Astrobiology: from the Origin of Life on Earth to Life in the Universe

Angelica Sartori

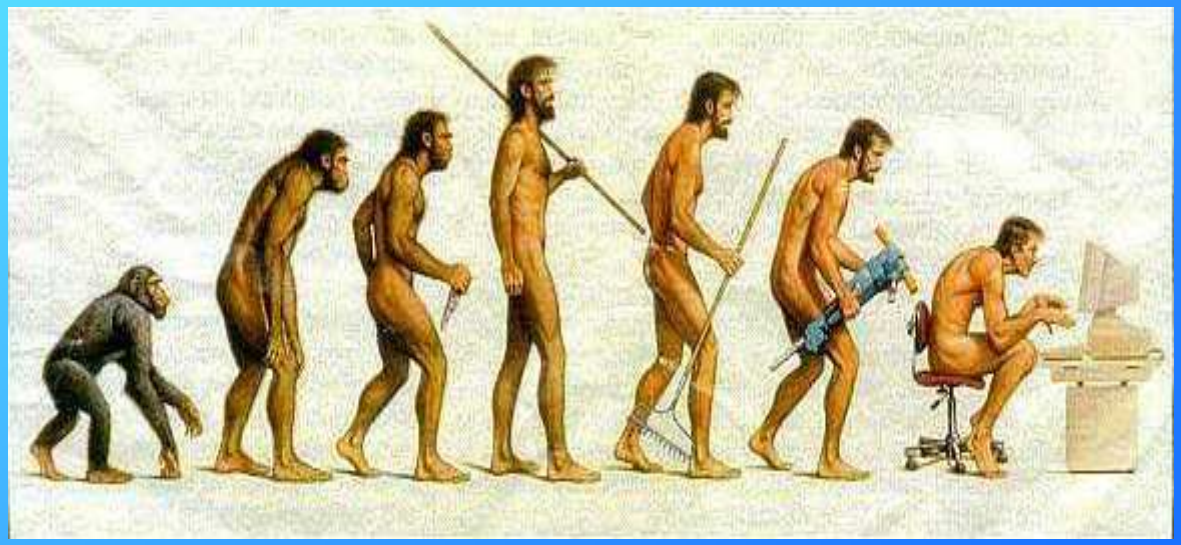
Astrosiesta

September 29th, 2011

What is Life?

NASA Exobiology Program 1992:

Life is a self sustaining chemical system capable of undergoing Darwinian evolution



Astrobiology

1. Search for traces of primitive life on Earth

2. Attempts to recreate an artificial primitive life *in vitro*

3. Search for other examples of life beyond our planet

Astrobiology

1. Search for traces of primitive life on Earth

2. Attempts to recreate an artificial primitive life *in vitro*

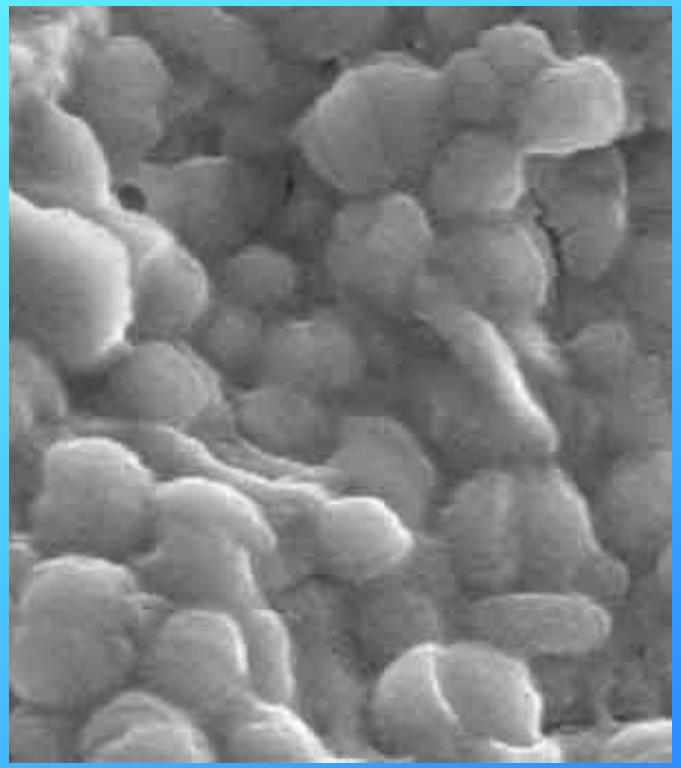
3. Search for other examples of life beyond our planet

Search for extraterrestrial life

- *In situ* (and ultimately, sample return) searches within the solar system
- Spectral examination of solar and extrasolar planetary atmospheres for chemical evidence of life
- Searches for evidence of extraterrestrial technology

Life on Earth

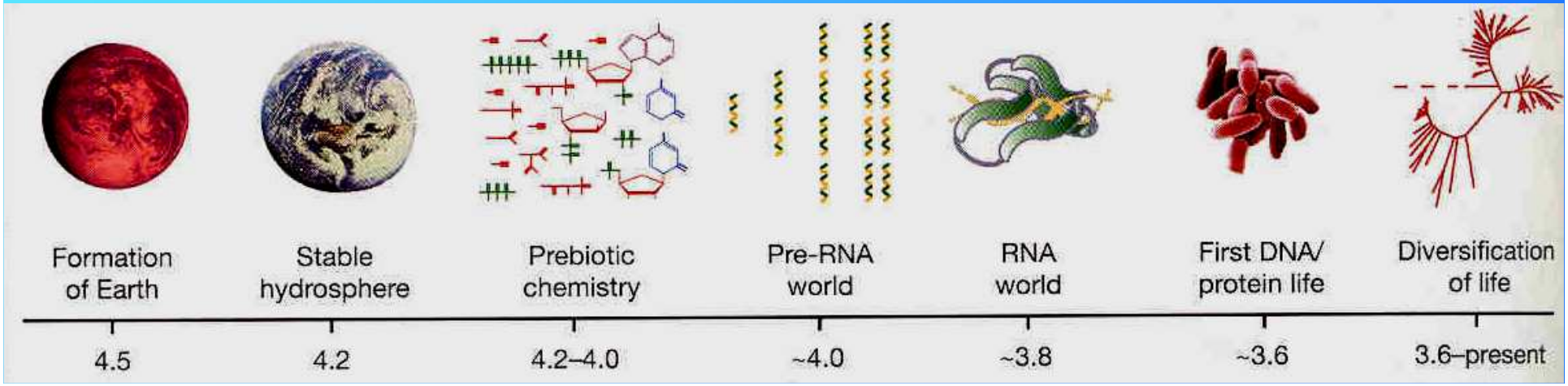
- 4 billions years ago



Fossil bacteria dating back to 3.5 billions years ago, South Africa

Life on Earth

- 4 billions years ago
- Primordial “soup” of CH_4, NH_3, H_2S, CO_2 and phosphates into liquid water, from which more complex biomolecules originated



Life on Earth

- 4 billions years ago
- Primordial “soup” of CH_4, NH_3, H_2S, CO_2 and phosphates into liquid water, from which more complex biomolecules originated
- **Organic chemistry** + **liquid water**
- 98% of biological tissues: **CHNOPS**

Habitability

Chemical-physical conditions
for an environment to host
a ***specific*** kind of life

Habitability

Chemical-physical conditions
for an environment to host
a ***specific*** kind of life

Which kind of life?

Hypothetical biochemistry

- Carbon chauvinism?

Hypothetical biochemistry

- Carbon chauvinism?
- Silicon-based chemistry
- Ammonia as a solvent

Hypothetical biochemistry

- Carbon chauvinism?
- Silicon-based chemistry
- Ammonia as a solvent
- Various problems
- No experimental evidence

Hypothetical biochemistry

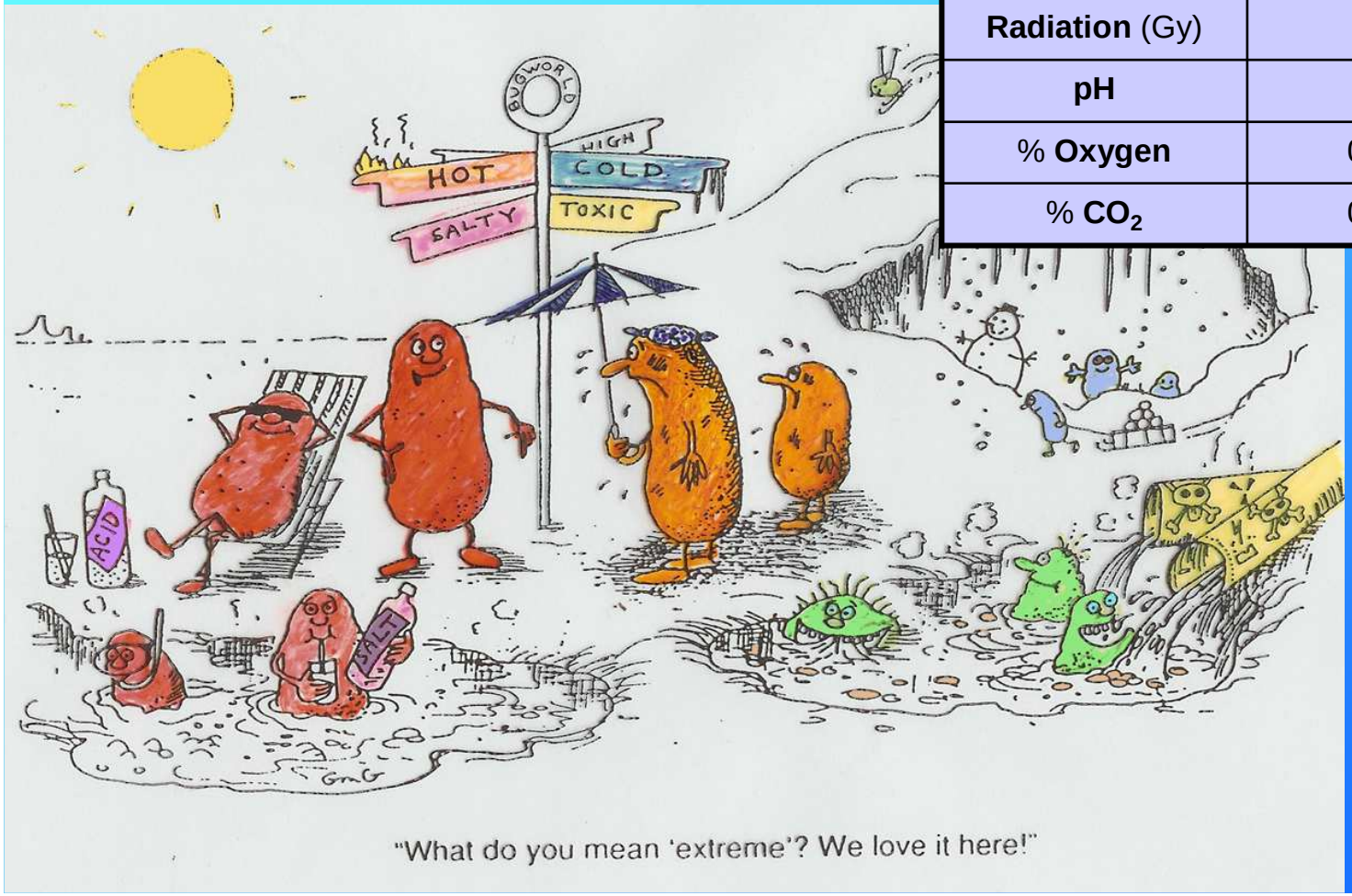
- Carbon chauvinism?
- Silicon-based chemistry
- Ammonia as a solvent

- Various problems
- No experimental evidence

Habitability should be defined by life as we know it

Extremophiles

	Microorganisms	Humans
Temperature (℃)	-12 ÷ +121	0 ÷ +30
Pressure (mbar)	<50 ÷ >10000	700 ÷ 5000
Radiation (Gy)	4000	1 ÷ 3
pH	0 ÷ 13	neutral
% **Oxygen**	0 ÷ 100	15 ÷ 25
% **CO_2**	0 ÷ 100	<1



"What do you mean 'extreme'? We love it here!"

What determines habitability?

- Liquid water, CHNOPS
- Energy
- Temperature (greenhouse effect, snow coverage, C-Si cycle...)
- Magnetic field
- Plate tectonics

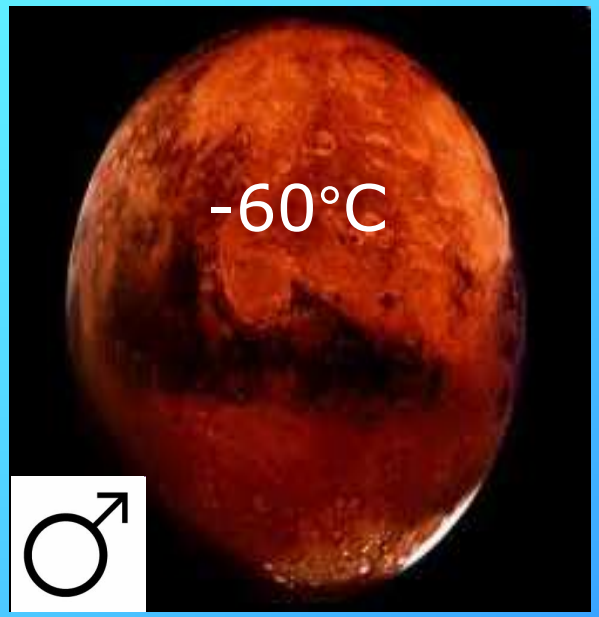
What determines habitability?

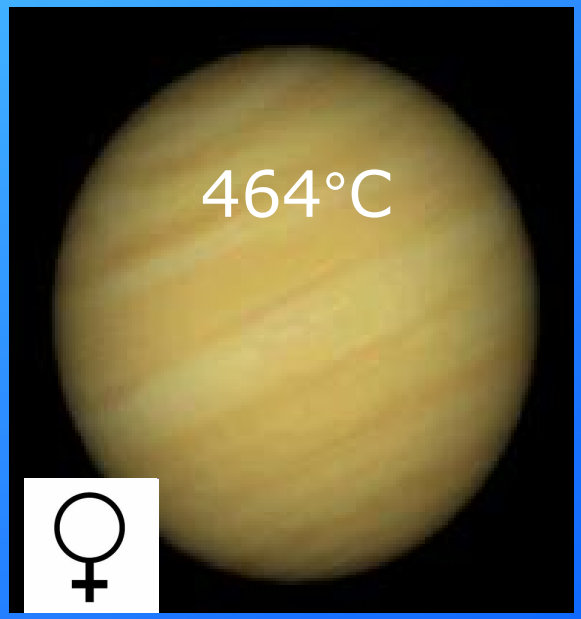
- Liquid water, CHNOPS
- Energy
- Temperature (greenhouse effect, snow coverage, C-Si cycle...)
- Magnetic field
- Plate tectonics

***Habitable zone* (HZ):**

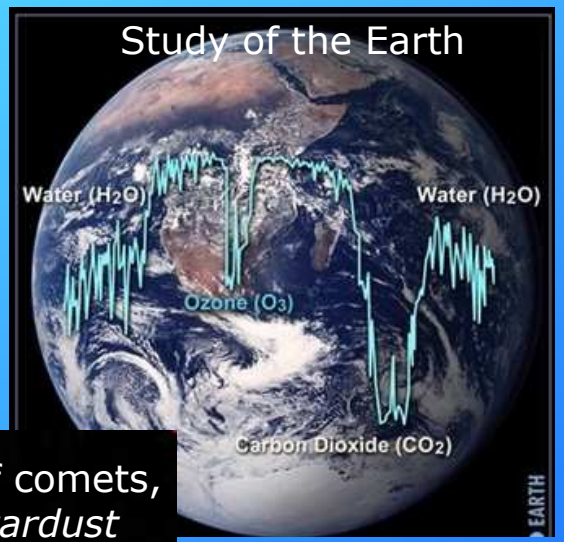
distance from a star within which a planet could host liquid water

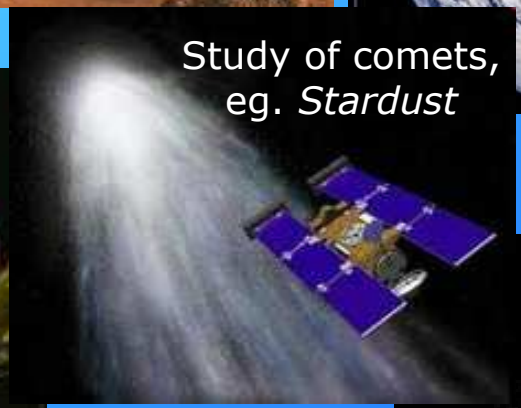
Habitability and temperature

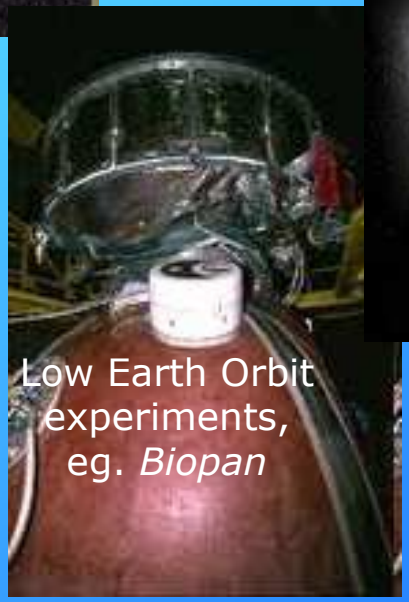




Astrobiology from the Space







Mars

	Earth	Mars
M (10^{23}kg)	59.74	6.42
D (km)	12756	6805
ρ (kg m^{-3})	5515	3934
g (m s^{-2})	9.78	3.69

Mars and life

- Presence of ice and hints of the presence of an hydrosphere
- Organic molecules found on martian meteorites

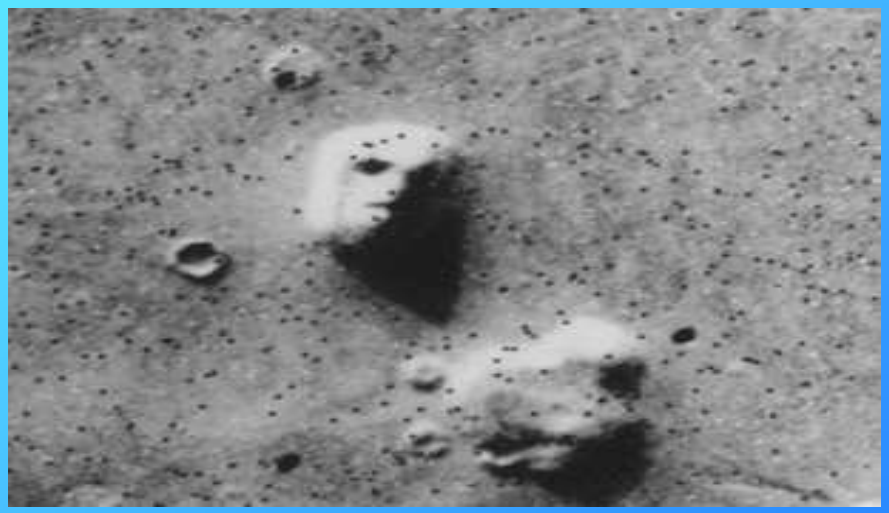
Mars and life

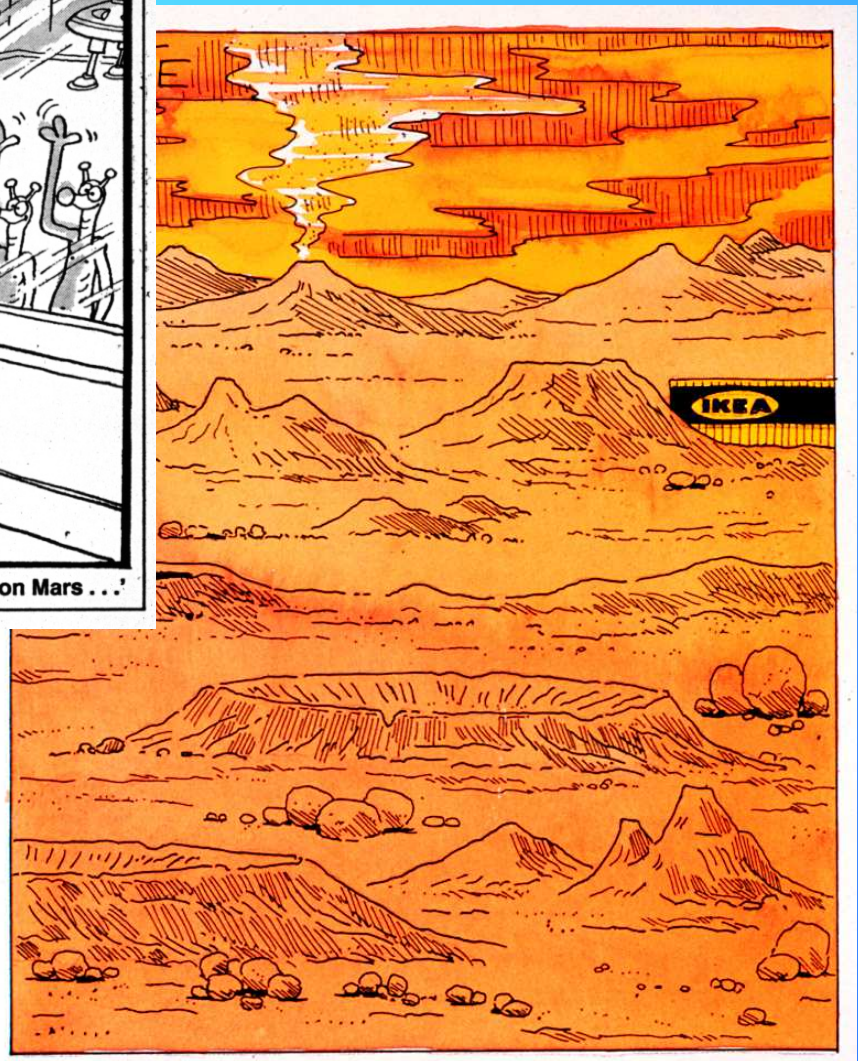
- Presence of ice and hints of the presence of an hydrosphere
- Organic molecules found on martian meteorites

- Possible extint or extant life in the subsoil
- Possible exchanges of materials with the Earth through meteorites

Daily Mail, Thursday, August 8, 1996

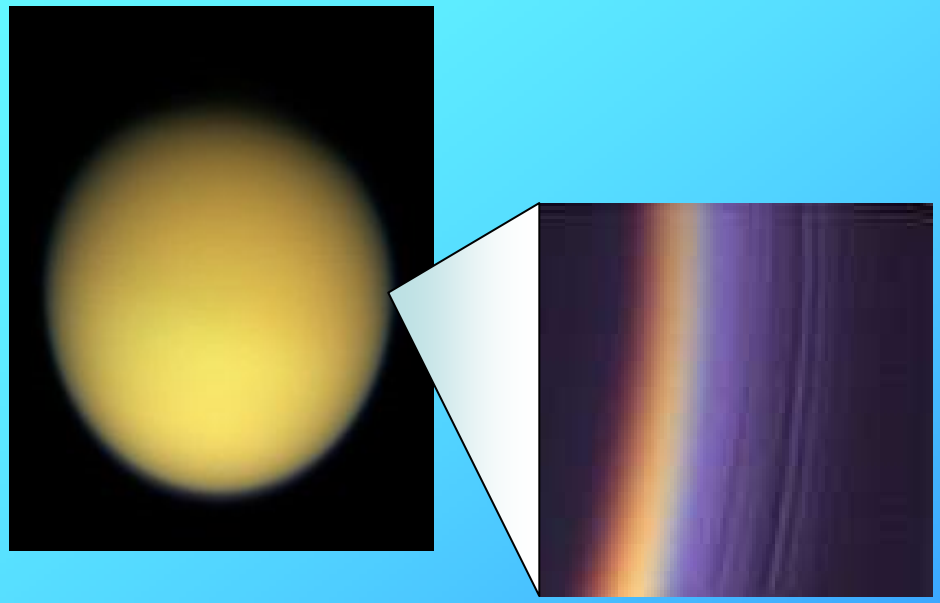
'Okay. It's only circumstantial evidence but let's take a vote. Hands up those who think there's life on Mars . . .'

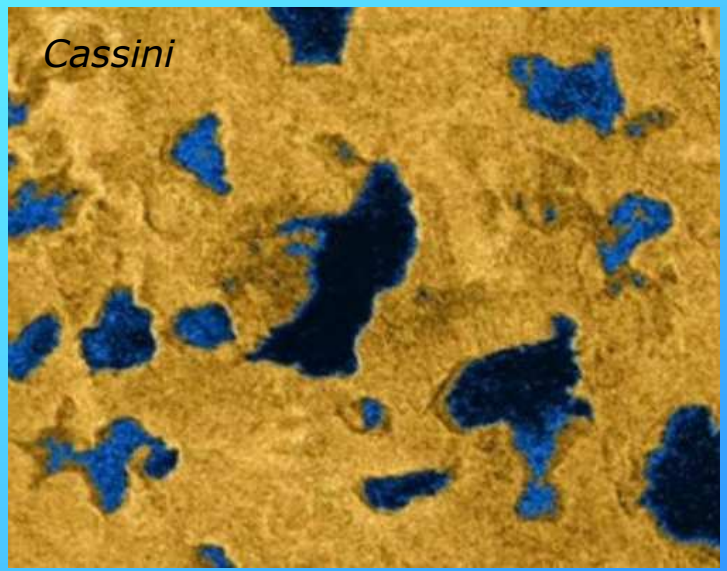




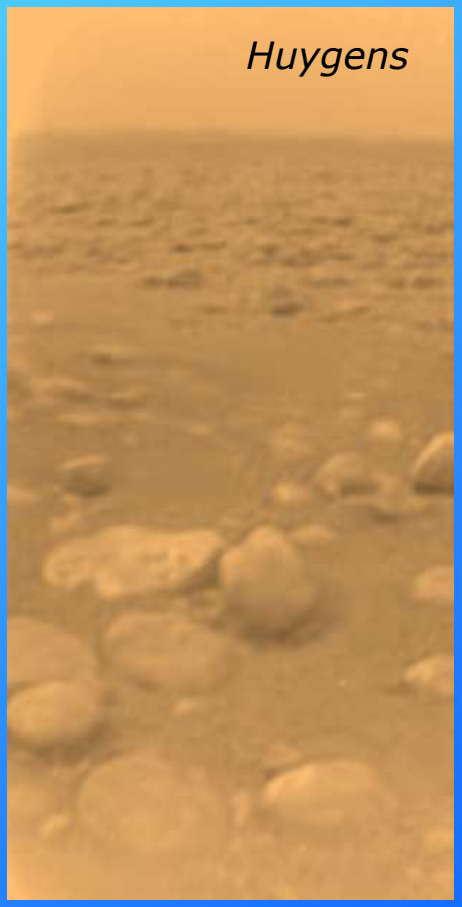
A RECENT PHOTOGRAPH SUGGESTS THAT THERE IS LIFE-STYLE ON MARS

Titan





	Earth	Titan
M (10^{23}kg)	59.74	1.34
D (km)	12756	5150
ρ (kg m^{-3})	5515	1880
g (m s^{-2})	9.78	1.35



Titan and life

- Stratified atmosphere with N_2, CH_4 and other hydrocarbons
- Methan cycle
- Synthesis of organic molecules
- Subterranean ocean of H_2O and NH_3?
- Cryovulcanism

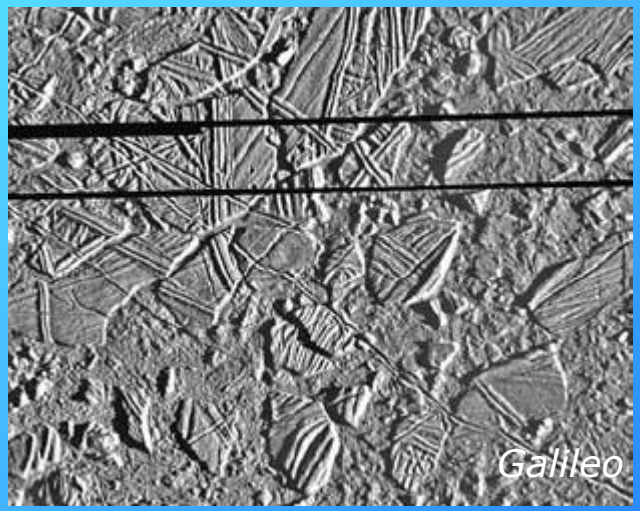
Titan and life

- Stratified atmosphere with N_2, CH_4 and other hydrocarbons
- Methan cycle
- Synthesis of organic molecules
- Subterranean ocean of H_2O and NH_3?
- Cryovulcanism

- Study of the formation of organic molecules
- Possible life in the ocean

Europa

	Earth	Europa
M (10^{23}kg)	59.74	0.48
D (km)	12756	3122
ρ (kg m^{-3})	5515	3014
g (m s^{-2})	9.78	2.00



Europa and life

- Possible liquid ocean under a layer of ice
- Hydrothermal vents?
- Organic molecules from impacts
- Analogy with Lake Vostok, Antarctica

Europa and life

- Possible liquid ocean under a layer of ice
- Hydrothermal vents?
- Organic molecules from impacts
- Analogy with Lake Vostok, Antarctica

- Possible chemiosynthetic anaerobic life in the subglacial ocean

Extrasolar planets

- 688 exoplanets, 565 planetary systems (81 multiple systems)*
- Sampling bias: “Hot Jupiters”

* 9-26-11 http://exoplanet.eu/catalog.php

Extrasolar planets

- 688 exoplanets, 565 planetary systems (81 multiple systems)*
- Sampling bias: “Hot Jupiters”
- *Kepler*: 1235 candidates, of which 68 have dimensions similar to Earth (5 of them in the HZ)

* 9-26-11 http://exoplanet.eu/catalog.php

Extrasolar planets

- 688 exoplanets, 565 planetary systems (81 multiple systems)*
- Sampling bias: “Hot Jupiters”
- *Kepler*: 1235 candidates, of which 68 have dimensions similar to Earth (5 of them in the HZ)

  → 6% of stars could host a new Earth!

* 9-26-11 http://exoplanet.eu/catalog.php

Extrasolar planets

- 688 exoplanets, 565 planetary systems (81 multiple systems)*
- Sampling bias: “Hot Jupiters”
- *Kepler*: 1235 candidates, of which 68 have dimensions similar to Earth (5 of them in the HZ)

  → 6% of stars could host a new Earth!
- Gliese 581 g (M~3-4 M_T, p~37 days)

* 9-26-11 http://exoplanet.eu/catalog.php

Search for intelligent life

Drake's equation:

$$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

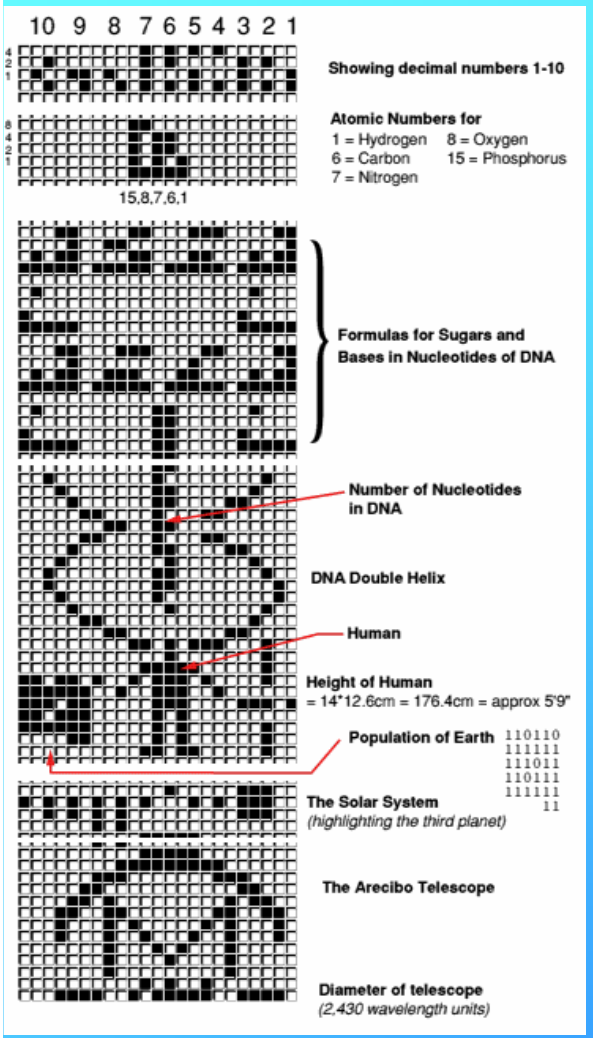
Search for intelligent life

Drake's equation:

$$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

Search for Extraterrestrial Intelligence (SETI): search for signs from other civilizations

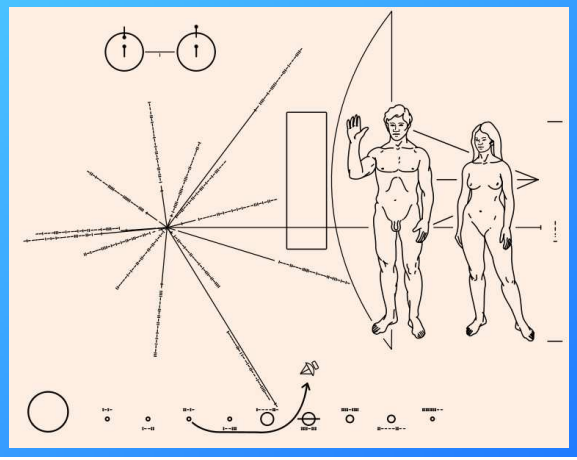
Search for intelligent life



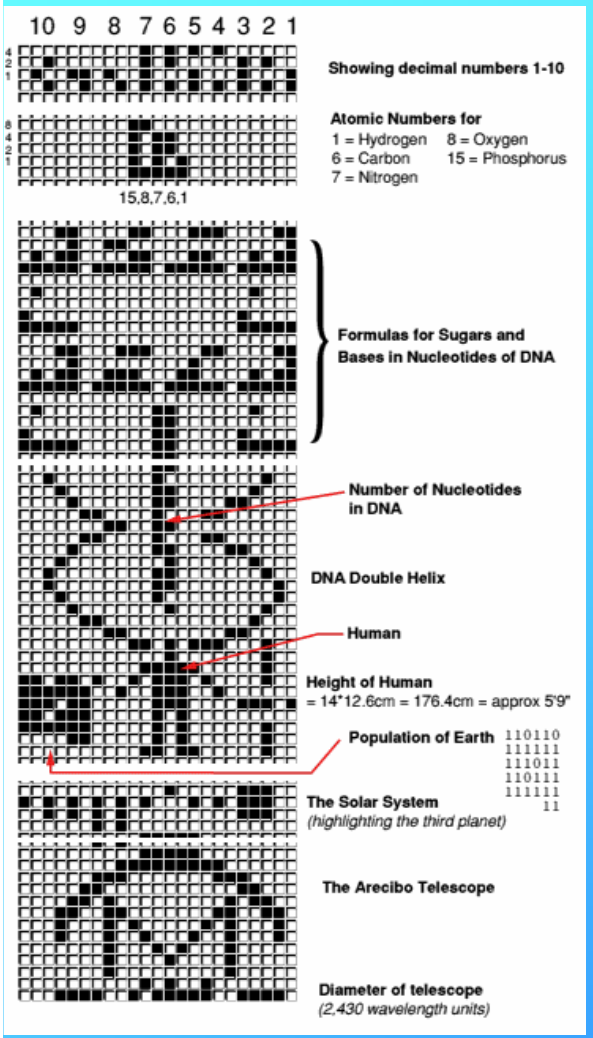
Drake's equation:

$$N=R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

Search for Extraterrestrial Intelligence (SETI): search for signs from other civilizations



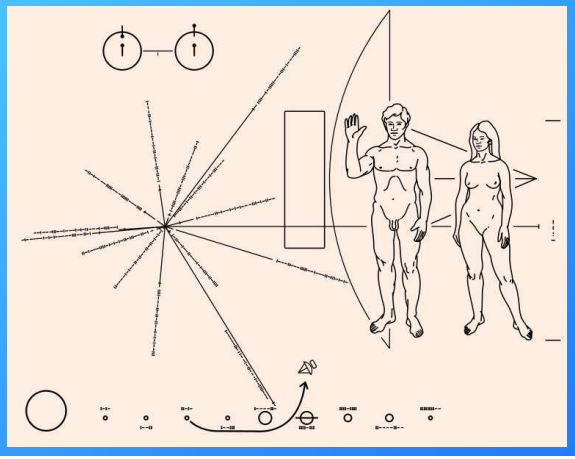
Search for intelligent life



Drake's equation:

$$N=R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

Search for Extraterrestrial Intelligence (SETI): search for signs from other civilizations

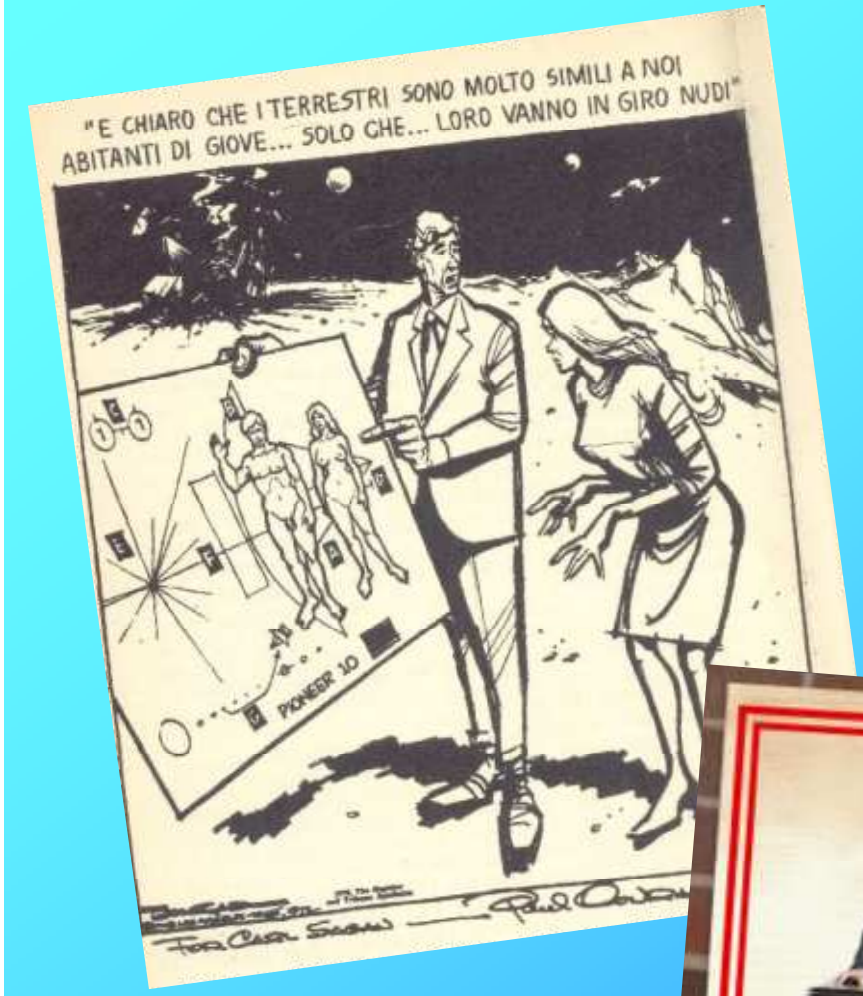


Where are they?


"E CHIARO CHE I TERRESTRI SONO MOLTO SIMILI A NOI ABITANTI DI GIOVE... SOLO CHE... LORO VANNO IN GIRO NUDI"
PIONEER 10


"E CHIARO CHE I TERRESTRI SONO MOLTO SIMILI A NOI
ABITANTI DI GIOVE... SOLO CHE... LORO VANNO IN GIRO NUDI"
PIONEER 10

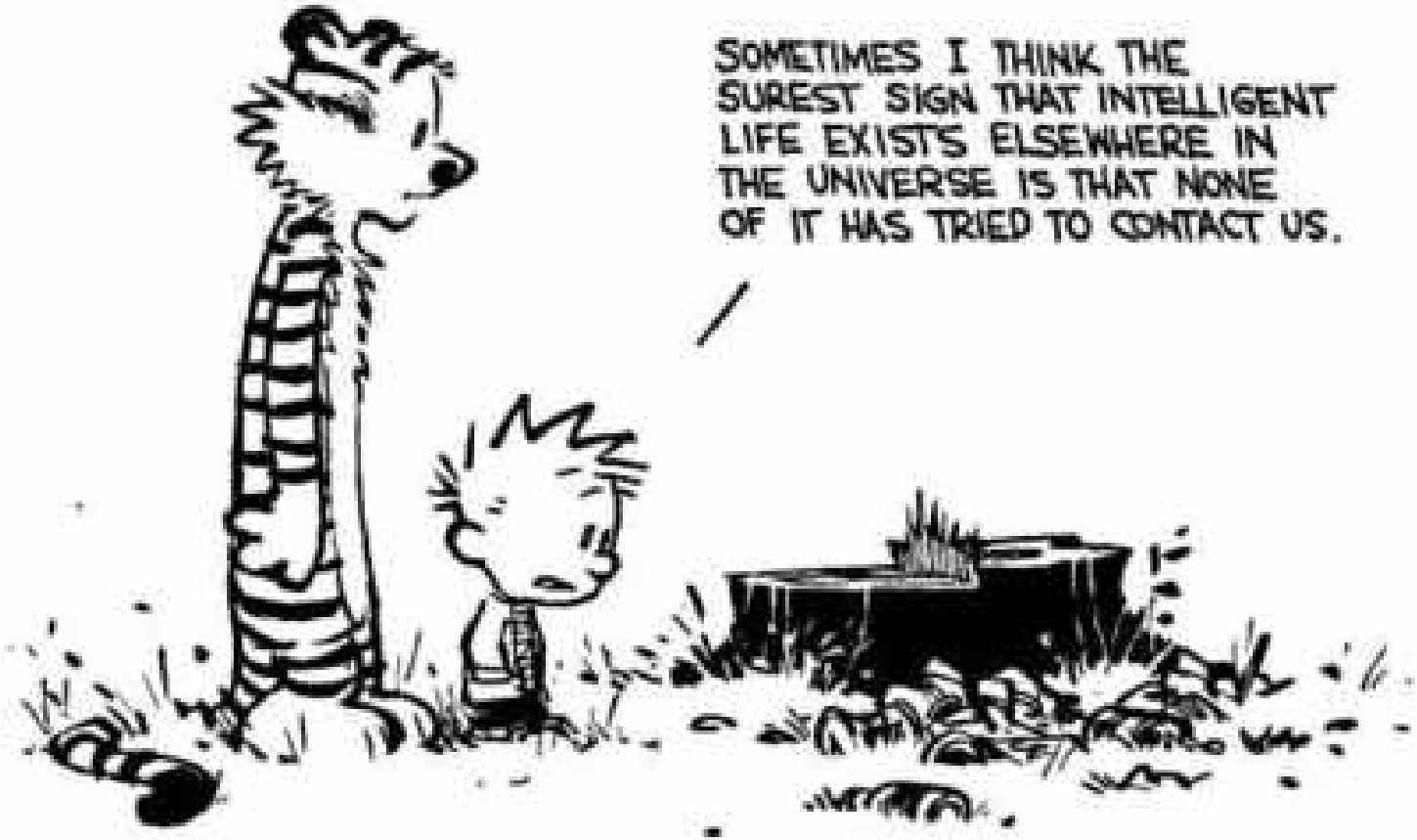

VOYAGER


"E CHIARO CHE I TERRESTRI SONO MOLTO SIMILI A NOI ABITANTI DI GIOVE... SOLO CHE... LORO VANNO IN GIRO NUDI"
PIONEER 10


VOYAGER


I WANT YOU
FOR SCIENTOLOGY!!

The end


SOMETIMES I THINK THE SUREST SIGN THAT INTELLIGENT LIFE EXISTS ELSEWHERE IN THE UNIVERSE IS THAT NONE OF IT HAS TRIED TO CONTACT US.

Some books

- Barrow, John D., & Tipler, Frank J., *The anthropic cosmological principle*, 1986, Oxford University Press
- Bignami, G. F., *I marziani siamo noi*, 2010, Zanichelli
- Clancy, P., Brack, A., & Horneck, G., *Looking for life. Searching the Solar System*, 2005, Cambridge University Press
- Gargaud, M., Hervé, M., & Clayes, P. (eds.), *Lectures in Astrobiology I*, 2005, Springer
- Gargaud, M., Hervé, M., & Clayes, P. (eds.), *Lectures in Astrobiology II*, 2007, Springer
- Horneck, G., & Rettberg, P. (eds.), *Complete course in Astrobiology*, 2007, WILEY-VCH Verlag GmbH & Co. KGaA
- Orgel, L. E., *The origins of life*, 1973, Chapman and Hall Ltd.
- Pudritz, R., Higgs, P., & Stone, J. (eds.), *Planetary systems and the origin of life*, 2007, Cambridge University Press