ESF/ESA/ESPI Conference
Humans in Outer Space - Interdisciplinary Odysseys

Are we alone?
Searching for Life in the Universe and its Creation

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Six Theses from Genova

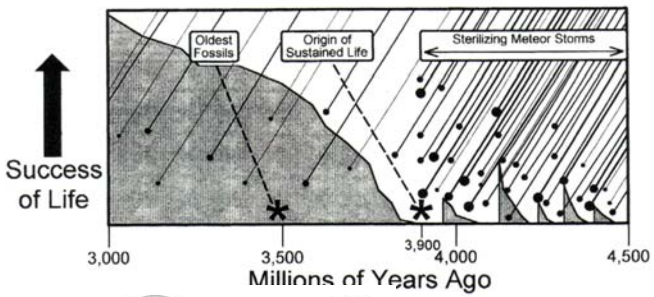
- Life is common in the universe
- Life elsewhere in the solar system must be microbial
- Research on extrasolar planets may eventually reveal the existence of life supporting environments
- We are physically confined to the solar system
- SETI is the only way to find out whether we are not alone in the universe
- Sending signals into the galaxy ("active SETI") may be regarded as a moral obligation

Life is common in the universe (1)

"Spontaneous" appearance

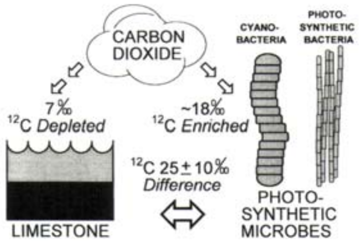
Almost "immediately" after the Earth had cooled and was able to hold an atmosphere and ocean, life seem to have developed.

Why should this not have happened elsewhere?

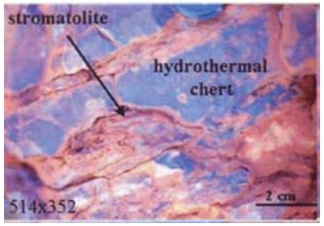


Heavy impacts by planetesimals and radioactive heating subsided about **3.9 billion years** ago

The Earth a magma ocean



(left): Biological organisms enrich ^{12}C versus ^{13}C: This isotopic anomaly was discovered in southwestern Greenland in carbon globules in metamorphic rocks from already **3.8 billion years ago.**

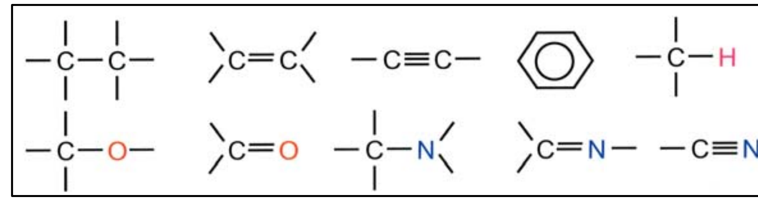


(left): **3.5 billion years ago**: bio mats and **stromatolites** from photosynthetic bacteria were found in western Australia. (right) "Modern" stromatolites.

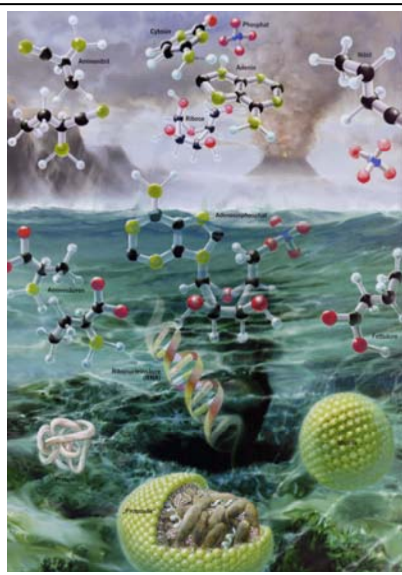
Life is common in the universe (2)

All life is carbon-based

Carbon is abundant in sun, planets, other stars, dust and molecular clouds. Carbon can form stable chain and ring molecules. More than 10 Million carbon (organic) compounds are known and only 100 000 inorganic ones.



It is unlikely that nature ignored this potential on other habitable planets.

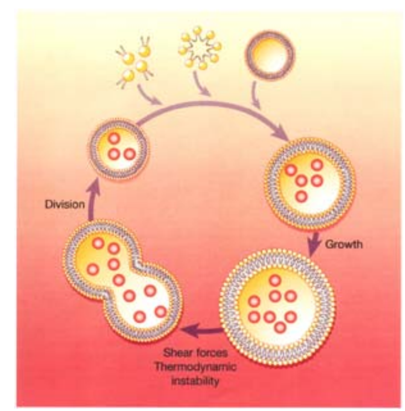


Prebiotic molecules may have been imported from space (panspermia theory) or formed on Earth in shallow ponds or hydrothermal vents.

Bilayers of amphiphilic lipid molecules eventually formed the first membranes and cells leading to the compartmenta-lization of life.

Cell growth naturally led to cell division and to replication.

A living entity is a compartment that has metabolism and the ability to reproduce.

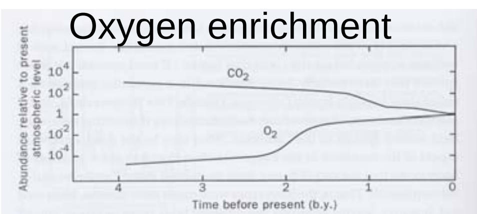


Life is common in the universe (3)

The long way to multicellular life

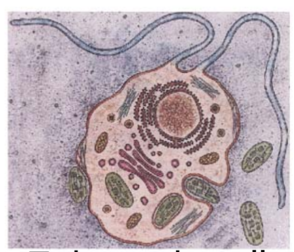
The coarse time-line: **Monocellular life dominated for about 3 billion years. Only 650 Mio years ago multicellular life appeared.**

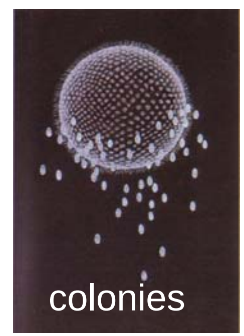
<u>The steps</u>: anaerobic cells – photosynthesis – oxygen enrichment of atmosphere – oxidation versus fermentation – ozone formation – occupation of the solid Earth - symbiosis – eukaryotes – cell colonies – multicellular organisms – the Cambrian explosion - intelligence

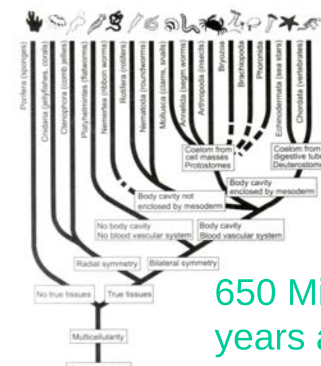


Oxygen enrichment


Chain molecules


Eukaryotic cell


colonies

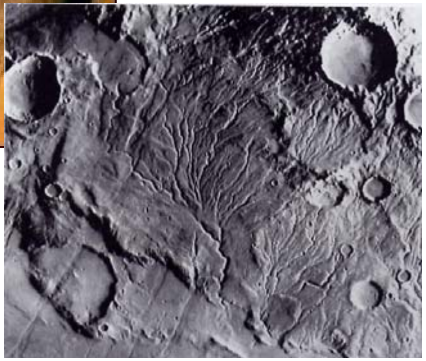

650 Mio years ago

A similar chain of events might have happened elsewhere.

Microbial Life in the Solar System (1)

The promises of Mars

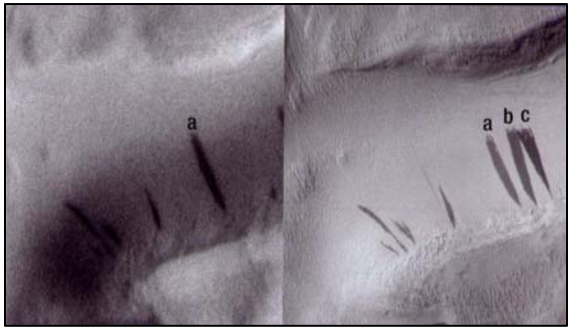
Mars is our most promising candidate for extinct and, much less likely, for extant life elsewhere in the solar system. The subsurface ocean of Europa is another candidate.



Strong evidence that Mars once possessed a dense atmosphere and liquid water comes from the erosion of craters more than 3.5 billion years old, dried-up river channels, and a dendritic valley network. However,

time was too short to develop multicellular life.

Surface water flows still seem to exist, probably caused by episodic heating of layers of a dust and ice mix.

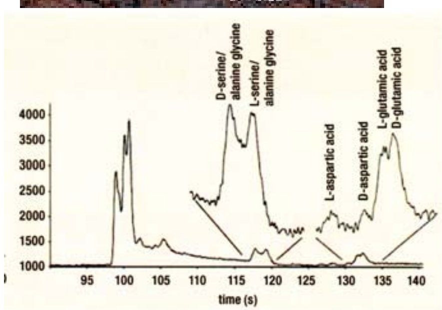


The present conditions are too hostile (-53^{0}C and 6 mbar) and unstable to bear great hopes for extant life on Mars.

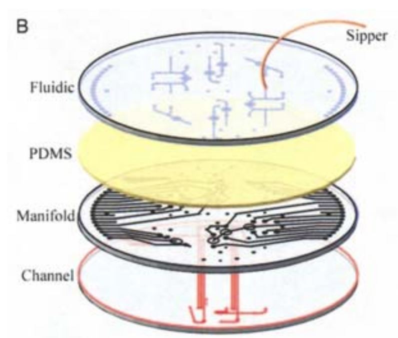
Microbial Life in the Solar System (2)

The ExoMars Mission

ESA's ExoMars mission will be launched in 2013. On the "Pasteur" rover there will be several instruments searching for the signature of life, on the molecular and structural level. They may be successful!

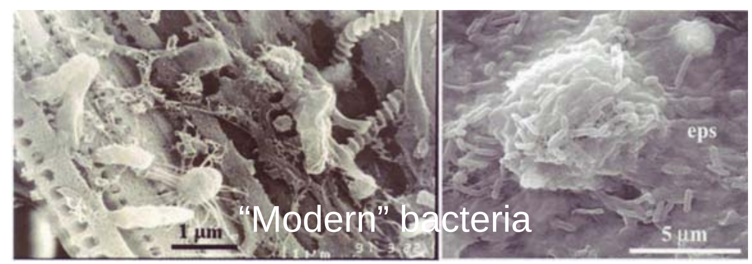


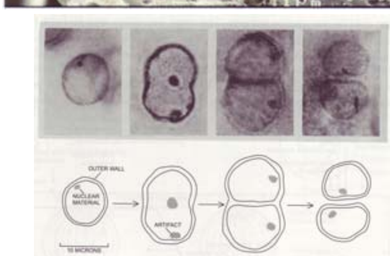
Analysis of biomolecules (e.g. amino acids) by electrophoresis.



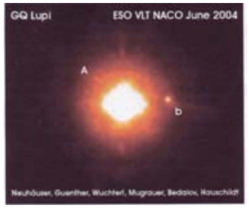
The Urey instrument: Mars Organics Detector and Mars Oxidant Instrument (J. L. Bada et al.)

Microbial material and morphologies may be preserved if rapidly mineralized after their death. Optical and infrared microscopes on ExoMars. (F. Westall et al.)

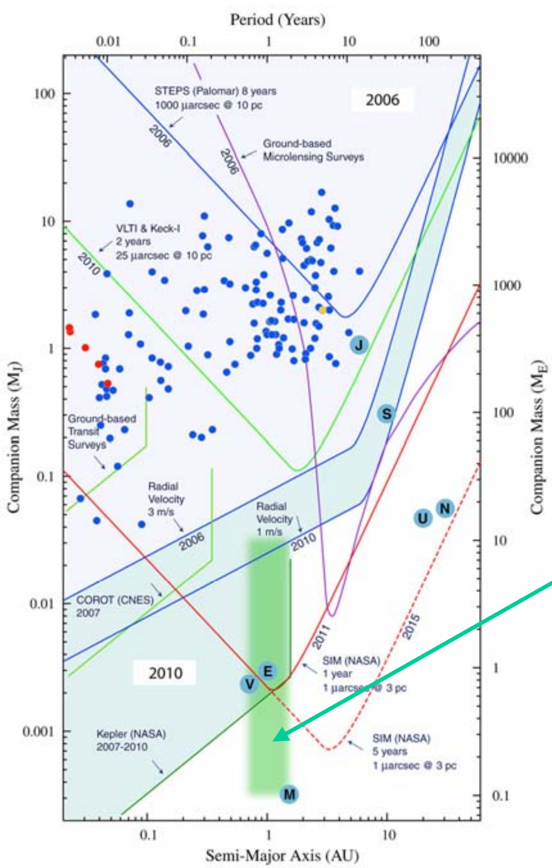




one billion year old fossilized eukaryotic cells



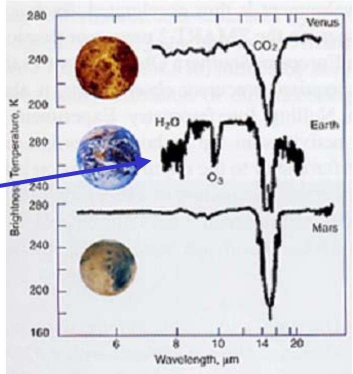
Extrasolar Planets



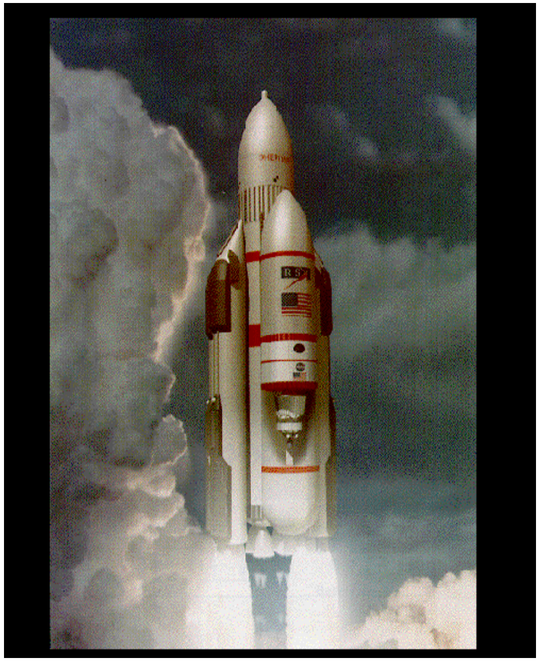
253 extrasolar planets have so far been discovered mostly by indirect methods, all within 600 light years. Almost all have **Jupiter size** and are gaseous.

Life-bearing planets must be **telluric** and reside in **stable orbits in the zone of habitability** (-10^0C - $+30^0$C average temperature).

Direct detection of Earth-like planets may eventually be achieved by **nulling interferometry** with a cluster of telescopes like ESA's **Darwin** mission. **H_2O** and **O_3** bands in their spectra would be **indicators of a life-supporting environment.**



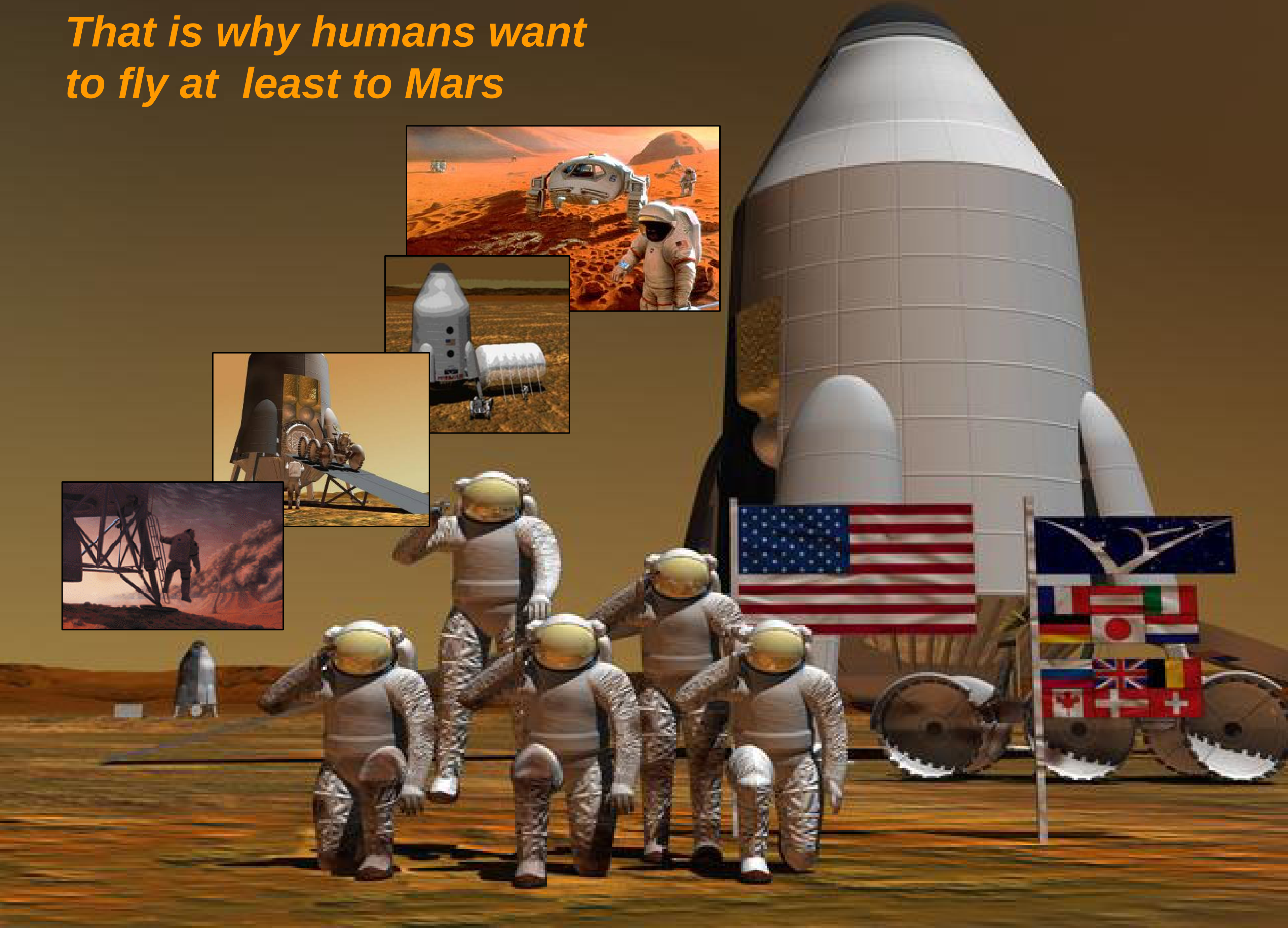
Humankind is Confined to the Solar System



Sending a spaceship **within 40 years** to one of the nearest stars (e.g. α-Centauri) requires an average travel speed of **10% of the speed of light**. Relativity theory says that the energy needed to bring a space ship of **1000 tons** to that velocity is about **4.5 10^{20} Joule,** or the present world's **total annual energy consumption**. If a nuclear reactor were to be used, it would require **7000 tons of fission fuel**, not to speak of the reactor. Even if one would eject the fission material at optimum speed, the accommodation of such an engine seems to be impossible.

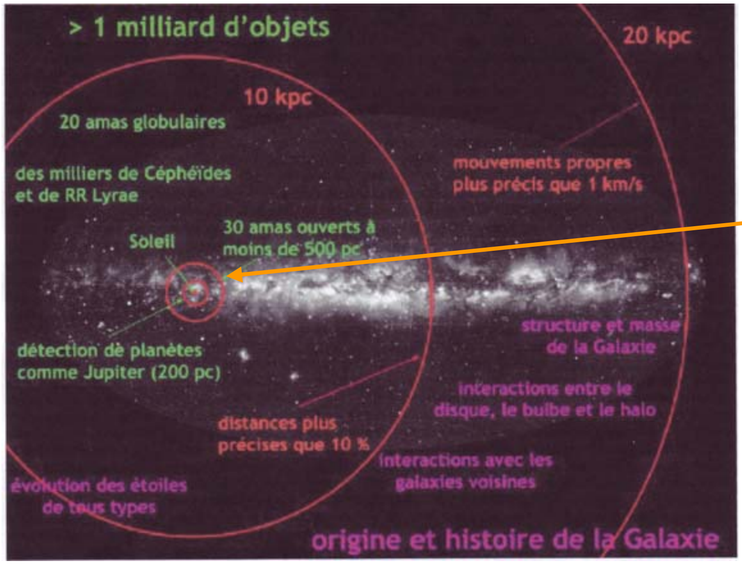
Human spaceflight to other stars is prohibited by non-available resources and technology.

That is why humans want to fly at least to Mars



Are we alone?

Communication is possible



The planned Square Kilometer Array

The Earth's civilization possesses already today the technology to successfully send radio signals to distances of more than 1000 light years. This requires:

•transmitted power of 1 MW,

•extremely narrow bandwidths of the signal (~1 Hz), implying 100's of millions of narrow-band channels,

•radio antennas (dishes) of 200 m diameter,

• a good strategy for scanning the sky and tuning the spectral window (Doppler shift).

•guidance by yet to be discovered extrasolar planets.

Chances of Contact

Drake equation (1961): no of civilizations in our galaxy

$$N = N_s/L_s \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

$$\left.\begin{array}{l}
N_s = \text{no of sun-like stars in the galaxy} = 4\cdot10^9 \\
L_s = \text{lifetime of a sun-like star} = 10^{10}\ \text{years} \\
f_p = \text{fraction of stars with planets} = 1 \\
n_e = \text{no of (habitable) Earth-like planets} = 0.01 \\
f_l = \text{fraction with life developing} = 1 \\
f_i = \text{fraction with intelligence developing} = 0.5 - 0.01 \\
f_c = \text{fraction with communicating ability} = 1 \\
L = \text{lifetime of such a civilization} = 10^3 - 10^5\ \text{years}
\end{array}\right\} N = 2\cdot10^2 - 4\cdot10^{-2}$$

Even with the most optimistic estimates there would be only one or a few civilizations within reach of today's technology.

Nevertheless searching for and transmitting signals is a moral obligation of humankind. The others are as lonely in the universe as we are.