
The background of the slide is a dark blue and black cosmic map, likely representing the Cosmic Microwave Background (CMB) with temperature fluctuations. Overlaid on this are numerous thin, golden-yellow lines that form a complex, tangled web, resembling particle tracks or a network of connections. The overall aesthetic is scientific and cosmic.

**The Origins
of Physics, Chemistry, and Biology
or
the Big Bang is the Culprit**

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In the beginning
was the word:
*** BIG BANG ***

...TRULY, IT IS THE CULPRIT...

- **+10⁻⁴³ second: Planck time – start of PHYSICS:**
Temperature **10³² K**; Energy per particle **10²⁸ eV**
Density **10⁹⁷ kg/m³**: **EXPANSION OF SPACE →**
Continuous Decrease of Temperature & Density:
Supersymmetry breaking (gravity detaches from
GUT – Grand Unification Theory),
Matter/Antimatter asymmetry (violation of parity):
(10⁹+1)/10⁹

- **10^{-35} second: COSMIC INFLATION** – hyperexpansion $10^{30}x$!!!
Free quarks, leptons & photons: Energy $<10^{23}$ eV, Temp. $<10^{27}$ K
GUT breaks down (strong nuclear force detached from EW)

- 
- **10^{-10} second: HADRON ERA**
ELECTROWEAK FORCE breaks down to
electromagnetic & weak nuclear force:
Energy 100 GeV, Temperature 1 PK

- **0.1 millisecond: LEPTON ERA:**
Energy 100 MeV, Temperature 1 TK, Density 10^{17} kg/m³

- 
- **0.1 s:** Universe transparent to neutrinos
Density 10^7 kg/m^3
Positron-electron pairs annihilate to gamma rays

- **10 seconds:**

Radiation era

Energy 500 keV , Temperature 5 GK , Density 10^4 kg/m^3

- **3 minutes:**

Simple nuclei created: $\text{H/He} = 3/1$ (Mass ratio)

Very hot relic radiation dominates the scene

- **380 thousand years:**

Detachment of radiation from matter – transparent Universe

Electrons attached to atomic nuclei – first neutral atoms

Dark Age begins

- **200 million years:**

Birth of Generation I very massive
(= short-lived) pure H/He stars

Stellar black holes merge together
into black superholes –
seeds of galactic cores and quasars

- **1 billion years:**

First mature galaxies and galactic clusters;
birth of less massive Generation II stars



THE ORIGIN OF CHEMISTRY

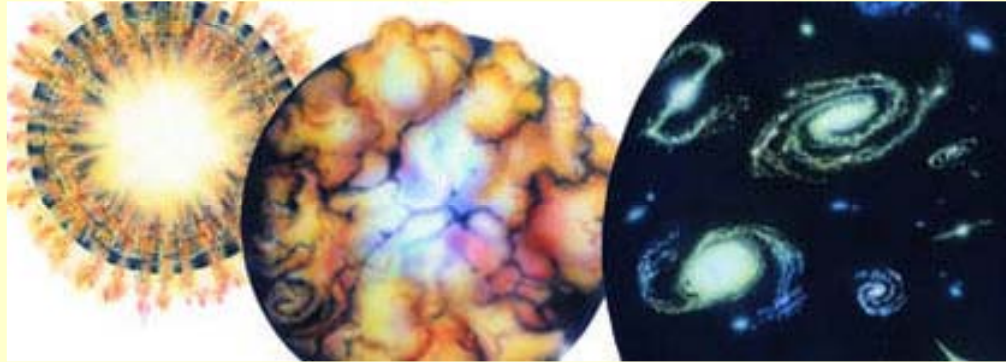
It is well-known that **carbon** is required to make physicists

Robert Dicke (1916-1997)

American physicist

Whence the CARBON?

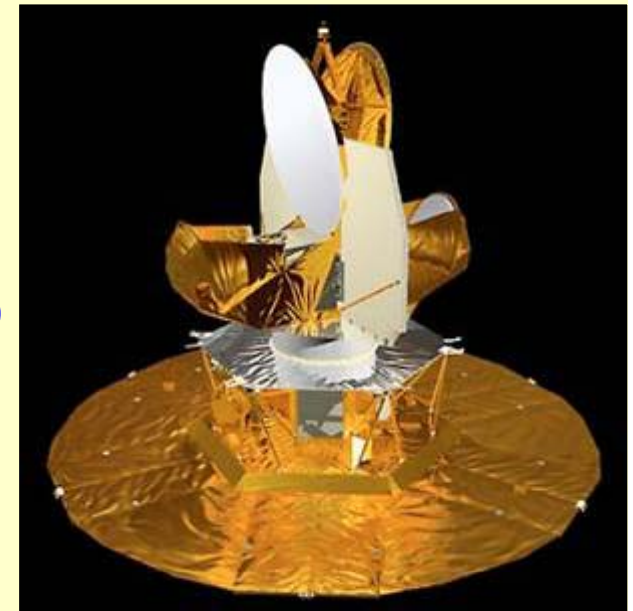
R. Alpher & G. Gamow (1948-1950): **Big Bang theory:** ridiculed, because it failed to create **C** etc.



S. Weinberg, 1977: **The First 3 Minutes:**
Primordial elements: $3/4$ H; $1/4$ He; (Li, Be, B)

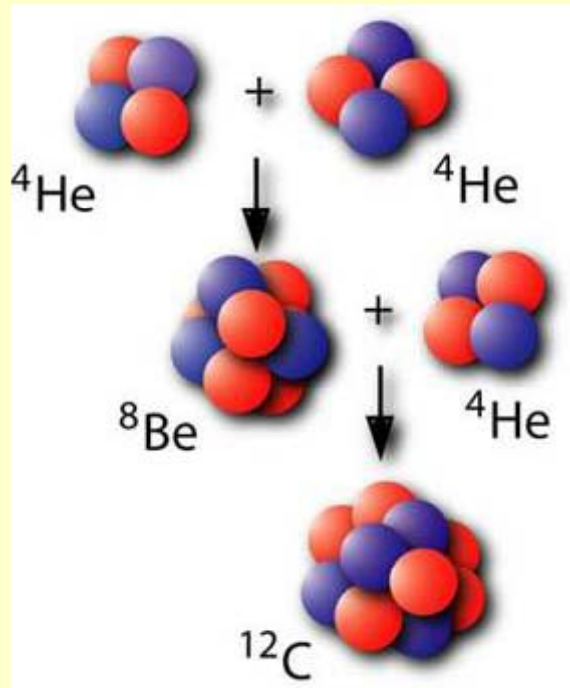
WMAP – background microwave radiation
2003: Age of the Universe: **13.7 gigayears**

First H/He stars formed 200 Myrs after the Big Bang; Ignition of thermonuclear (>12 MK) reactions in their cores



H. A. Bethe, 1939:

Basic Thermonuclear Reaction in All Stars: Transmutation of Hydrogen into Helium via **p-p chain** (0.7 % of the rest-mass)



E. E. Salpeter, 1952: miraculous synthesis of **CARBON** in *triple-alpha process*

F. Hoyle, 1954: *Anthropic principle:* probability of capture of alpha-particles is enhanced due to approximate **resonance** of energies: ground state of *triple-alpha* \approx excited state of ${}^{12}\text{C}$ (7.82 MeV vs. 8.13 MeV)

E. M. & G. R. Burbidge, W. Fowler, F. Hoyle: **nucleogenesis**
Synthesis of the elements in stars. Rev. Mod. Phys. 29(1957), 547

Elements Cycle in the Universe

a) Carbon ($Z = 6$) to Iron ($Z = 26$): Series of thermonuclear reactions due to substantial increases of core temperatures of ageing stars (up to **3 GK** in massive stars). Time span for a star is inversely proportional to the square of its initial mass (10^6 to 10^{11} years)

b) Mass-loss of Stars:
Stellar Winds & Supernova Explosions (Enrichment of interstellar medium with heavier elements [*“metals”*])

(Supernova 1987A remnant in the Large Magellanic Cloud – 165,000 light years)



c) **Neutron capture** during SN hours-long explosions creates the rest of elements (Cu...precious metals...U); very low abundances!

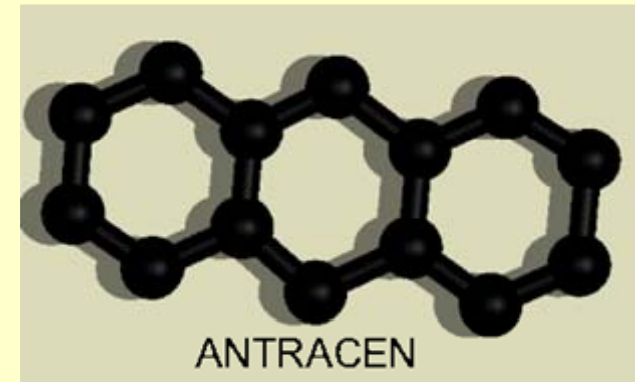
d) Enriched Interstellar medium
(diluted cold gas and dust)
concentrated into Giant Molecular
Clouds. Stars of generation II are
born in groups by gravitational
contraction of cloud fragments

Orion nebula (1,300 light years) →



Giant Molecular Clouds are big (several hundred light years), massive (up to million Solar masses), cold (10 ÷ 200 K) and stable for many hundred million of years

Infrared & MW spectroscopy: >100 molecules found in the interstellar space (di-atomic to polycyclic aromatic hydrocarbons and fullerenes)



e) **Formation of Generation III of Stars:** abundance of metals increased to $\approx 2\%$ (solar). Our Sun was born 4.6 billion years ago. It will release luminous energy from the **p-p chain** for the next 6.6 billion years. Then it will evolve to red giant star; Earth will evaporate. Finally, Sun will collapse into very hot white dwarf surrounded by a planetary nebula

White dwarf *density* will be million times higher than water; its *radius* as small as of the (former) Earth

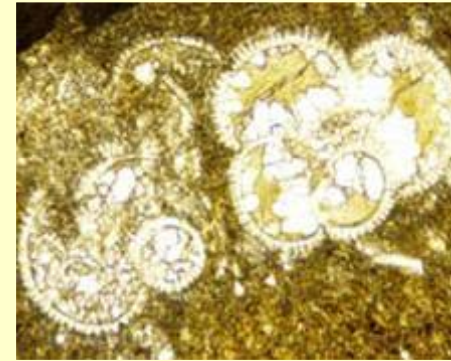


The Beginning of Life on Earth

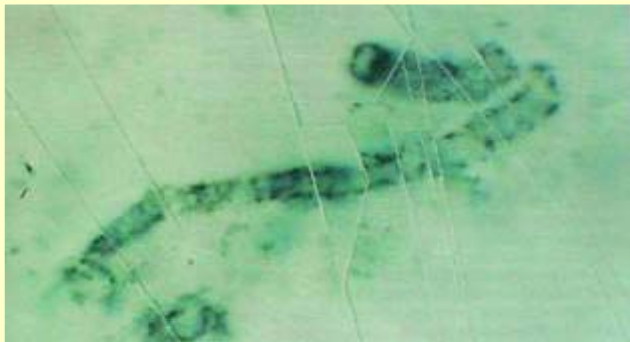


- **4.6 billion years:** accretion disk of the Solar System evolved in ProtoSun & Planets

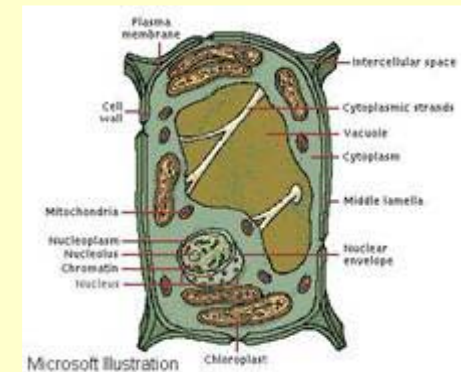
- **3.5 billion years:**
first microfossils



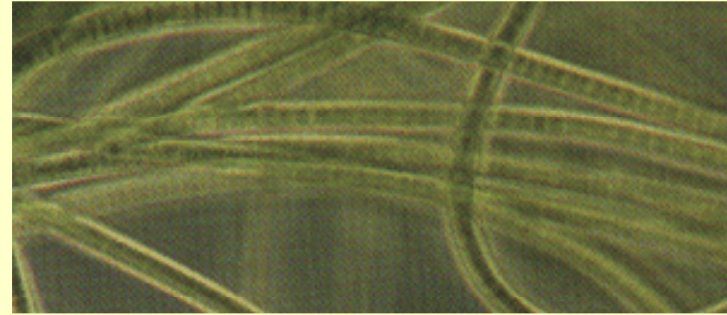
- **2.7 billion years:**
eukaryotic cells



- **800 million years:** first multicellular organisms



- 600 million years: Blue-Green
Algae on the Ground



- 210 million years: Dinosaurs;
Sudden extinction: - 65 million years

- 100 million years:
Mammals



- 80 million years: Birds

- 5 million years: hominids



- 100,000 years: *Homo sapiens sapiens*



C. H. Lineweaver, T. M. Davis (2002): Life on Earth appeared soon after the end of Heavy Bombardment (- 4 Gyr); thus in the Universe a *simple (monocellular) life is common*



However, *complex life* evolved here very slowly; thus in the Universe it *is very rare*

Speculative deliberation

Genetic code codes 20-22 **aminoacids**, all optically left-handed. **Saccharides** are, however, always right-handed although in the nature both optical versions are abundant

Is the **similar biochemistry** and an **universal genetic code** the proof of a common (unique?) origin of life?

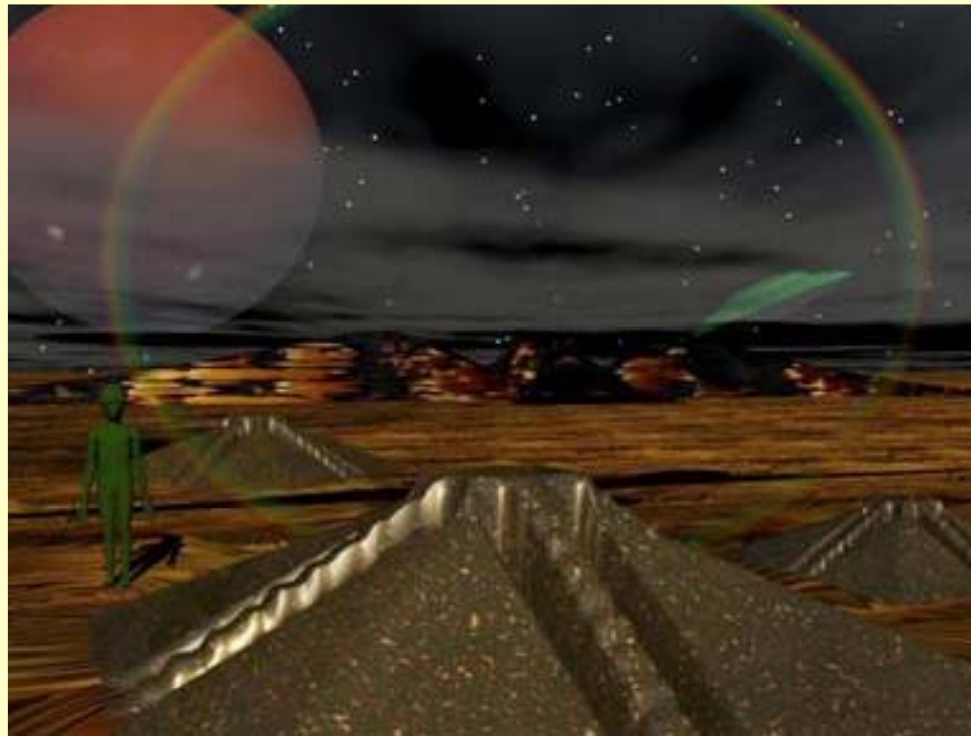
Is the life:

- I. A **lucky coincidence** of an improbable accident, or
- II. an **inevitable consequence** of the evolution course of the Universe?

In case I. we are most probably alone in the Universe;
in case II. it is suspiciously strange that we were not yet visited by the Aliens (**Fermi paradox**)

We are alone in the Universe or we are not; either way it's mind-boggling

Lee Du Bridge, president, *Caltech* (1979)



State of Physics

Kvarky	u up	c charm	t top
	d down	s strange	b bottom
Leptony	ν_e e- neutrino	ν_μ μ - neutrino	ν_τ τ - neutrino
	e electron	μ muon	τ tau
I II III Tri generace hmoty			

BEGINNING at Planck time
 Evolved due to the expansion of space:

3 generations of mass particles
 6 flavours of quarks (+ antiquarks):

d, u, s, c, b, t

6 leptons (3 modes of neutrino;
 3 modes of electron)

4 fundamental interactions:

GRAVITY: universal, attractive, very weak, infinite range: *gravitons*

ELECTROMAGNETIC: applies to charged particles: *photons*
 attractive/repulsive, infinite range

2 NUCLEAR: strong & weak: very short range; *gluons, bosons W + Z*

State of Chemistry

Building stones:

3 minutes after the Big Bang: atomic nuclei H, He, Li, Be, B

380 thousand years after BB: neutral atoms of H, He, Li, Be, B

200 million years after the BB: thermonuclear reactions in the stellar cores (C, N, O, F,...Fe, Co, Ni)

203 million years after BB: Cu, Zn,....Pt,Au,...Th, Pa, U
during the explosions of first
supernovae
(gravitational collapse of very massive stars)

203,,000,000.001 years after BB: **Beginning of true chemistry**
in the cold interstellar space: neutral atoms and molecules,
including organic chemicals

Soon after: Complex molecules on *planets & moons*

State of Biology

Dark Ages:

Definition of Life: *unknown*

Start of an unknown form of life in an unknown corner of the Universe in an unknown time?

Panspermia to Earth is almost certainly impossible

Life on the Earth:

9.7 – 10.2 billion years after the Big bang: most probably in the depth of the oceans (black smokers) – monocellular life

13.1 billion years after BB: Multicellular life on the ground

13.6 billion years after BB: Mammals

13.699 900 000 billion years after BB: *Homo sapiens sapiens*

13.700 000 000 billion years after BB: *this lecture is just finished*

THE END



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LEARNED SOCIETY**

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