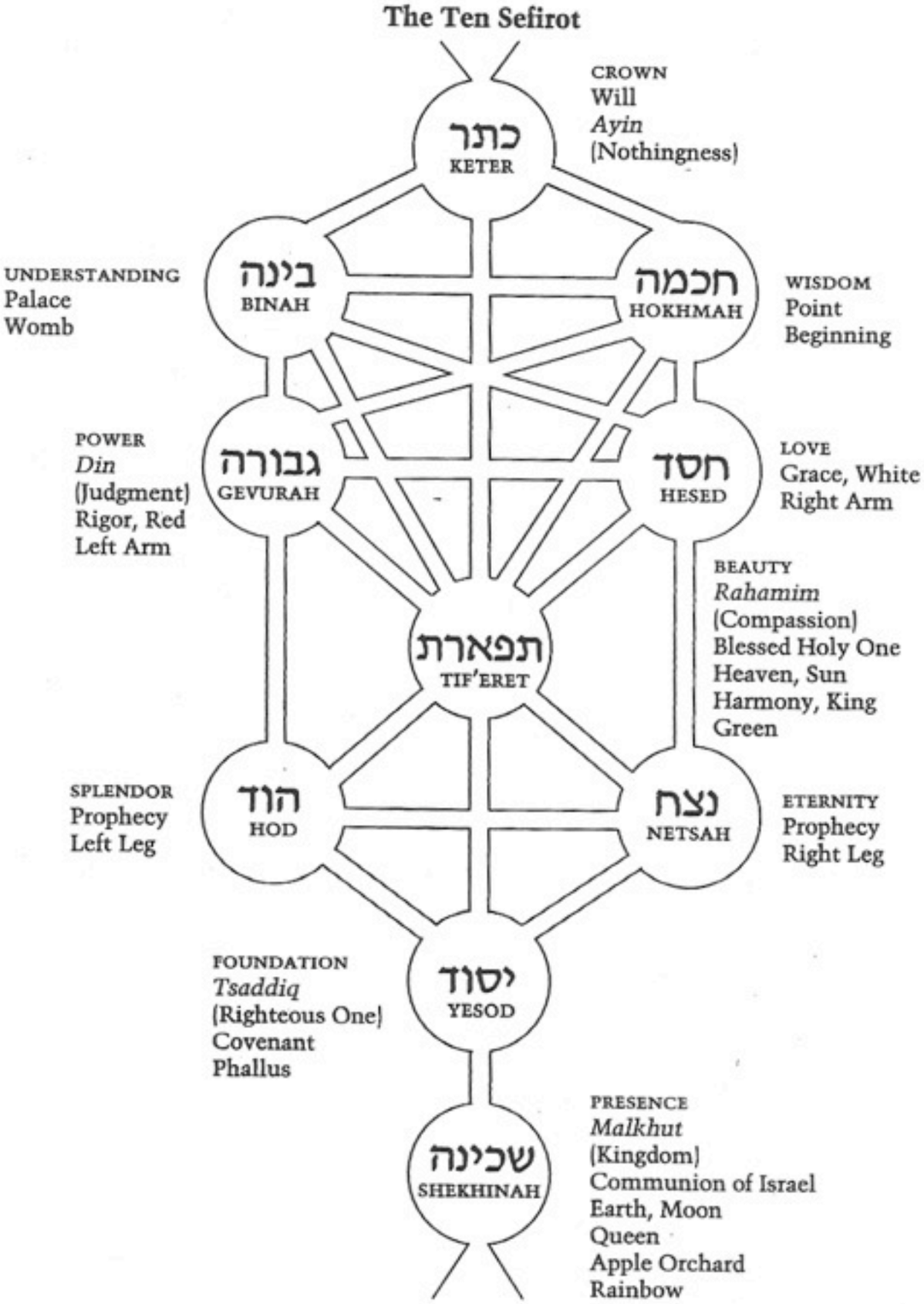

כתר
בינה
חכמה
דין
חסד
תפארת
הוד
נצח
יסוד
מלכות


The Ten Sefirot
כתר
KETER
CROWN
Will
Ayin
(Nothingness)
בינה
BINAH
UNDERSTANDING
Palace
Womb
חכמה
HOKHMAH
WISDOM
Point
Beginning
גבורה
GEVURAH
POWER
Din
(Judgment)
Rigor, Red
Left Arm
חסד
HESED
LOVE
Grace, White
Right Arm
תפארת
TIF'ERET
BEAUTY
Rahamim
(Compassion)
Blessed Holy One
Heaven, Sun
Harmony, King
Green
הוד
HOD
SPLENDOR
Prophecy
Left Leg
נצח
NETSAH
ETERNITY
Prophecy
Right Leg
יסוד
YESOD
FOUNDATION
Tsaddiq
(Righteous One)
Covenant
Phallus
שכינה
SHEKHINAH
PRESENCE
Malkhut
(Kingdom)
Communion of Israel
Earth, Moon
Queen
Apple Orchard
Rainbow

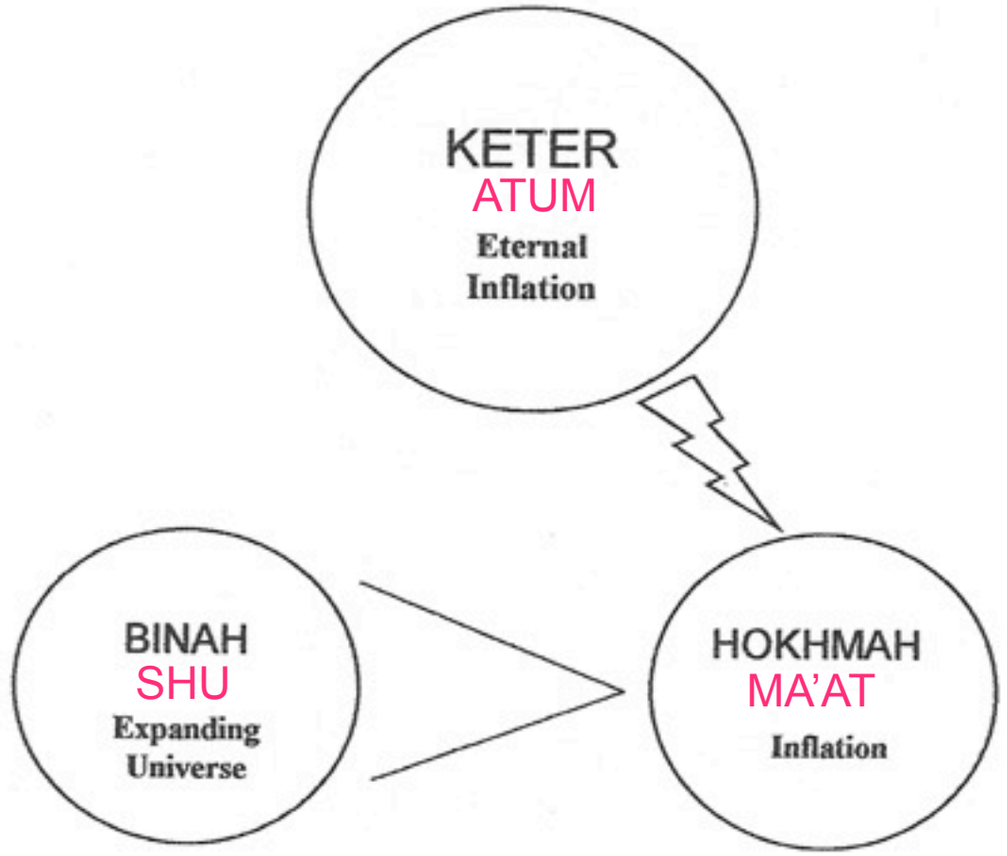


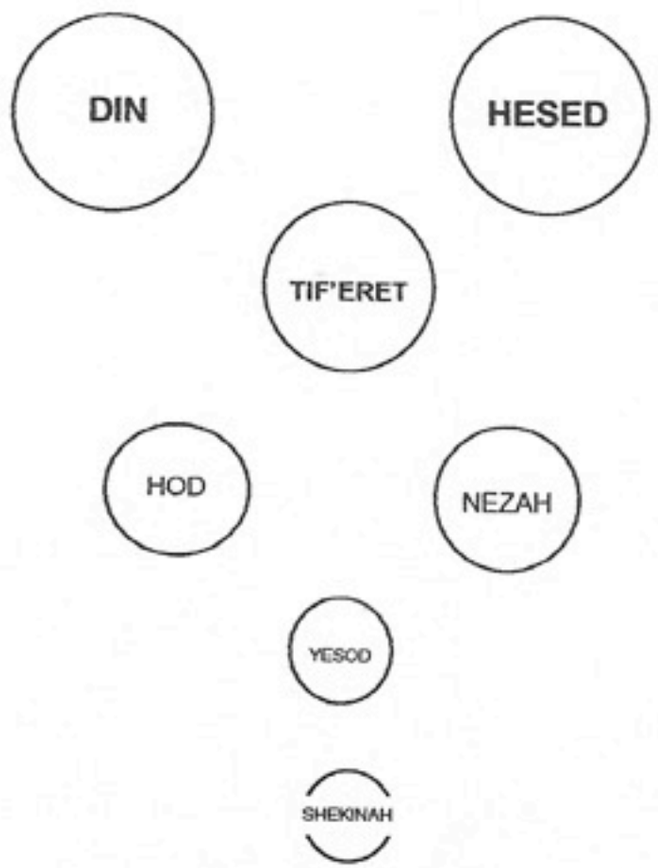


Daniel Matt, *Zohar*

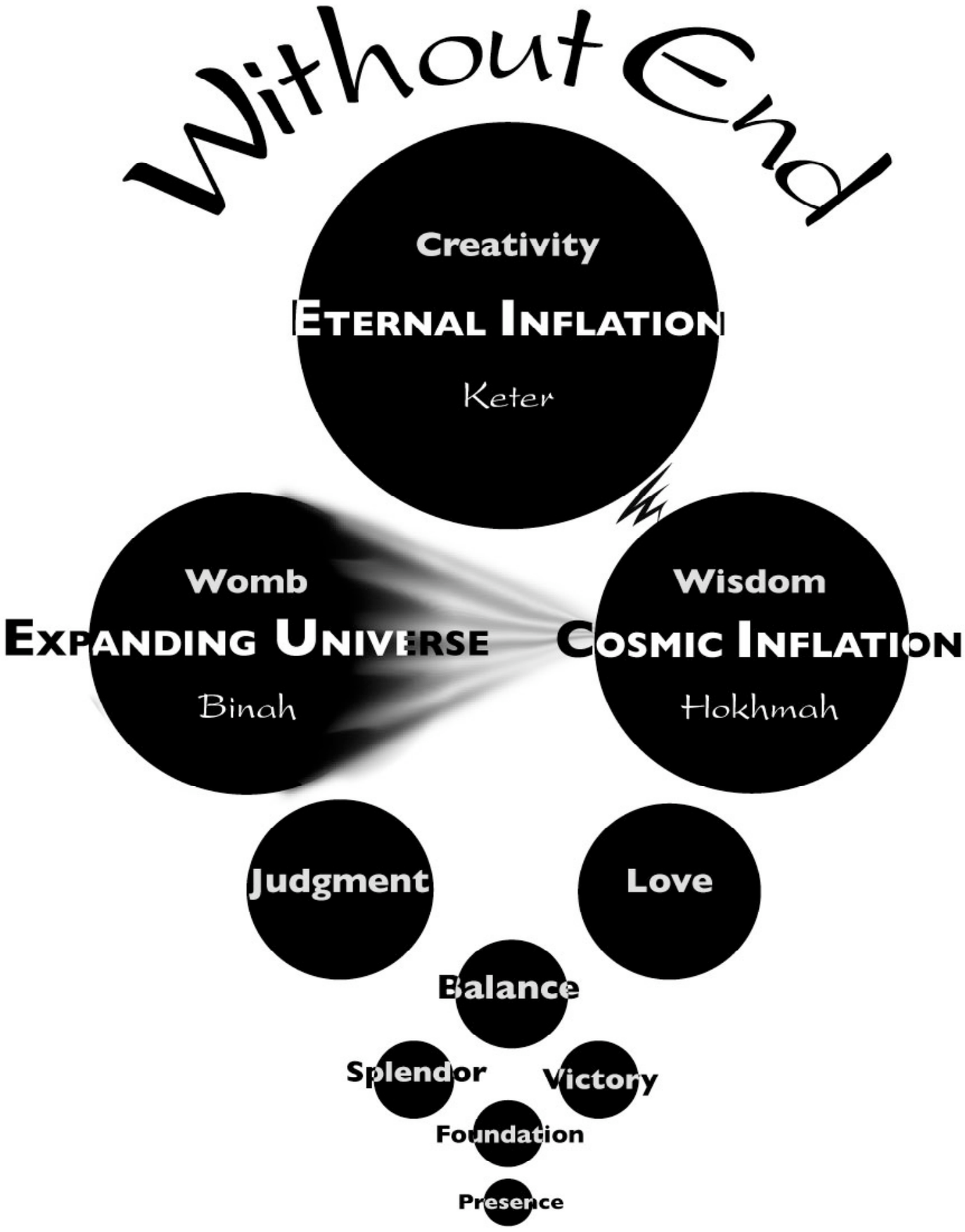


Daniel Matt, *Zohar*

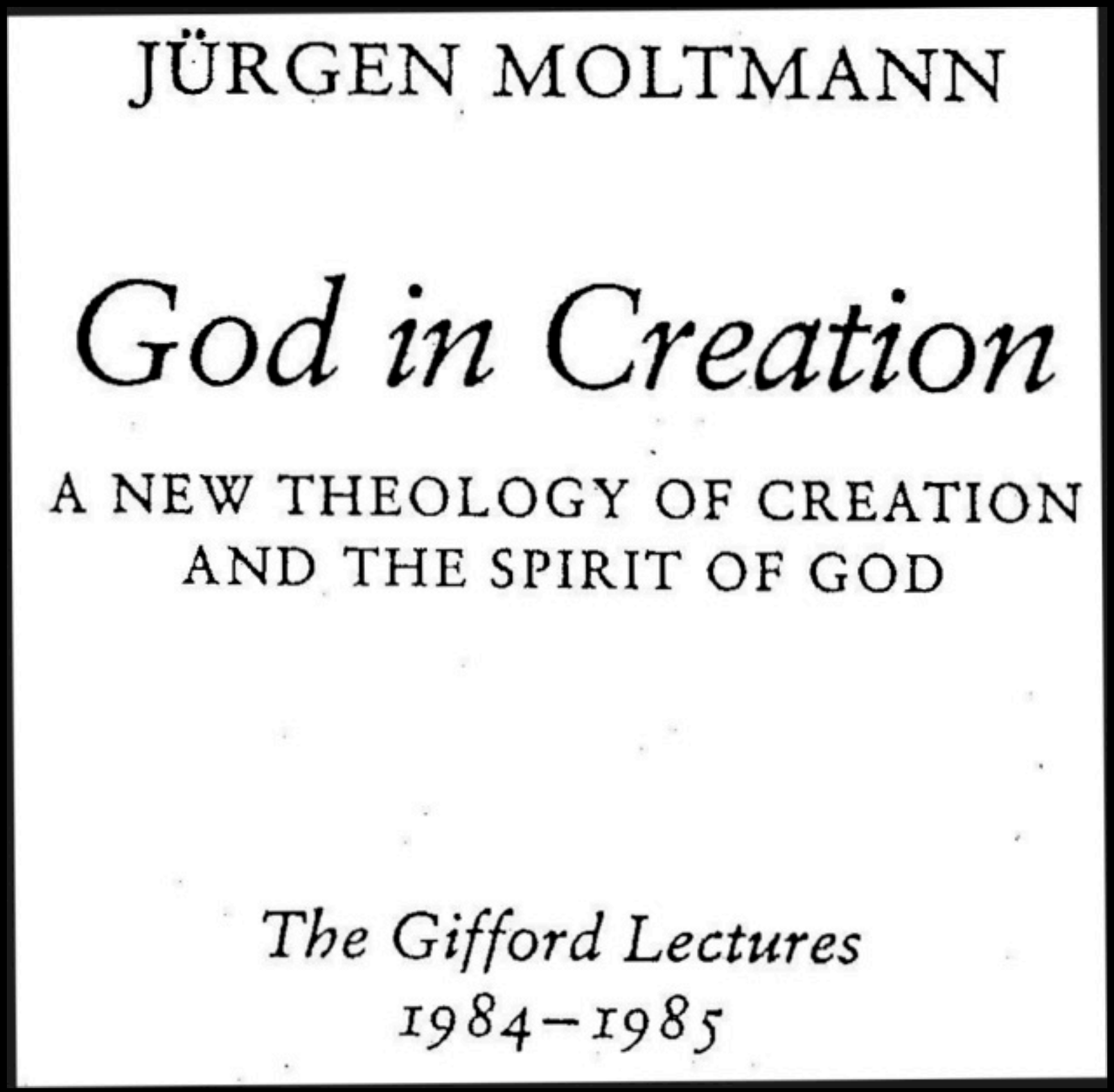




Nancy Abrams
& Joel Primack


Without End
Creativity
Eternal Inflation
Keter
Womb
Expanding Universe
Binah
Wisdom
Cosmic Inflation
Hokhmah
Judgment
Love
Balance
Splendor
Victory
Foundation
Presence

Moltmann on Kabbalistic Cosmology

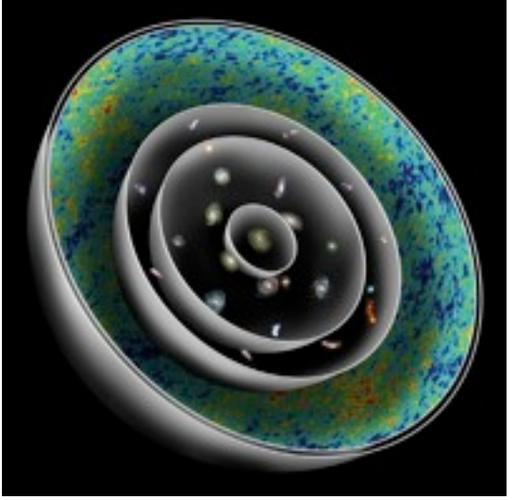


Zimzum

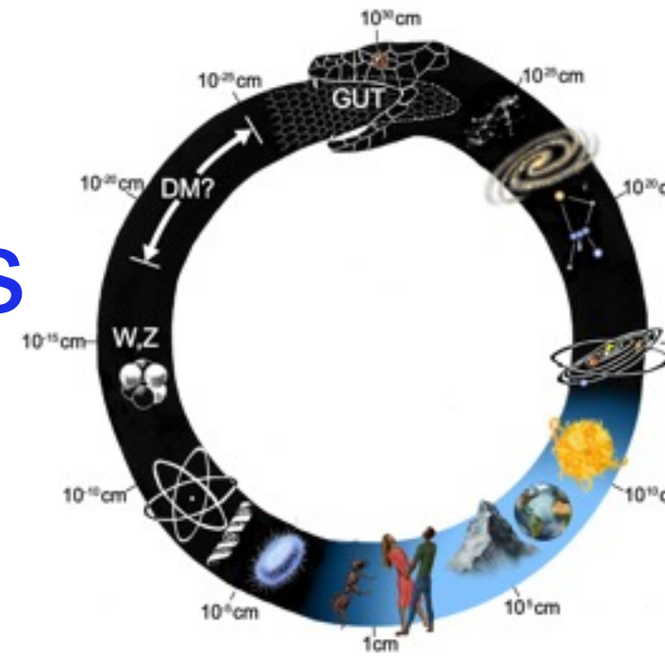
… ***creatio ex nihilo*** only comes into being because - and in as far as - the omnipotent and omnipresent God withdraws his presence and restricts his power.

It was Isaac Luria who first of all developed these ideas in his doctrine of ***zimzum***. ***Zimzum*** means concentration and contraction, and signifies a withdrawing of oneself into oneself. Luria was taking up the ancient Jewish doctrine of the Shekinah, according to which the infinite God can so contract his presence that he dwells in the temple. But Luria applied it to God and creation. The existence of a world outside God is made possible by an inversion of God. This sets free a kind of 'mystical primordial space' into which God - issuing out of himself - can enter and in which he can manifest himself. The Creator is not an 'unmoved -mover' of the universe. On the contrary, creation is preceded by this self-movement on God's part, a movement which allows creation the space for its own being. … It is the affirmative force of God's self-negation which becomes the creative force in creation and salvation.

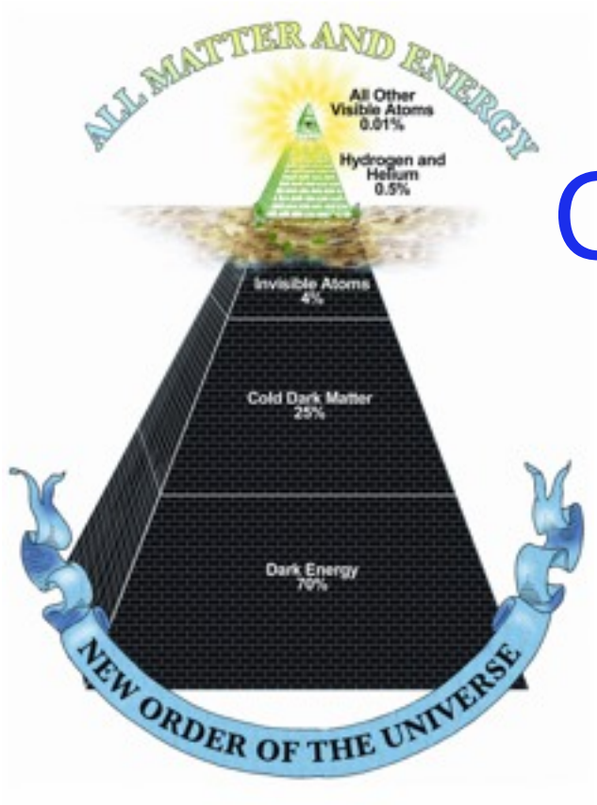
The kabbalistic doctrine of the self-limitation of God has also found a place in Christian theology. Nicholas of Cusa … and others all saw that when God permitted creation, this was the first act in the divine self-humiliation which reached its profoundest point in the cross of Christ. [The idea of ***kenosis.***]



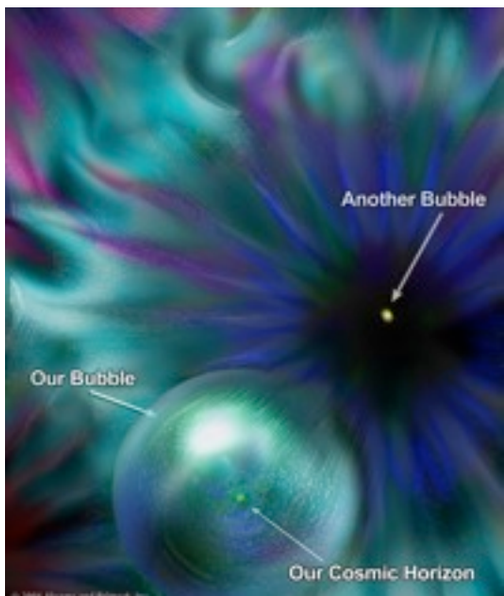
Cosmic Spheres of Time
– the visible universe



Cosmic Uroboros
– size matters



Cosmic Density Pyramid –
what the universe is made of



Cosmic Bubble
– our place in the meta-universe

Midterm Exam in Class May 13

The Midterm Exam will be next week, after the break.

The exam covers everything in the lectures and in *The View from the Center of the Universe* through chapter 8. There will also be some simple problems involving powers of ten.

Remember that your Astronomy Journals are to be handed in at the May 27 class, and returned at the last class.

Note: I will be speaking at a conference on Thursday, so I will not be available for Office Hours then. I could meet after 2 pm this Friday, by appointment.