A Natural World-view

A dive into cosmology, encountering the vast amounts we do and do not know about the universe, and provoking some discussion of philosophy from a natural perspective

Fermilab philosophy society meeting

Jim Hylen

Nov. 22, 2019

- Each of us has to approach life with our own individual world-view, based on limited information.

Me

I am:

Someone trying to understand the world I am in.
(An experimental particle physicist)

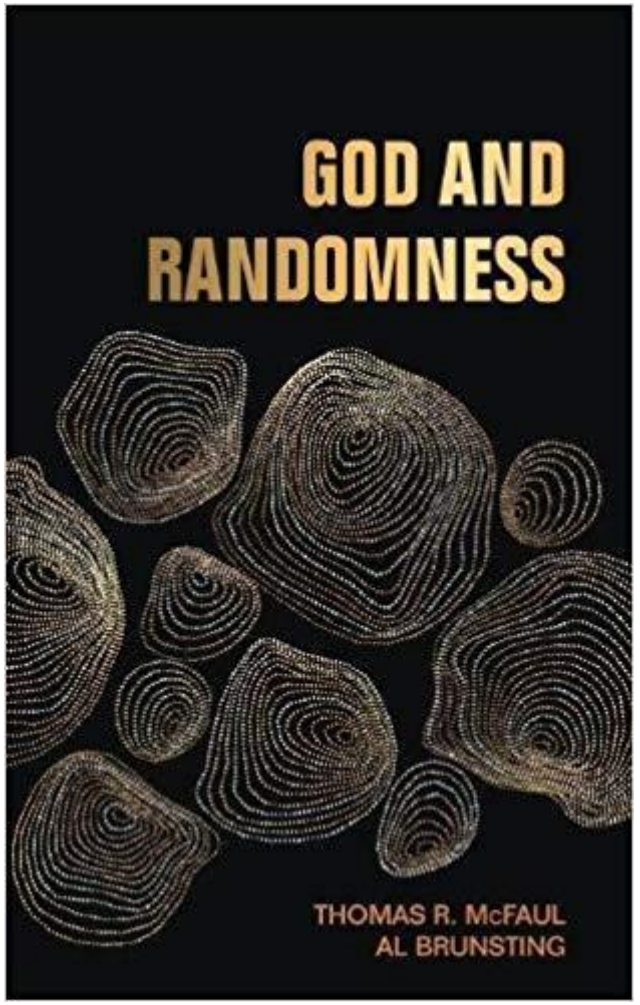
I am NOT:

A philosopher
A cosmologist
A theoretical physicist
A historian
A biologist
A theologian
…

I am NOT:

Representing the views of any institution or organization, nor am I here in any official capacity. I am just me.

Crisis in cosmology ?



At a previous Fermilab Philosophy meeting, Al Brunsting presented ideas from his book “God and Randomness”, where he ended by saying that the “crisis in cosmology” gave him reason to say it was more probable than not that God exists and created the universe.

What do cosmologists say about a crisis in cosmology?

Couple books by cosmologists:

- The big picture - Sean Carroll
- The Singular Universe and the Reality of Time
  - Roberto Mangabeira Unger & Lee Smolin

- Carroll promotes the idea of Multiverse.
- Smolin investigates concept of one universe, but one which changes over time

Oh, and what “crisis in cosmology” was AI referring to?

Astrophysical measurements are actually very broadly consistent
Pretty solid understanding back to Time ~ 1 second after big bang, and even before

(There are fairly minor issues, such as current few percent disagreement between different measurements of the Hubble constant.)

What AI was referring to is “the fine-tuning problem”

Our physics models have a couple dozen constants in them (speed of light, strength of various interactions, …) that we do not know the basis of, and that seem pretty precisely tuned to allow life.

If the constants are different by even small amounts, the world would not form in a way we could exist.

Does that imply a God that decided on the numbers for the parameters, and set them to be exactly that needed for life?

Seems easy; figure out numerator and denominator, and calculate how improbable what we see is. (Admission in advance: I failed)

A slight change of course

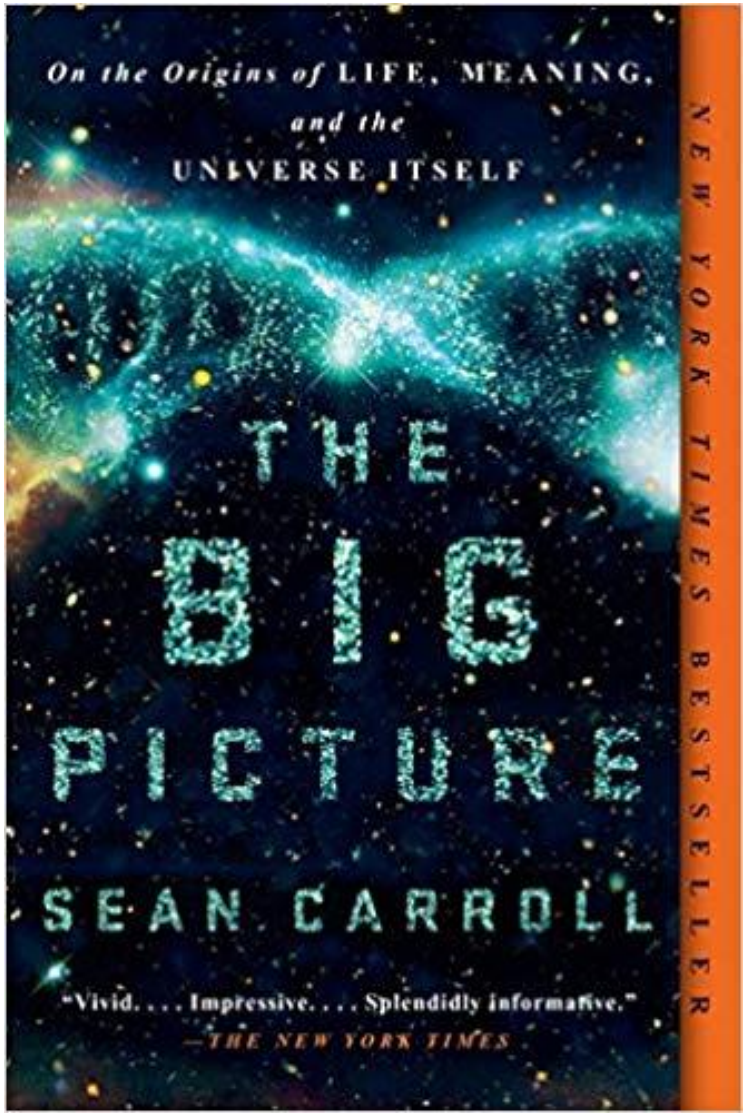
Planned to present a summary of

"The Big Picture" by Sean Carroll

On the Origins of LIFE, MEANING,

and the

UNIVERSE ITSELF



But recently noticed there is a you-tube video by Sean himself of "The Big Picture"

He is a much better speaker than I am -

- so suggest you listen to him directly

Quotes about philosophy and/or science

“A knowledge of the historic and philosophical background gives that kind of independence from prejudices of his generation from which most scientists are suffering.

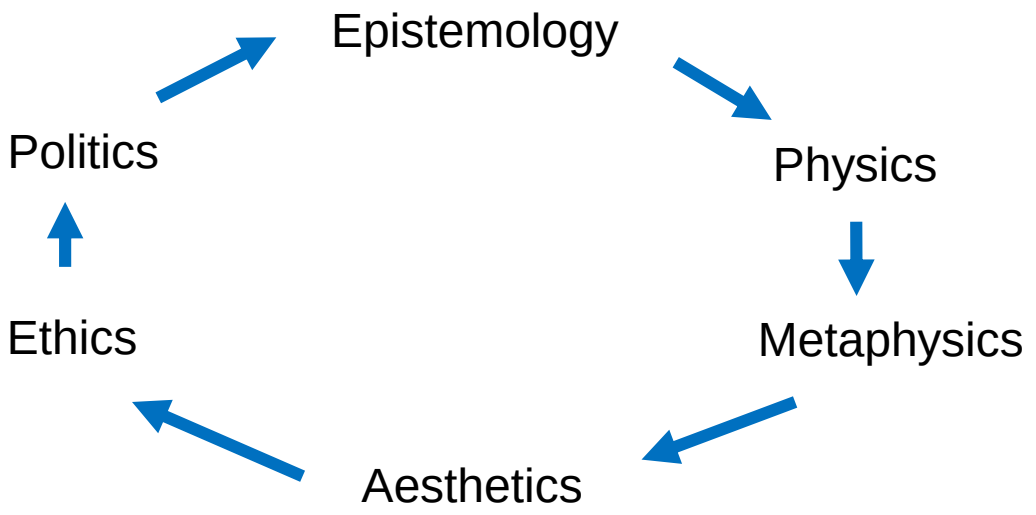
This independence created by philosophical insight is — in my opinion — the mark of distinction between a mere artisan or specialist and a real seeker after truth.”

Albert Einstein, 1879 – 1955 Letter to Thornton, 1944

“Aristotle maintained that women have fewer teeth than men; although he was twice married, it never occurred to him to verify this statement by examining his wives’ mouths.”

Bertrand Russell, 1872 – 1970 The Impact of Science on Society, 1951

A philosophical framework



Requires iteration

“If what you have is a hammer, every problem looks like a nail”

- I am a physicist, and physics is my toolset. I recognize this bias.

(I had some philosophical intro after this, but cut it to fit in an hour)

Knowledge comes at various levels of confidence

I will try to label:

Conventional physics – well supported experimentally

Physics motivated -- have experimental physics motivation, but not strong confirmation or dis-confirmation

Just-so stories – anecdotal type views

Some personal views of physics and mathematics for this talk

Just-so stories

Physicists build models of the world, using mathematics as a tool set.
Modern physics cannot be done without sophisticated mathematics in the model.
The physicist must figure out how to model the world with the mathematics.
You have to relate some measurable quantity to some variable in the math.
The model with sophisticated and powerful mathematics can be predictive and constraining over very large ranges of parameters, so can be very powerful.

Mathematics does not tell you how the real world works, you have to do that with experiment, and you can then use the mathematics to tie the experiments together.

The map is not the territory; the math is not the real world. (Some will disagree).

There are (infinitely?) many mathematical models that do not describe the real world.

In **human social law**, a mind makes the law and tries to enforce it.
In **physics law**, the law is a recognized pattern of the natural world.
What are called laws of nature are (almost?) all approximations good over some parameter range.

Rather than laws, theories, hypotheses, I am just going to use the word **models**.

To understand cosmology, need some understanding of basic physics

General relativity: time & space

Space expands? Space is curved (parallel lines can meet)? Twins can be different ages?

Standard model of particle & fields physics: particle and interaction zoo

Layers of the onion: solids, molecules, atoms, nuclei, nucleons, quarks, excitation of fields …

Quantum mechanics: how interactions are precisely (?) calculated

We can calculate a lot of stuff, but do we know what we are really calculating?

Some background information

Is the **Big Bang** the *absolute start* of the universe? Maybe, but not necessarily:

- Need theory of **quantum gravity** to get near the beginning, don't have
- The big bang may be part of a continuing universe:
  - Eternal inflation (Physics motivated)
  - Cyclic
  - …
- we just don't know for sure the next layer of that onion

Since gravity has negative energy, a universe can be created without violating conservation of energy

Thermodynamics:

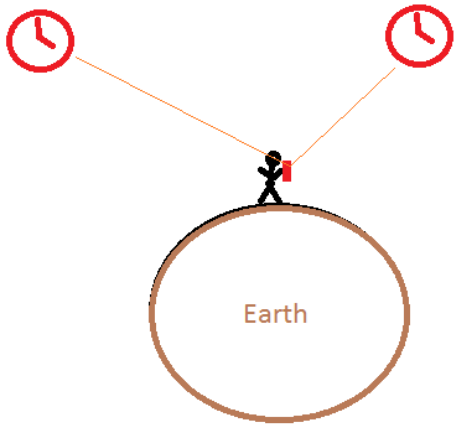
- 1st law – energy is ***almost*** always conserved
- 2nd law – entropy ***almost*** always increases
- 3rd law - entropy low at low temperature in certain cases
- 0th law - systems in equilibrium with third system are in equilibrium with each other

General Relativity

May seem pretty academic, but you probably use the technology often.

General relativity says time runs slower in stronger gravity.

We are in stronger gravity than the satellites that provide GPS timing.



Conventional physics

The GPS position of your phone would drift 6 miles per day

if the system did not include the general relativity difference

Standard model particle zoo *and 7 layers of the onion*

Particles				Forces				
				Gravity	Higgs	Weak	Electro-magnetic	Strong
atoms				graviton ?	Higgs boson	W & Z	photon	gluon
u quark	c quark	t quark	⇔	Y	Y	Y	Y	Y
d quark	s quark	b quark	⇔	Y	Y	Y	Y	Y
electron	muon	tau	⇔	Y	Y	Y	Y	*N*
ν_e	ν_μ	ν_τ	⇔	Y	*Y?*	Y	*N*	*N*
Dark matter ?			⇔	Y	*?*	*?*	*N*	*N*

Quantum field theory calculates excitations of fields ➔ particles (electrons, quarks, …)
Quarks + gluons ➔ nucleon (proton, neutron)
Protons + neutrons ➔ nucleus (such as oxygen nucleus, charged)
Nucleus + electrons ➔ atoms (like oxygen atom, neutral)
Atoms join ➔ molecules (oxygen + two hydrogen make water molecule)
Molecules join ➔ solids (and liquids; also very loosely as gases)

Physics motivated

Two models of **Quantum Mechanics** (there are several others)

Copenhagen (~1927)	Everett Multi-Worlds (1957)
The wave function is a two-dimensional square-root of probability	The wave function is a two-dimensional square-root of probability
Wave function follows Schrodinger's equation for time evolution	Wave function follows Schrodinger's equation for time evolution
Wave function has superposition	Wave function has superposition
At a "measurement", wave function collapses over the entire universe; start over again with new wave function	Wave function continues; "you" are part of the wave function, entangled with different "measurement outcomes"
QM gives probability of what the measurement will pick randomly – probability is deterministic, but what the measurement will show is totally random following that probability distribution	Wave function proceeds totally deterministically
Schrodinger's cat is either dead or alive after measurement (but not before)	Schrodinger's cat is both dead and alive; versions of you are entangled with each
Collapse of wave-function serves as an arrow of time	Schrodinger's equation is symmetric in time, as Newtonian equations are
Entanglement is spooky action at a distance when wave function collapses	Entanglement is continuous; spooky action at a distance not necessary

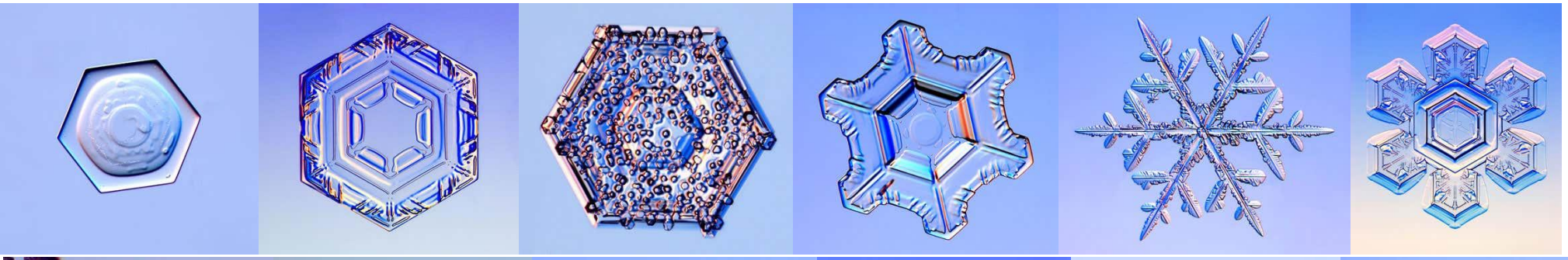
Conventional physics

An analogy to cosmological history *(will use this twice)*

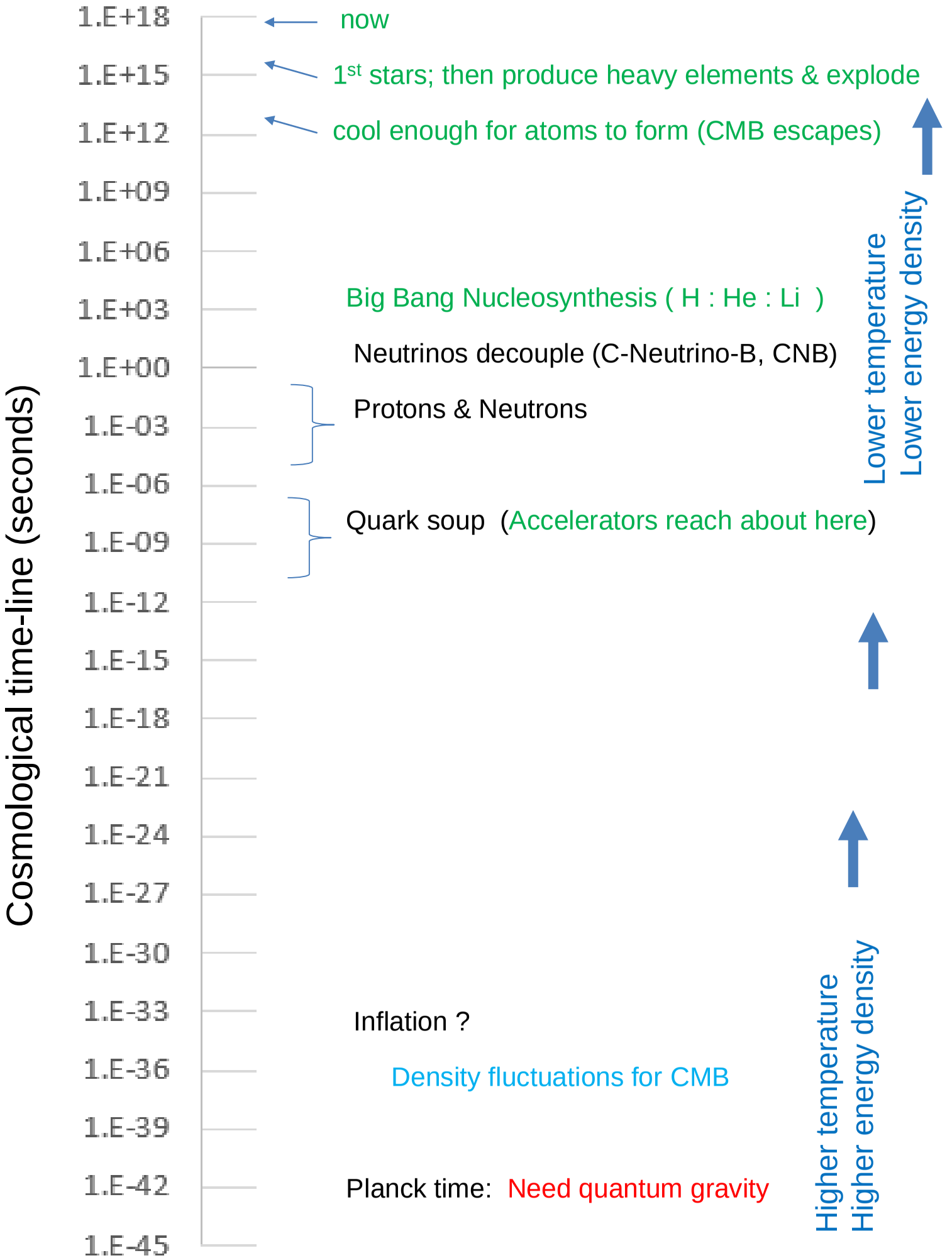
Humidity to water drops to snowflakes:

two phase transitions
gas => liquid => solid

temperature high => low
simple => complex



Snowflake pictures: Kenneth Libbrecht / CalTech

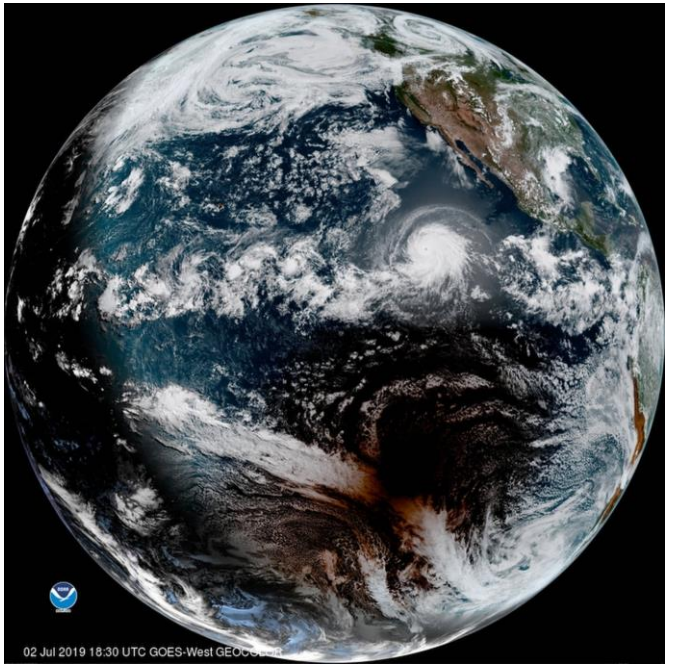

Cosmological time-line (seconds)
1.E+18
1.E+15
1.E+12
1.E+09
1.E+06
1.E+03
1.E+00
1.E-03
1.E-06
1.E-09
1.E-12
1.E-15
1.E-18
1.E-21
1.E-24
1.E-27
1.E-30
1.E-33
1.E-36
1.E-39
1.E-42
1.E-45
now
1st stars; then produce heavy elements & explode
cool enough for atoms to form (CMB escapes)
Big Bang Nucleosynthesis (H : He : Li)
Neutrinos decouple (C-Neutrino-B, CNB)
Protons & Neutrons
Quark soup (Accelerators reach about here)
Inflation ?
Density fluctuations for CMB
Planck time: Need quantum gravity
Lower temperature
Lower energy density
Higher temperature
Higher energy density

Starting backwards means we can look at real pictures

The flat earth society still exists, in spite of satellite view

From NOAA/NASA GOES satellite

During solar eclipse

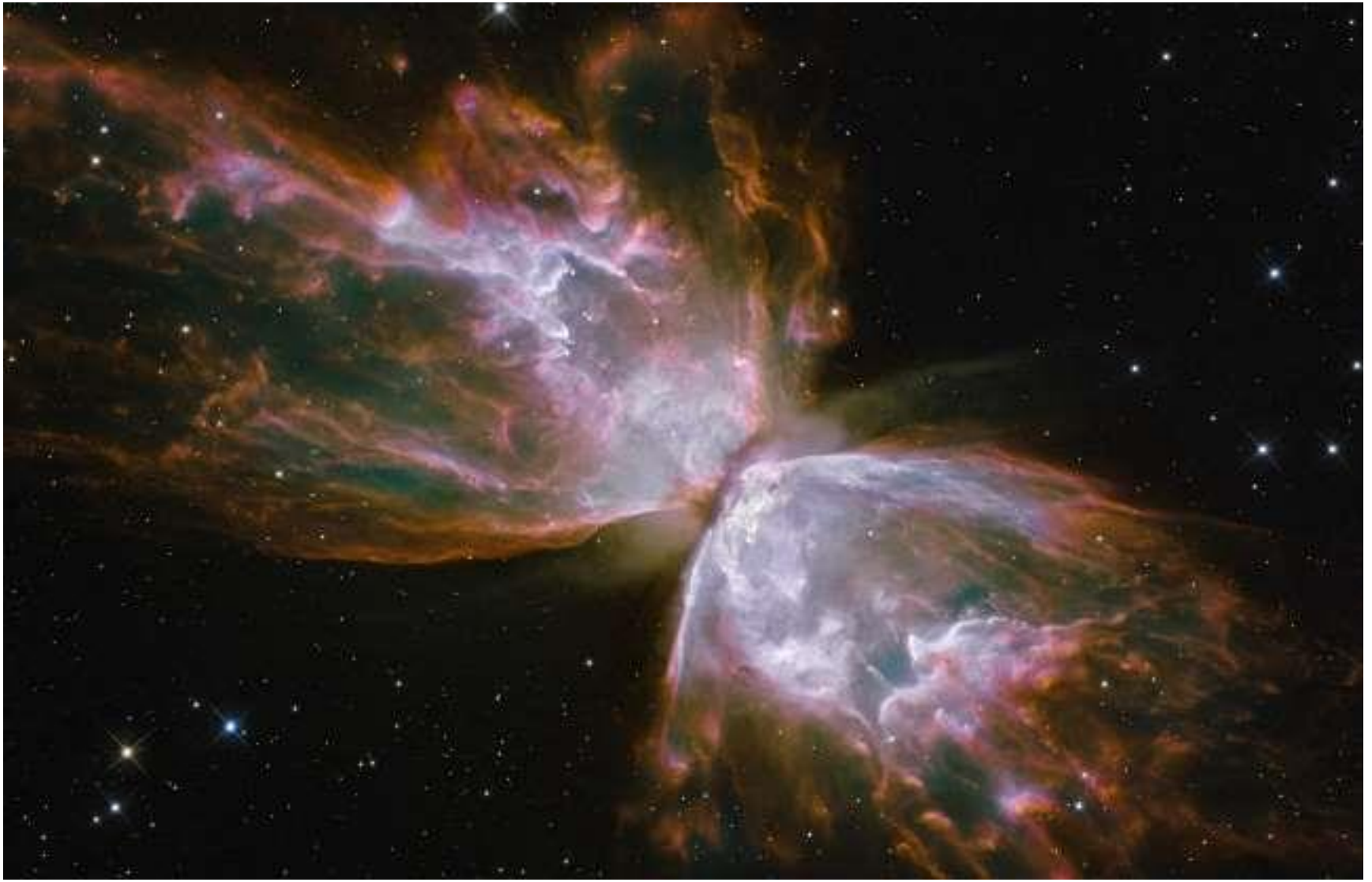


Can look for planets around the nearest stars; > 4,000 planets detected so far

From that sampling, most suns have planets, somewhat randomly configured

Supernova, hypernova, neutron star mergers

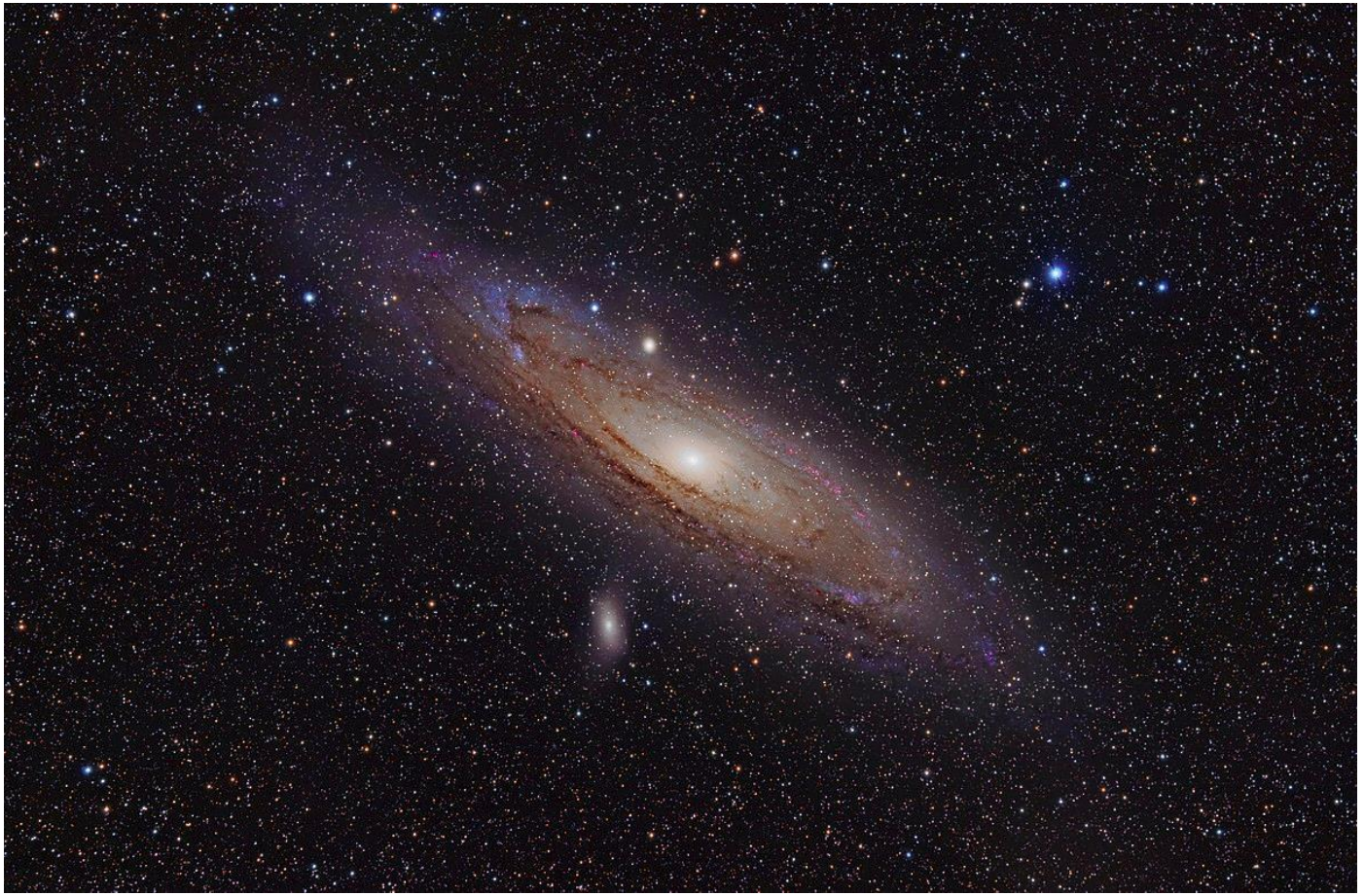
Out of the big bang, there was essentially only Hydrogen, Helium and a little Lithium.
The rest of the elements are created in star burning and stellar explosions.
In particular, Oxygen is created by stars, and is available for planets only
after previous stars have exploded



Galaxy

> 10^{11} (100,000,000,000) suns in our galaxy

We don’t have a picture of our galaxy from the outside, but it seems similar to this:



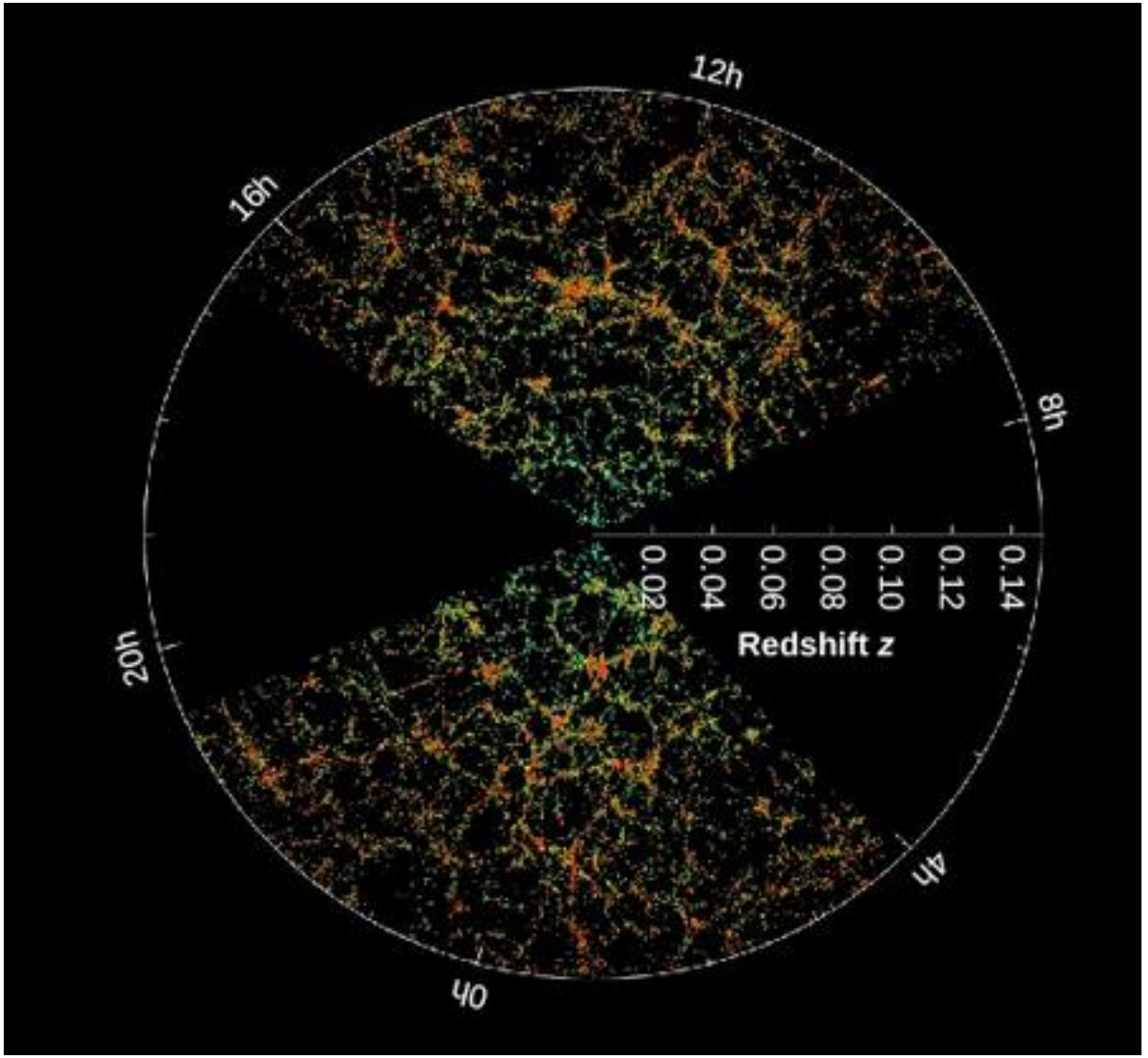
Andromeda Galaxy
(nearest big galaxy)

2.5 million lightyears from us

headed toward us

collision alert: 4.5 billion years from now

3D mapping of galaxies is ongoing



2D slice from Sloan Digital Sky Survey

We are plotted at center.

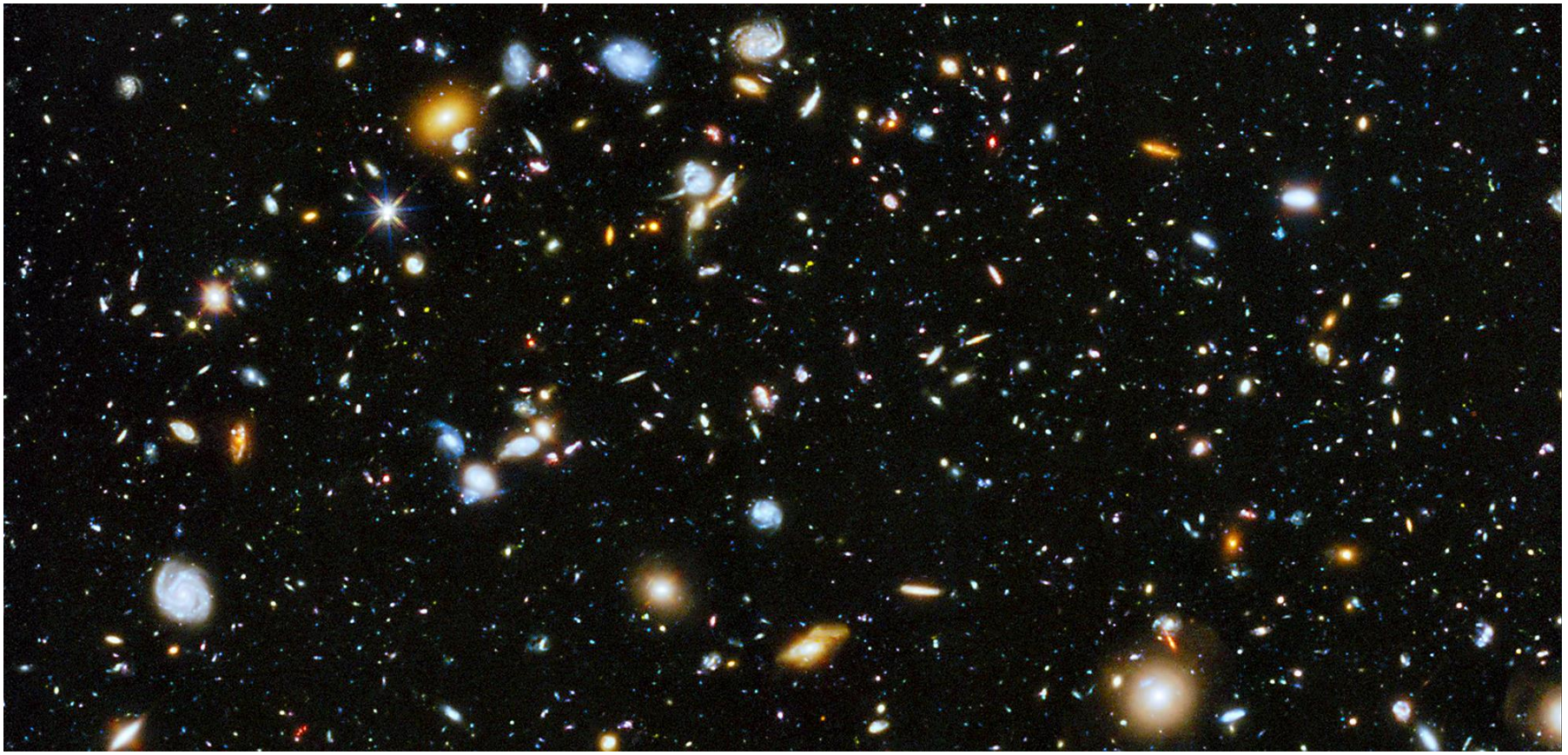
Circle is
2 billion light-years away

Dark pie slices are
un-mapped regions

How many galaxies?

> 10^{11} (100,000,000,000) galaxies in our visible universe

so > 10^{22} (10,000,000,000,000,000,000,000) suns in our visible universe



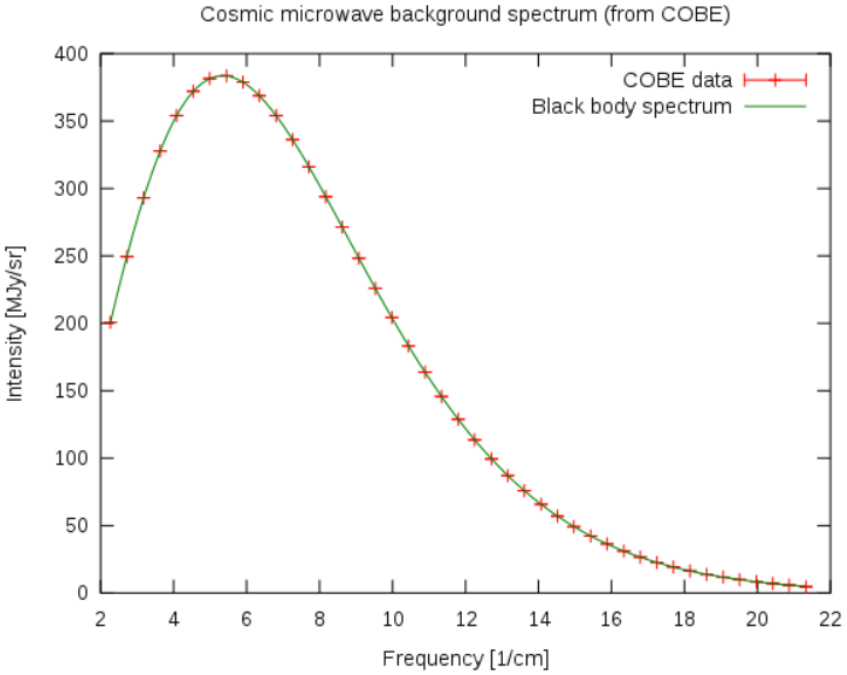
Hubble deep 2D picture

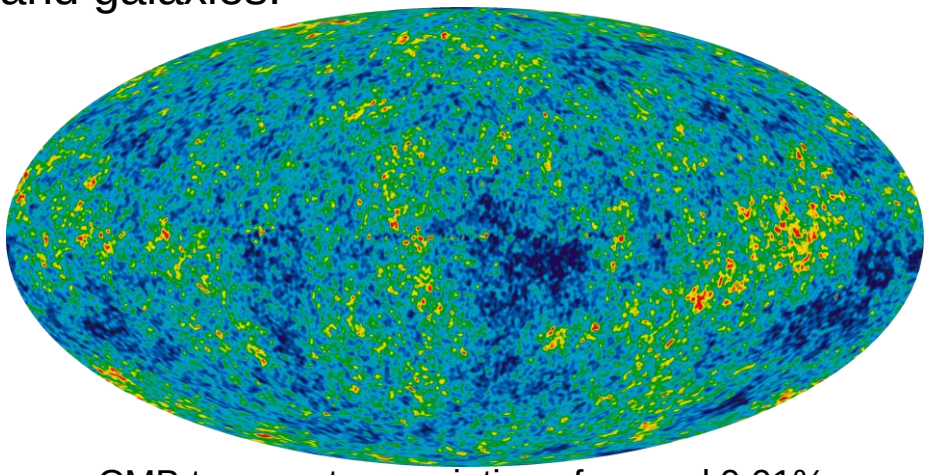
See galaxies near edge of observable universe, from up to about 13 billion years ago

Cosmic Microwave Background (CMB)

When charged plasma became neutral atoms

Light from 380,000 years after the start of Big Bang.
Before there were stars and galaxies.

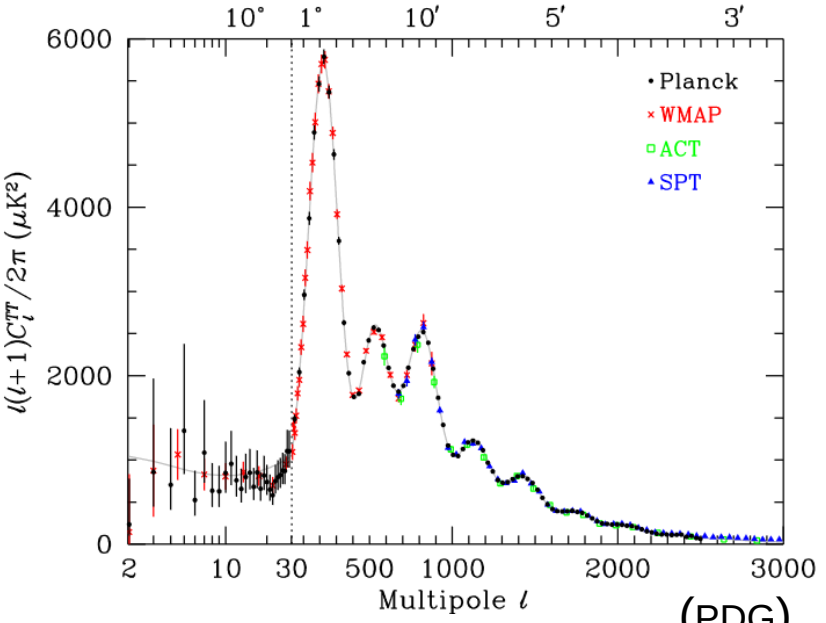




CMB temperature variation of around 0.01%
plotted by position on sky (WMAP data)

Started out as visible light (~3000 K).
As it traveled to us over 13.8 billion years
it red-shifted to microwave (~2.7 K)

Every wiggle contains convoluted
information about stages before.
The ΛCDM model fit is plotted
through the data.



(PDG)

Big Bang Nucleosynthesis

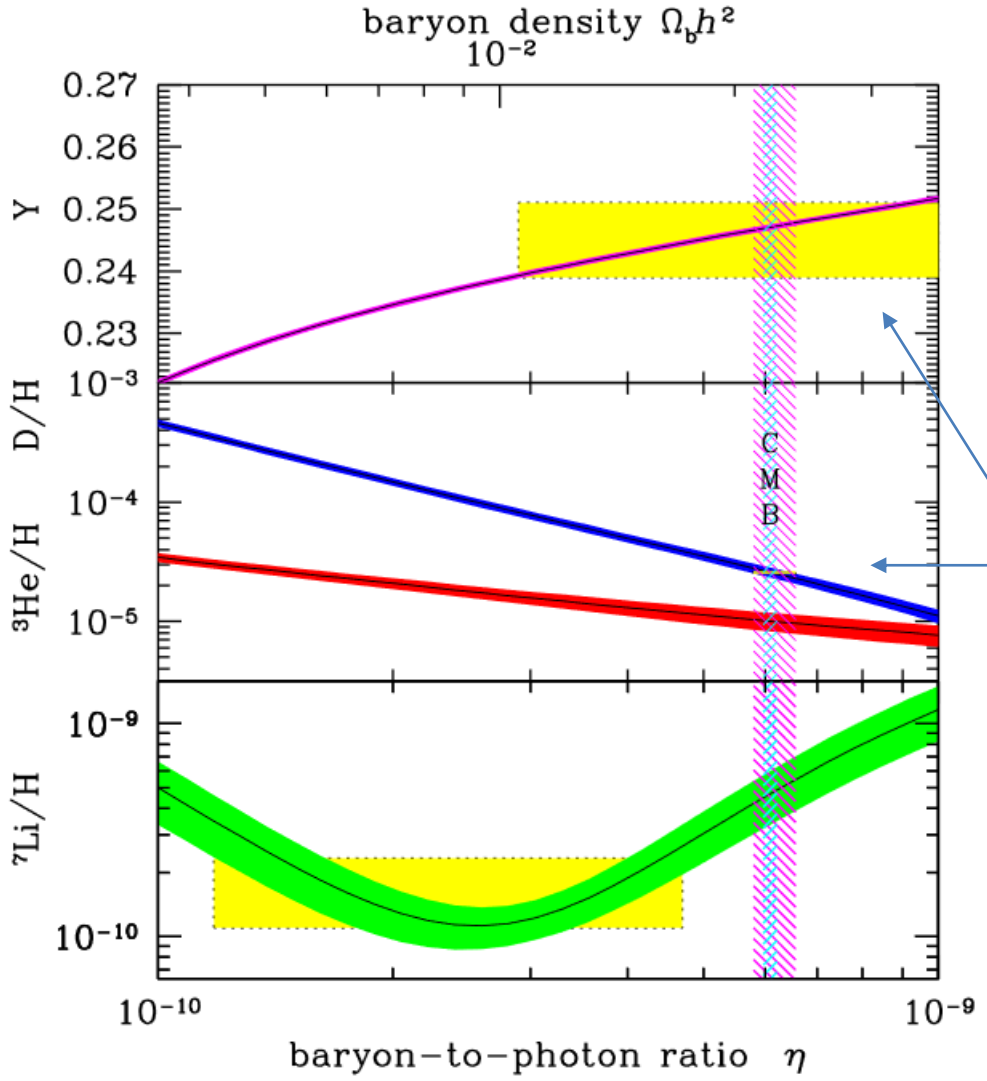


Figure 23.1: The primordial abundances of ^{4}He, D, ^{3}He, and ^{7}Li as predicted by the standard model of Big-Bang nucleosynthesis — the bands show the 95% CL range [5]. Boxes indicate the observed light element abundances. The narrow vertical band indicates the CMB measure of the cosmic baryon density, while the wider band indicates the BBN D+^{4}He concordance range (both at 95% CL).

(PDG)

Neutrons & Protons forming light elements from ~10 seconds to ~ 180 seconds after big bang

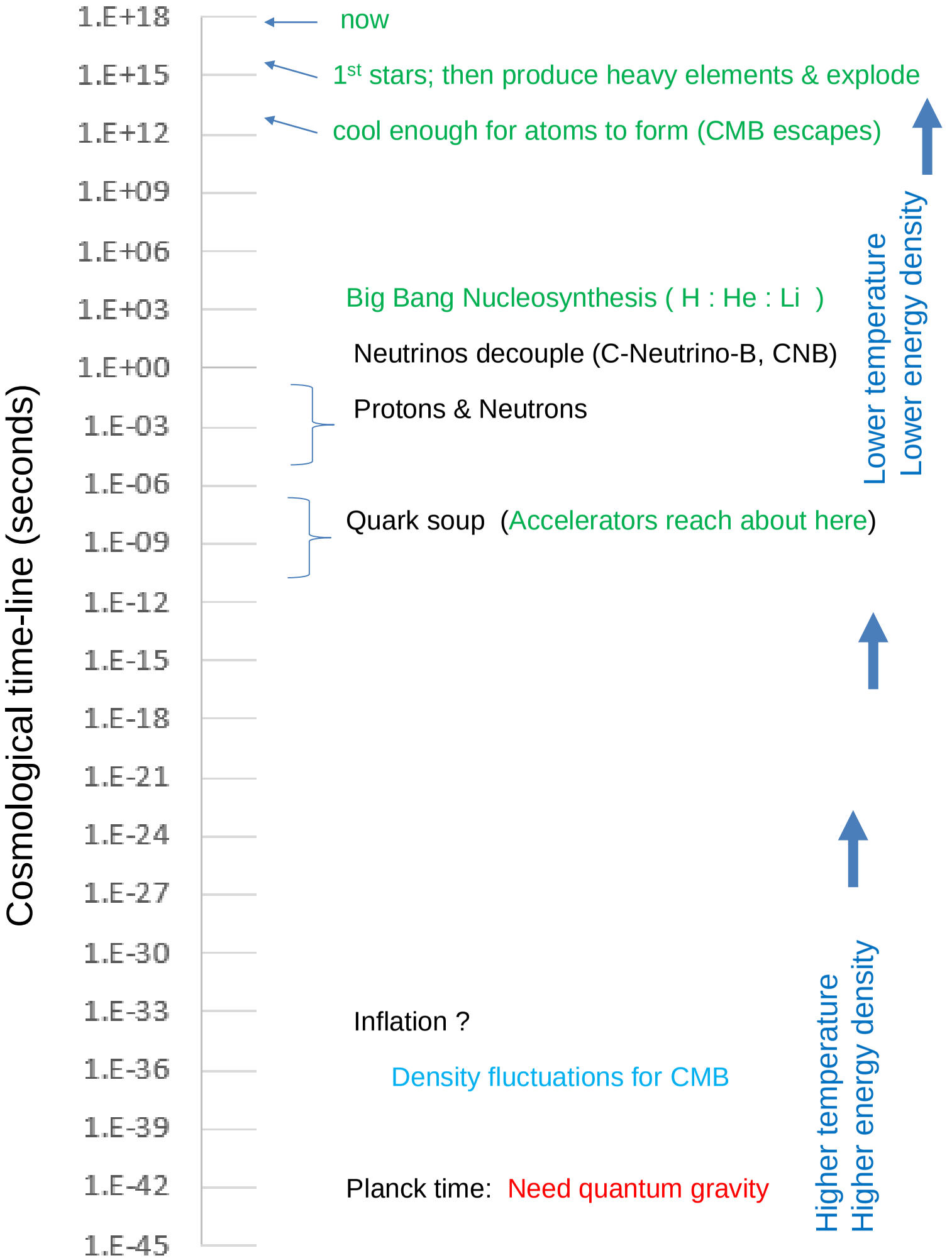
Lines:
Nuclear physics predictions as function of …

Yellow boxes:
Measurements (except ^{3}He)

Vertical band:
CMB constraint

H, ^{4}He, D in good agreement

^{7}Li nine orders of magnitude lower than H, x3 off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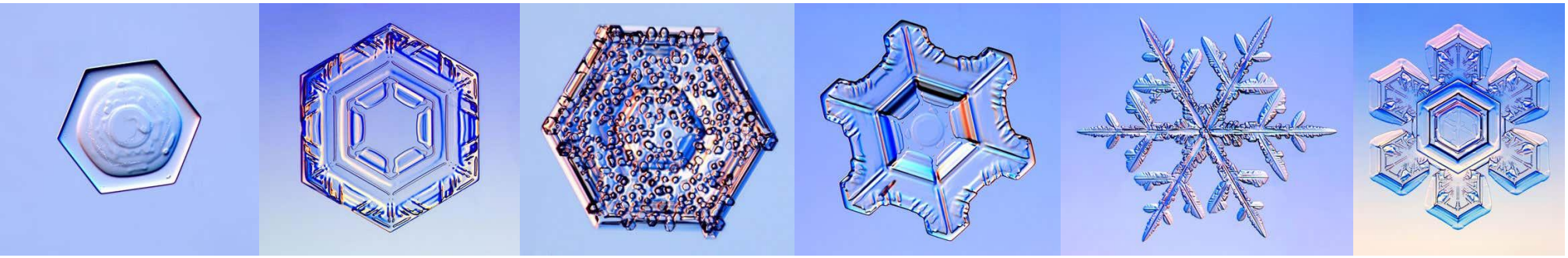
Protons & Neutrons
Quark soup (Accelerators reach about here)
Inflation ?
Density fluctuations for CMB
Planck time: Need quantum gravity
Lower temperature
Lower energy density
Higher temperature
Higher energy density

Our analogy to cosmological history

Cosmology: High temperature plasma
freezes down to galaxies and planets

Humidity to water drops to snowflakes:
gas => liquid => solid

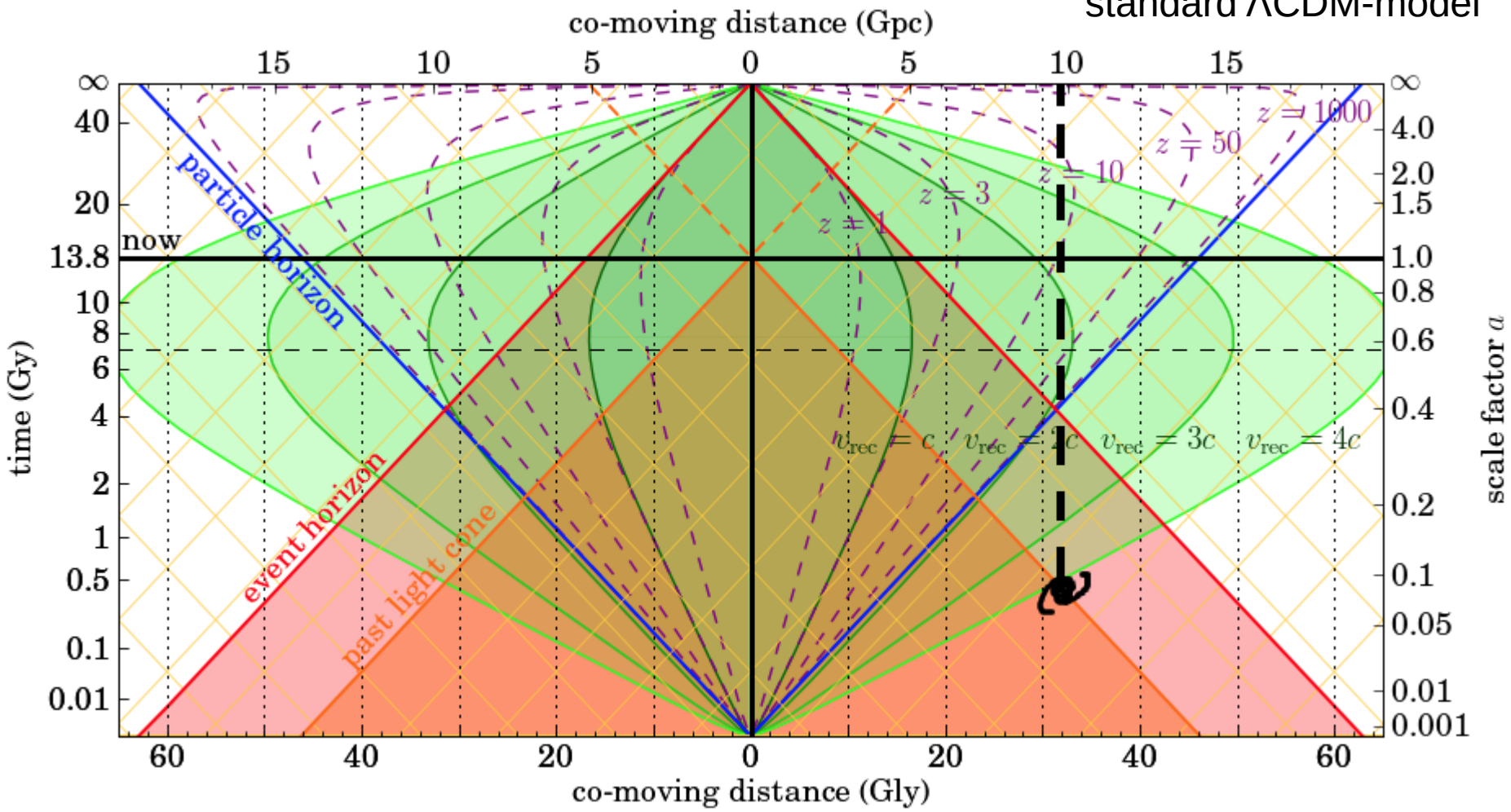
temperature high => low
simple => complex



Snowflake pictures: Kenneth Libbrecht / CalTech

What is observable ?

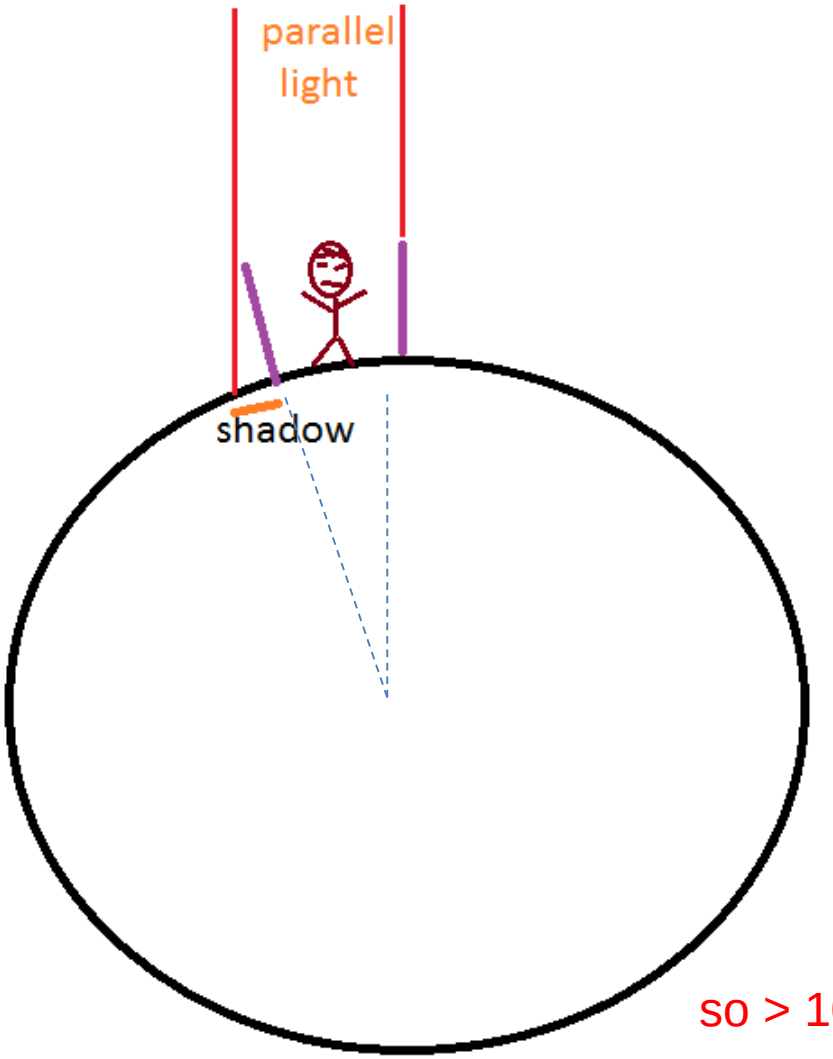
standard ΛCDM-model



Stolen from https://physics.stackexchange.com/questions/60519/can-space-expand-with-unlimited-speed/63780#63780

Flatness of the observable universe

Analogous to the way the size of the earth was estimated by local measurement of non-flatness



measurement of the flatness of the observable universe gives an estimate of the size of the unobservable universe. (How this is actually done is somewhat complicated)

Measurement is within experimental error of being flat; flat is consistent with infinite size.

Maximum deviation < 1% of flat, so diameter of universe is > 100 times bigger than observable

Volume of unobservable universe
> millions of times that of observable universe

up to possibly infinite

so > 10^{28} (10,000,000,000,000,000,000,000,000,000) suns ?

Multiverse 101 - unobservable part of expanding universe

Observed flatness of the universe plus general relativity implies
"unobservable universe" >> "observable universe"

So big that many parts of the unobservable universe are unobservable from other parts of the unobservable universe.

That is, flatness measurement indicates there are at least many millions of mutually unobservable universes.

Since they don't interact with us, are we allowed to scientifically talk about them?
In any case, philosophy and Metaphysics certainly would seem to allow…

Are we allowed to include them in the calculation of probability of life?

A hint here of limits to our knowledge even in principle – we will never know exactly what is going on in the unobservable universe because it is unobservable, and it appears that is most of the universe.

Eternal inflation

Physics motivated

Inflation model says space (for a period of time) expanded much more rapidly than we see now. "Much more" is a vast understatement.

Inflation models were invented to explain several features of the big bang.

- Magnifies early quantum fluctuations so they are large enough to match galaxy formation.
- Allows different patches of sky to have communicated with each other to explain why we see so uniform a temperature across the sky.
- Helps explain not seeing monopoles and other relics.

Different parts of space can inflate at different rates.

As one region stops inflating (creating a 'local bubble universe"), other parts can keep inflating, and eternally spinning off other bubble universes.

Easily allows for another type of Multiverse.

String theory

Physics motivated

Theorists really wanted to find a mathematical theory (Theory of Everything) that

- Would predict what the constants and particle content were
- Was unique, so the world could only be like that

String theory initial motivation

- Based on vibrations of extended objects, eliminates point singularities (infinities)
- Contains the graviton – potential for Quantum Gravity theory
- (Am told it is a BEAUTIFUL theory)

However

- Describes > 10^{500} different types of universe (bug or feature?)

  Different number of space dimensions, particle content, constants (The Landscape)

Combined with something like eternal inflation, or just fluctuations into universes

- There could be an infinite number of bubble universes of each type of > 10^{500} different types - Multiverse that could easily produce us.
- (Yes, I have heard of the Boltzmann Brain objection, but…)

My calculational failure (for now) on “crisis in cosmology”

What we see:

- Could be result of String Theory Multiverse (Physics motivated) freezing out into many types of universe ?

- Could be unique result of some physics model we don’t have yet ?
- Could be special creation ?

Not enough data yet (or possibly ever…)

Deism

Deism: Assertion that a supreme being created the universe.
"Unmoved mover", "1st cause", "Cosmological fine tuner"

OK, I failed to be able to do the direct probability calculation. Will note one time-worn argument that I personally find fairly strong.

Opinion: the assertion that the most complicated, powerful, intelligent supreme being was there from nothing, and then started the universe is counter-intuitive

- Compare "initial complexity" to the known evolution of the observable universe, from a relatively simple state to greater and greater complexity.
- Compare "initial complexity" to the observed evolution of life, from simple to complex organisms
- Compare "initial complexity" to the observed evolution of intelligence on Earth, from simple to complex.

Deism possible, but seems to me less likely than a simpler origin.
And yes, my opinion is: Just-so story

A more specific model comparison

Theological creation in order Genesis chapter 1		**Observational history of universe**
V1-2: heaven & **earth** & **waters** (in darkness)		Big Bang: high energy plasma of **light** (photons), quarks, gluons, electrons, neutrinos
V3-5: let there be light; divide **light** from darkness; 1st day		Transition to where quarks and gluons bind into nucleons, then nuclei (hydrogen, helium, lithium)
V6-8: firmament divides waters from waters, the firmament is called heaven: 2nd day		Cool enough that electrons bind to nucleons (atoms); neutral matter so CMB propagates
V9-13: dry land, grass & trees (**life**): 3rd day		Hydrogen & some helium form **stars**, burning to heavier elements: create oxygen
V14-19: lights in the firmament, for days, years; **stars**: 4th day		Supernova & Hypernova spread heavier elements, so **water** & **planets** can form (**water = H_2O**)
V20-23: every living creature that moves in water & fowl: 5th day		Planets can have day & night
V24-31: land creatures & man: 6th day		**Life** on planet Earth

Genesis in the bible fails the observational cosmology test.

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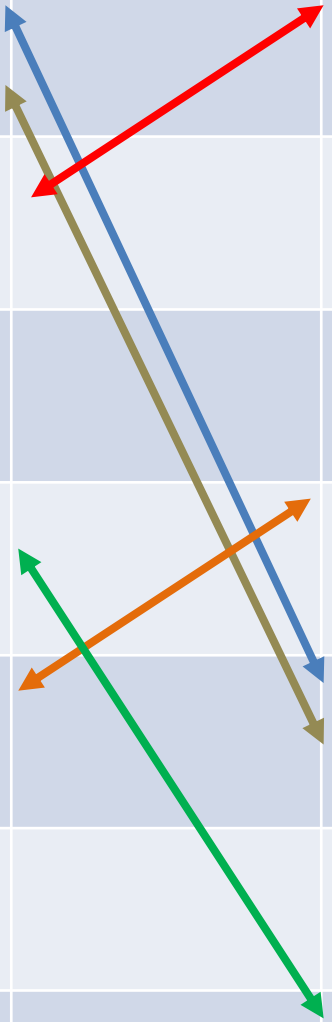
V1-2: heaven & **earth** & **waters** (in darkness)		Big Bang: high energy plasma of **light** (photons), quarks, gluons, electrons, neutrinos
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Nature can be pretty amazing…

Sorted circles 2–3 m in diameter with gravel borders about 0.25 m high, Broggerhalvoya, NW Spitsbergen.

Stone circles: form and soil kinematics by Bernard Hallet
Philosophical Transactions of the Royal Society A
Published 4 November 2013. DOI: 10.1098/rsta.2012.0357