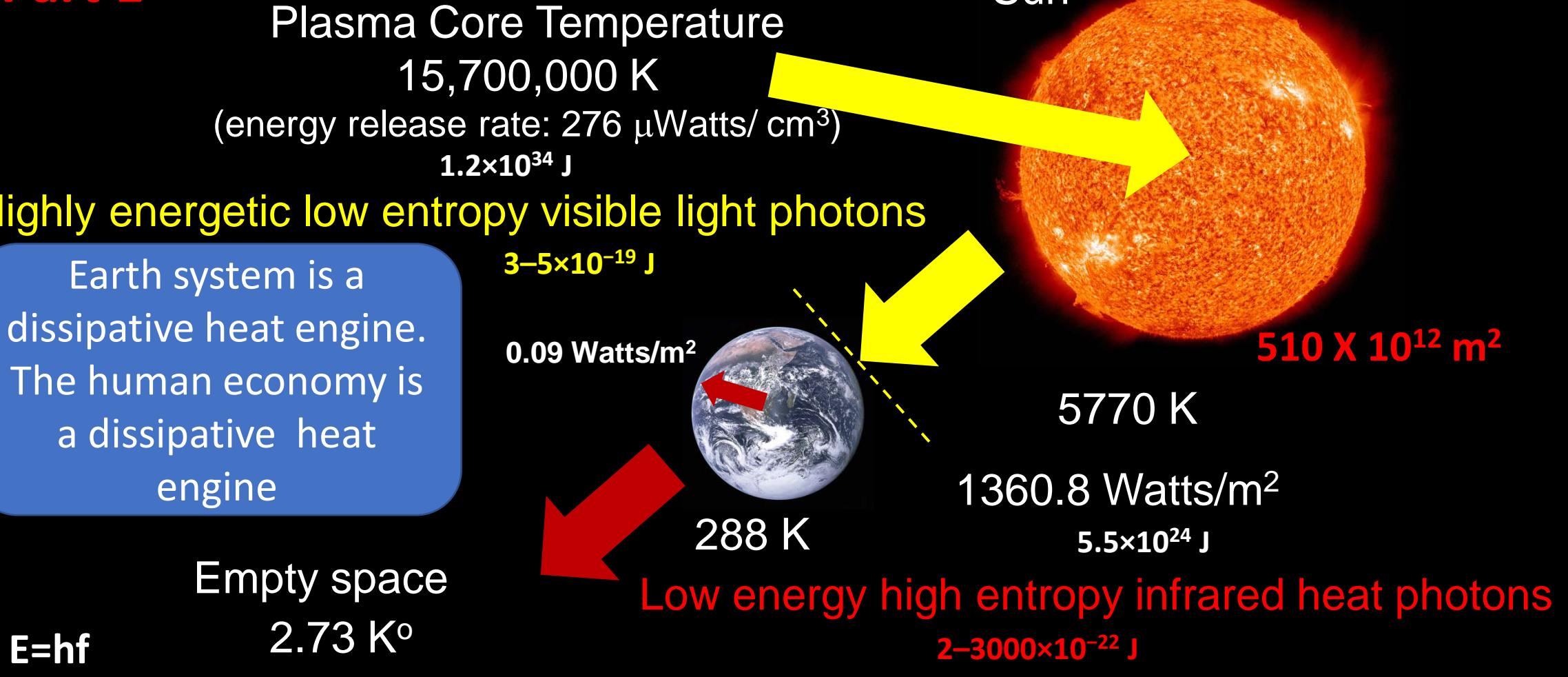


An Engineer's perspective on the Human condition the evolution of the universe

Part 1



$$E=hf$$

Not to scale

2.72 W/m⁻² Effective Radiative Forcing due to human emissions IPCC AR6

The entire history of the evolution of our environment

- Part 1 The evolution of the universe the first 9.3 billion years
 - Where did we come from
 - What are the laws
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- Part 6 solution space and discussion

Cliff notes version of Charles Langmuir and Wally Broecker's "How to Build a Habitable Planet" or Paolo Saraceno, "Beyond the Stars"

What is this course about?

“We need to address the question of separating true from false before we can adequately attempt to apply such understanding to separate good from bad.” Roger Penrose, *The Road to Reality*

How do we tell the difference between true and false, i.e., develop Moral Judgment?

First true observation we need to grasp:

“Energy conversion and entropy production drive life, the universe, the economy and everything.”

The rest is updated Carl Sagan, very useful and fun to know

Scope of human knowledge

Unknown unknowns, i.e.,
?????

Flat Earth



Denial of evolution



Young Earth < 10,000 years old

Climate Change denial



Holocene extinction denial



Neoliberal/neoclassical
economics



And so on...

“Things we ‘know’ for sure which just ain’t so”

Mark Twain

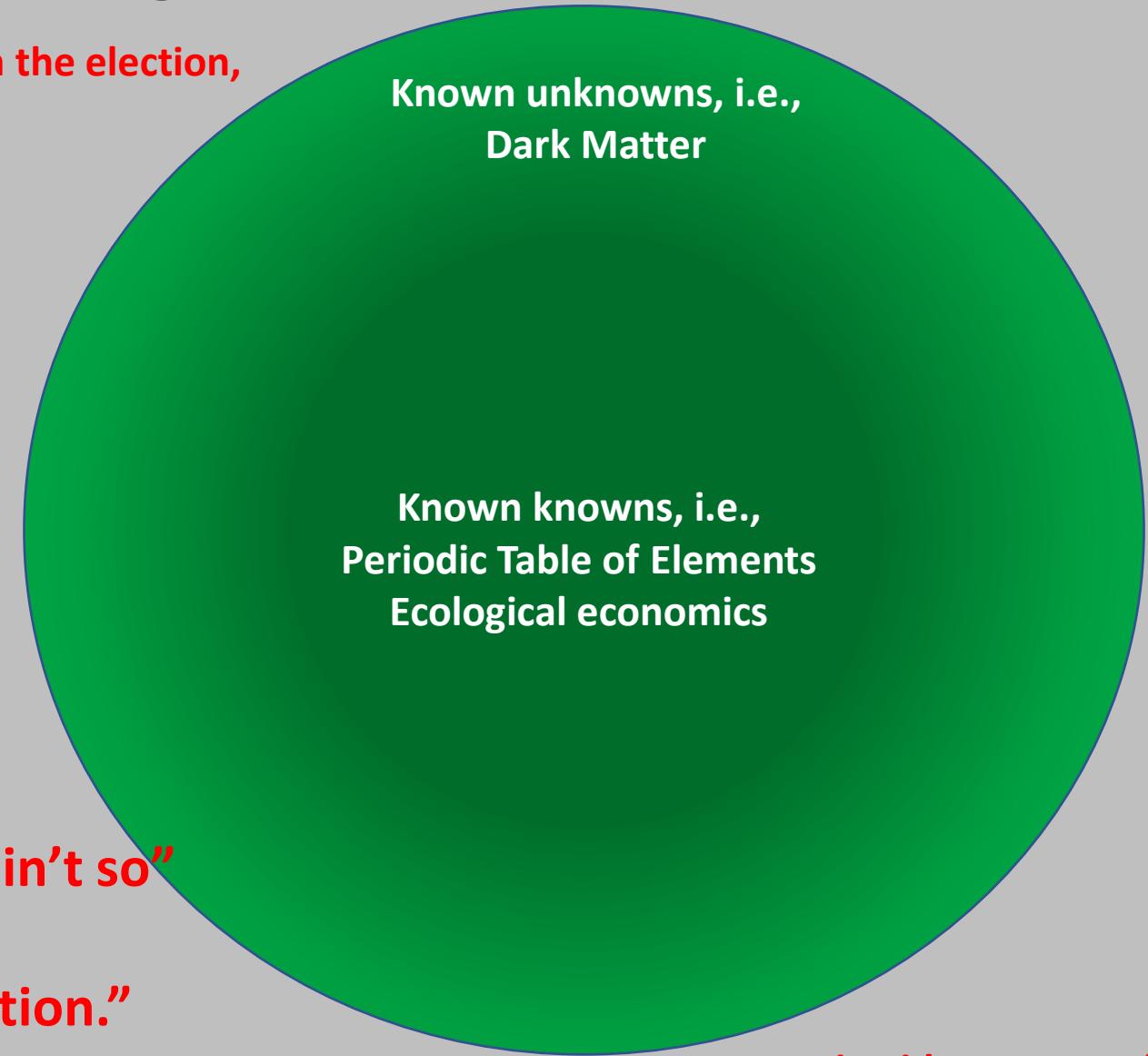
“Much of what we take to be real, is fiction.”

Yuval Harari

Trump won the election,
Q-ANON



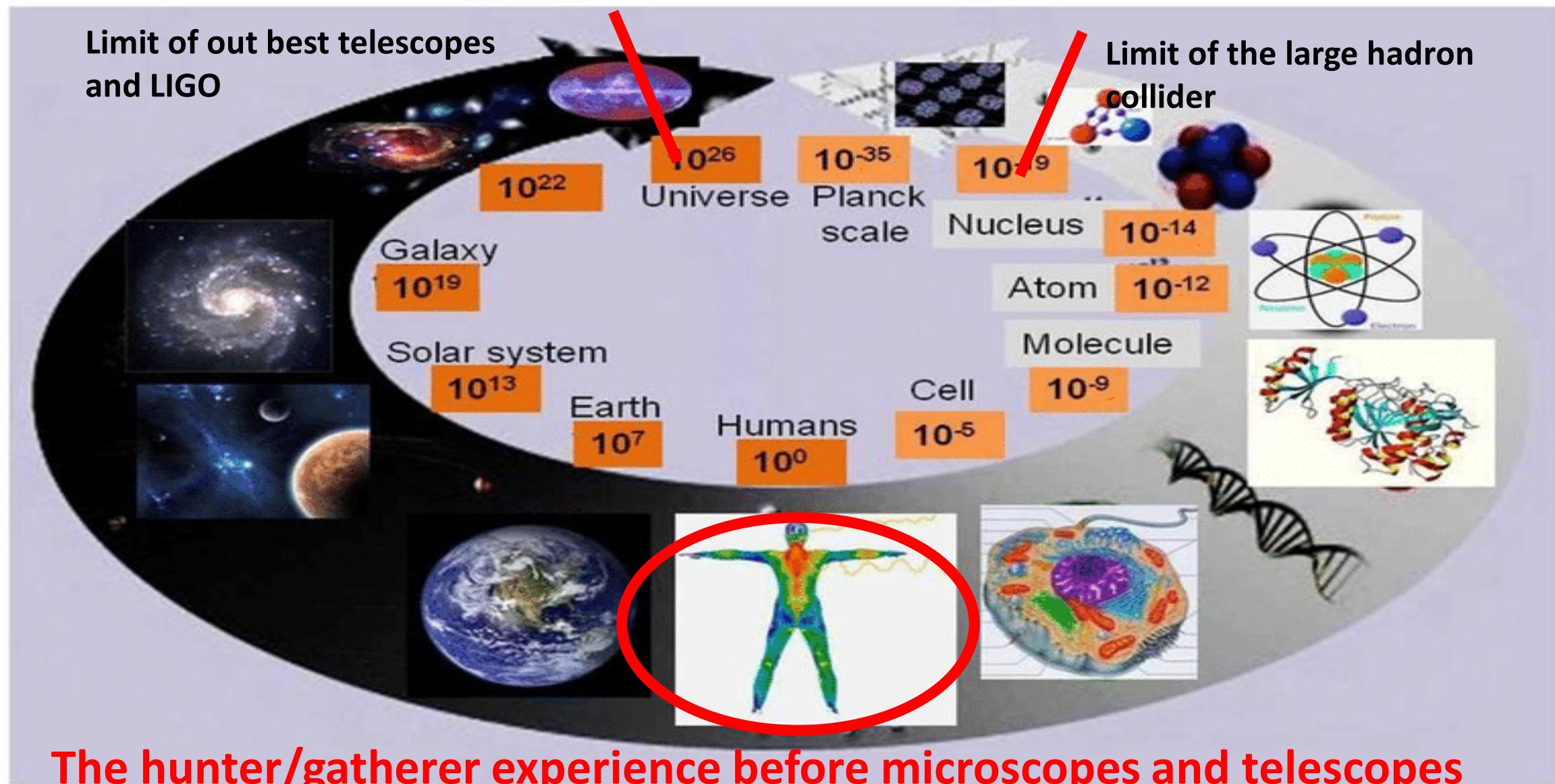
Known unknowns, i.e.,
Dark Matter



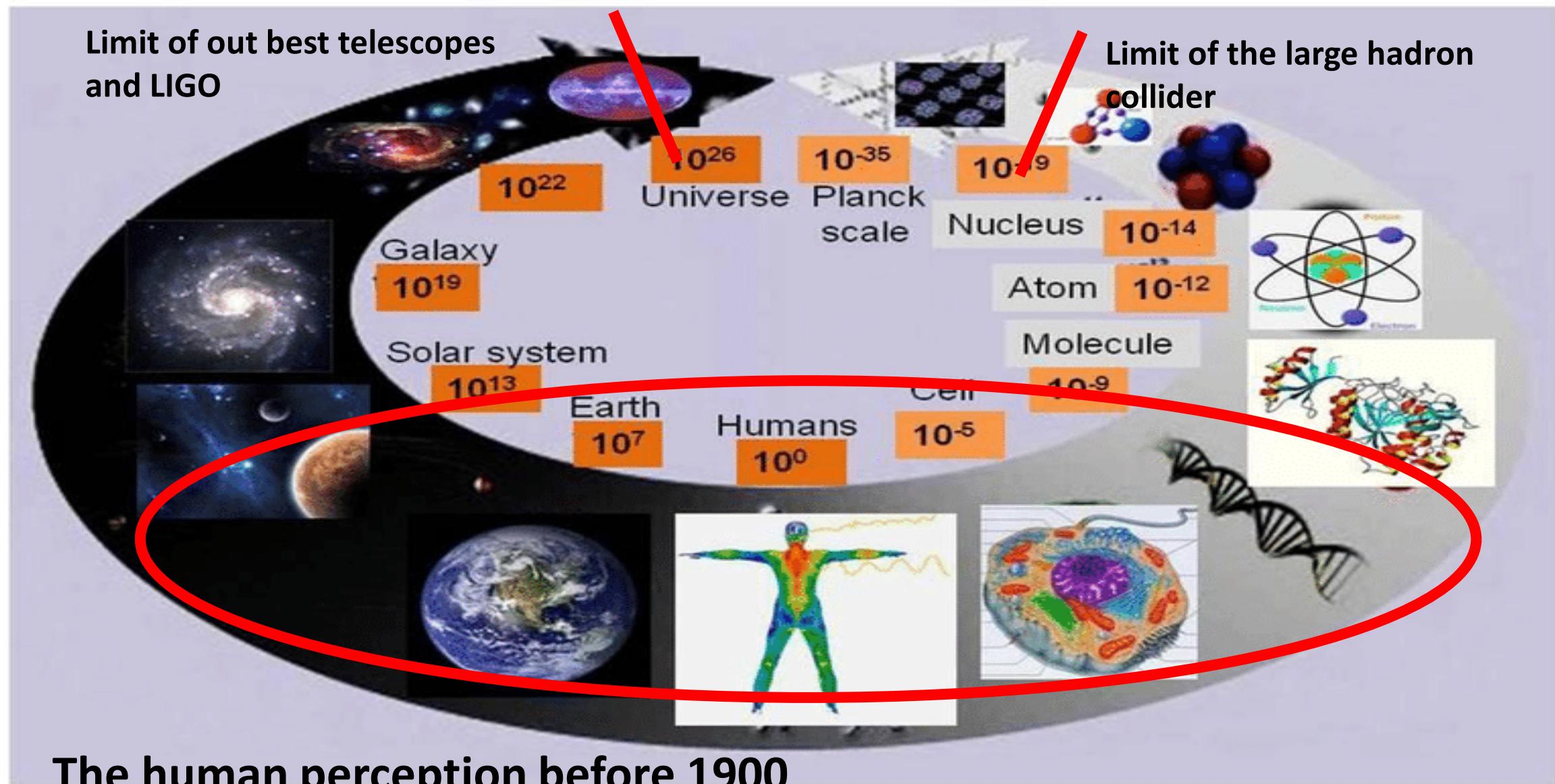
Known knowns, i.e.,
Periodic Table of Elements
Ecological economics

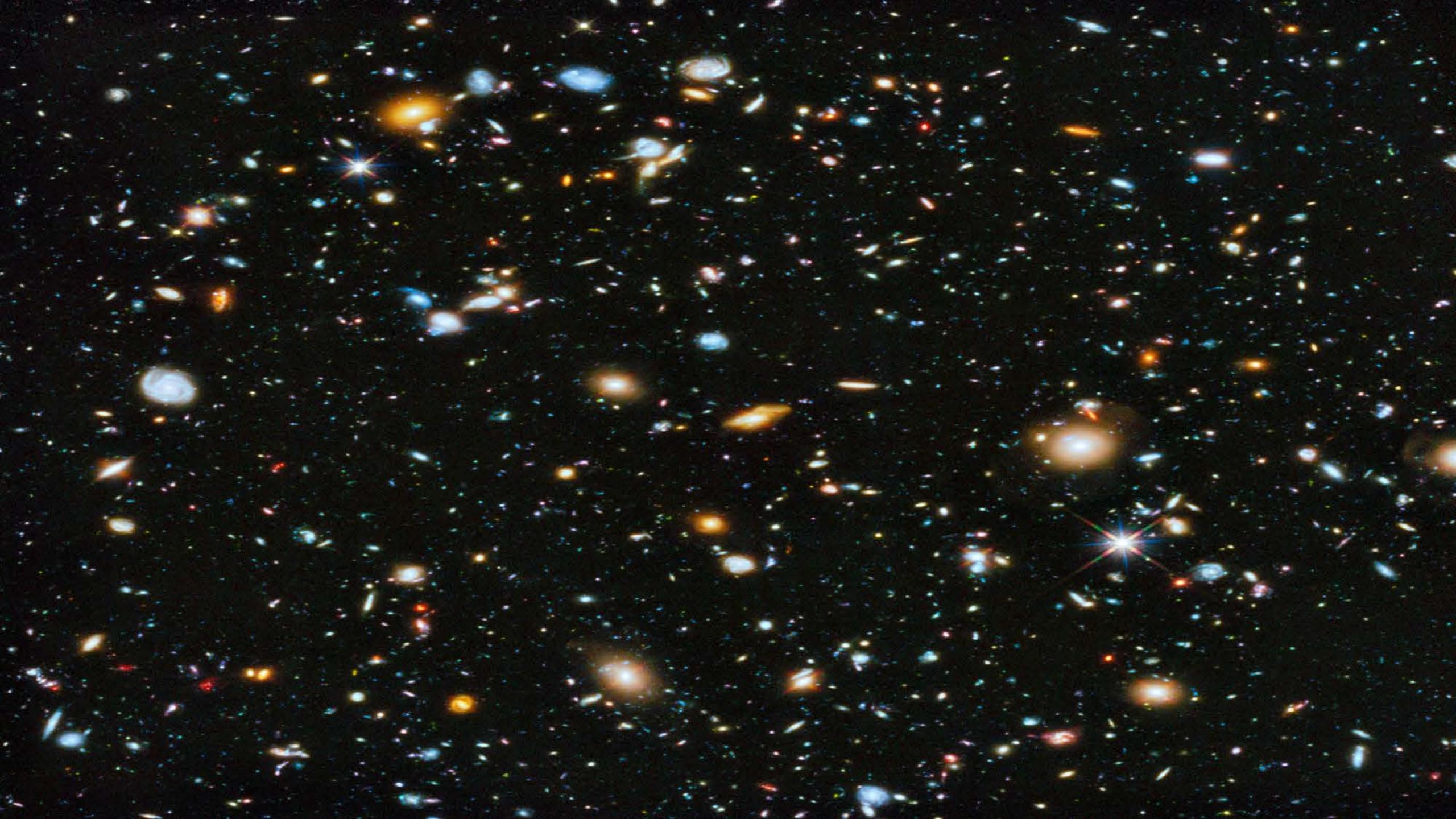
Denis Diderot, 1745, first
encyclopedia

Scaling the Universe from the macro to micro level in meters



Scaling the Universe from the macro to micro level in meters



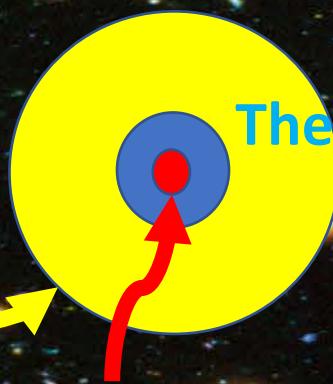


The Universe System

The solar subsystem

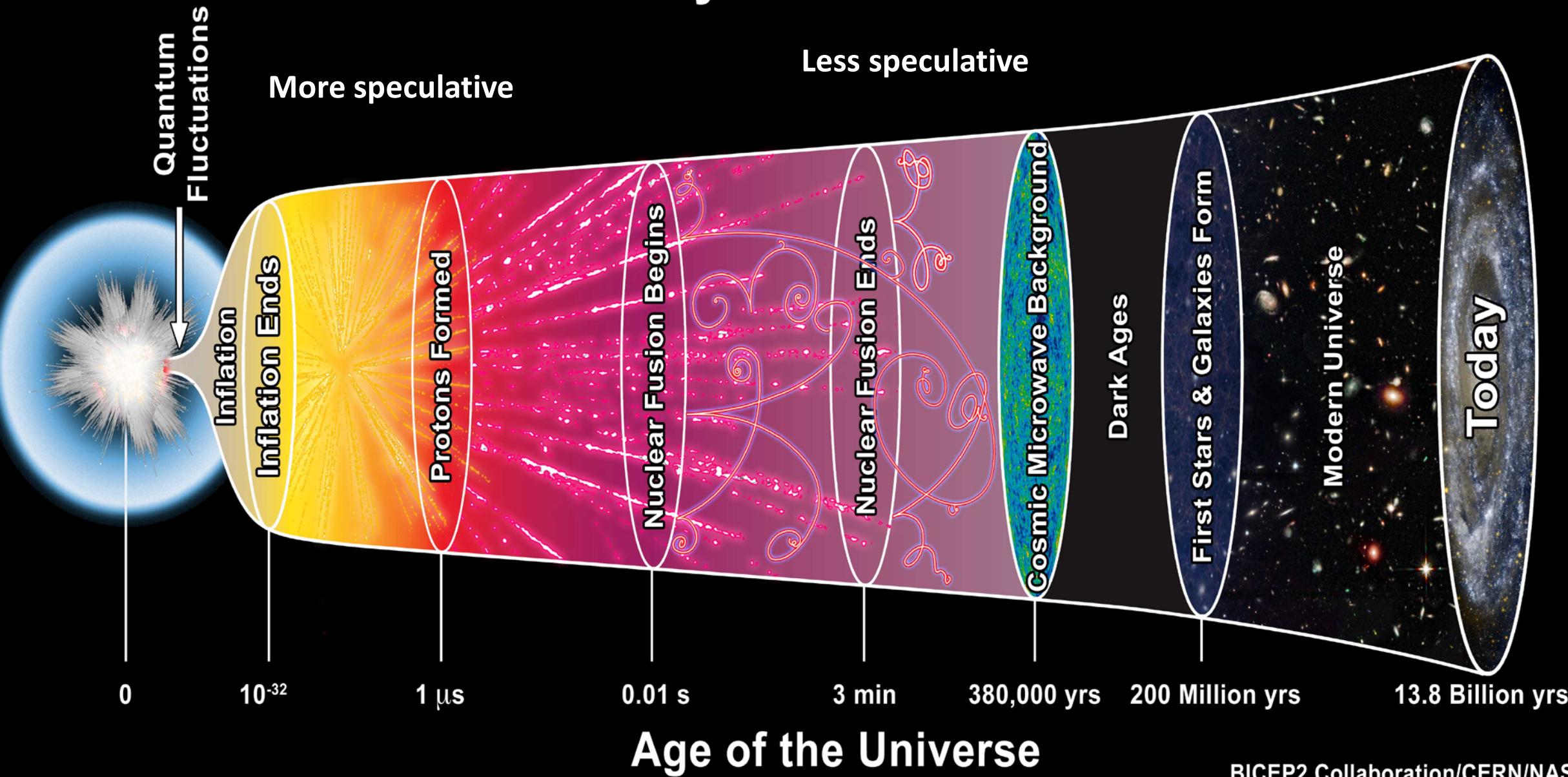
The Earth subsystem

The human economy subsystem



History of the Universe

Radius of the Visible Universe



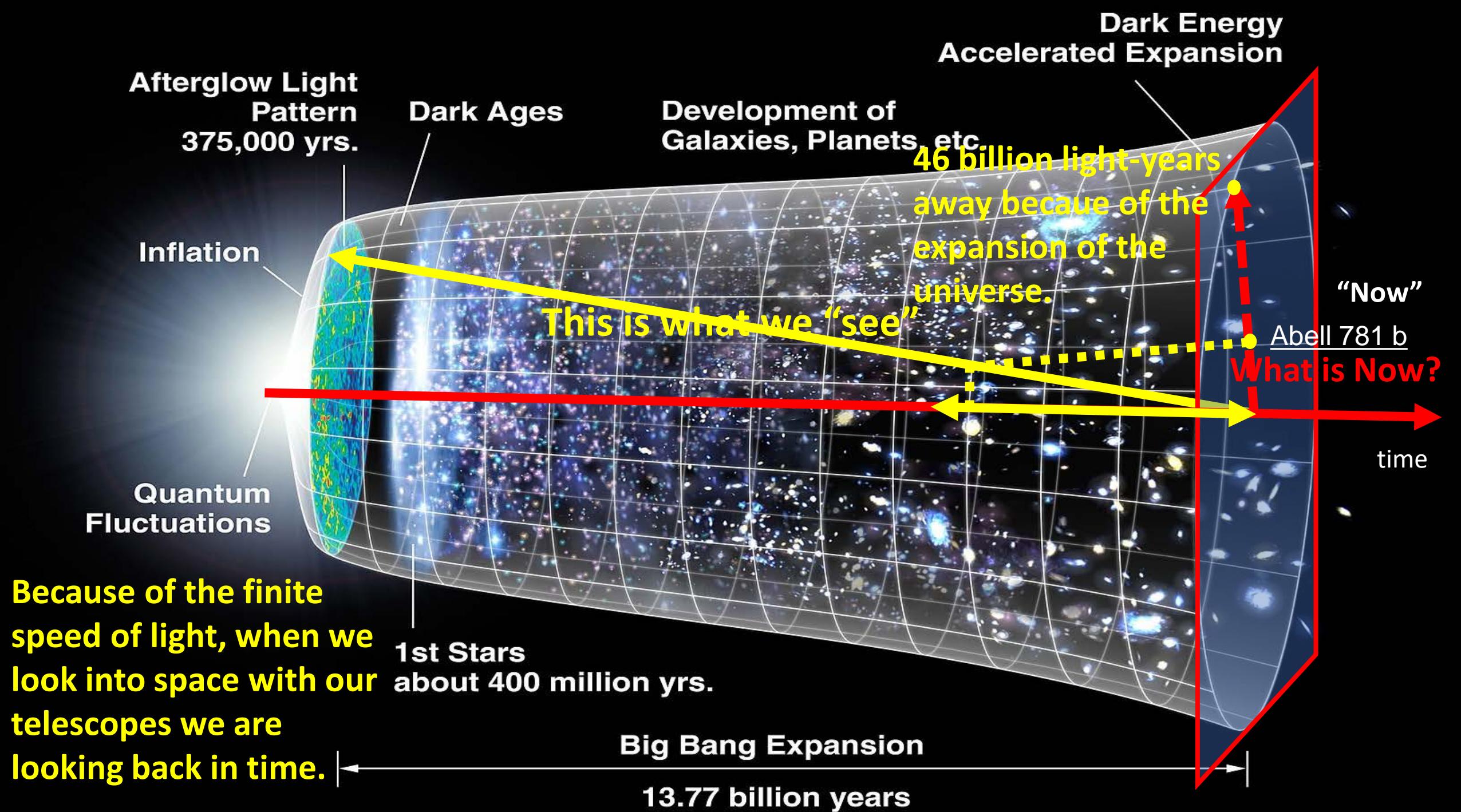
Cosmic microwave
background

Ralph Apher predicted
the CMB in 1948

Work requires an energy gradient

The red parts are colder and more dense by a factor of 1 part in 10,000

Don Lincoln, FermiLabs, <https://www.youtube.com/watch?v=AYFDN2DSVgc>



• Satellites in Geostationary orbit	0.14 seconds
• Moon	1.25 seconds
• Lagrange 2 point	5 seconds
• Sun	8 minutes
• Mars	12 minutes
• Nearest star Proxima Centauri	4.25 years
• Center of Milky Way	30,000 years
• Andromeda	2.5 million years
• Tadpole Galaxy	400 million years
• Comet Galaxy	3.2 billion years
• NGP-190387**	12.4 billion years
• SPT0311-58*	12.88 billion years
• Earendel oldest observed star	13 billion years (28 billion light years away)
• GN-z11 oldest	13.4 billion years (32 billion light years away)
• Cosmic microwave background	13.8 billion years

*water and carbon monoxide found in this star forming galaxy, Sreevani Jarugula, et al., “Molecular Line Observations in Two Dusty Star-Forming Galaxies at $z = 6.9$ ” 3 November 2021, The Astrophysical Journal.

<https://scitechdaily.com/water-a-requirement-for-life-as-we-know-it-detected-in-a-galaxy-far-far-away/> .

**fluoride measured Maximilien Franco, et al., “The ramp-up of interstellar medium enrichment at $z > 4$ ” 4 November 2021, Nature Astronomy. <https://doi.org/10.1038/s41550-021-01515-9>

Universal laws (we think, so far)

- General theory of relativity
- Special theory of relativity
- Maxwell's equations
- Darwinian Evolution
- Thermodynamics, Law of Entropy “anytime you use thermodynamics to explain something that explanation lasts forever.” Einstein
 - To do anything, requires the dissipation of an energy gradient
 - And this is irreversible and generates entropy
 - Entropy is time
- Conservation laws: energy, angular momentum, electric charge, lepton number, momentum, strangeness, baryon number
- Periodic Table of Elements
- Navier-Stokes equation
- Equivalence principle
- Quantum physics
- Concordance Model
- Quantum Electrodynamics
- ...

Science is what we can measure

[Sean Carroll, https://www.youtube.com/watch?v=-nTQi_LgIQ4](https://www.youtube.com/watch?v=-nTQi_LgIQ4)

Electron magnetic dipole moment (Dirac's number)

Theory $11596521807.3 \pm 2.8 \times 10^{-13}$

Really 1.00115965218

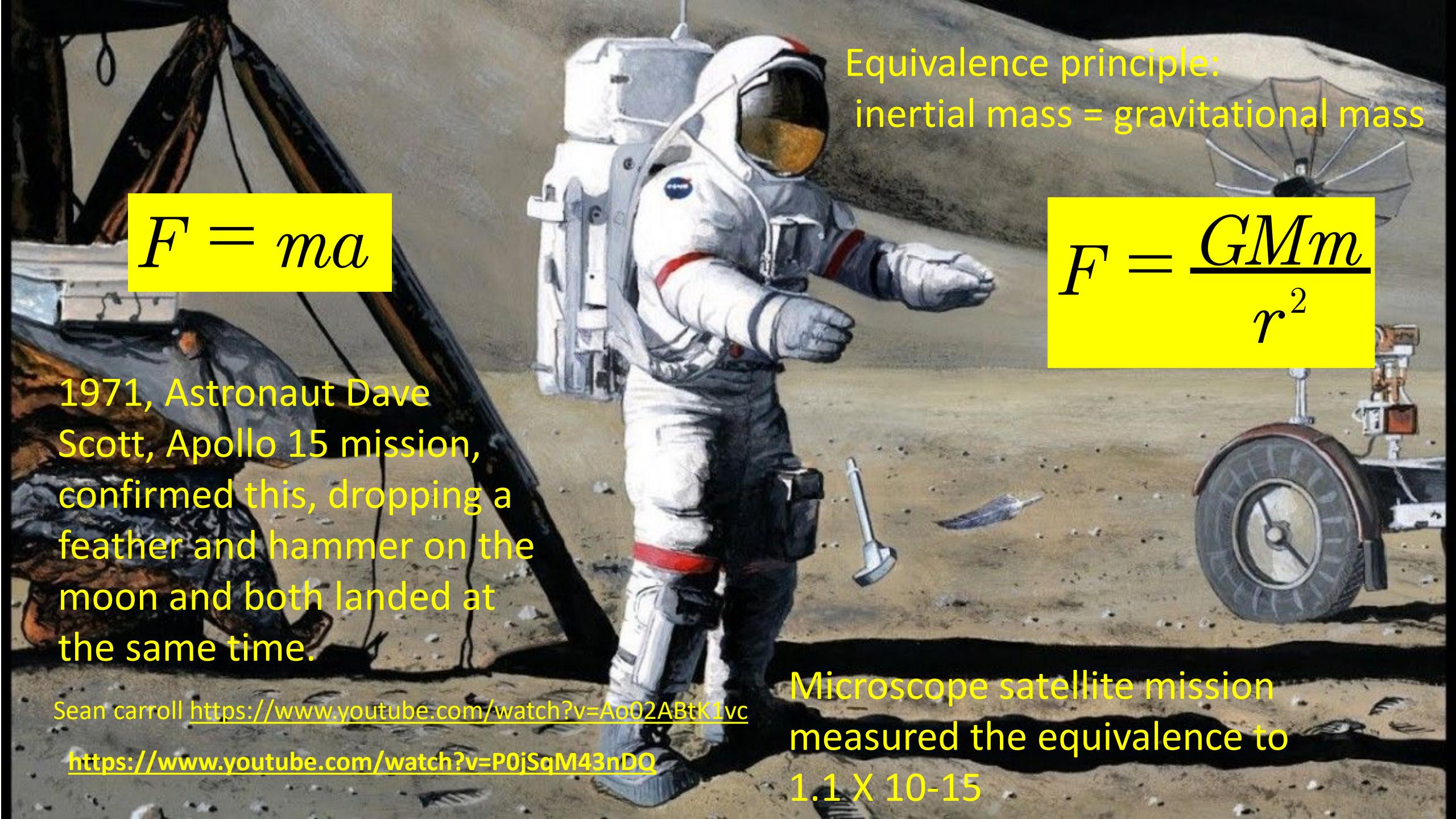
Experiment $11596521817.8 \pm 7.6 \times 10^{-13}$

Really 1.00115965218



The cosmological principle, the universe is isotropic and homogeneous at large scale.

Equivalence principle, inertial mass and gravitational mass of a body are the same.

A photograph of Astronaut Dave Scott in a white spacesuit standing on the light-colored, cratered surface of the Moon. He is holding a tool in his right hand. In front of him, a hammer and a feather are lying on the ground. A large, dark, cylindrical object, likely a scientific instrument or part of the lander, is visible in the foreground on the left. The background shows the vast, desolate landscape of the Moon's surface. $F = ma$

1971, Astronaut Dave Scott, Apollo 15 mission, confirmed this, dropping a feather and hammer on the moon and both landed at the same time.

sean carroll <https://www.youtube.com/watch?v=Ao02ABtK1vc>

<https://www.youtube.com/watch?v=P0jSqM43nDQ>

Equivalence principle:
inertial mass = gravitational mass

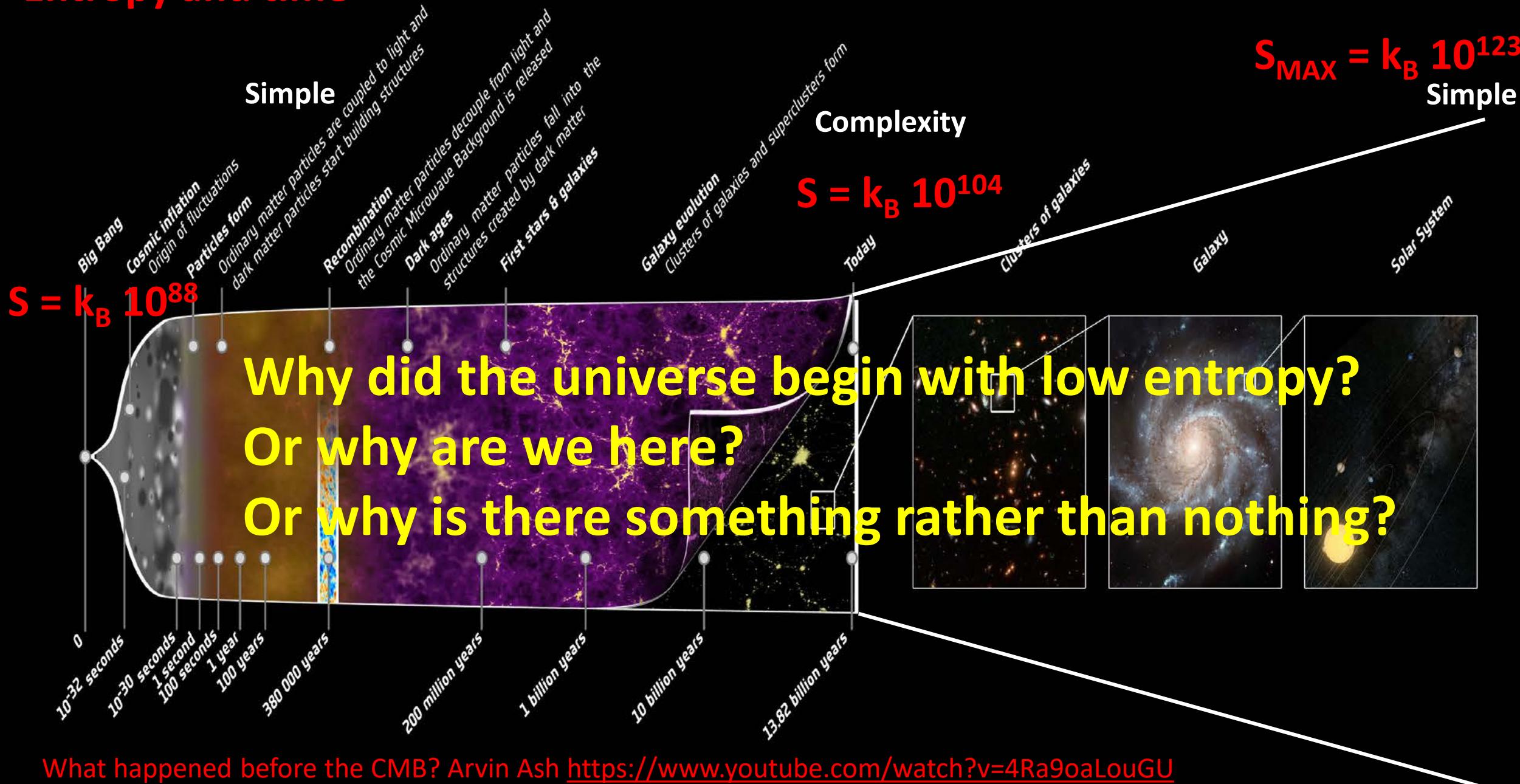
$$F = \frac{GMm}{r^2}$$

Microscope satellite mission measured the equivalence to 1.1×10^{-15}

Entropy and time

Stars will form normally for between 1 and 100 trillion years

$$S_{MAX} = k_B 10^{123}$$

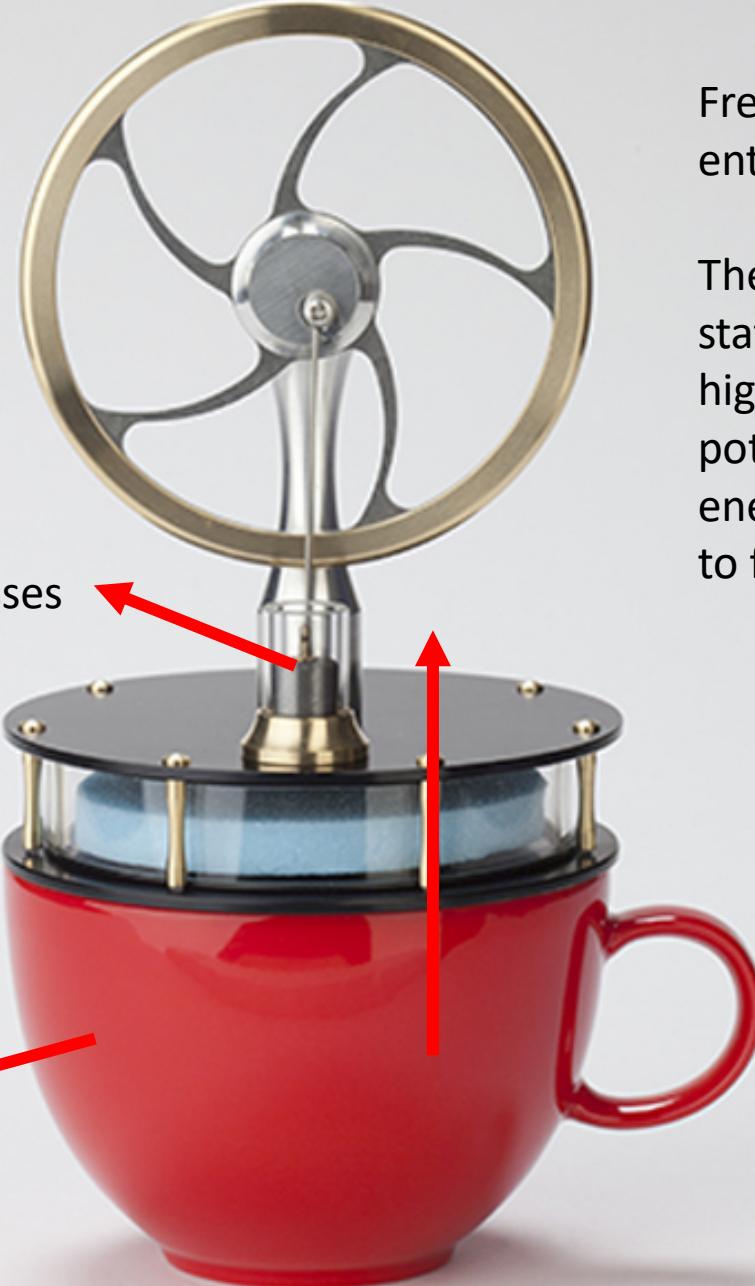


Stirling Engine

Ambient air at 20°C or
293 K

Friction losses

Heat loss



Cup of Hot Tea

Free energy is lost and entropy is created

The universe began in a state of low entropy or high free energy or potential energy or large energy gradient for energy to flow

Hot tea at 100°C or
373 K

Thermodynamics – its not just a good idea, it's the law

- To do any work requires a flow of energy
- To flow energy requires dissipation of an energy gradient
- Dissipating an energy gradient burns exergy and produces entropy
- Definition of entropy
 - Irreversibility (Carnot and Clausius)
 - Dissipation of potential energy or energy gradients or loss of free energy
 - Disorder (Boltzmann)
 - Amount of Information necessary to characterize a system (Shannon)
 - Time (Rovelli, Smolin, Verde)
 - Entanglement or quantum entropy (von Neumann)

Dr. Carl Pilcher, Interim Director of the NASA Astrobiology Institute, <https://www.youtube.com/watch?v=oY2itQu5hnI>

"The law that entropy always increases-the second law of thermodynamics-holds, I think, the supreme position among the laws of Nature. If ... your theory is found to be against the second law of thermodynamics I can give you no hope; there is nothing for it but to collapse in deepest humiliation."

Eddington, A.S., "The Nature of the Physical World," [1928], The Gifford Lectures 1927, Cambridge University Press: Cambridge UK, 1933, reprint, pp.74-75.

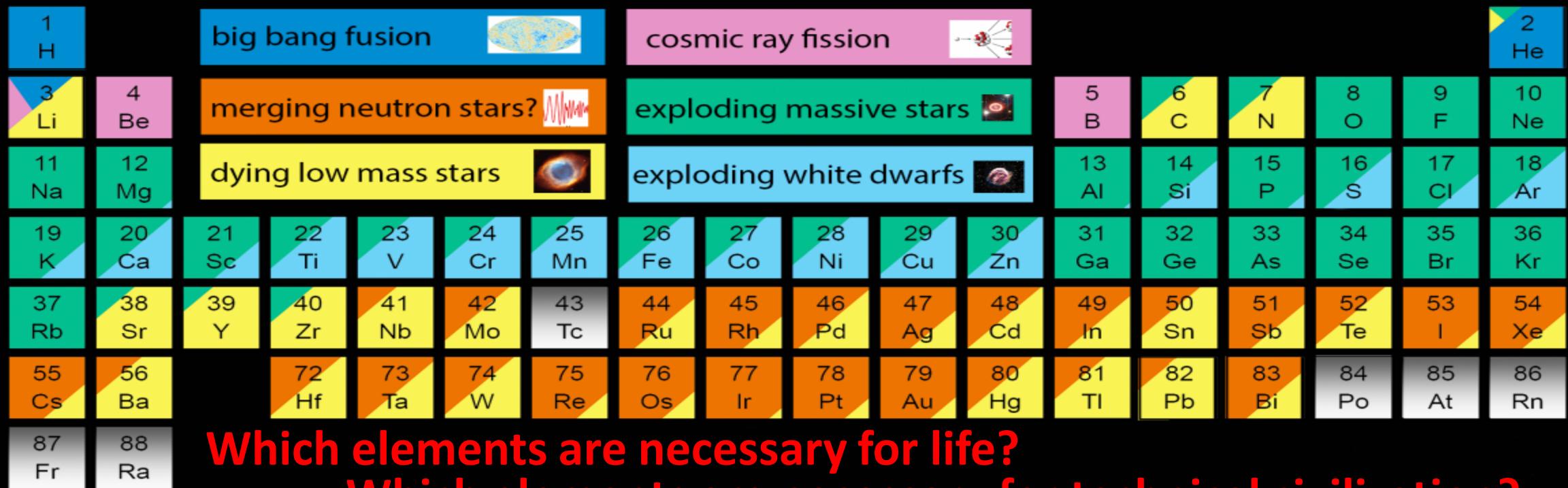
Dr. Matt O'Dowd, quantum entropy <https://www.youtube.com/watch?v=vgYQglmYU-8&t=2s>

Lee Smolin, Clelia Verde, The quantum mechanics of the present, April 20, 2021, <https://arxiv.org/abs/2104.09945>

Interesting stuff that may not explain anything

- Multiverse, predicts the most stuff but is the least predictive theory
 - Many worlds hypothesis
 - Qbism, quantum Bayesianism
 - The big bounce (cyclic cosmology)
 - Inflation theory
 - Holographic universe
 - Charge Parity Time reversal symmetric universe
 - String theory (string gas, membrane collision)
 - We are living in a simulation
 - M Theory
 - Supersymmetry
 - Superdeterminism
 - Loop quantum gravity
 - Quintessence (dark energy)
 - Geometrogenesis
 - Metaphysics (religion, spirituality, etc.)
 - Philosophy
- Laura Mersini-Houghton, Before the Big Bang: The Origin of Our Universe from the Multiverse,
https://www.youtube.com/watch?v=GYVg50_w1UA
- “Most of what theorists do is wrong. And theorists should recognize when they’ve gone wrong.”
“Wow, the universe is unbelievably simple.”
Neil Turok in an interview by Brian Keating, Oct 2, 2022,
<https://www.youtube.com/watch?v=Dt5cFLN65fI>
- Hossenfelder, <https://www.youtube.com/watch?v=CAUVq6BE1E>
- Products of imagination, creation tales, trying to answer that question**
- Hossenfelder and Palmer <https://arxiv.org/pdf/1912.06462.pdf>
- Matt Dowd, <https://www.youtube.com/watch?v=WfSZutedqIQ>
- ...yet

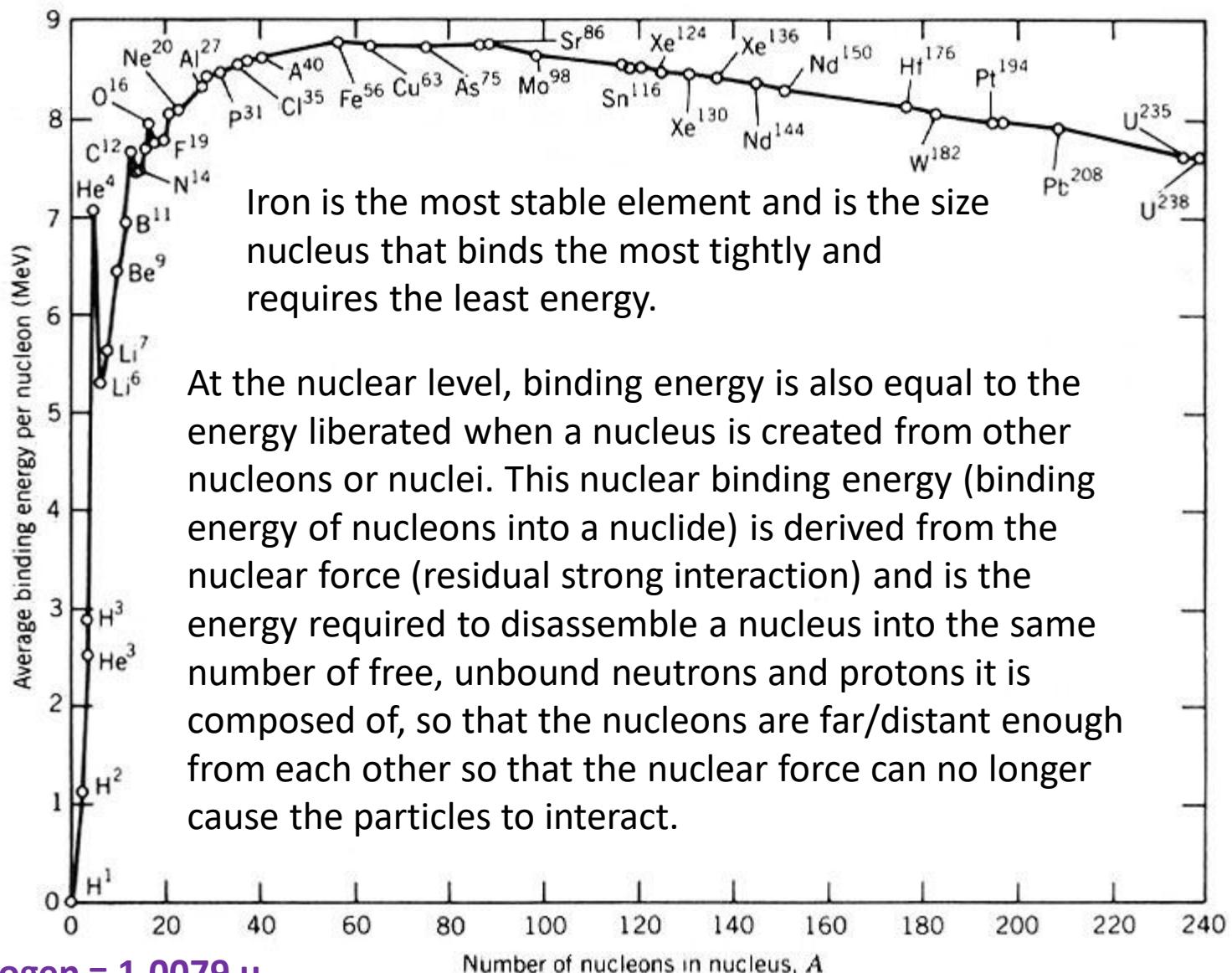
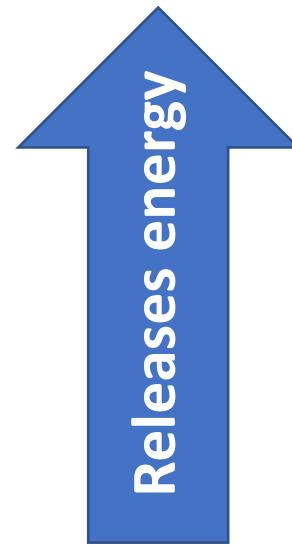
The Origin of the Solar System Elements



57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu									

Very radioactive isotopes; nothing left from stars

Atomic mass of iron = 55.845 u
Yet Iron atomic numbers are 56, 57 and 58

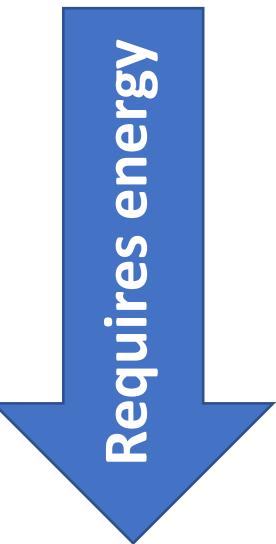


Iron is the most stable element and is the size nucleus that binds the most tightly and requires the least energy.

At the nuclear level, binding energy is also equal to the energy liberated when a nucleus is created from other nucleons or nuclei. This nuclear binding energy (binding energy of nucleons into a nuclide) is derived from the nuclear force (residual strong interaction) and is the energy required to disassemble a nucleus into the same number of free, unbound neutrons and protons it is composed of, so that the nucleons are far/distant enough from each other so that the nuclear force can no longer cause the particles to interact.

Atomic mass of hydrogen = 1.0079 u

$$E = mc^2 \quad *$$
$$S = k_B \log W$$

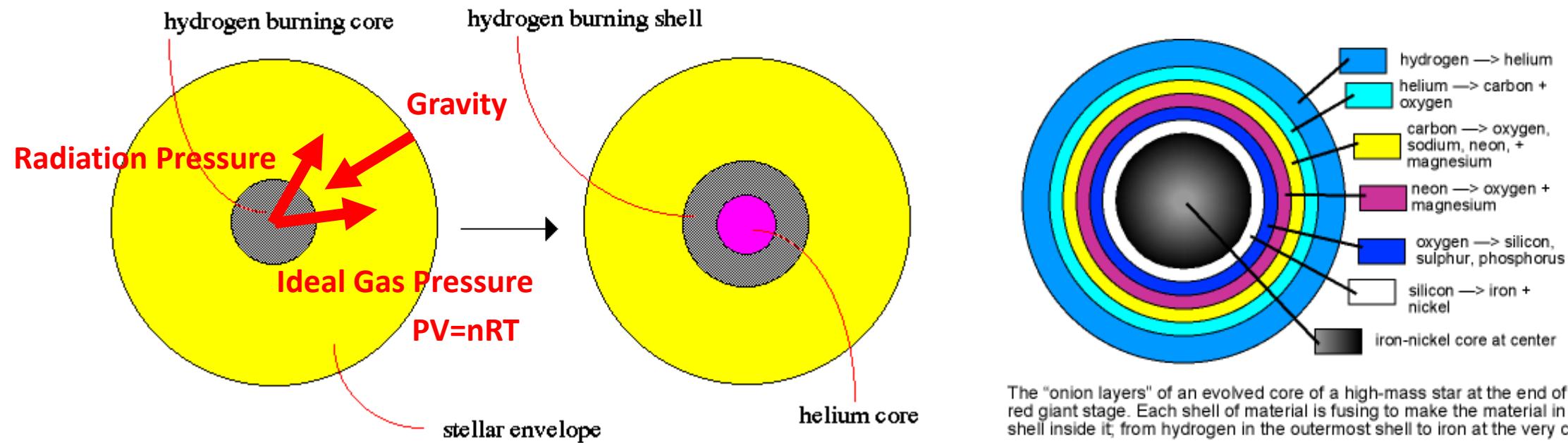


Solid -> Liquid -> Gas -> Plasma -> Energy entropy increases because there are more possible states

*Albert Einstein's original proof

https://sites.pitt.edu/~jdnorton/teaching/1632_Einstein_Almost Everyone/texts/Einstein_1905_Emc2.pdf

Core Exhaustion



The "onion layers" of an evolved core of a high-mass star at the end of its red giant stage. Each shell of material is fusing to make the material in the shell inside it; from hydrogen in the outermost shell to iron at the very center.

Name of process	Fuel	Products	Temperature
Hydrogen Burning	H	He	$60 \times 10^6 \text{ }^\circ\text{K}$
Helium Burning	He	C, O	$200 \times 10^6 \text{ }^\circ\text{K}$
Carbon Burning	C	O, Ne, Na, Mg	$800 \times 10^6 \text{ }^\circ\text{K}$
Neon Burning	Ne	O, Mg	$1500 \times 10^6 \text{ }^\circ\text{K}$
Oxygen Burning	O	Mg to S	$2000 \times 10^6 \text{ }^\circ\text{K}$
Silicon Burning	Mg to S	Elements near Fe	$3000 \times 10^6 \text{ }^\circ\text{K}$

Fermi Paradox: Are we alone or just isolated?

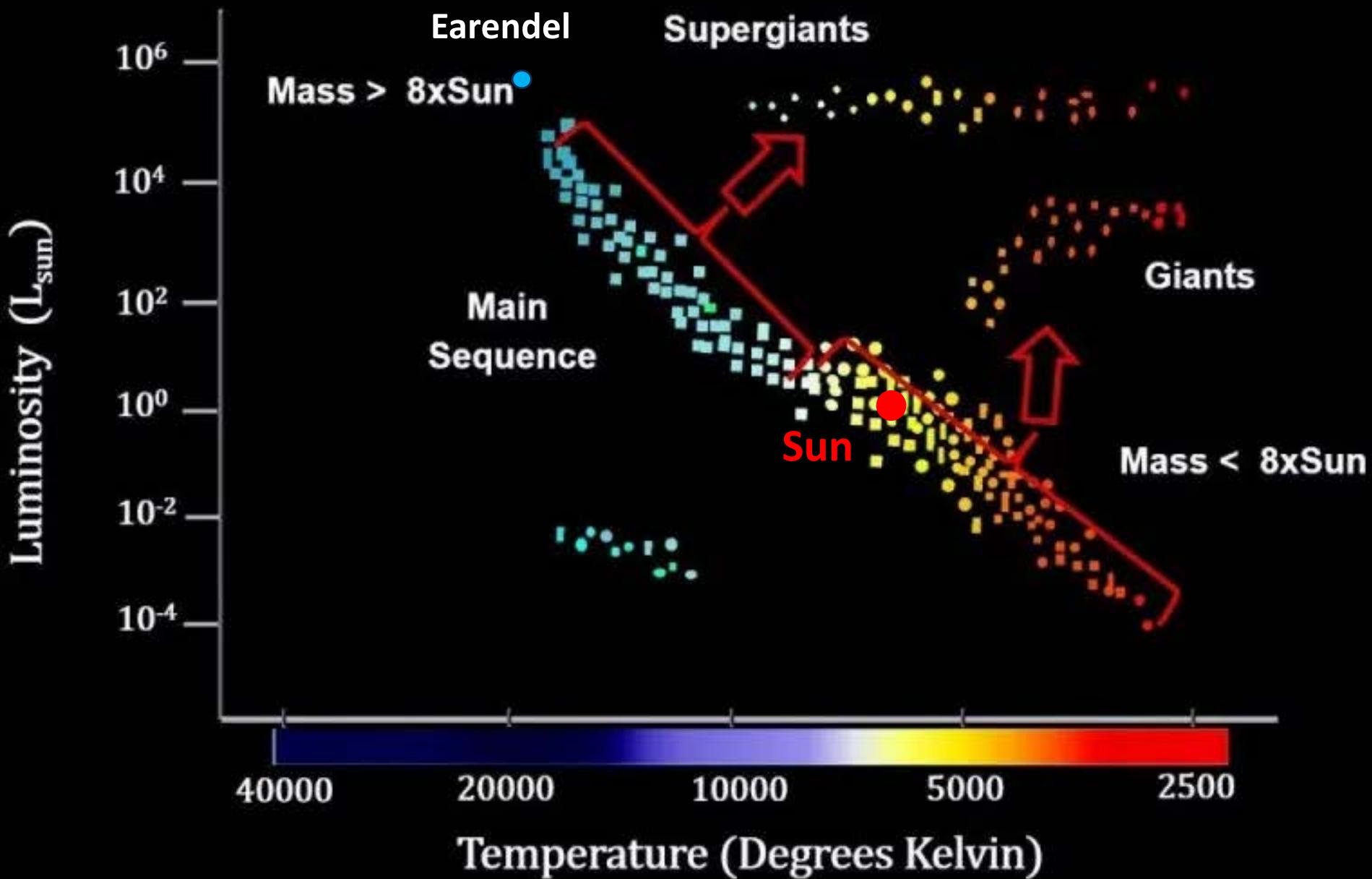
$$N = R_s \cdot f_p \cdot n_e \cdot f_I \cdot f_i \cdot f_c \cdot L$$

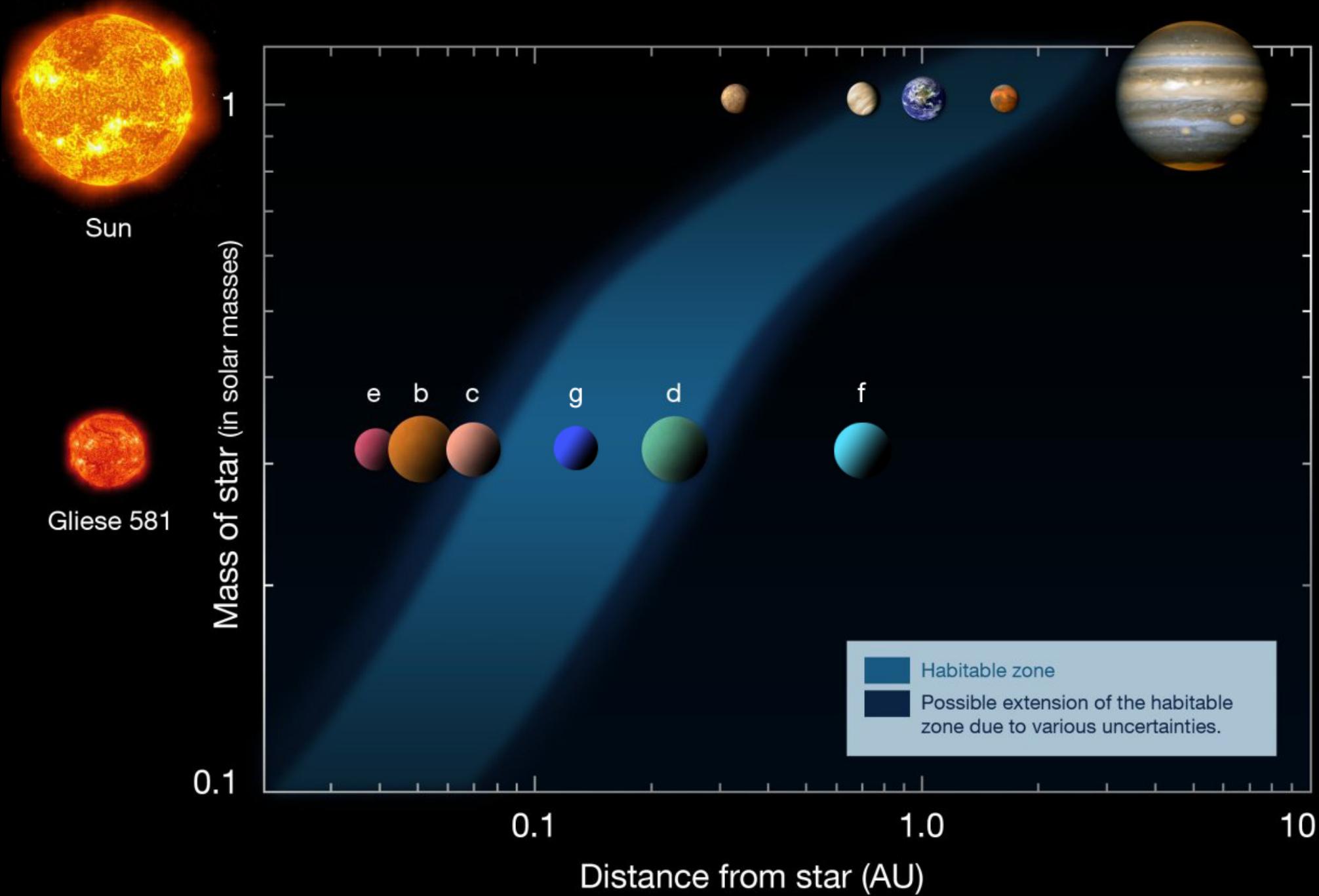
Drake's equation about isolation, not aloneness. All we really need to know
There are an estimated 300,000,000 habitable planets in the Milky Way Galaxy
There are an estimated 2,000,000,000 galaxies in the visible universe
The whole universe is estimated to be 1,000,000 times larger than the visible universe
Therefore there are potentially 600,000,000,000,000,000,000,000 planets in the Universe
which could have hosted, could host, or might someday host intelligent life.

Carl Sagan: "The universe is a pretty big place. If it's just us, it seems like an awful waste of space."

Enrico Fermi, 1950: "Where is everybody?"

The Fermi Paradox: 100 solutions and the survival of mankind, Alexander Popoff
Anton Petrov, January 2022, <https://www.youtube.com/watch?v=HcbQ3Gspyyo> new estimate of 36 (4-200) currently communicating alien civilizations nearest one may be 7,000 to 70,000 light years away





<https://scitechdaily.com/goldilocks-galore-hundreds-of-millions-of-planets-in-the-milky-way-could-potentially-harbor-life/>



Sarah Ballard and Sheila Sager, "The orbital eccentricity distribution of planets orbiting M dwarfs" 29 May 2023, Proceedings of the National Academy of Sciences.
<https://doi.org/10.1073/pnas.2217398120>

Body	Type of body and average distance from the sun	Why it might have life
Mars*	Planet, 1.5 AU	Might have subsurface pockets of liquid water
Ceres	Largest asteroid, 2.8 AU	Might have a subsurface ocean
Europa, Ganymede, Callisto	Large icy moons of Jupiter, 5.2 AU	Evidence for subsurface oceans
Enceladus**	Icy moon of Saturn, 9.6 AU	Evidence for a subsurface ocean and presence of organics
Titan	Largest moon of Saturn, 9.6 AU	Evidence for a subsurface ocean and presence of organics
Triton	Largest moon of Neptune, 30.1 AU	Might have a subsurface ocean
Pluto	Large Kuiper Belt object, 39.3 AU	Might have a subsurface ocean

Anton Petrov on NASA dragonfly mission
<https://www.youtube.com/watch?v=yzZs3t0QTfs>

*<https://scitechdaily.com/ancient-mars-may-have-been-teeming-with-life-until-it-drove-climate-change-that-caused-its-demise/>

“Early Mars habitability and global cooling by H₂-based methanogens” by Boris Sauterey, Benjamin Charnay, Antonin Affholder, Stéphane Mazevet and Régis Ferrière, 10 October 2022, Nature Astronomy. <https://doi.org/10.1038/s41550-022-01786-w>

**<https://scitechdaily.com/key-building-block-for-life-likely-discovered-on-one-of-saturns-moons/>

“Abundant phosphorus expected for possible life in Enceladus’s ocean” by Jihua Hao, Christopher R. Glein, Fang Huang, Nathan Yee, David C. Catling, Frank Postberg, Jon K. Hillier and Robert M. Hazen, 19 September 2022, Proceedings of the National Academy of Sciences. <https://doi.org/10.1073/pnas.2201388119>

Pluto may yet be a planet!

Dr. Becky Smethurst, January 20, 2022, <https://www.youtube.com/watch?v=fqHJ05IO-cA>
Anton Petrov, January 13, 2022, <https://www.youtube.com/watch?v=8-2HxrgqUnM>

<https://www.sciencedirect.com/science...>

<https://en.wikipedia.org/wiki/Planet#...>

<https://www.iau.org/administration/ab...>

<https://www.nature.com/articles/s4158...>

Summary

- We only know approximate laws to the laws of nature but they seem to be a good approximation
- The universe had to play out over some time, billions of years, to be able to host life.
- The universe began in a state of low entropy. We don't know why.
- The universe works to maximize entropy and dissipate energy gradients
- We are unique but we are not special
- Energy conversion and entropy production drive life, the universe, the human economy and everything
- We need to separate true from false before we can separate good from bad.

“A curious by-product of ever increasing entropy in the universe is that ordered, low-entropy structures, such as organisms, spring into existence.”

David Catling, Astrobiology, a very short introduction, Oxford, 2013

Limits

- Speed of light
- Shannon's limit on information transfer in a noisy channel
- Carrying capacity of Earth NPP
- Carnot heat engine efficiency
- Limited energy gradients to exploit
- Limited resources
- Limited ability to export entropy
- Limits to growth on a finite Earth*
- Maximum entropy $S = k_B 10^{123}$

*Meadows, Meadows, Randers, Behrens, Limits to Growth, 1972

Ugo Bardi, Limits to Growth Revisited, 2011

Ugo Bardi, ed., Limits and Beyond, 2022

Robert Hanlon, The History and Theoretical Foundations of Thermodynamics

Vaclav Smil, How the World Really Works.

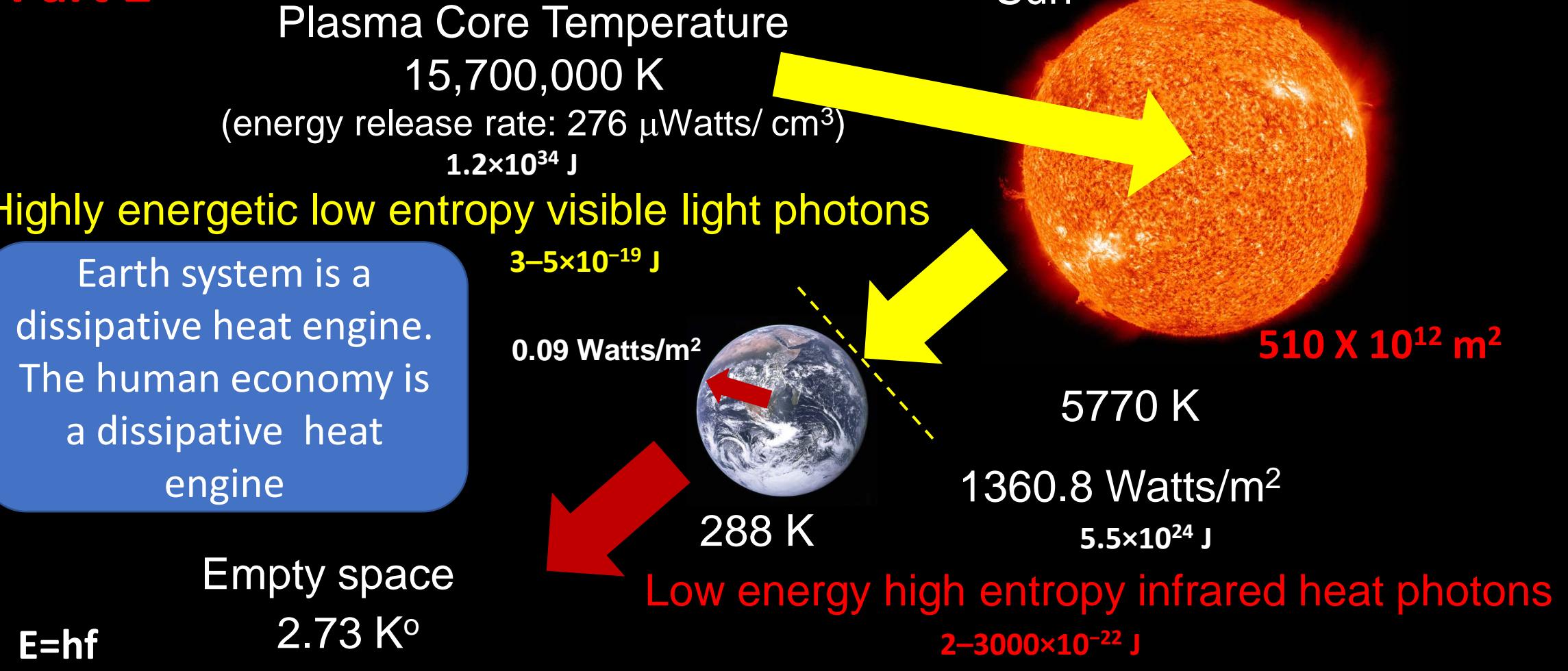
The entire history of the evolution of our environment

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An Engineer's perspective on the Human condition the evolution of the Earth

Part 2



$$E=hf$$

Empty space
2.73 K^o

Not to scale

2.72 W/m⁻² Effective Radiative Forcing due to human emissions IPCC AR6

Bonus

- Erika Nevold “Off-Earth: Ethical Questions and Quandaries for Living in Outer Space”