

# From Astrochemistry to Astrobiology to search bio- and technosignatures of extraterrestrial life forms

Enrico Catalano

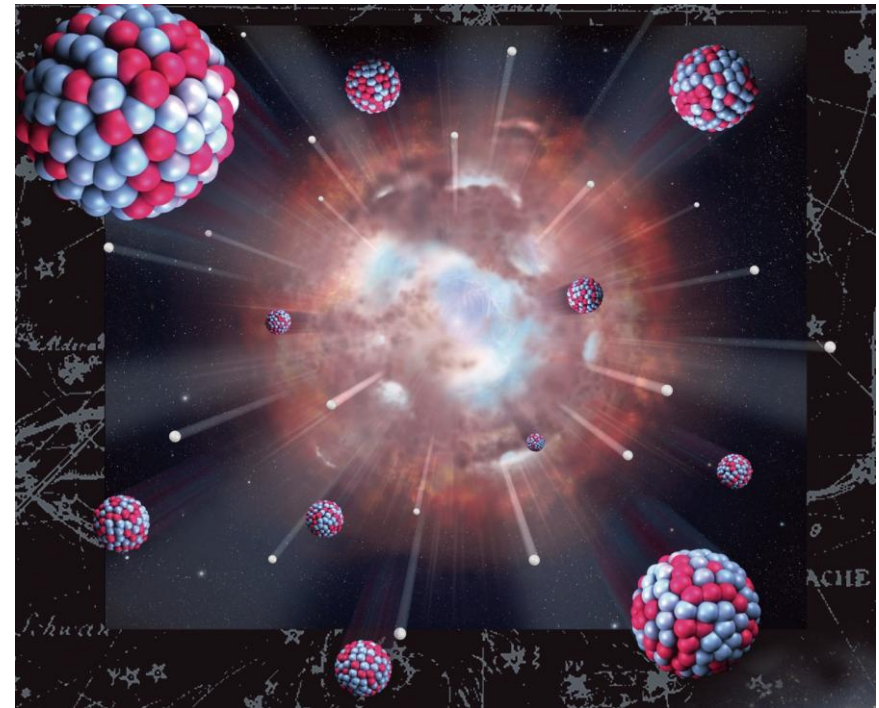
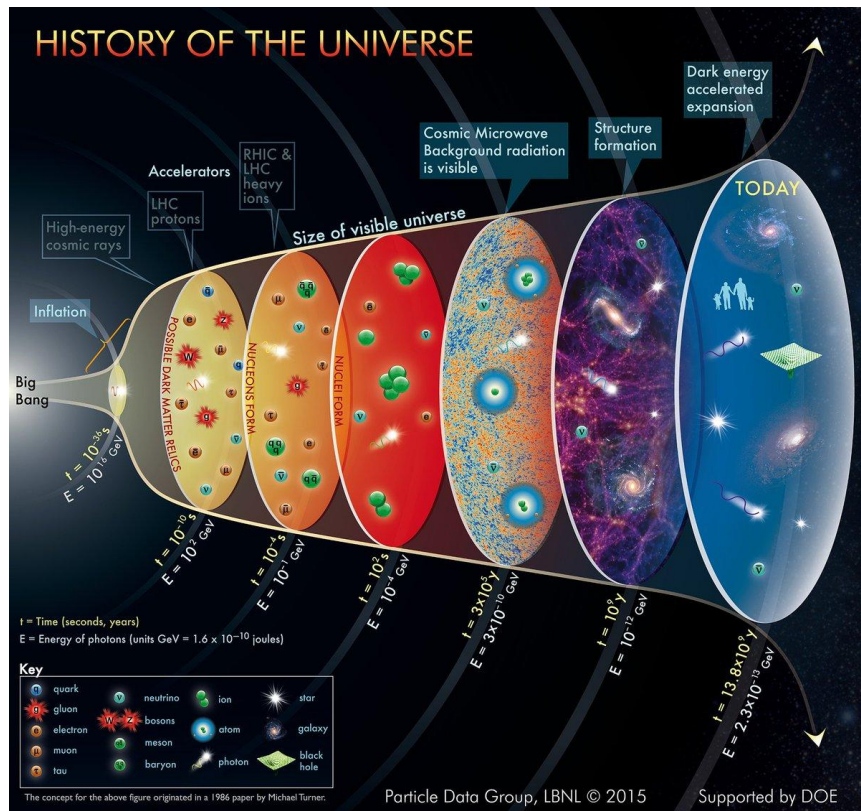
University of Oslo

Joint EPS-SIF International School on Energy 2019

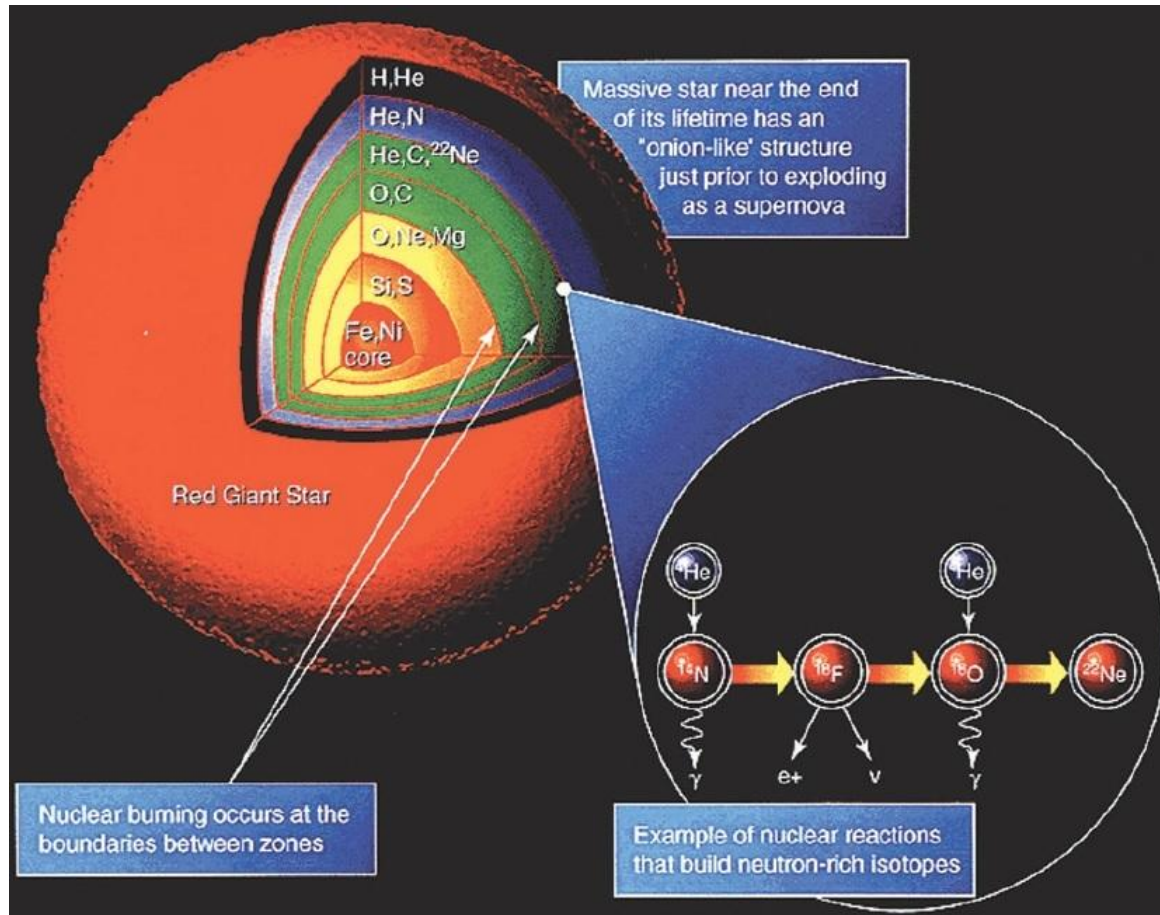
23th July 2019



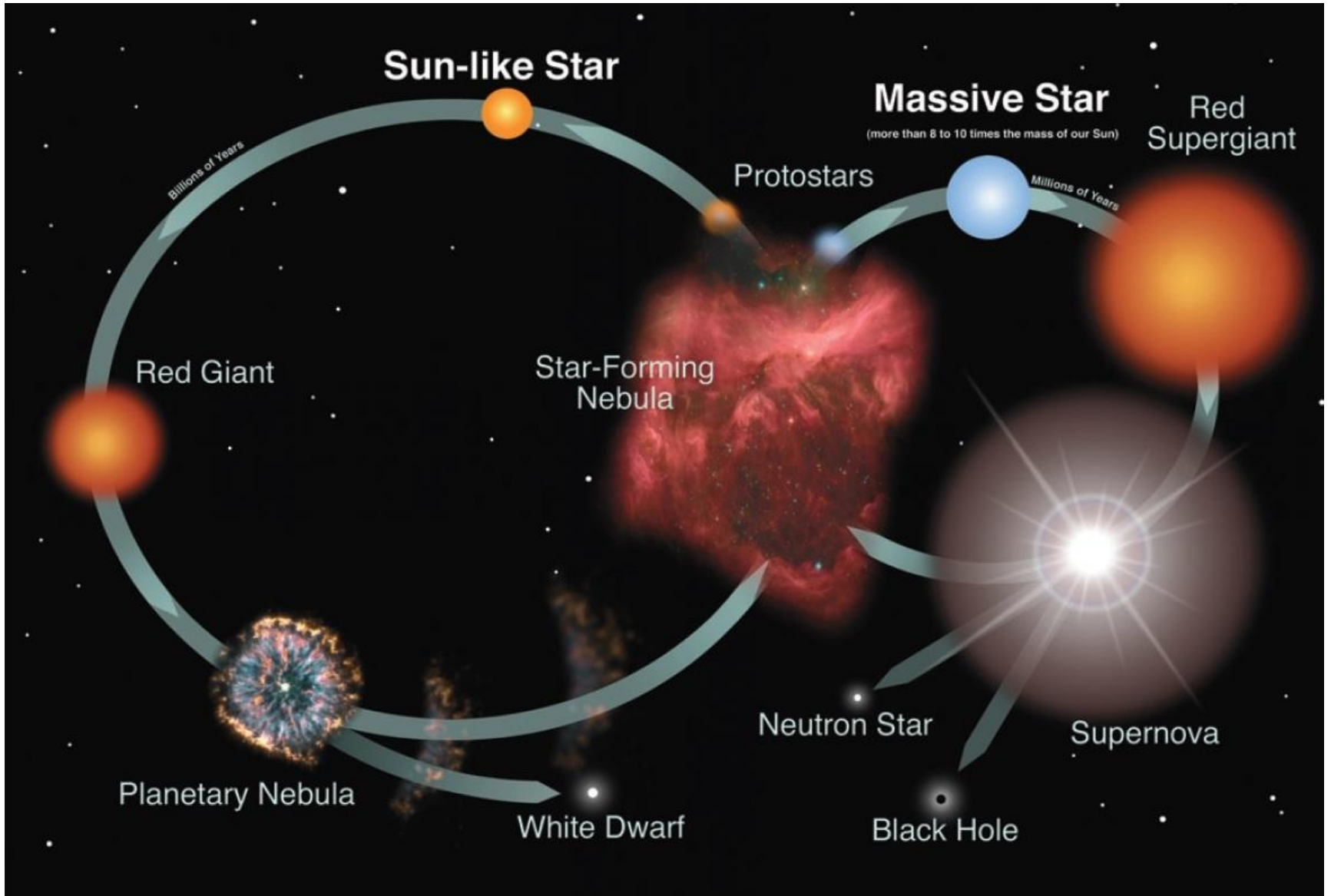
# Primordial nucleosynthesis



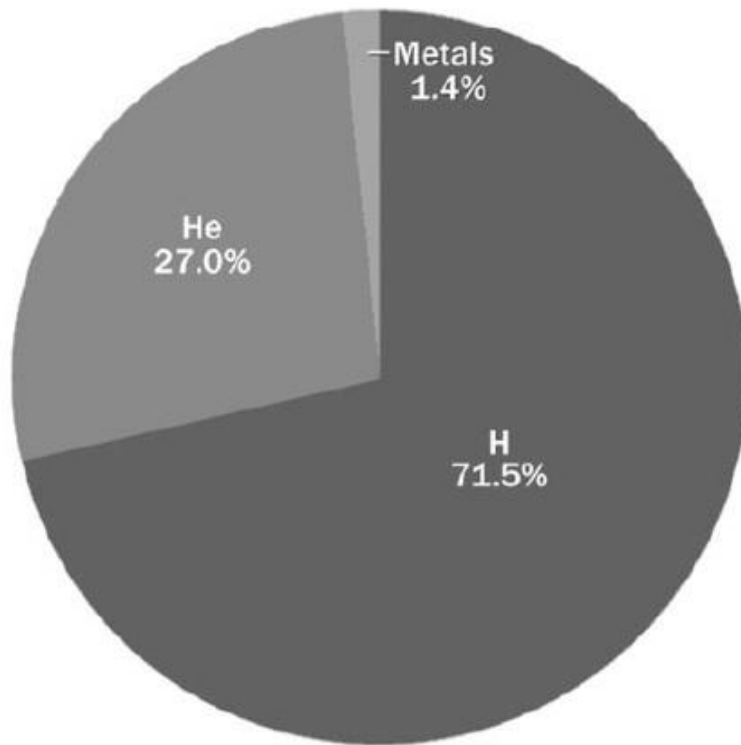
# Astrochemistry



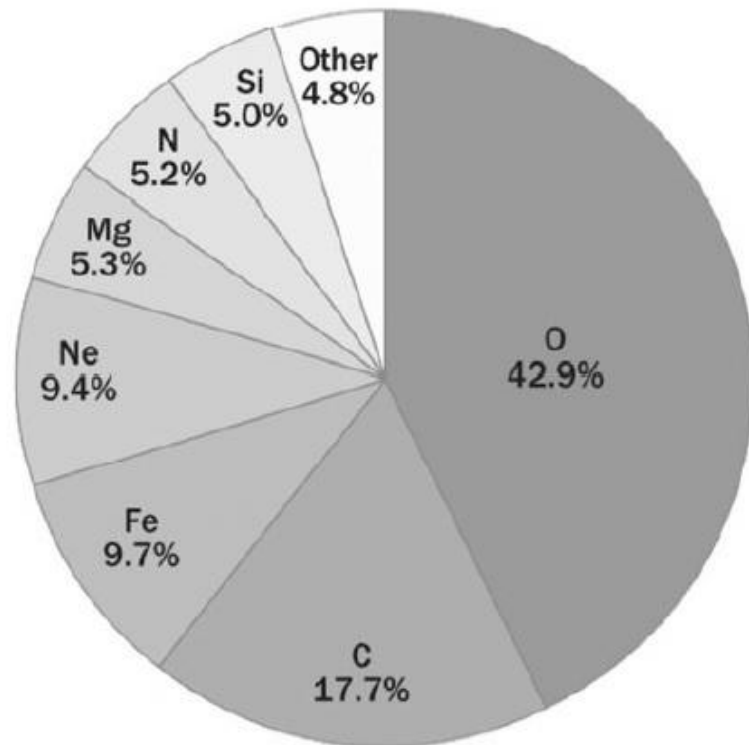




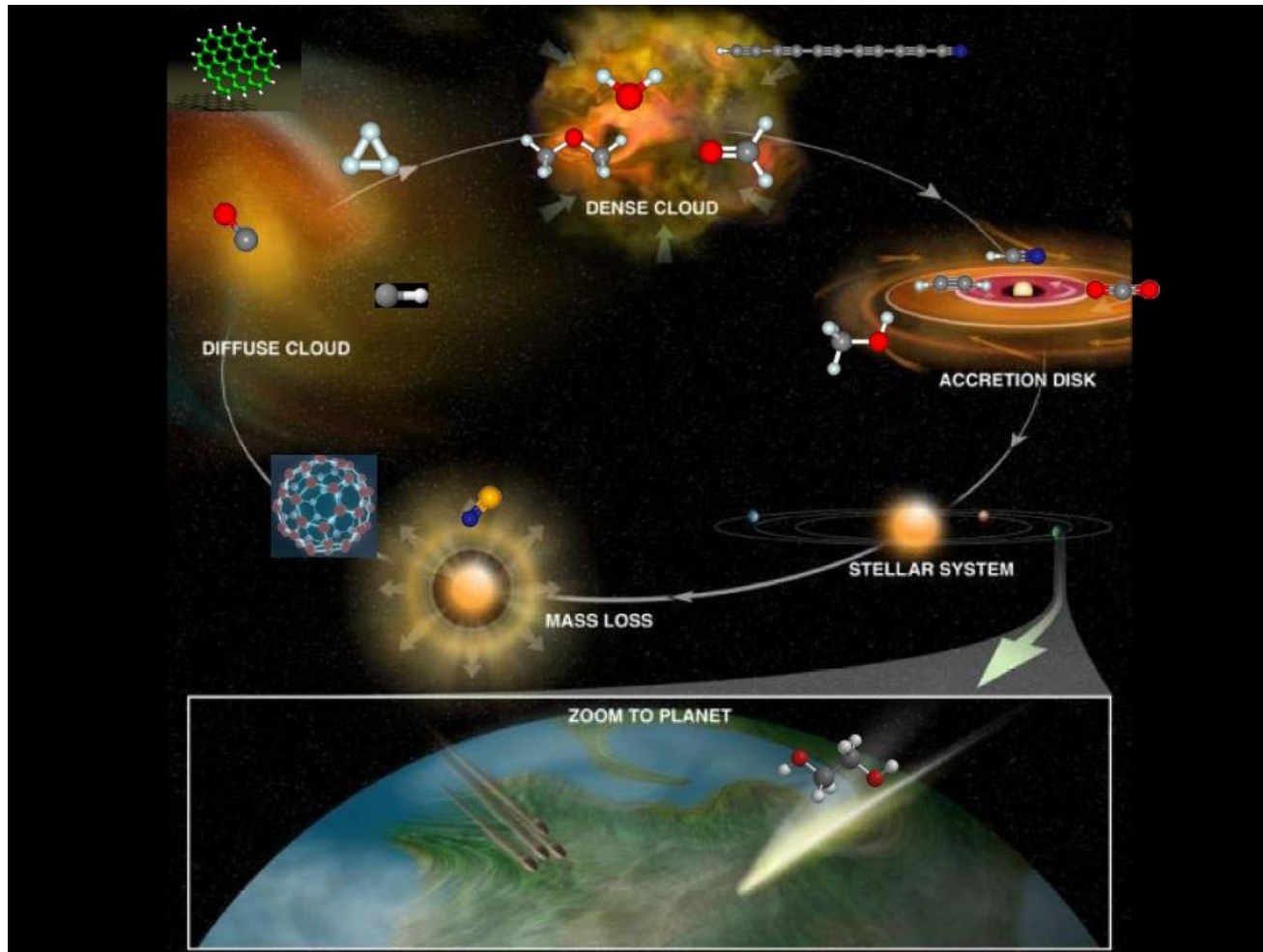
Total solar composition



Metal composition



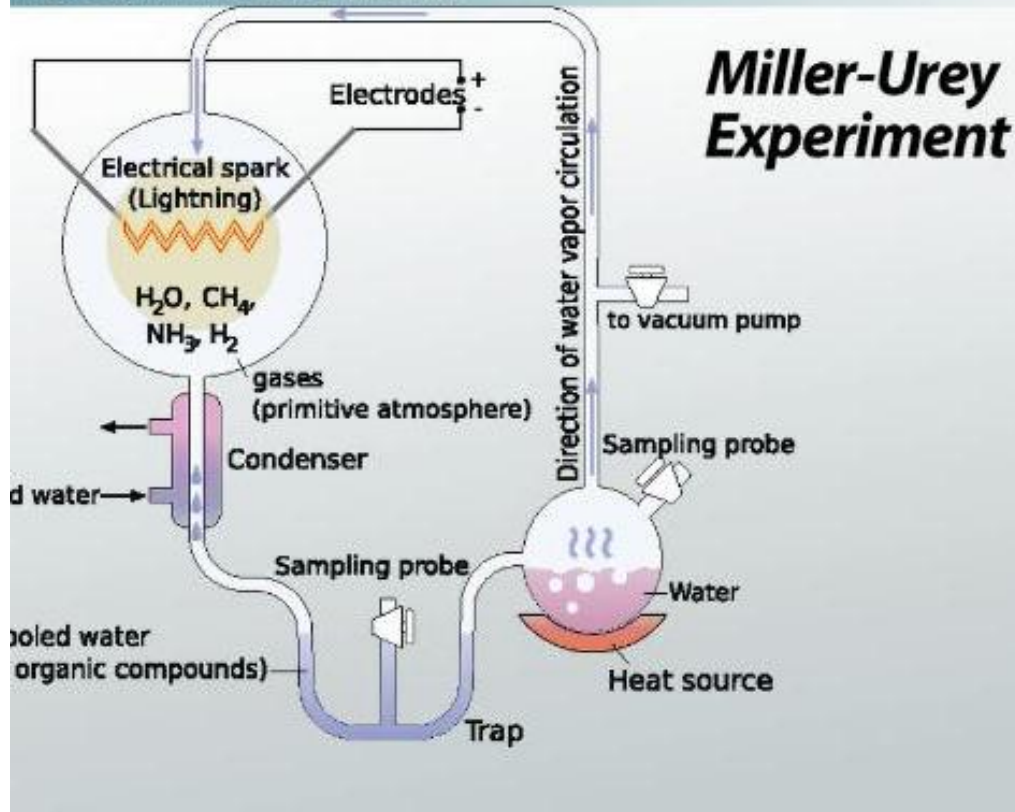
# Planetary Nebula





# Prebiotic Earth

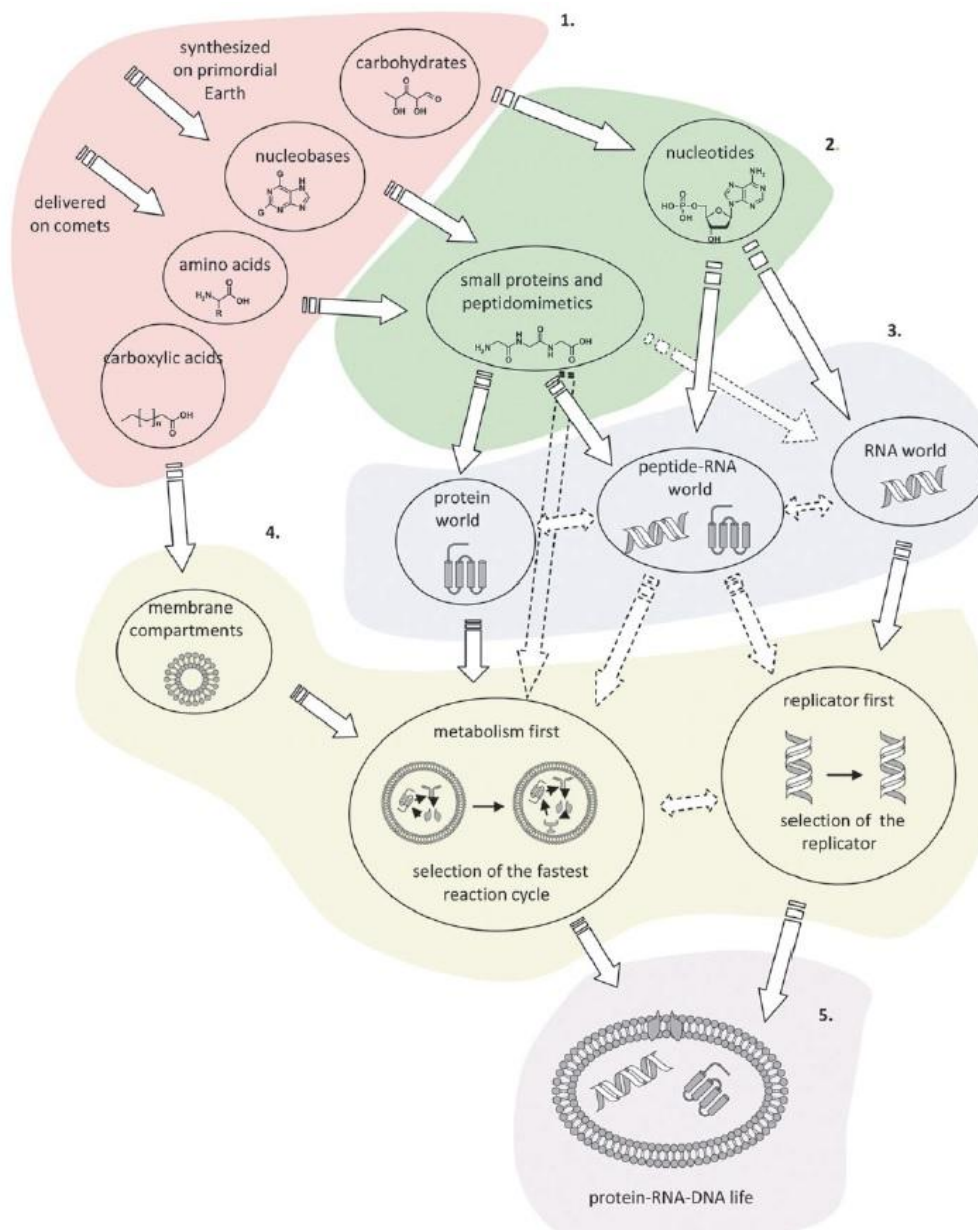
- All key components of the biochemical metabolic reactions can be synthesized, in various pathways leading to the amino acids, carbohydrates, lipids, and nucleobases.
- LUCA—the last universal common ancestor of all organisms
- Metabolic networks, self-replicating genetic systems, and compartmentalization of the metabolites.



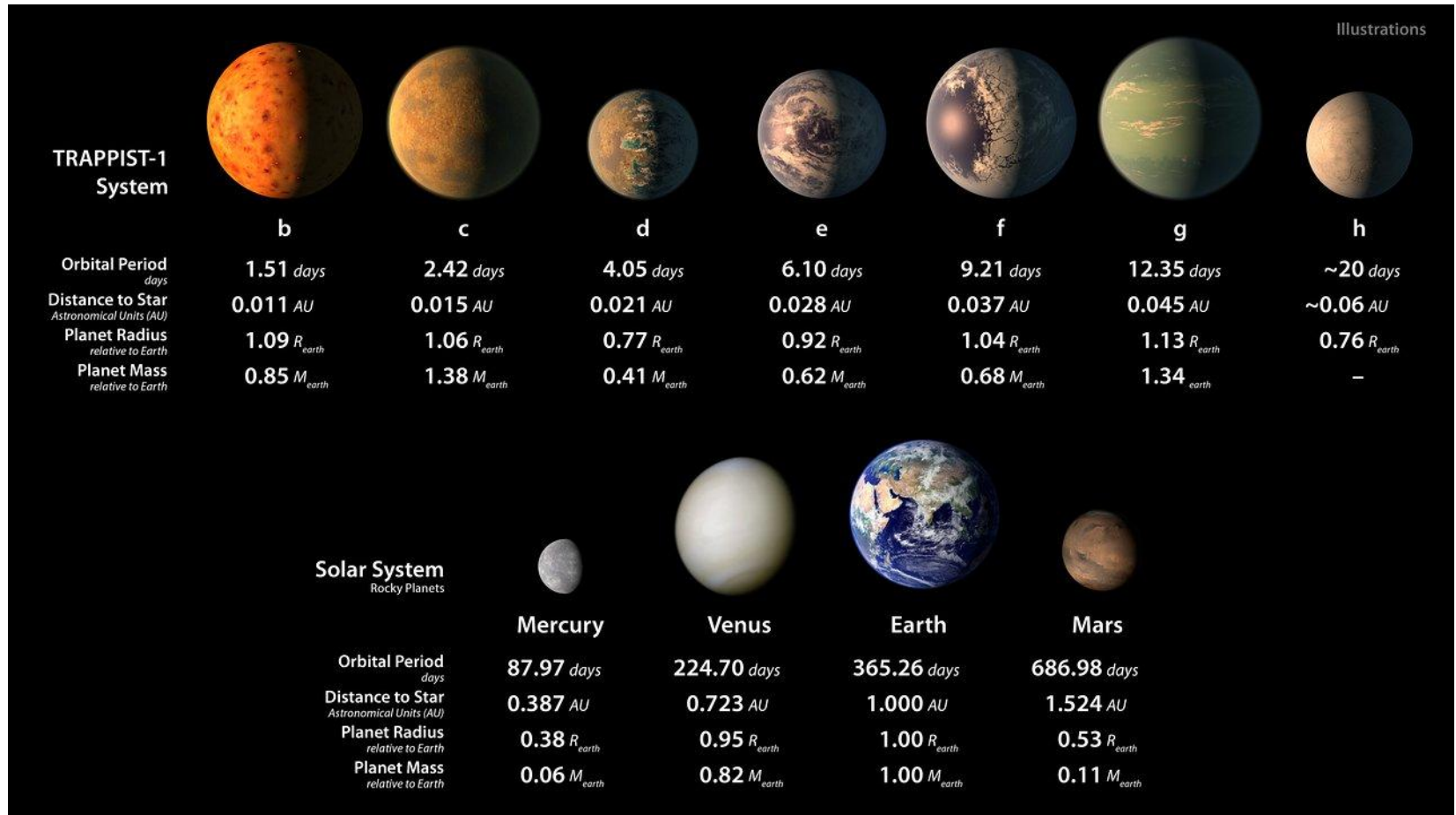
- The Miller-Urey experiment in 1953 produced **amino acids and other organic compounds** by passing an electric charge through a mixture of gases that were considered to be components of Earth's early atmosphere at the time of the experiment ( $\text{H}_2\text{O}$ ,  $\text{CH}_4$ , and  $\text{H}_2$ )

## Origin of organic compounds on the Earth

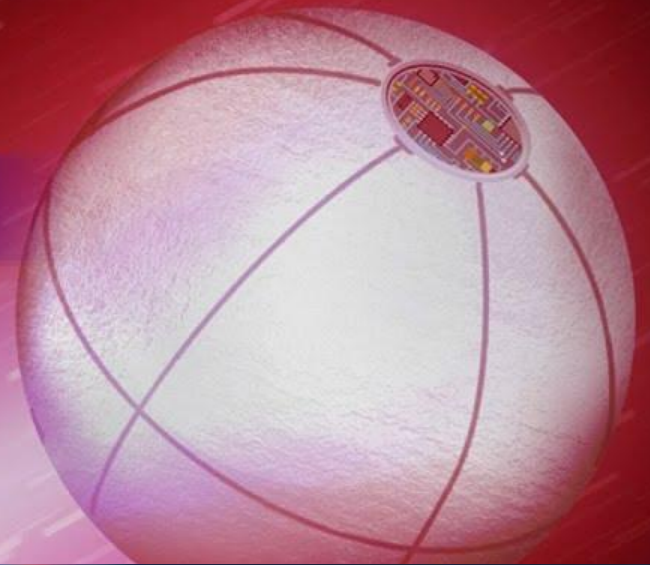




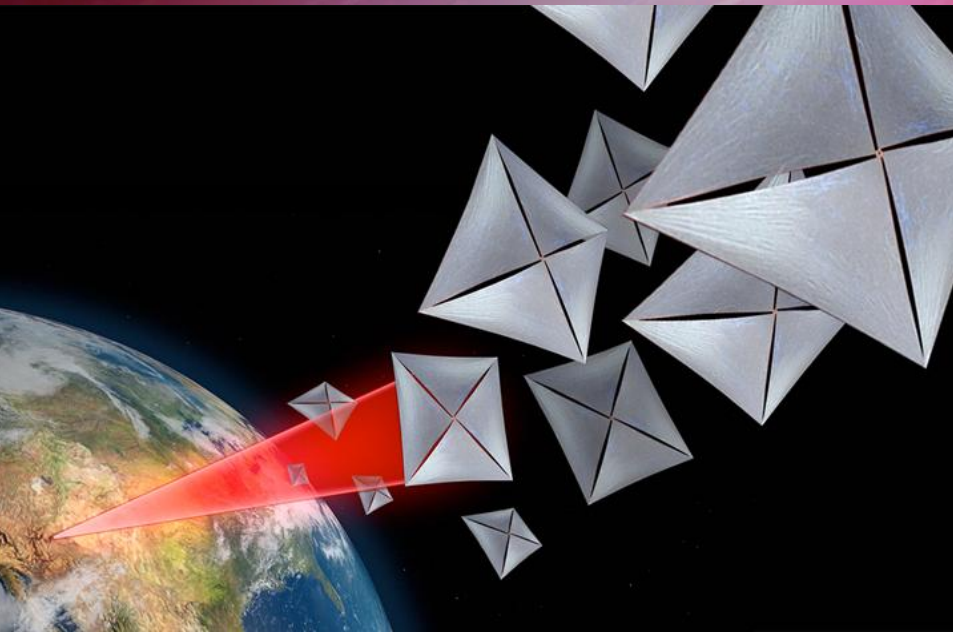
# Exoplanetary system



# BREAKTHROUGH STARSHOT MISSION EXPLAINED

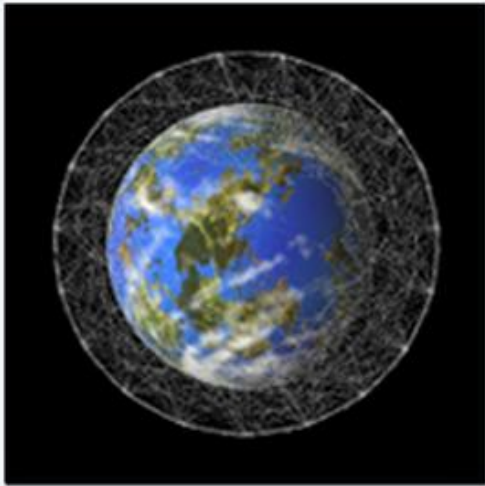


## PROXIMA CENTAURI DISTANCE

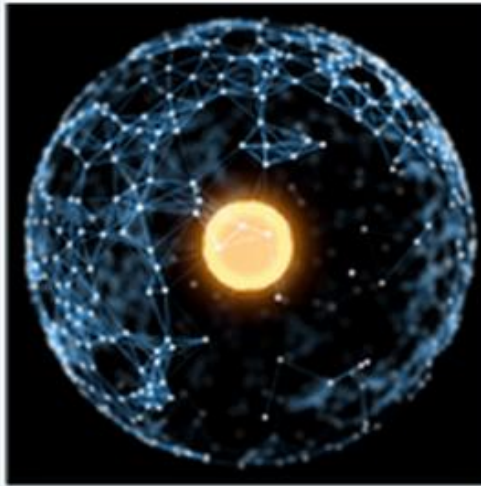




# THE KARDASHEV SCALE



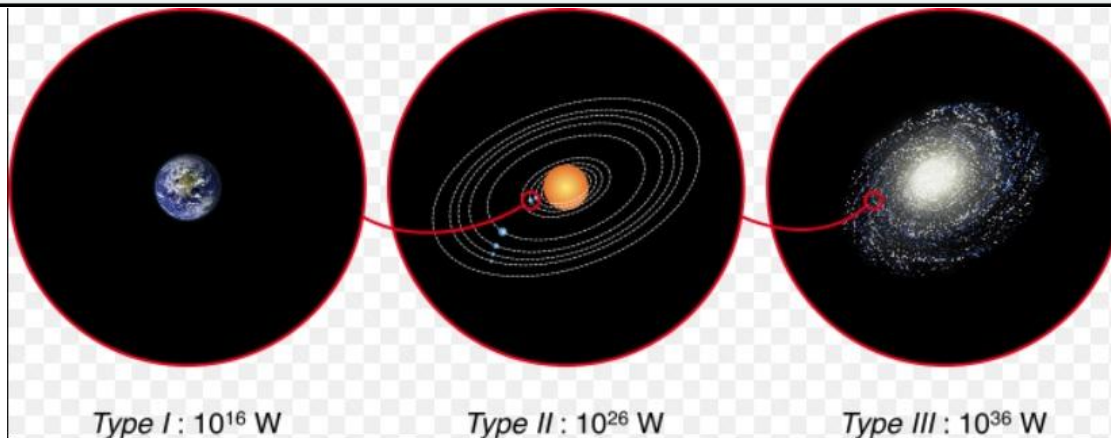
**TYPE I CIVILIZATION** harnesses all the resources of a planet. Carl Sagan estimated that Earth rates about 0.7 on the scale.



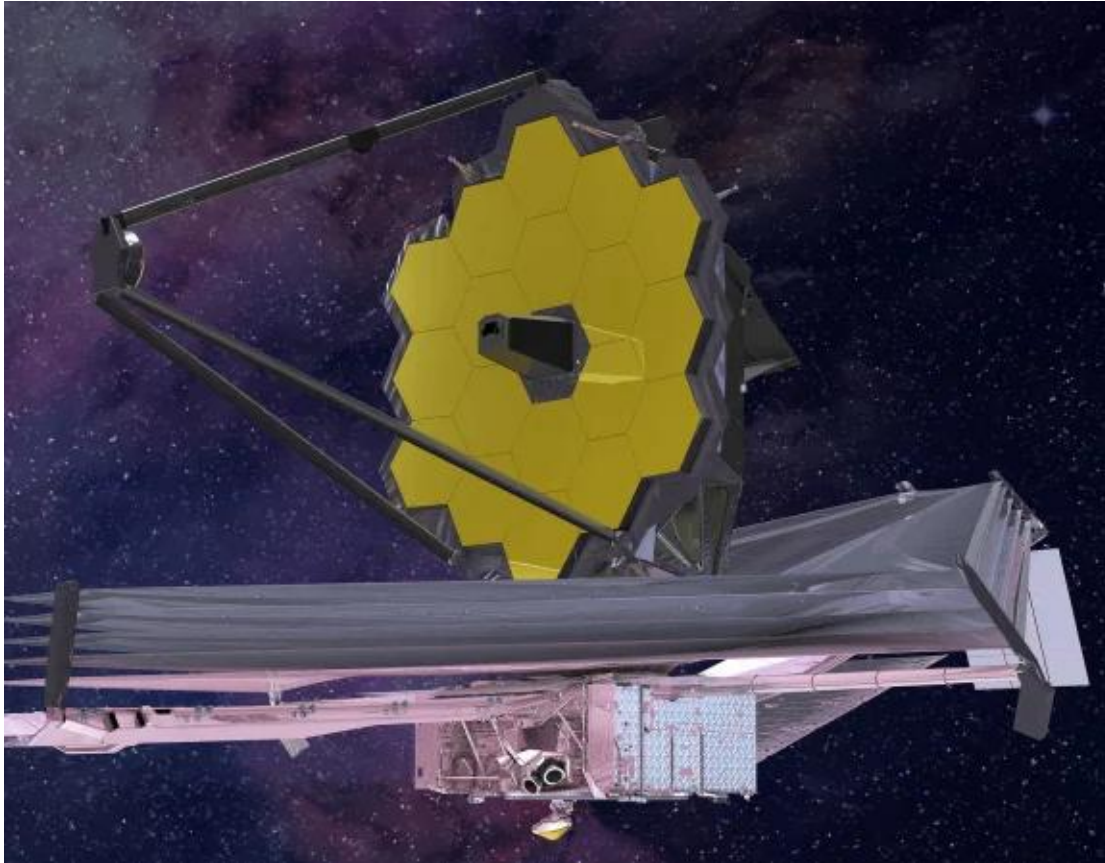
**TYPE II CIVILIZATION** harnesses all the radiation of a star. Humans might reach Type II in a few thousand years.



**TYPE III CIVILIZATION** harnesses all the resources of a galaxy. Humans might reach Type III in a few hundred thousand to a million years.







# Technosignatures

- Pollutant chemicals in an exoplanet or exomoon atmosphere that could be a sign of civilization
- Heat, pollutants, Chlorofluorocarbons (CFCs)
- A possible related detection of highly unusual atmospheric, thermal, surface and orbital conditions could be a signal of a candidate high-level technological intervention of an intelligent civilization