L'Universo e la vita

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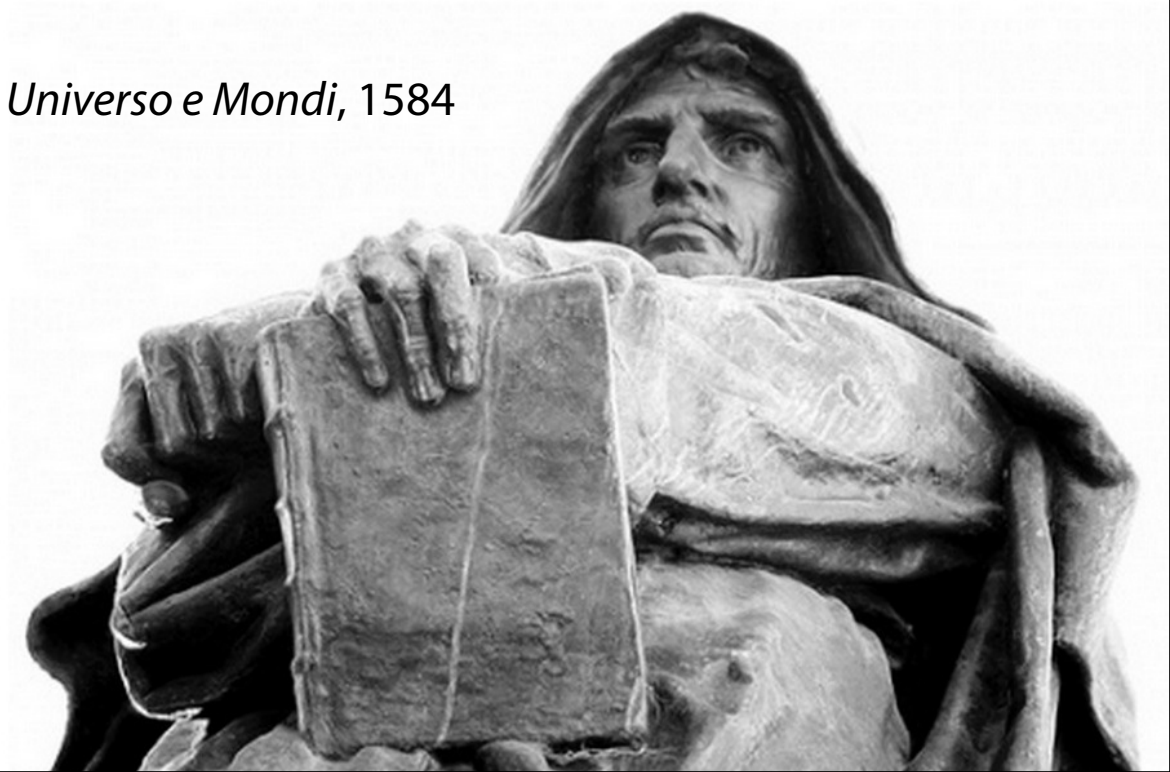
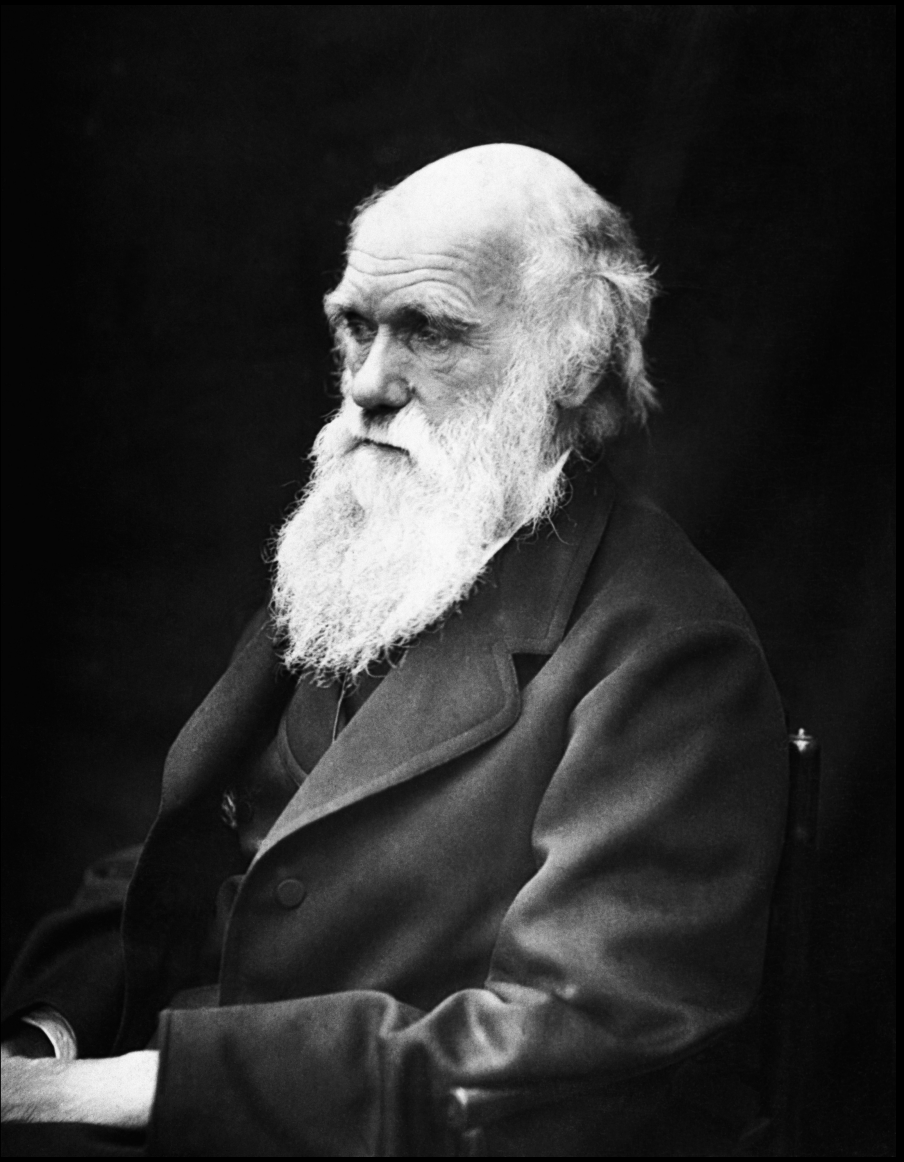
“Grande cosa è certamente alla immensa moltitudine delle stelle fisse che fino a oggi si potevano scorgere con la facoltà naturale, aggiungerne e far manifeste all'occhio umano altre innumeri, prima non mai vedute e che il numero delle antiche e note superano più di dieci volte.”

—Galileo Galilei, *Sidereus Nuncius*, 1610

“Perché è impossibile ch’un razionale ed alquanto svegliato ingegno possa imaginarsi, che sieno privi di simili e megliori abitanti mondi innumerabili, che si mostrano o cossì o più magnifici di questo.”

— Giordano Bruno, *De l’Infinito, Universo e Mondi*, 1584



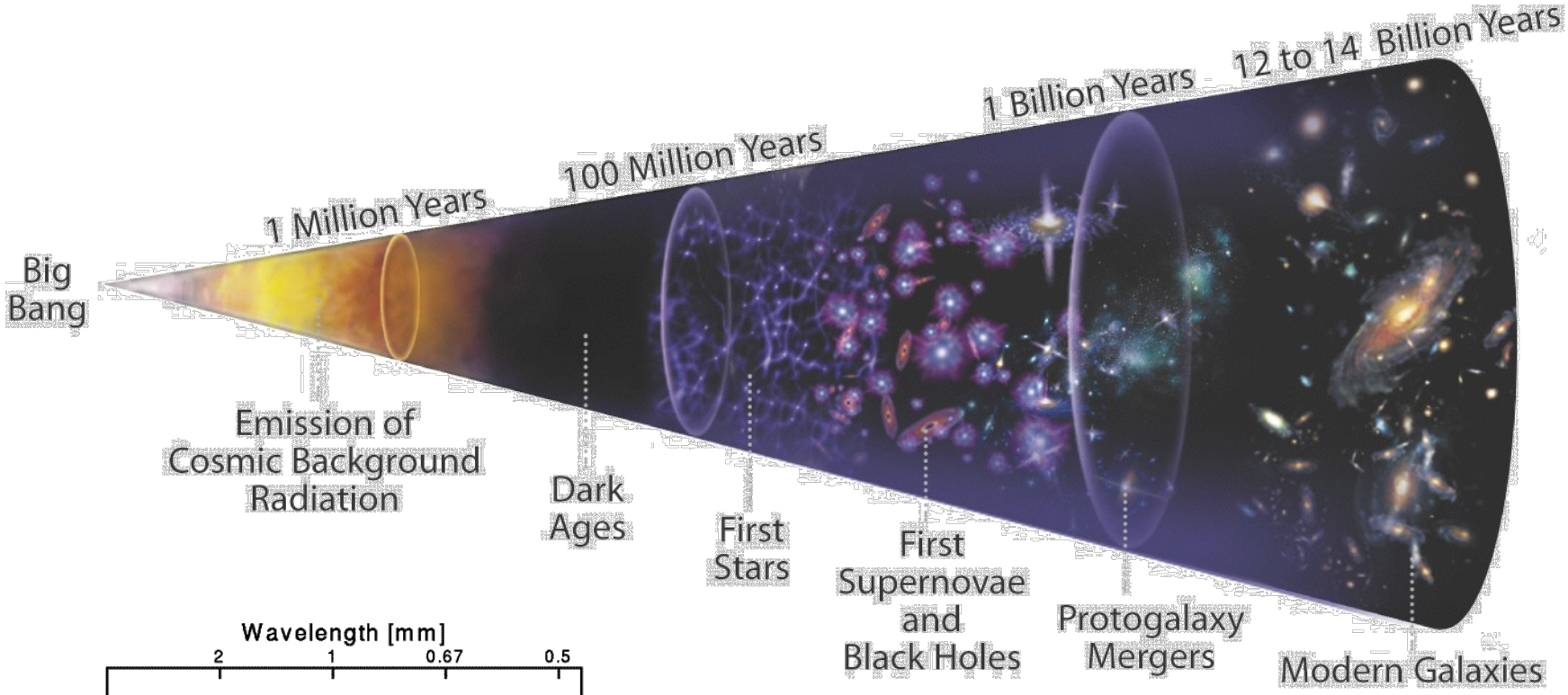


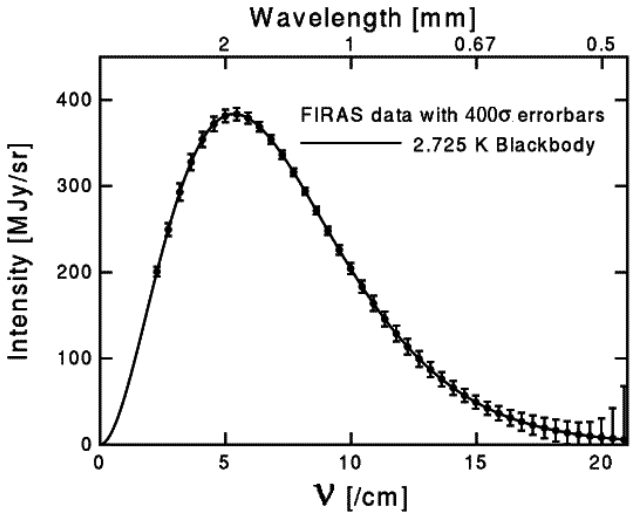
> It is mere rubbish, thinking at present of the origin of life.

— Charles Darwin, lettera a Joseph Hooker (1863)

> […] in some warm little pond, with all sorts of ammonia and phosphoric salts, light, heat, electricity, etc., […]

— Charles Darwin, lettera a Joseph Hooker (1871)



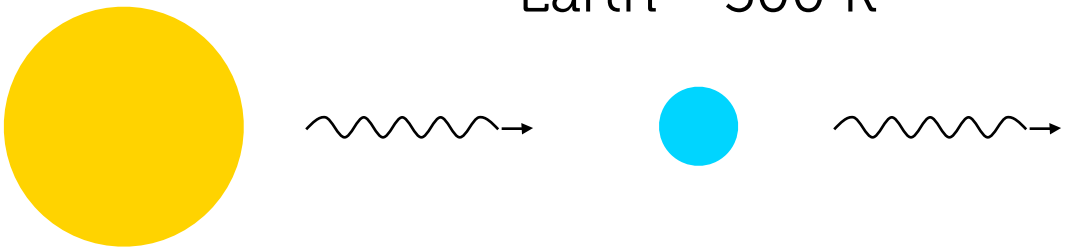


time

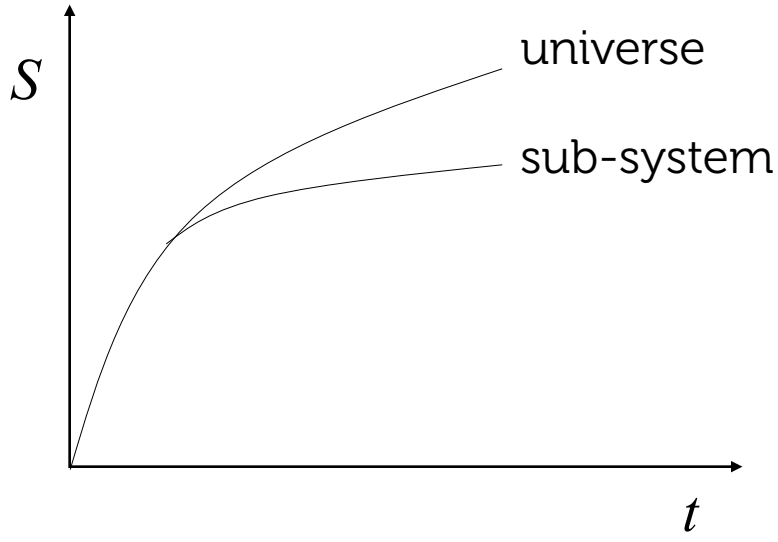
equilibrium

Sun ~ 6000 K

Earth ~ 300 K



empty space
(CMB) ~ 2.7 K



"branching"
[Reichenbach, 1956]

Cos'è la vita?

Crescita? Cristalli

Riproduzione ed evoluzione? Virus di computer

Capacità di immagazzinare e elaborare informazione? Calcolatori elettronici

Un unico caso di studio

Schroedinger ("What is life", 1944)

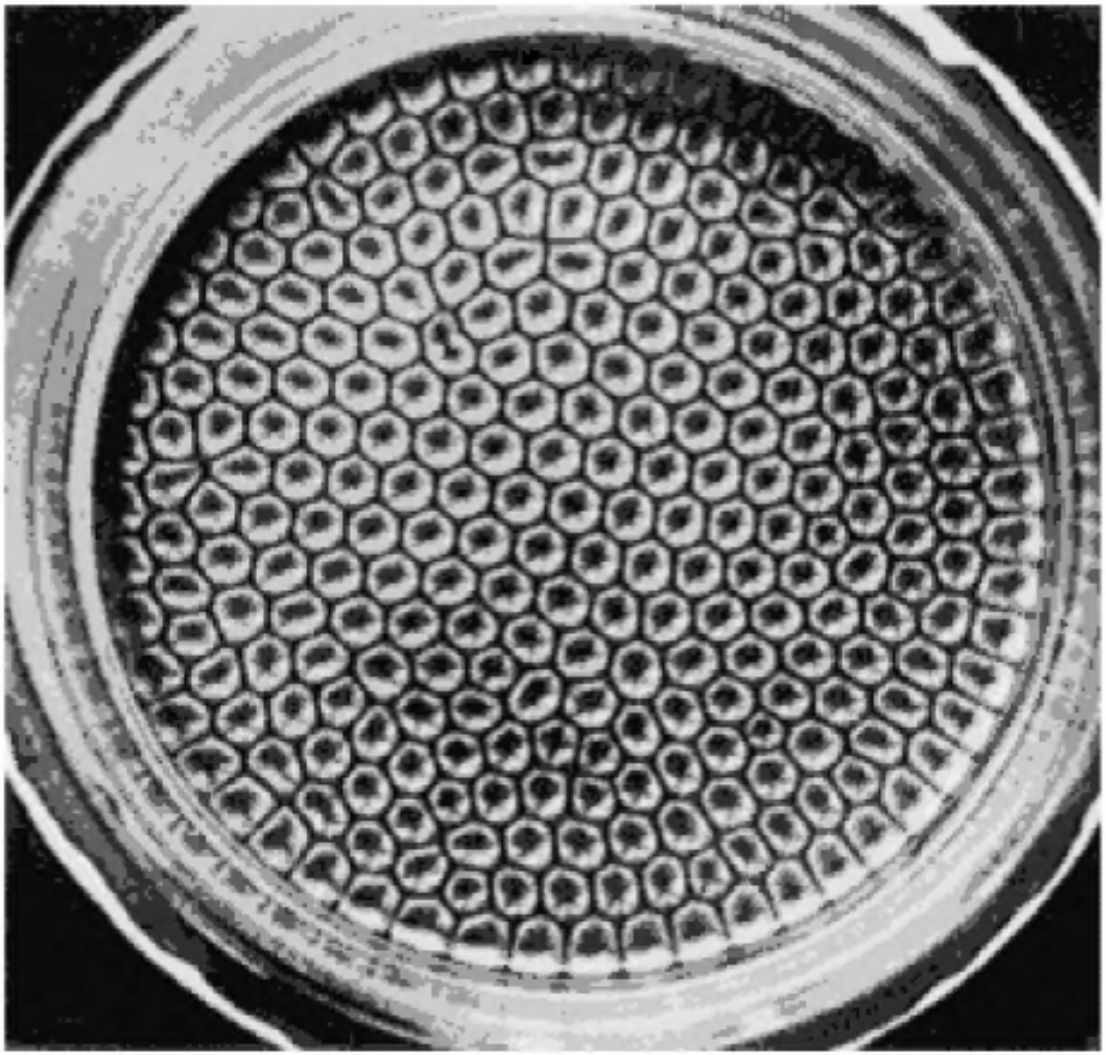
> "An organism feeds upon negative entropy [...] to compensate the entropy it produces by living and thus to maintain itself on a stationary and fairly low entropy level"

cfr. dissipative structures (Prigogine et al, 1972)

> Open, coherent, ordered structure, kept far from thermodynamical equilibrium by a flow of energy

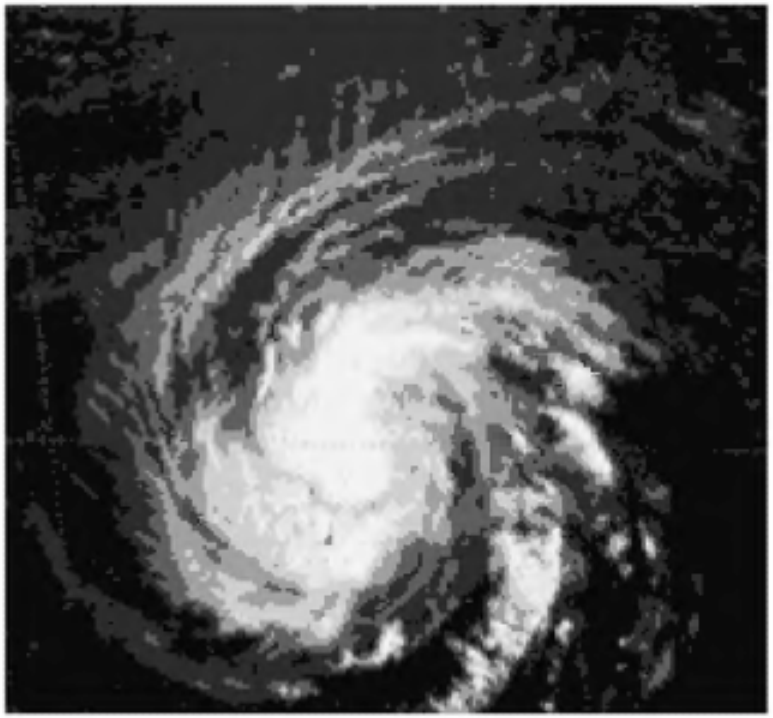
example: convective cells

(d)



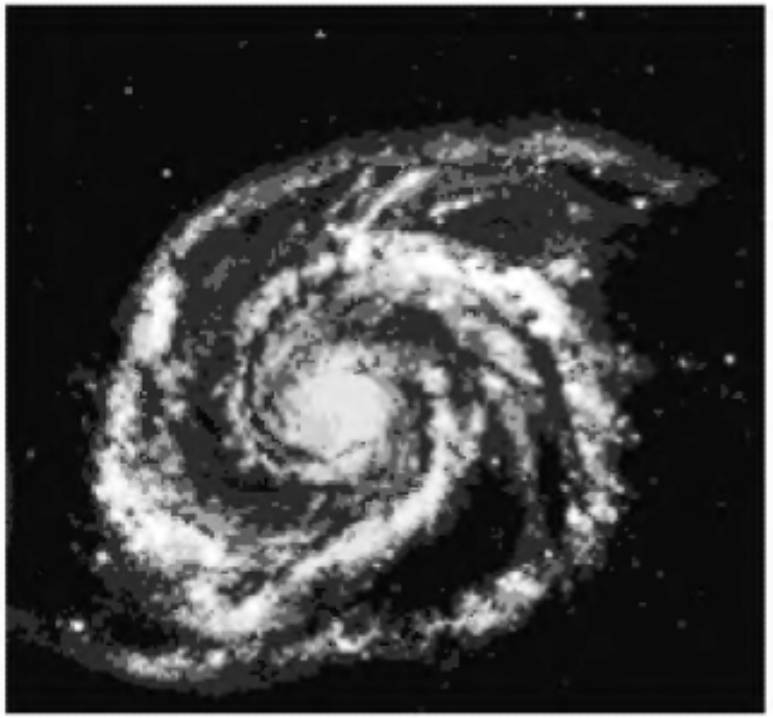
more examples:

hurricanes



(c)

galaxies



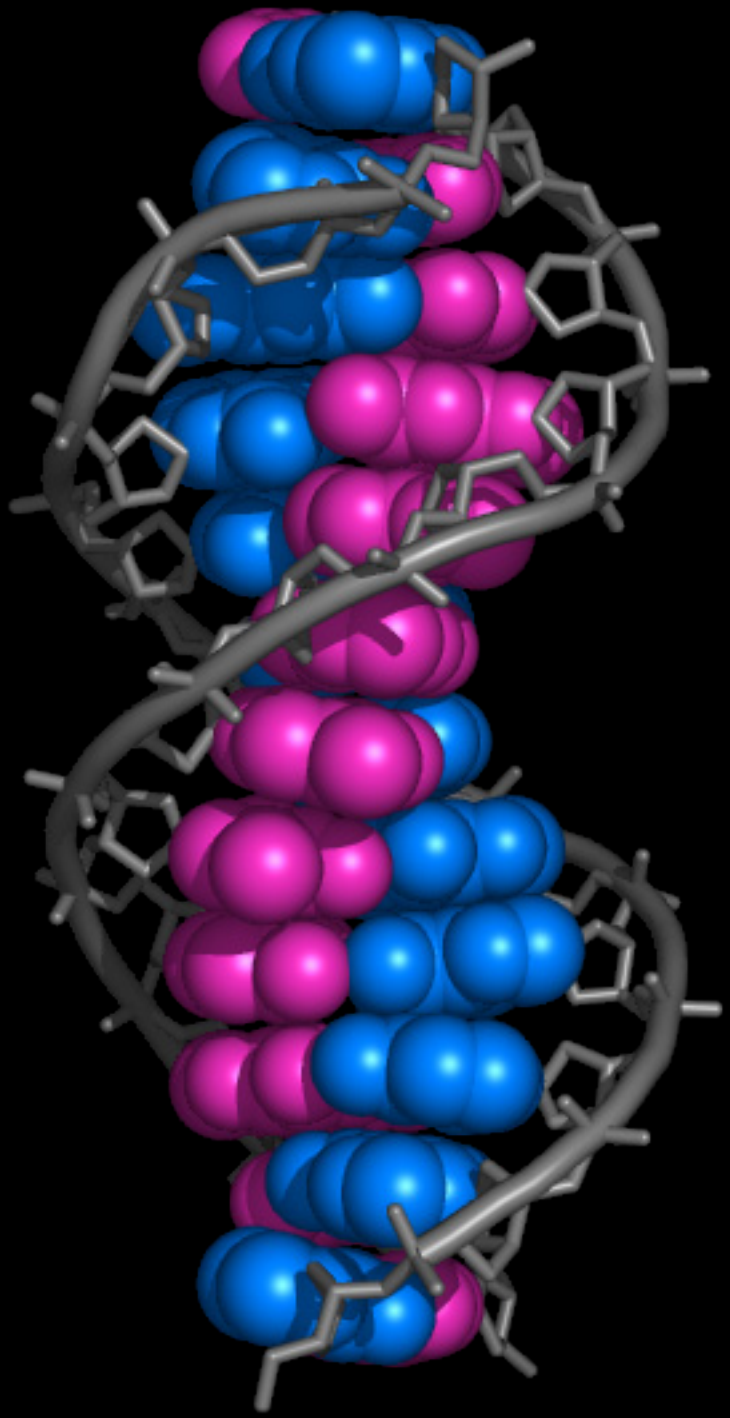
(d)

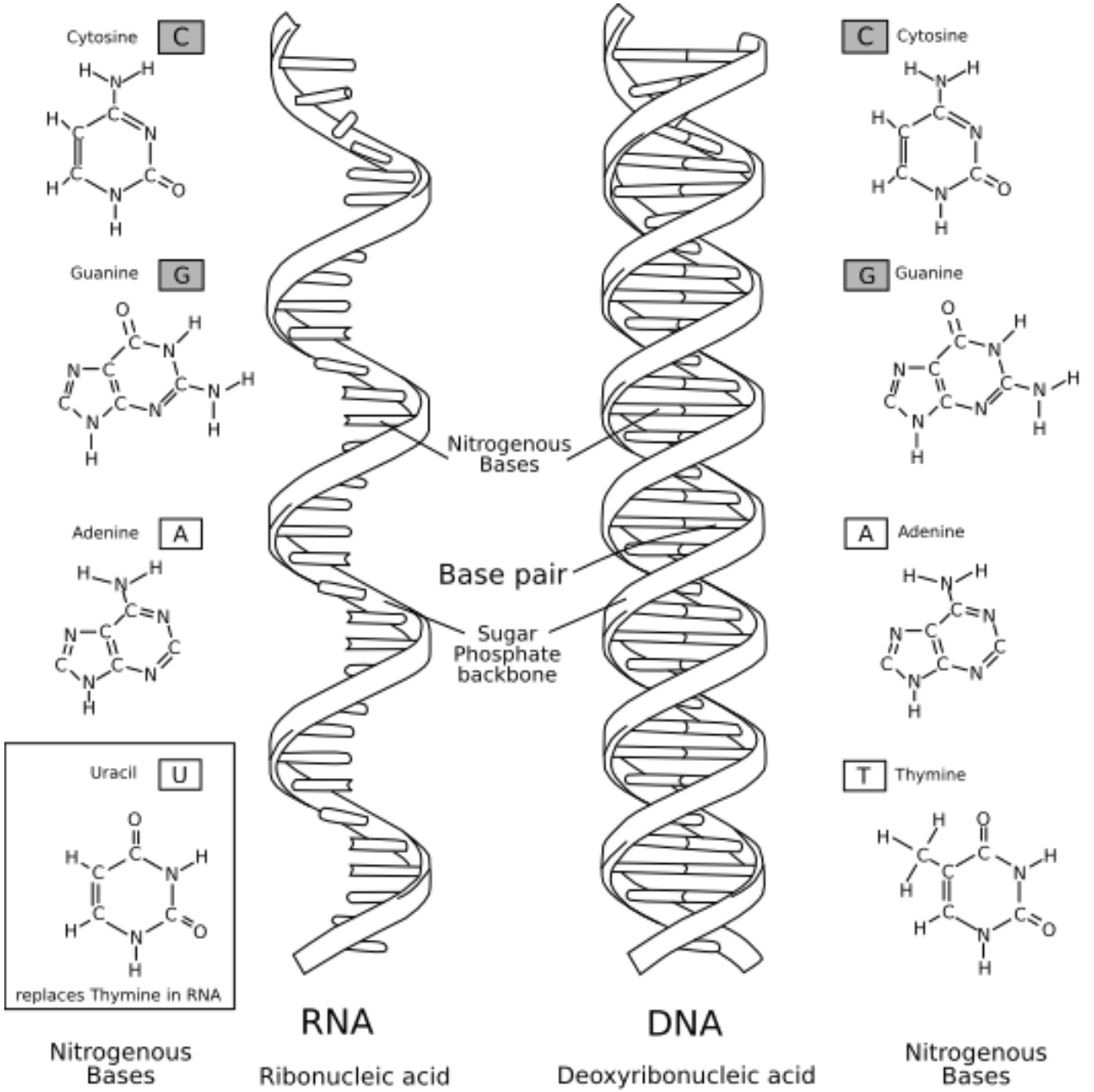
NASA Astrobiology Institute definition:

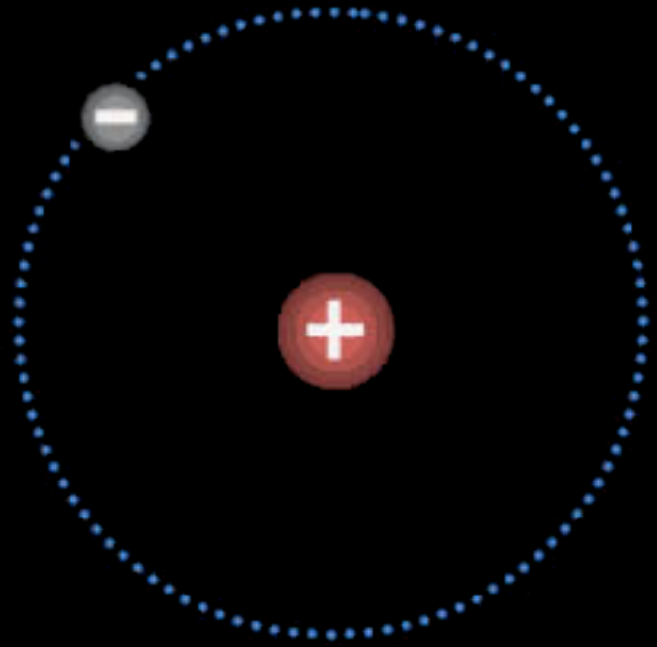
“Life is a self-sustaining system capable of Darwinian evolution”

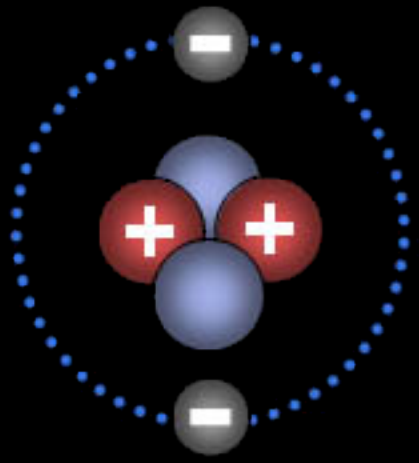
Ingredienti minimi

- ✓Molecole organiche complesse (CHONPS)
- ✓Un solvente liquido (acqua?)
- ✓Una sorgente di energia

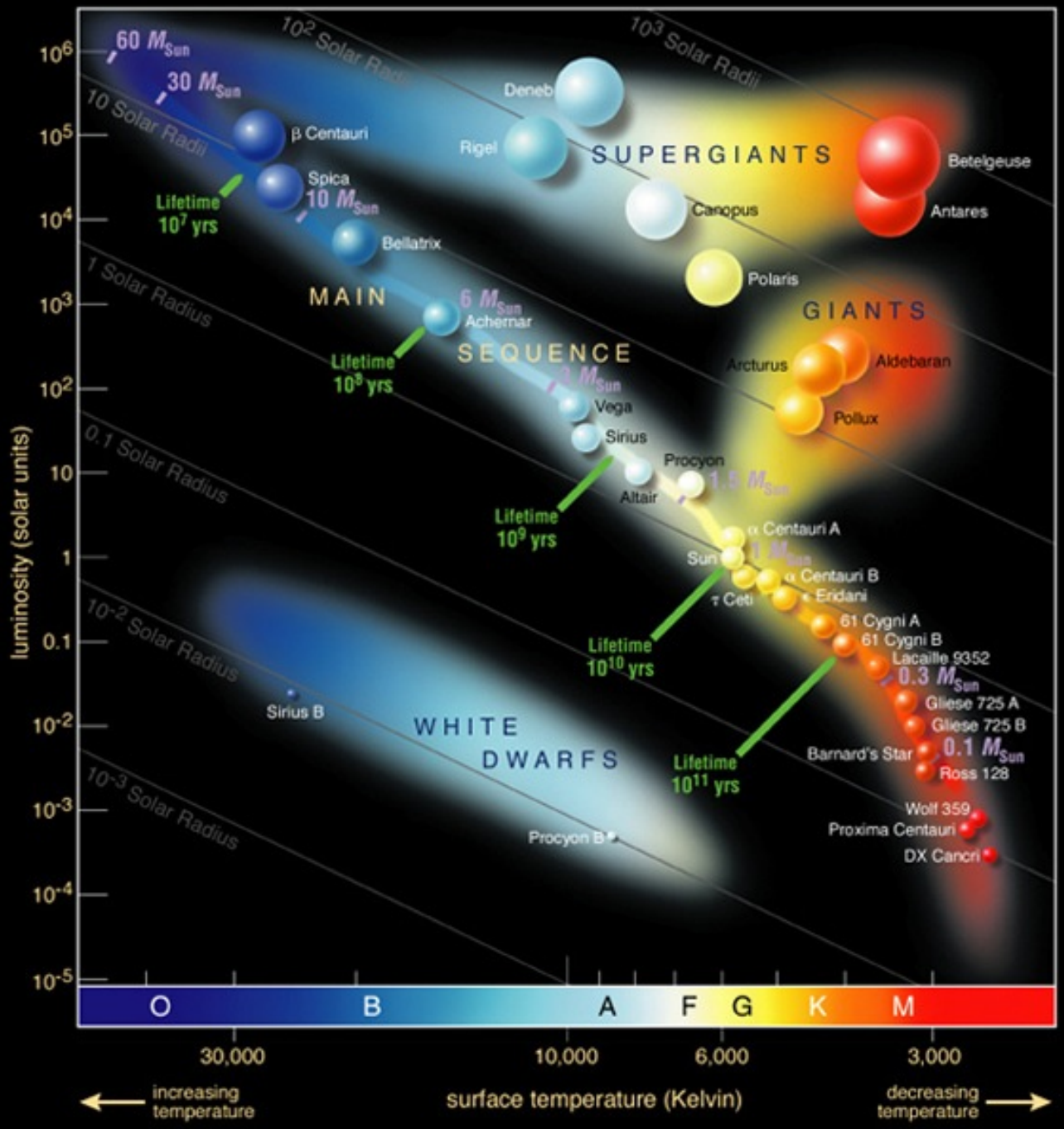



Cytosine
C
Guanine
G
Adenine
A
Uracil
U
replaces Thymine in RNA
Nitrogenous Bases
Nitrogenous Bases
Base pair
Sugar Phosphate backbone
RNA
Ribonucleic acid
DNA
Deoxyribonucleic acid
C
Cytosine
G
Guanine
A
Adenine
T
Thymine
Nitrogenous Bases

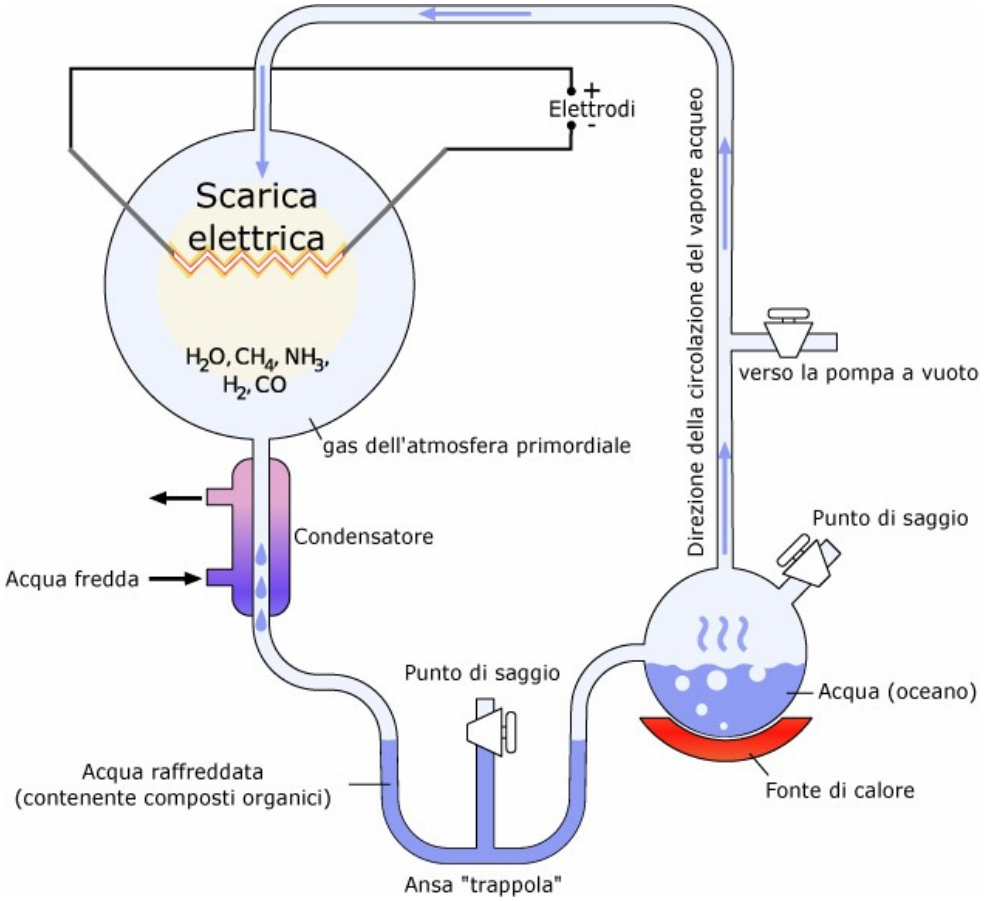




75% 25%


luminosity (solar units)
10^6
10^5
10^4
10^3
10^2
10
1
0.1
10^{-2}
10^{-3}
10^{-4}
10^{-5}
60 M_{Sun}
30 M_{Sun}
10 M_{Sun}
6 M_{Sun}
2 M_{Sun}
1.5 M_{Sun}
1 M_{Sun}
0.3 M_{Sun}
0.1 M_{Sun}
10^2 Solar Radii
10^3 Solar Radii
10 Solar Radii
1 Solar Radius
0.1 Solar Radius
10^{-2} Solar Radius
10^{-3} Solar Radius
Deneb
Rigel
SUPERGIANTS
Betelgeuse
Antares
Canopus
Polaris
β Centauri
Spica
Bellatrix
Lifetime 10^7 yrs
MAIN
SEQUENCE
Achernar
Lifetime 10^8 yrs
GIANTS
Arcturus
Aldebaran
Pollux
Vega
Sirius
Procyon
Altair
Lifetime 10^9 yrs
α Centauri A
Sun
α Centauri B
ε Eridani
τ Ceti
Lifetime 10^{10} yrs
61 Cygni A
61 Cygni B
Lacaille 9352
Gliese 725 A
Gliese 725 B
Barnard's Star
Ross 128
Lifetime 10^{11} yrs
Wolf 359
Proxima Centauri
DX Cancri
Sirius B
WHITE
DWARFS
Procyon B
O
B
A
F
G
K
M
30,000
10,000
6,000
3,000
increasing temperature
surface temperature (Kelvin)
decreasing temperature

Esperimento di Miller & Urey (1953)



energia libera

+

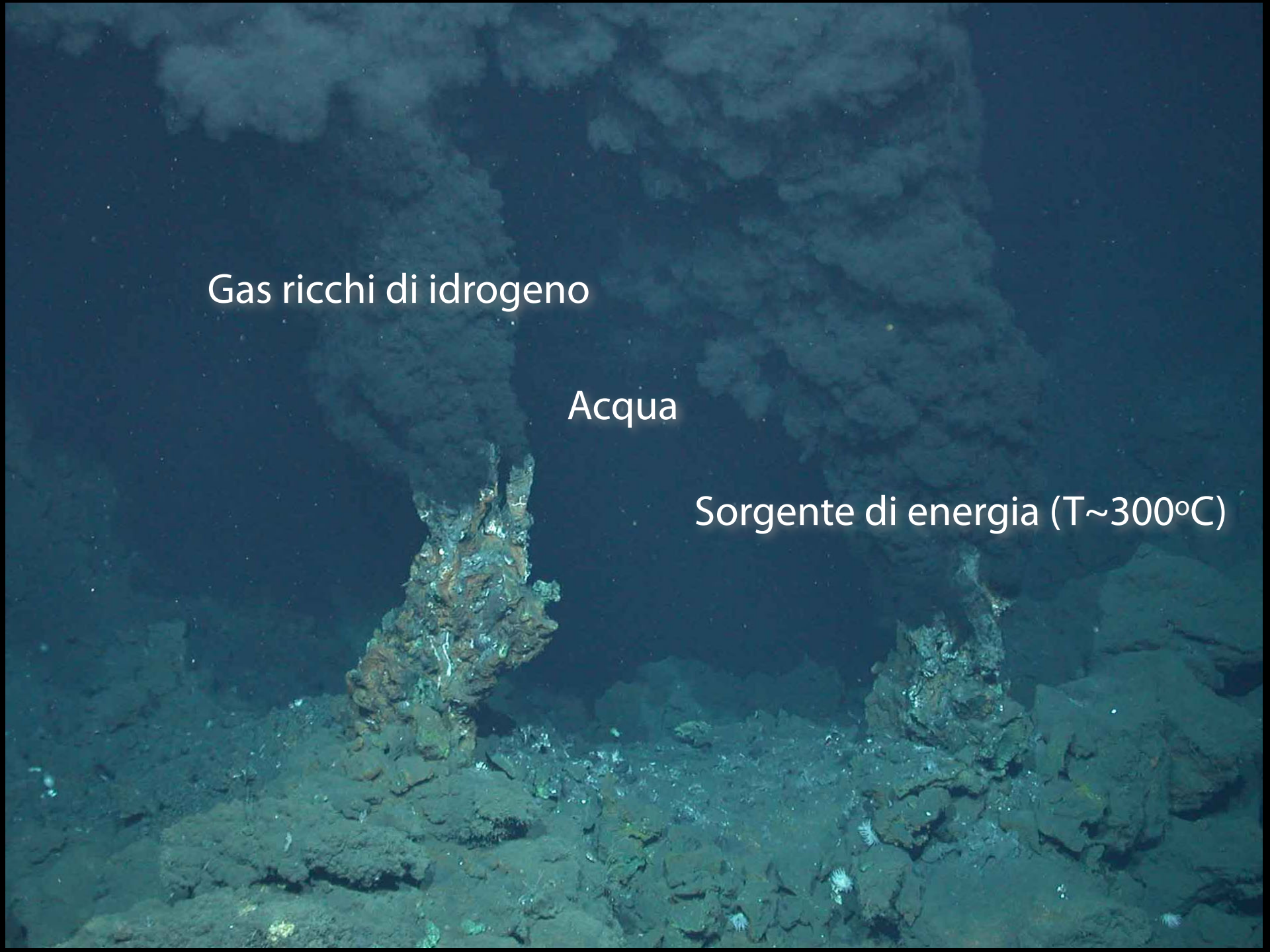
reagenti appropriati
(CH_4, NH_3, H_2, H_2O, CO)

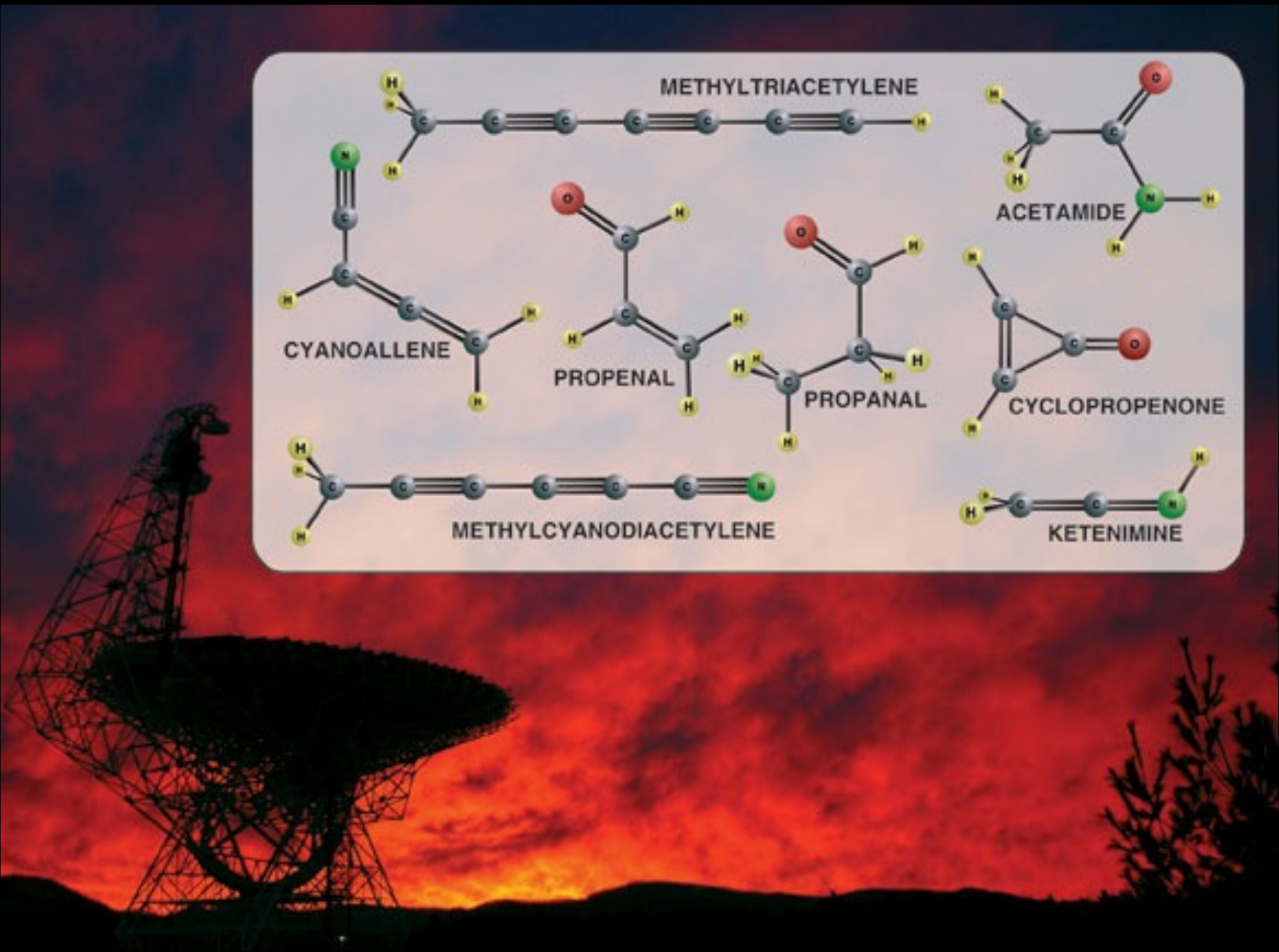
↓

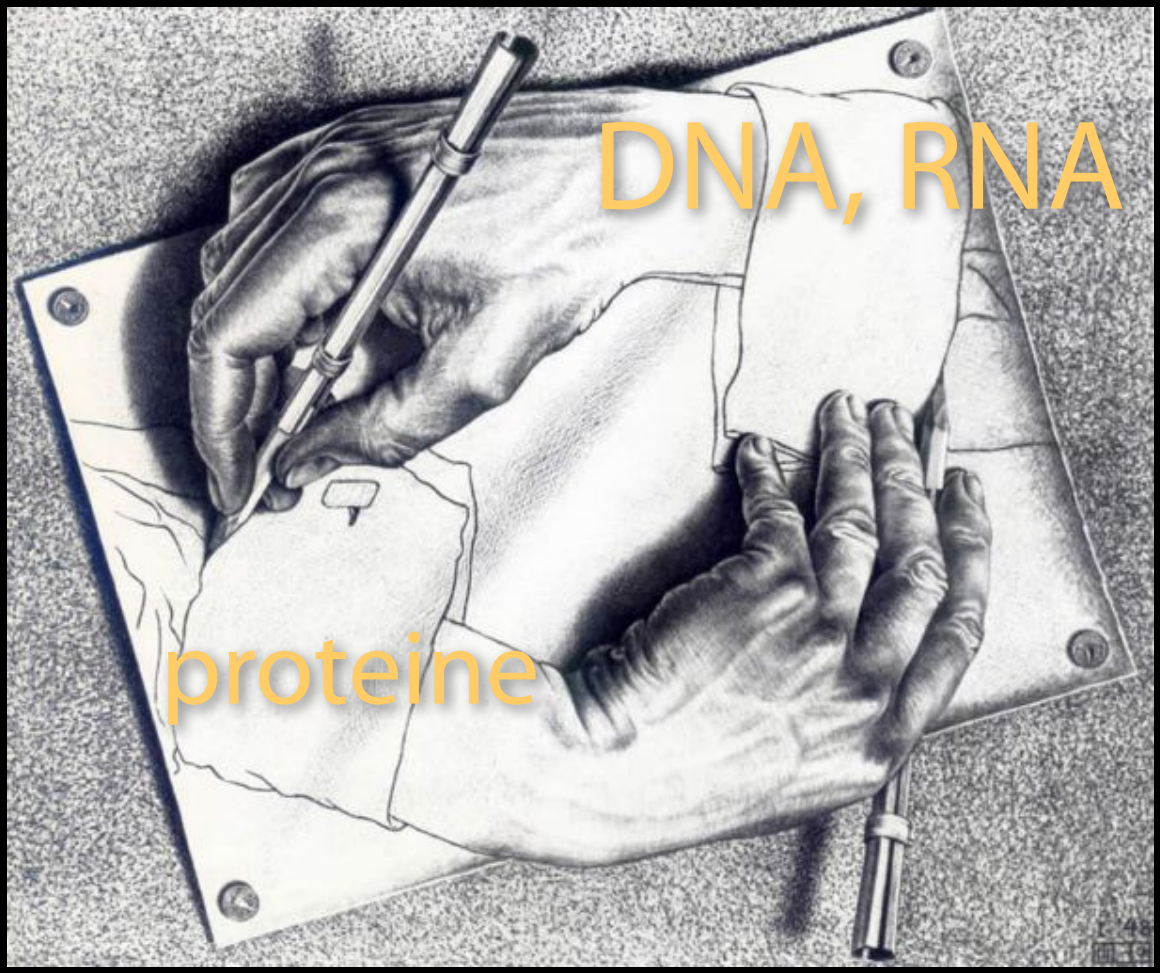
produzione di amminoacidi e altri composti organici

Ma…

1) L'atmosfera della Terra primordiale era diversa (CO_2, N_2, H_2O)
2) Gli amminoacidi coinvolti nei processi biologici sono solo di tipo levogiro


Gas ricchi di idrogeno
Acqua
Sorgente di energia (T~300ºC)


METHYLTRIACETYLENE
ACETAMIDE
CYANOALLENE
PROPENAL
PROPANAL
CYCLOPROPENONE
METHYLCYANODIACETYLENE
KETENIMINE

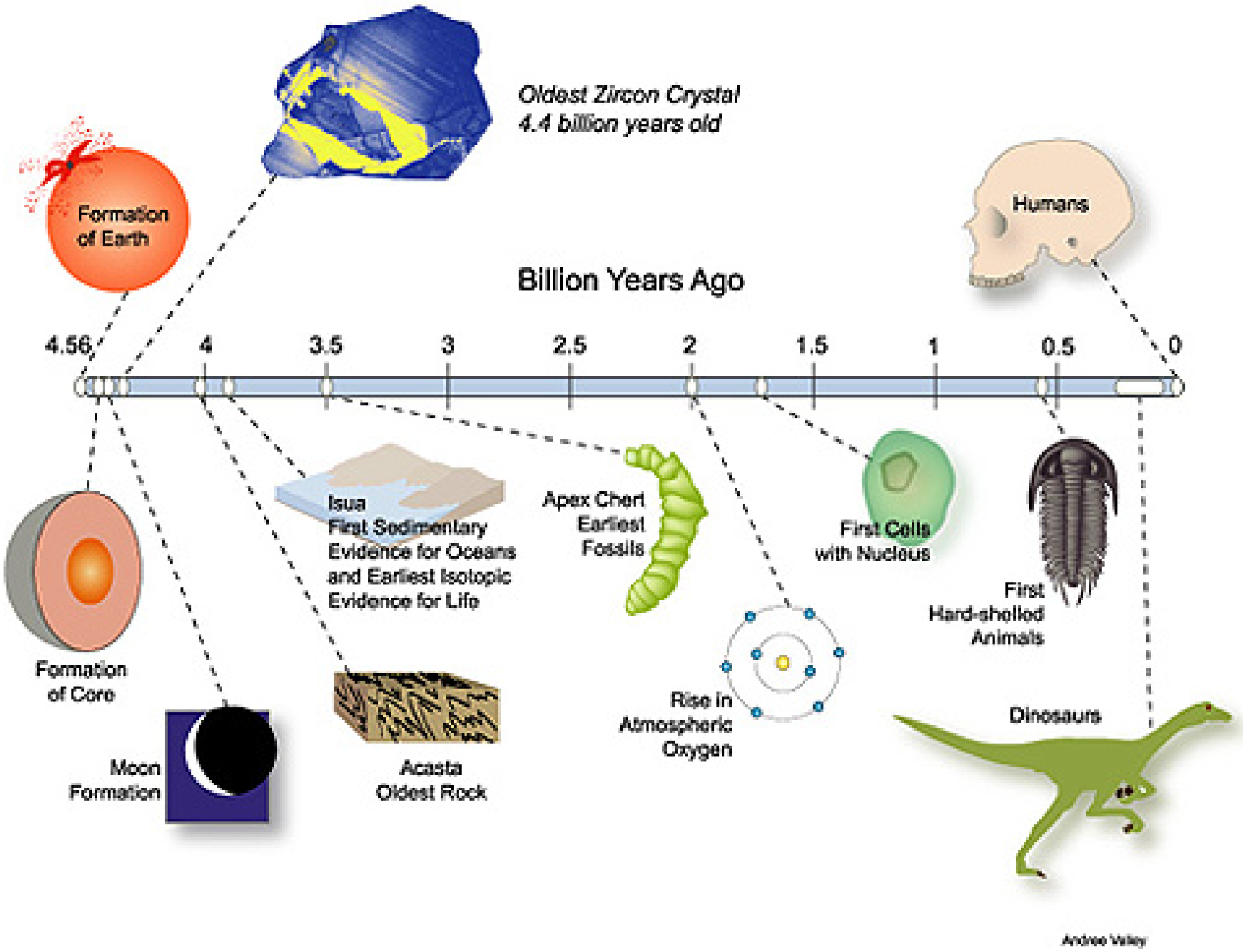

DNA, RNA
proteine

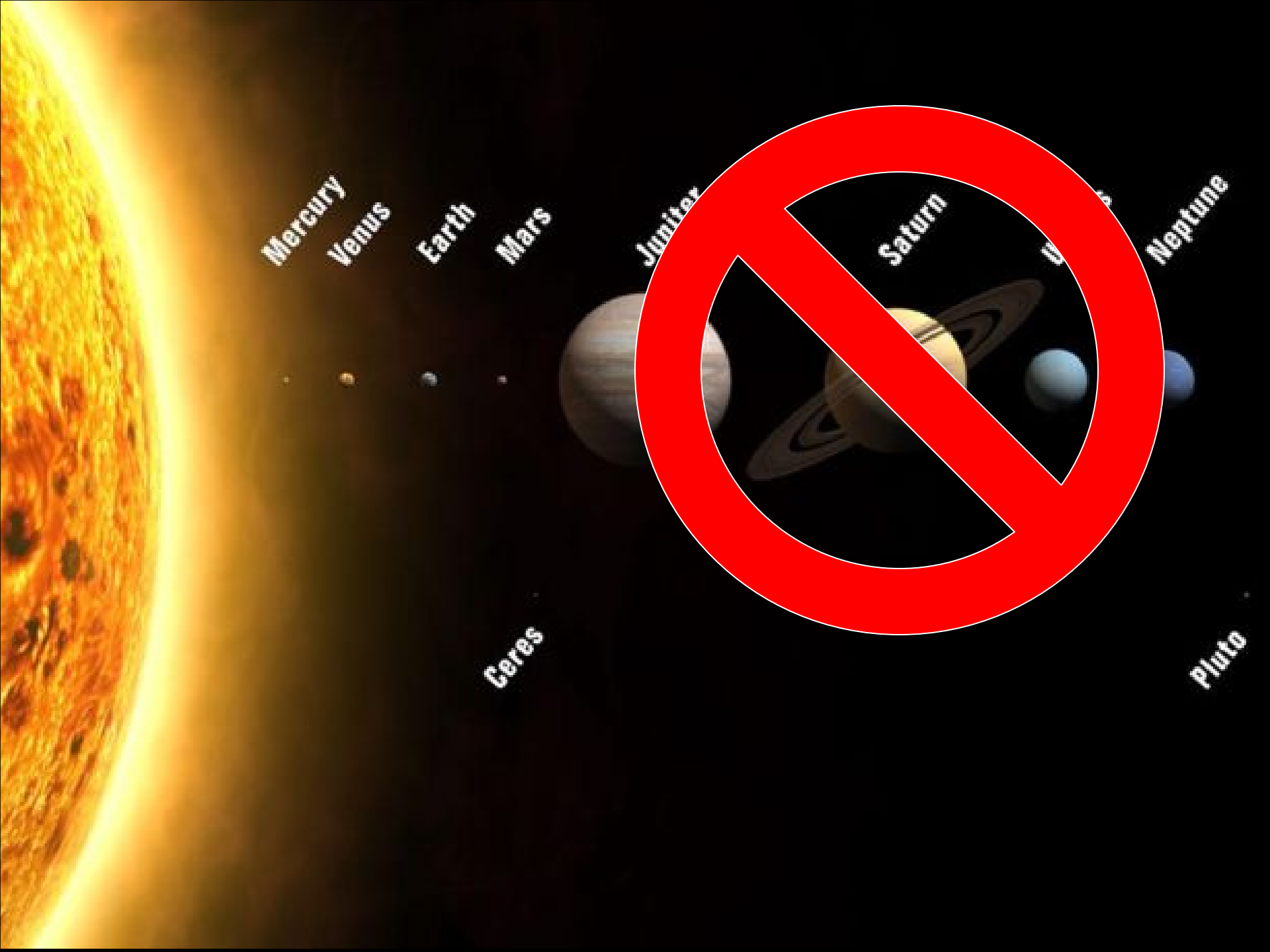
Prima l'RNA?

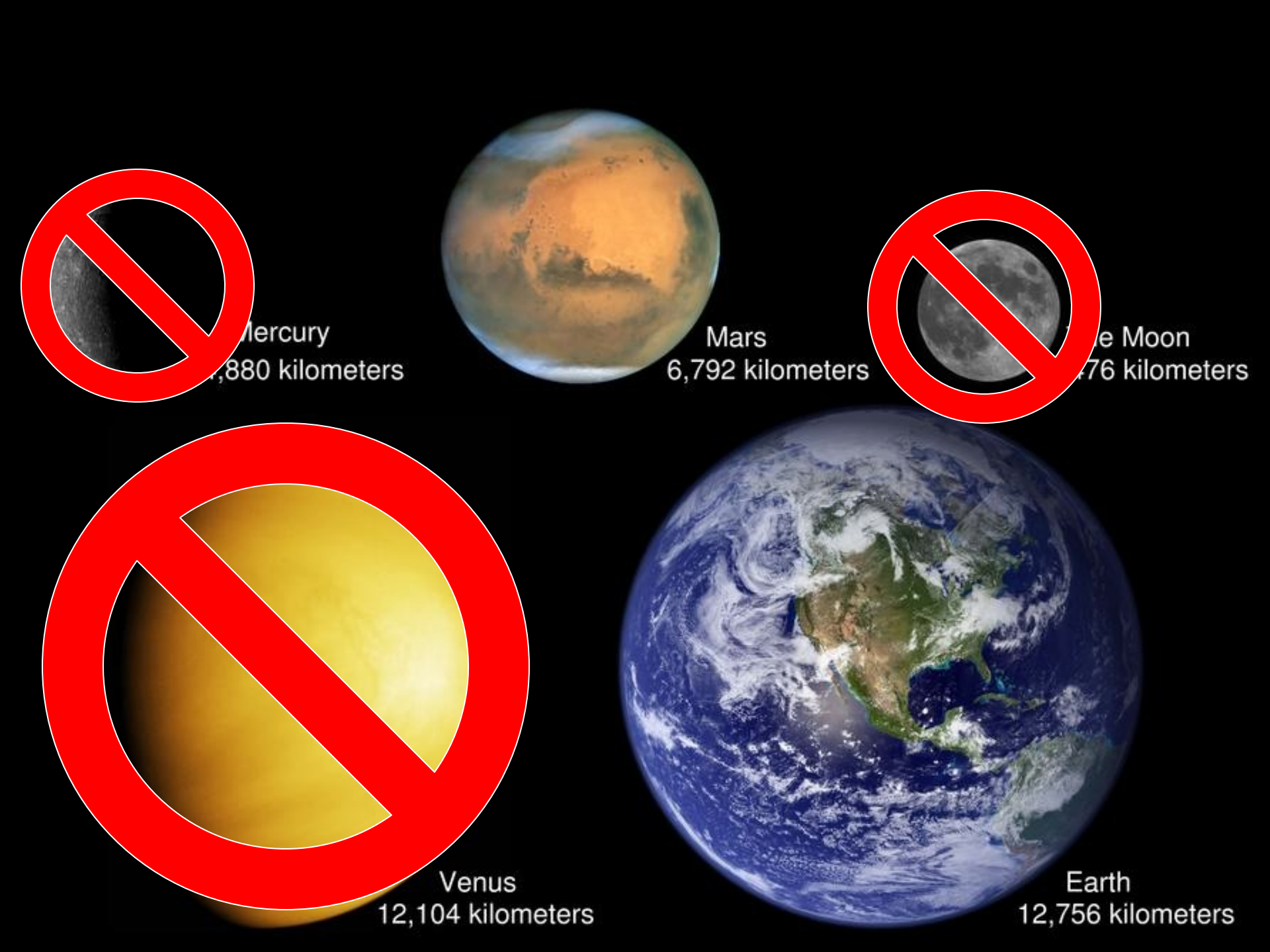
Può svolgere il ruolo di catalizzatore, decodificatore e comunicatore dell'informazione

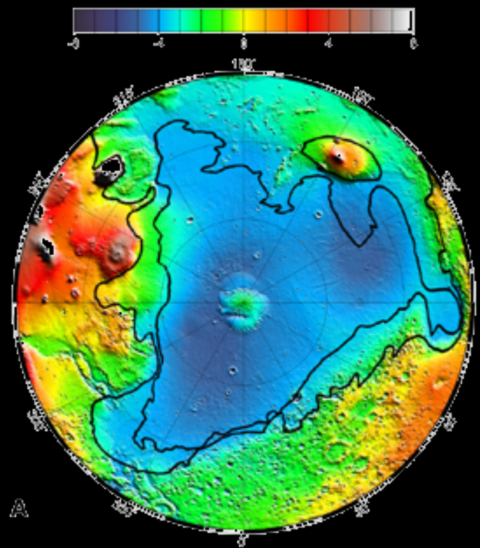
Prima le proteine?

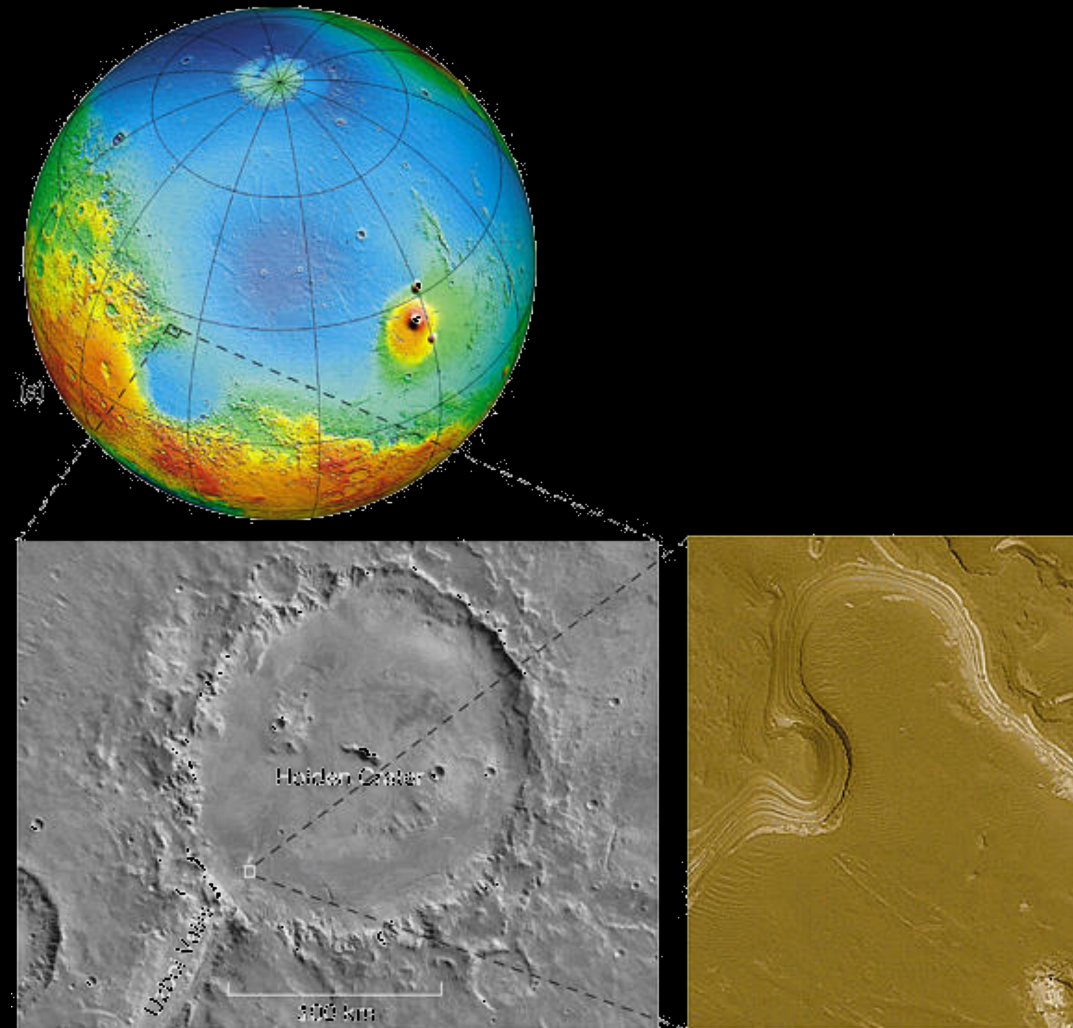
Esistono piccole catene molecolari in grado di autoreplicarsi

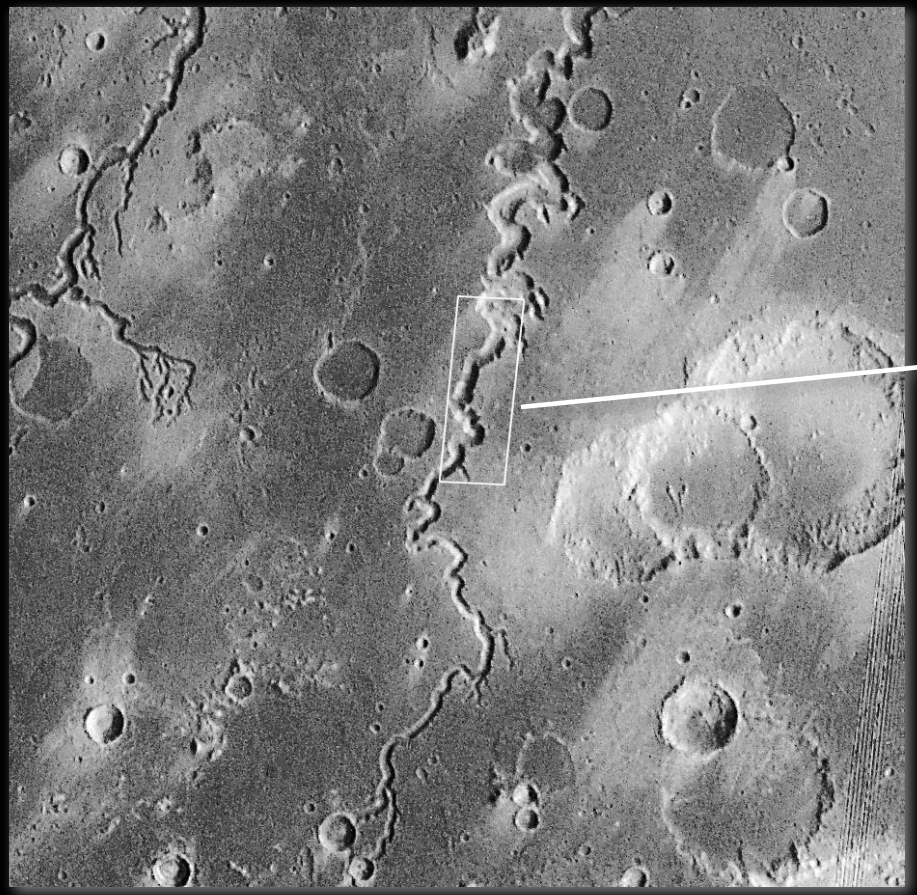

Oldest Zircon Crystal
4.4 billion years old
Formation of Earth
Humans
Billion Years Ago
4.56
4
3.5
3
2.5
2
1.5
1
0.5
0
Isua
First Sedimentary Evidence for Oceans and Earliest Isotopic Evidence for Life
Apex Chert
Earliest Fossils
First Cells with Nucleus
First Hard-shelled Animals
Formation of Core
Moon Formation
Acasta
Oldest Rock
Rise in Atmospheric Oxygen
Dinosaurs
Andrew Valley

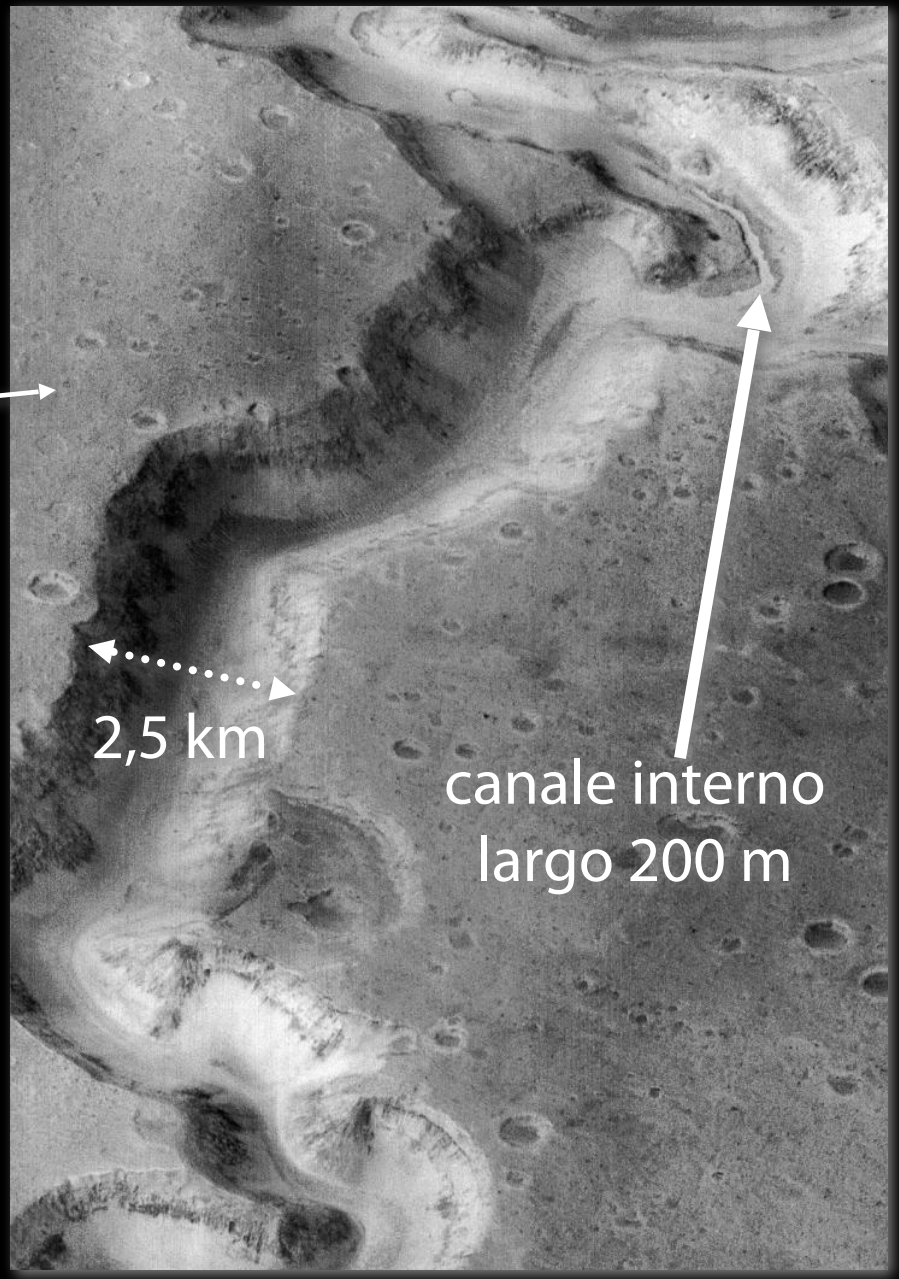

Mercury
Venus
Earth
Mars
Jupiter
Saturn
Neptune
Ceres
Pluto


lercury
,880 kilometers
Mars
6,792 kilometers
e Moon
76 kilometers
Venus
12,104 kilometers
Earth
12,756 kilometers

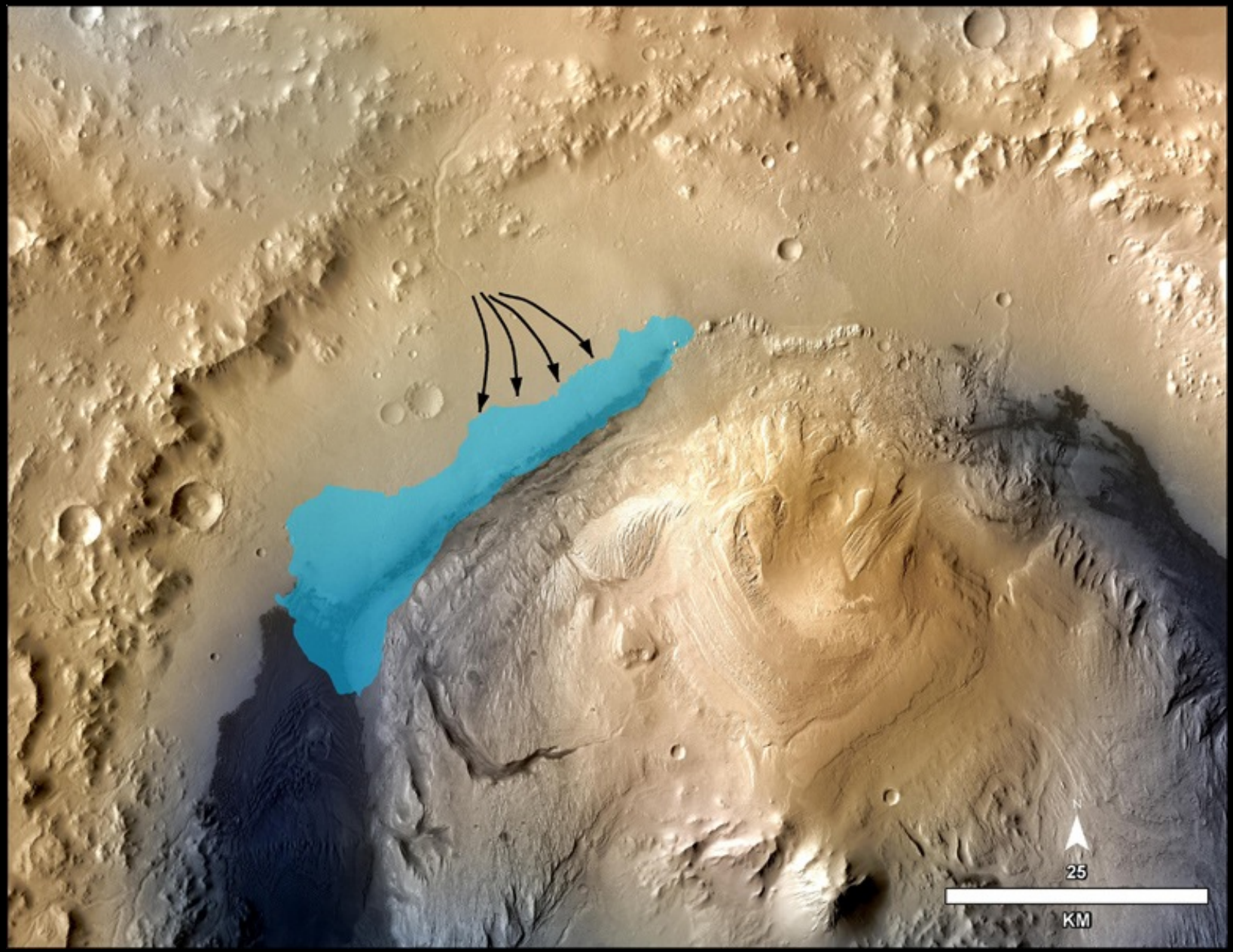

A


Holden Crater

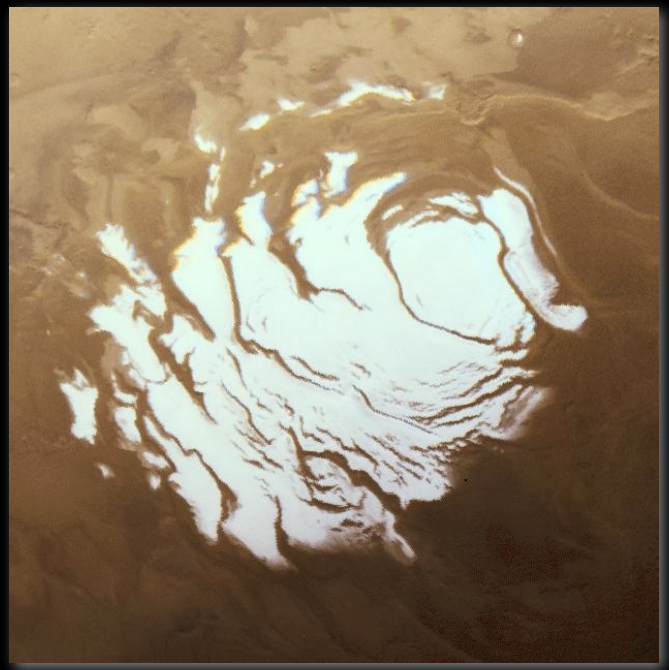


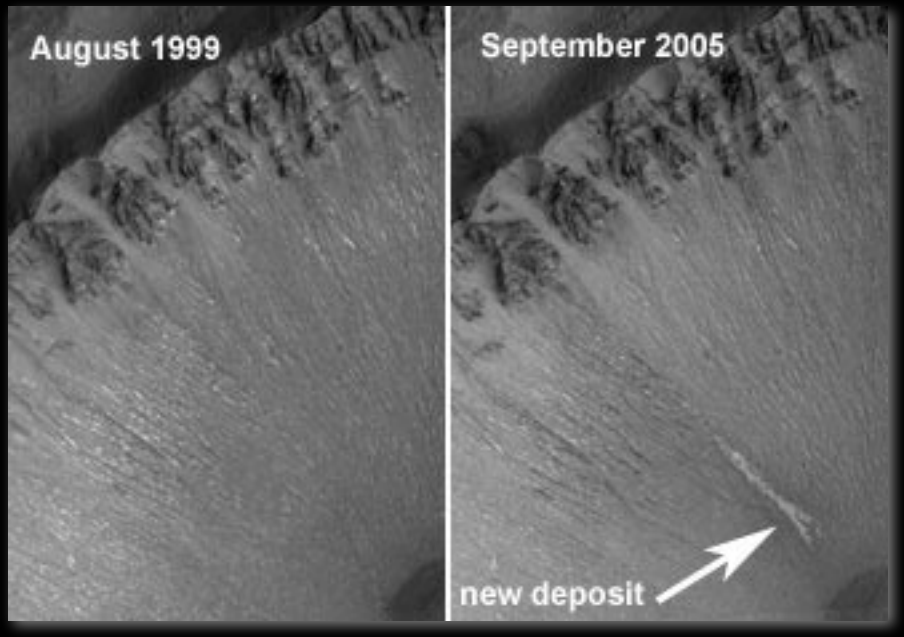


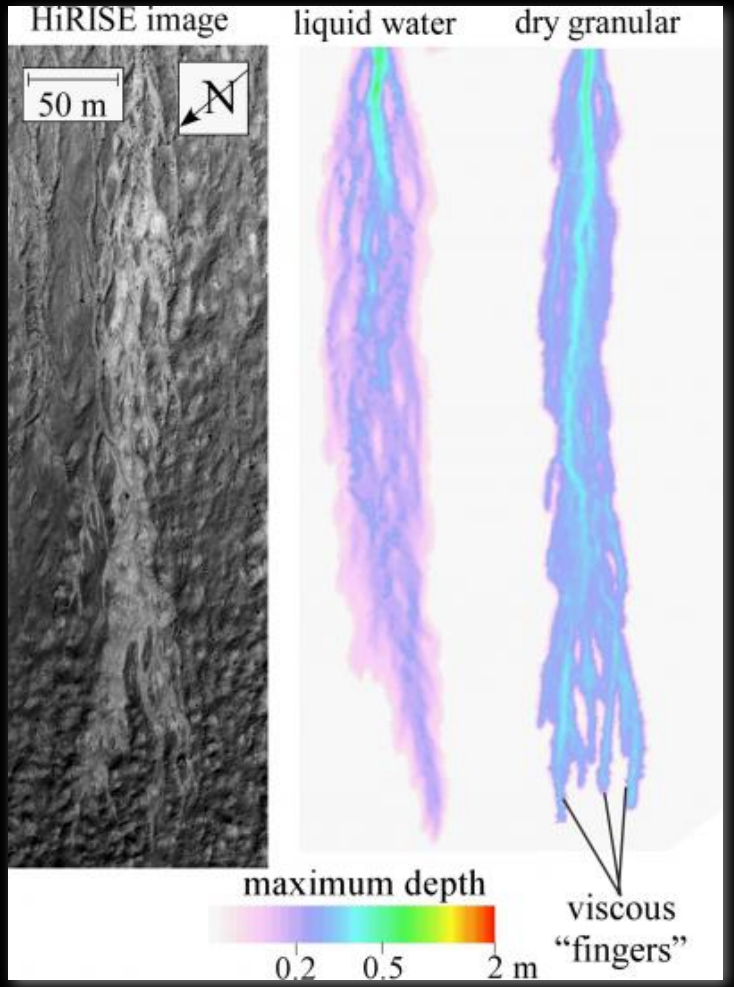
http://hirise.lpl.arizona.edu/

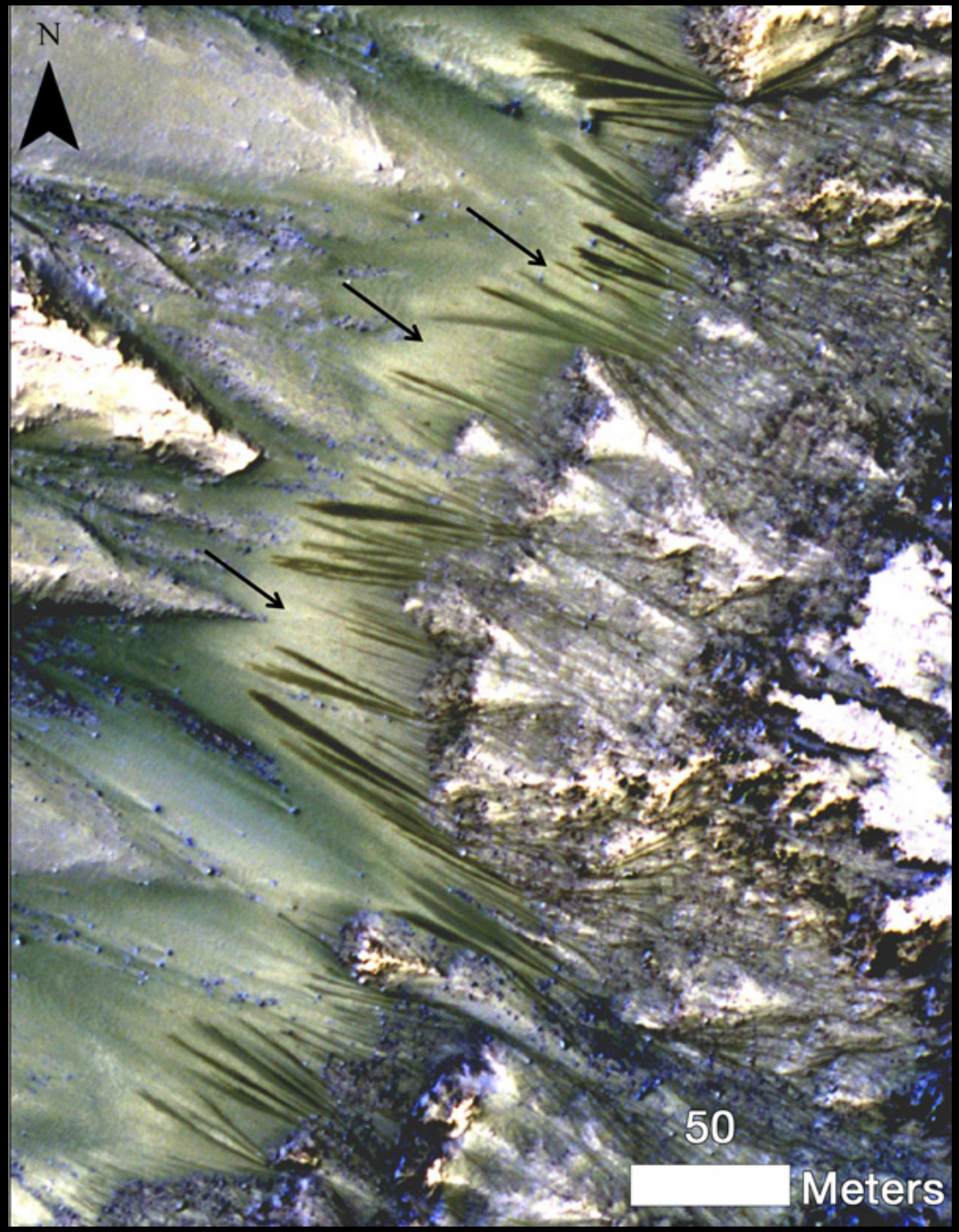


Curiosity, MRO - NASA/JPL Caltech/MSSS




August 1999
September 2005
new deposit


HiRISE image
liquid water
dry granular
50 m
N
maximum depth
0.2
0.5
2 m
viscous
"fingers"



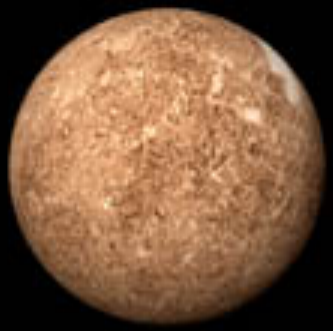
NASA/JPL-Caltech/Univ. of Arizona
feb 2014

Ganymede

5262 km

Titan

5150 km

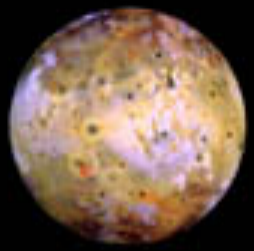


Mercury

4880 km

Callisto

4806 km



Io

3642 km

Moon

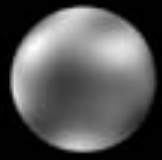
3476 km

Europa

3138 km

Triton

2706 km

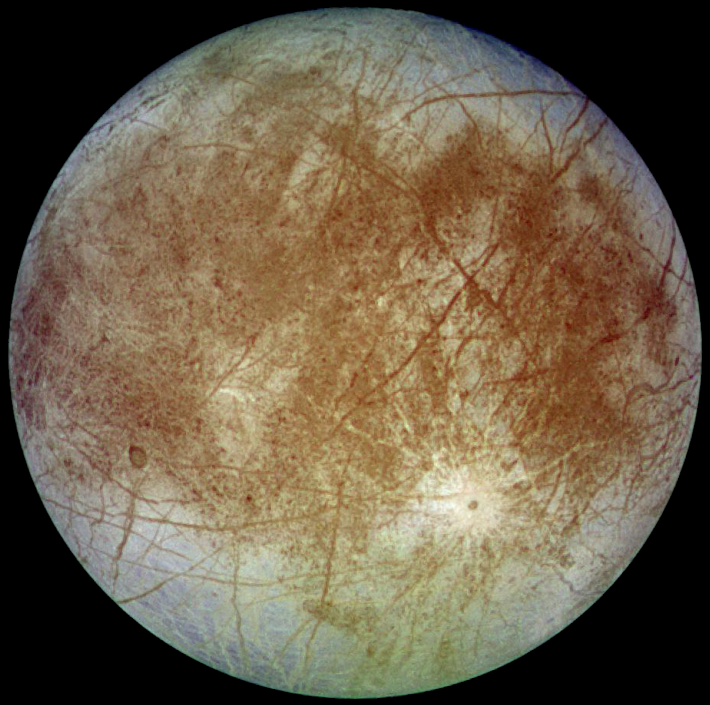


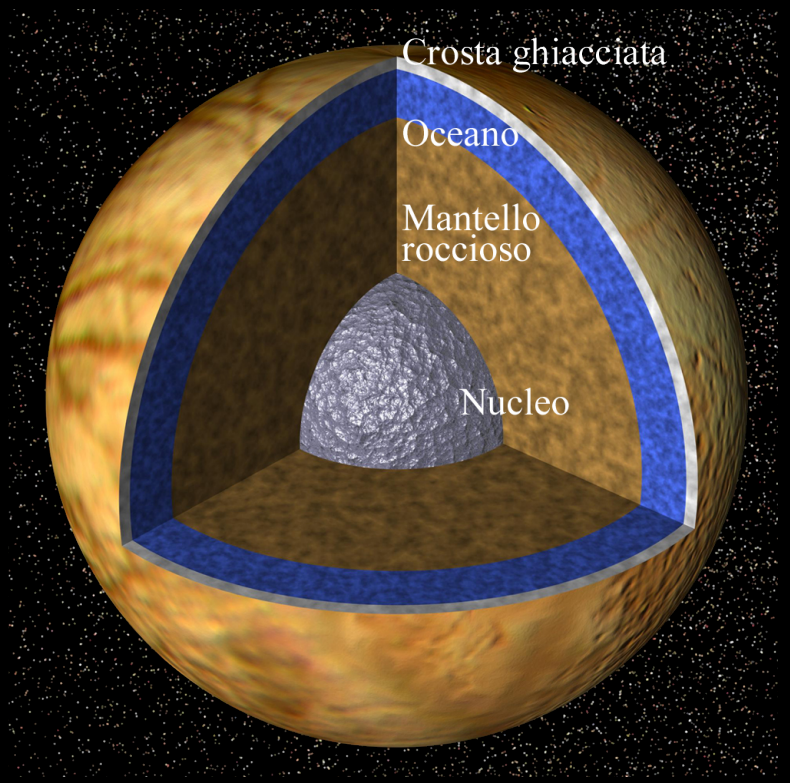
Pluto

2300 km

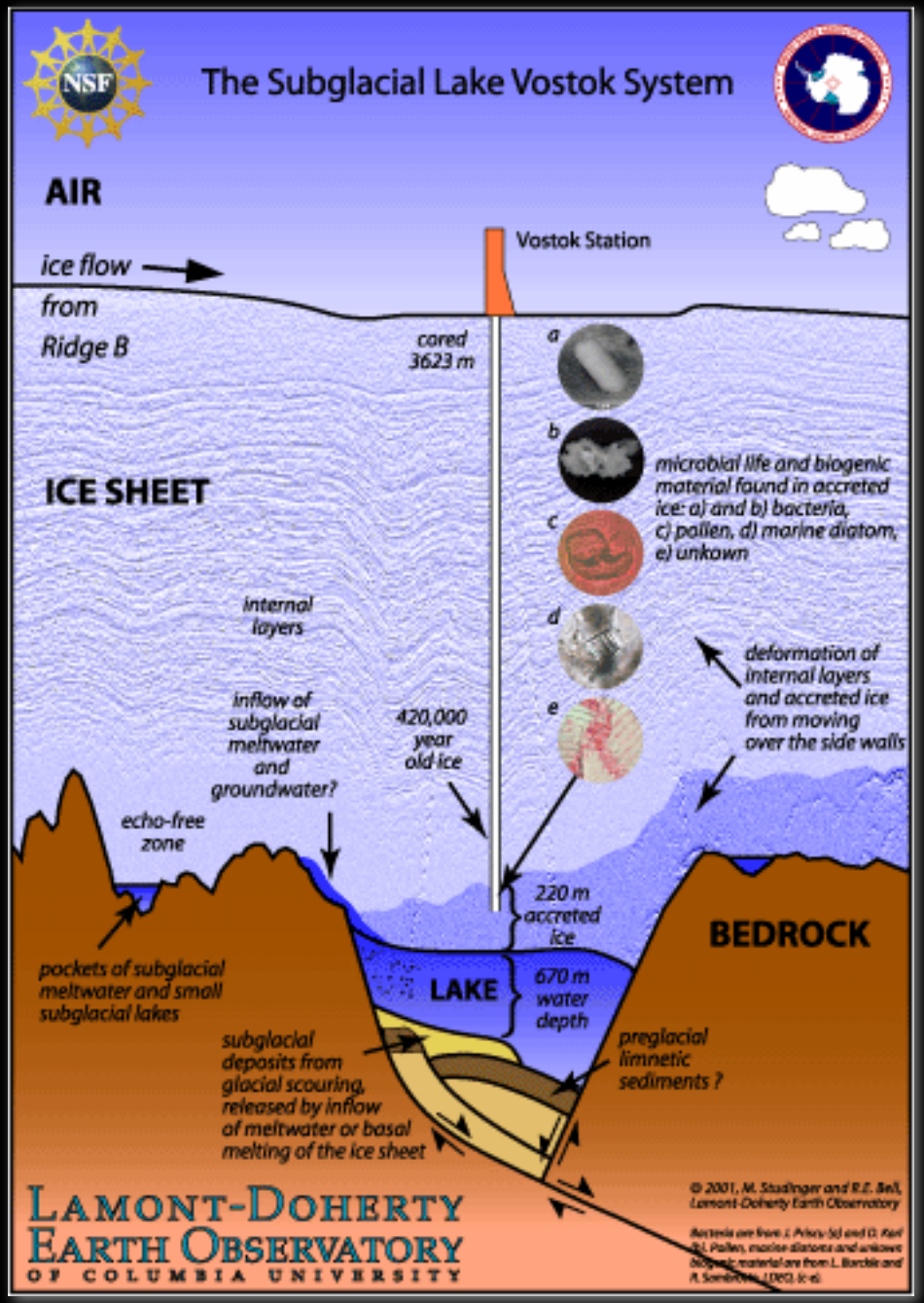
Titania

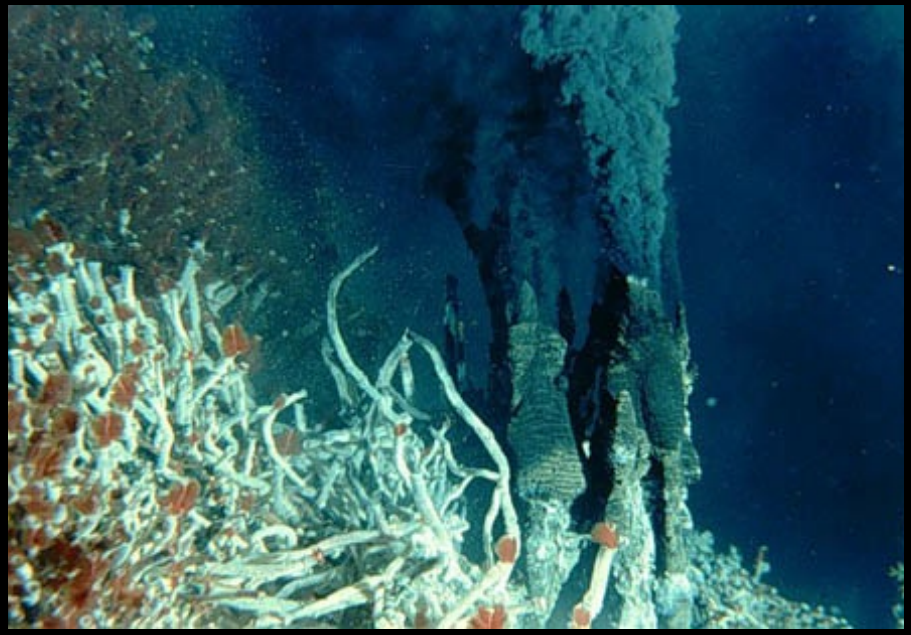
1580 km

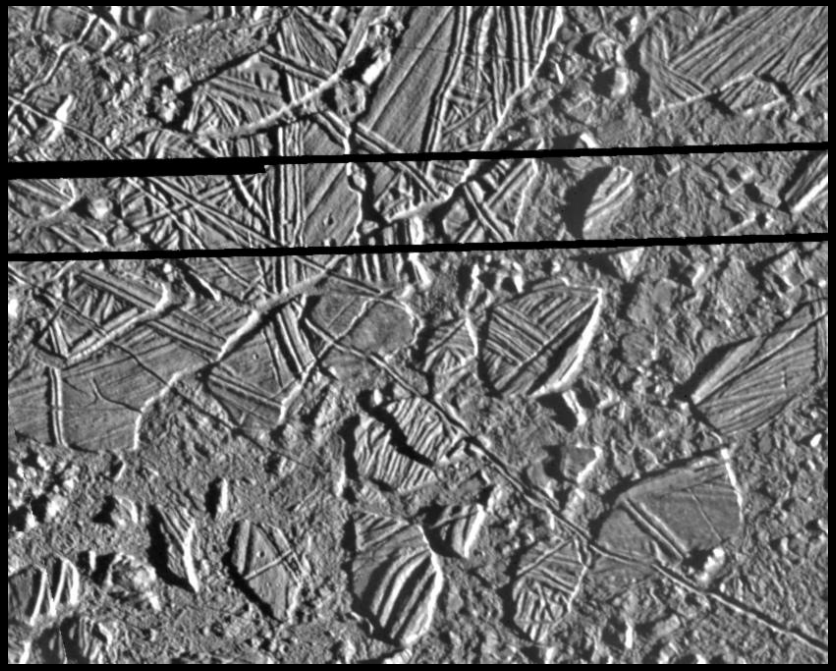


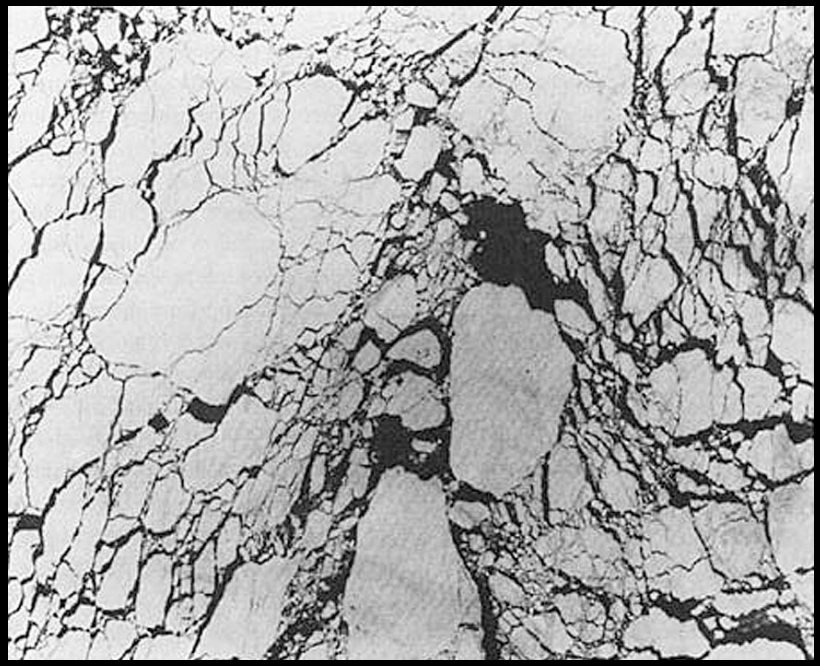

Crosta ghiacciata
Oceano
Mantello roccioso
Nucleo

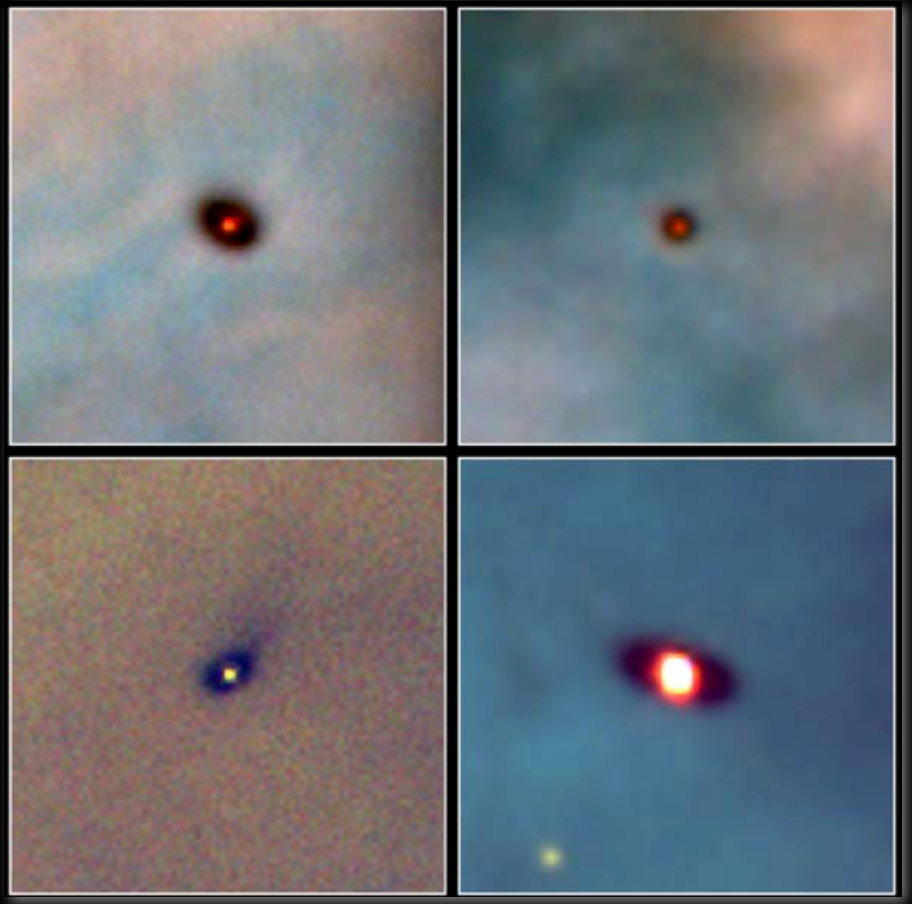
Lago Vostok
(Antartide)

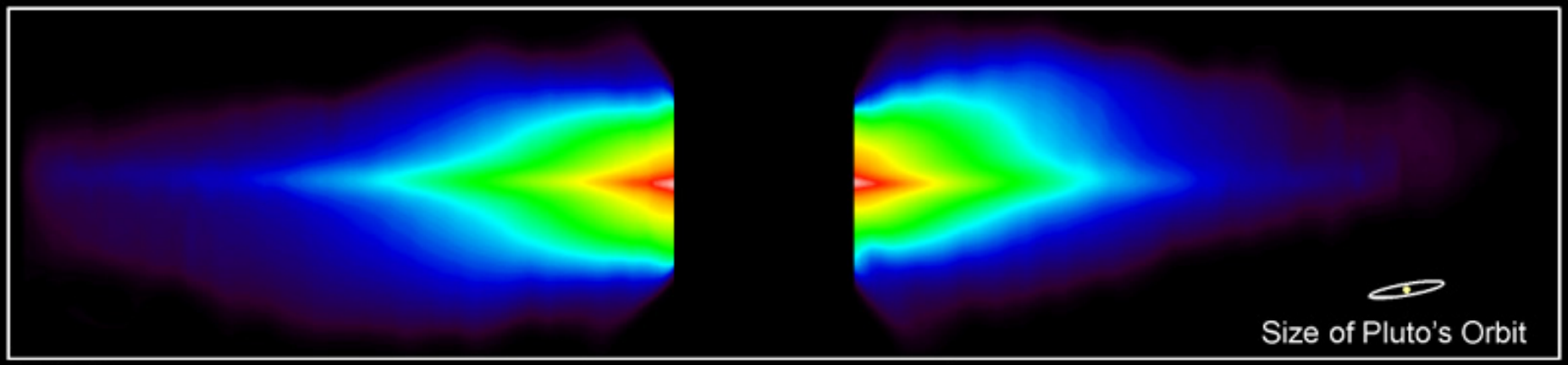




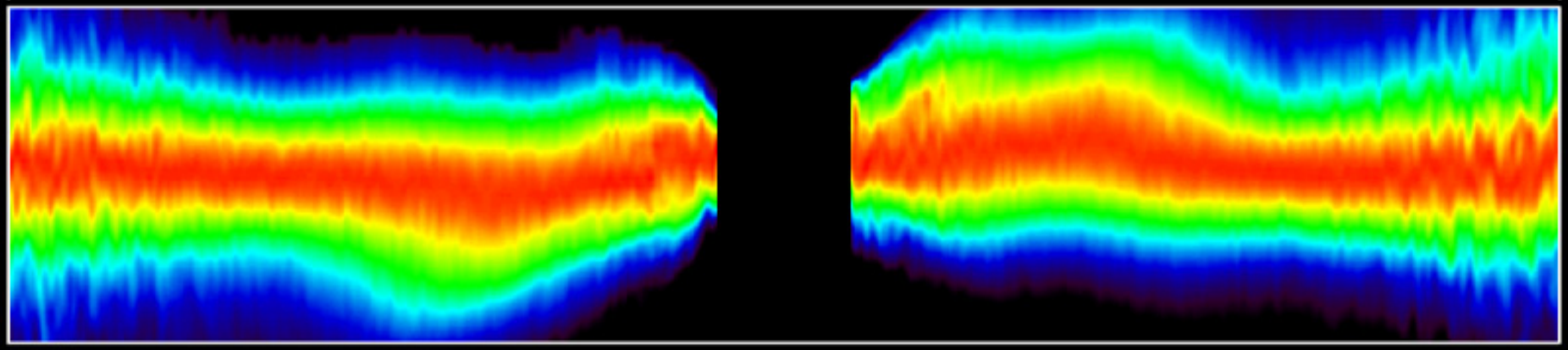








WFPC2

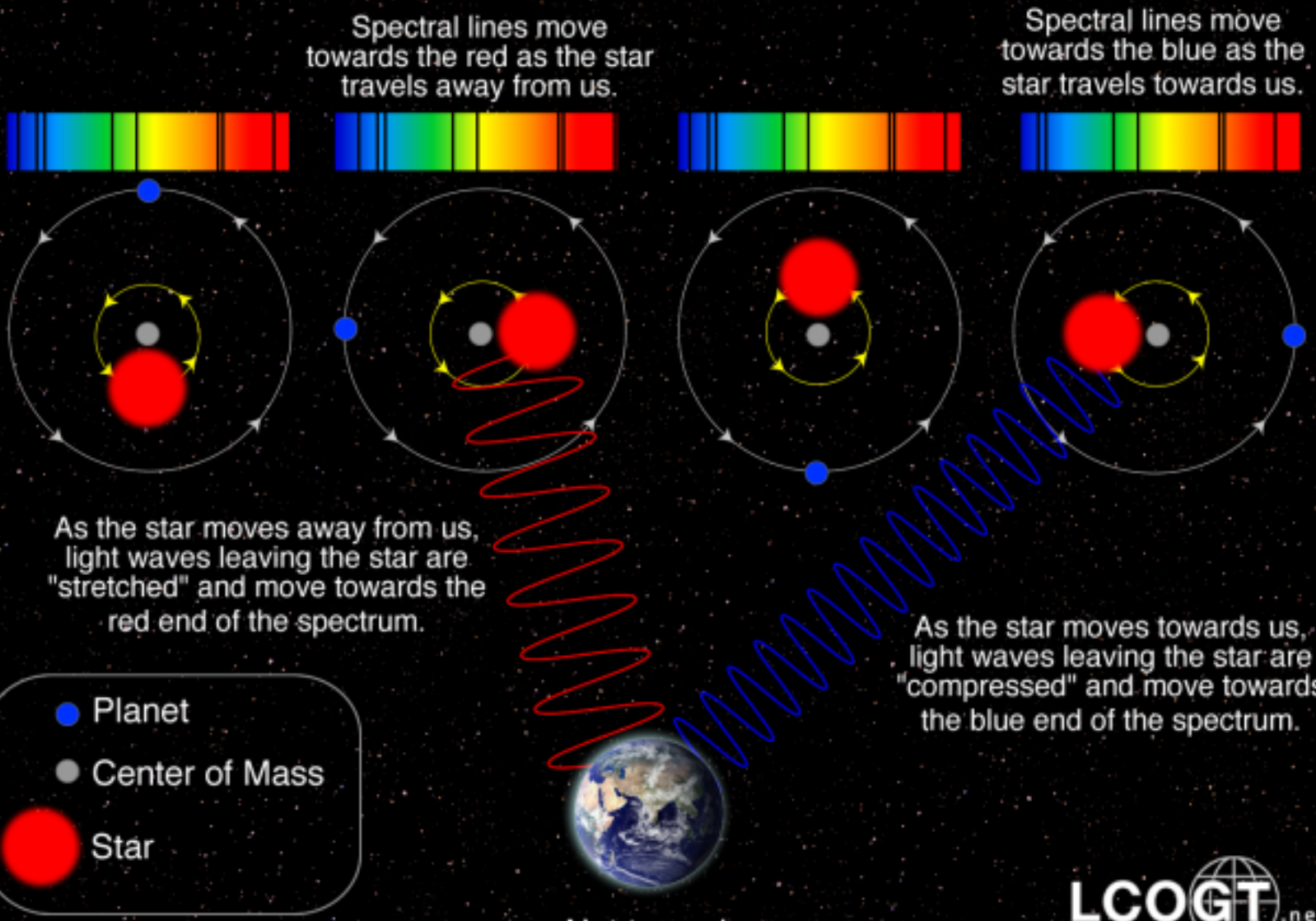


STIS

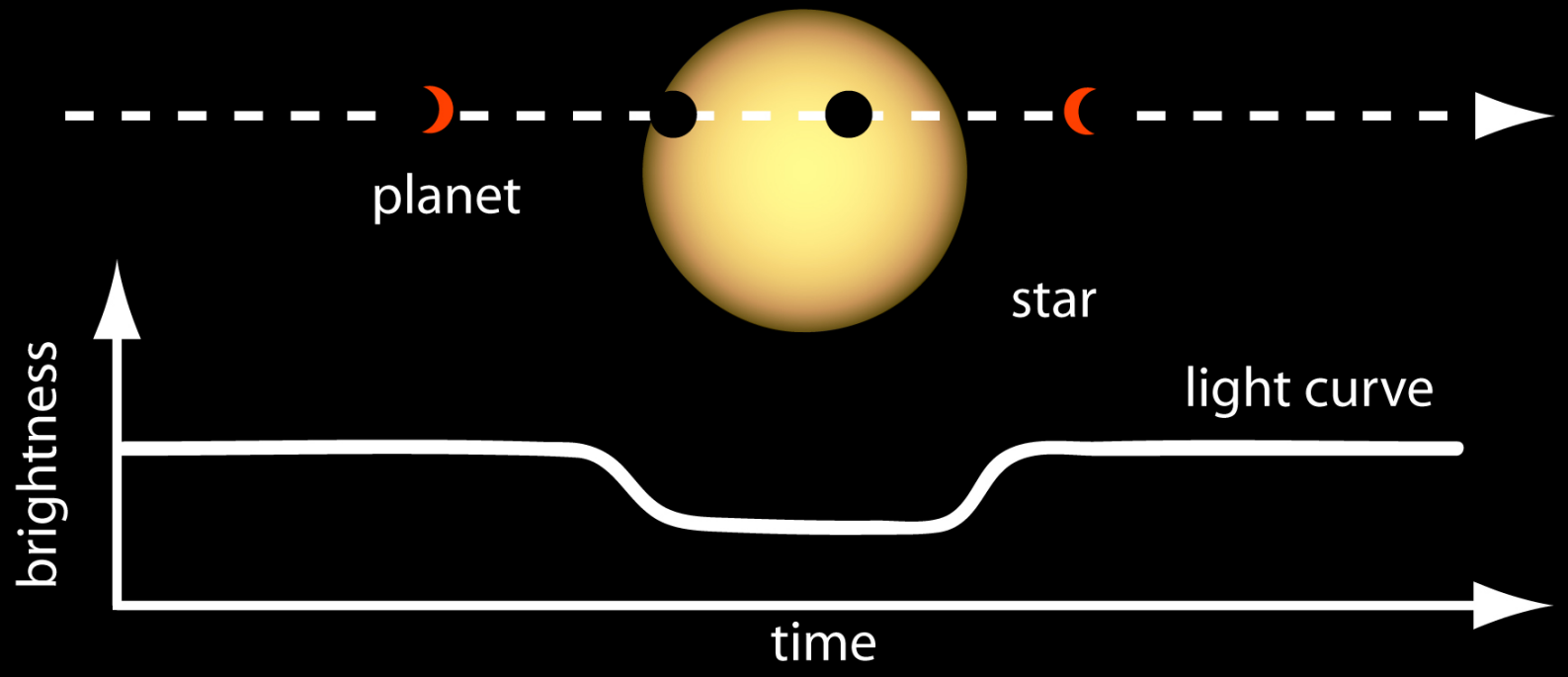
Solar System to Scale

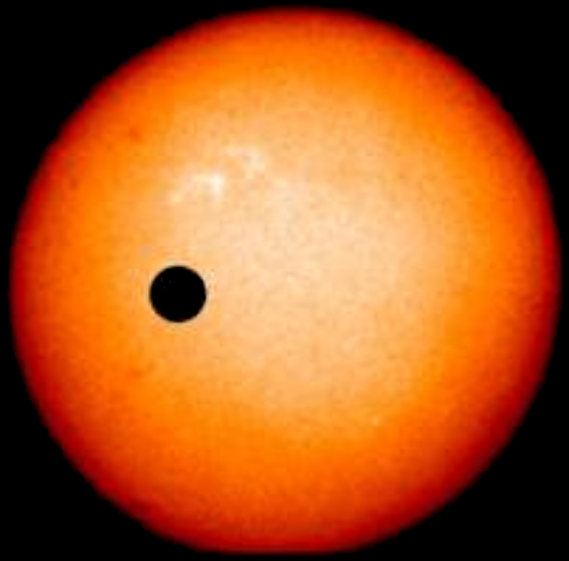
Radial Velocity Method

The star and planet orbit their common center of mass.



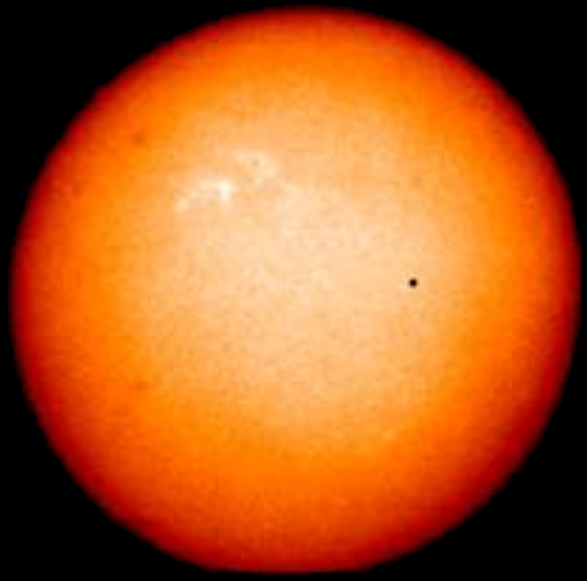
LCOGT.net


planet
star
light curve
brightness
time



Giove

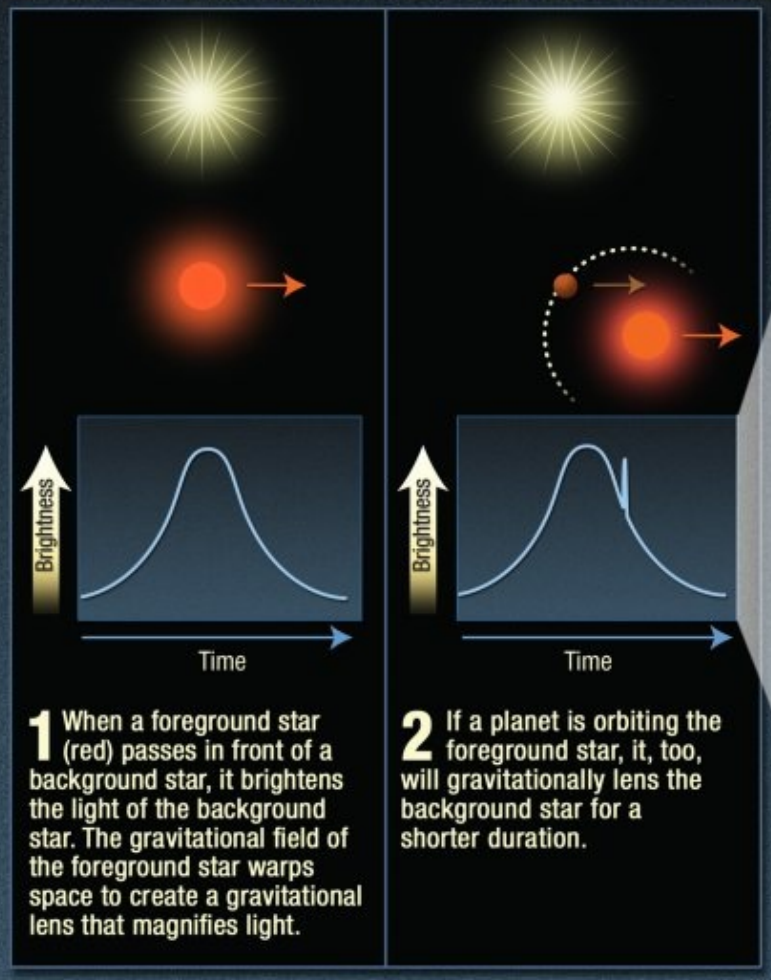
1/100 dell’area del Sole



Terra

1/10 000 dell’area del Sole

Extrasolar planet detected by gravitational microlensing



1 When a foreground star (red) passes in front of a background star, it brightens the light of the background star. The gravitational field of the foreground star warps space to create a gravitational lens that magnifies light.

2 If a planet is orbiting the foreground star, it, too, will gravitationally lens the background star for a shorter duration.

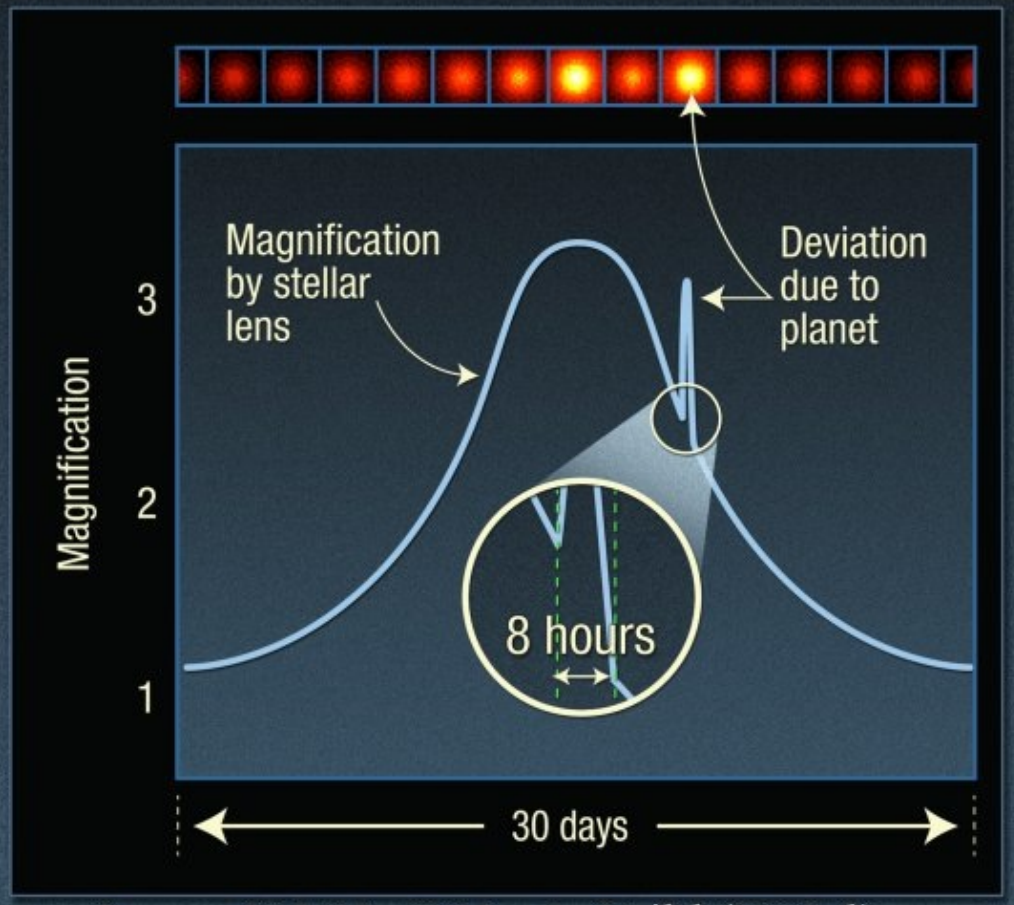
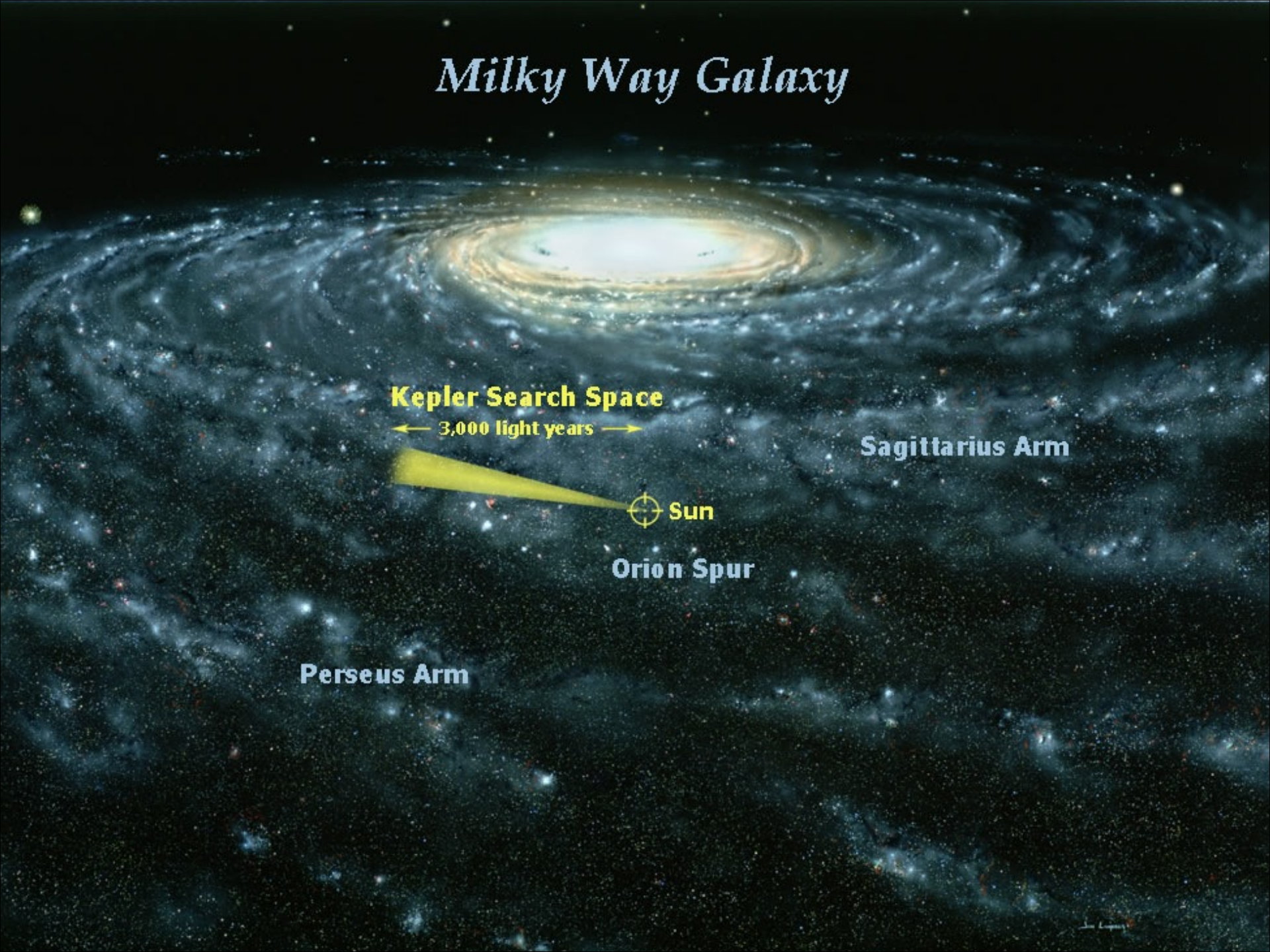
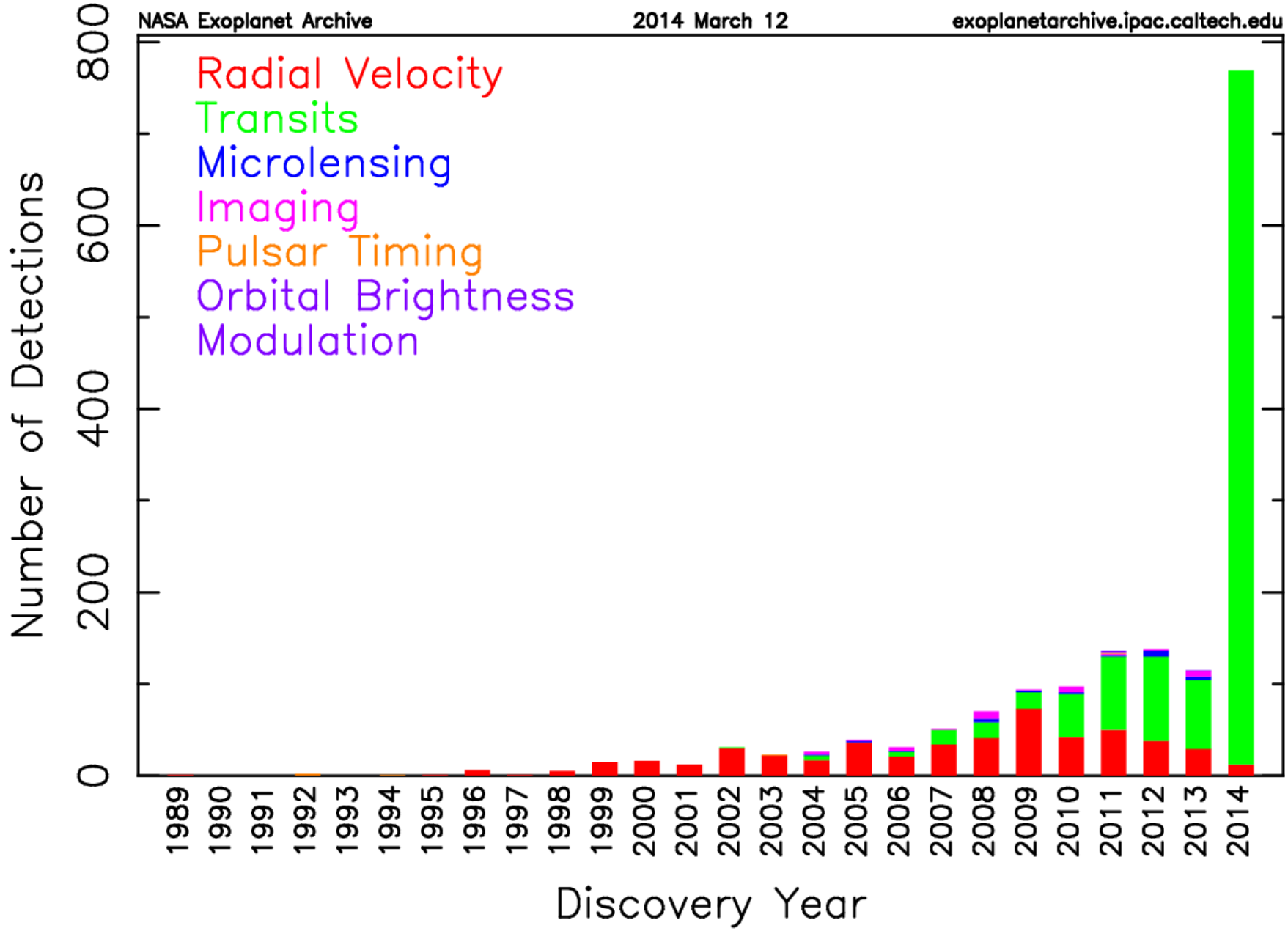
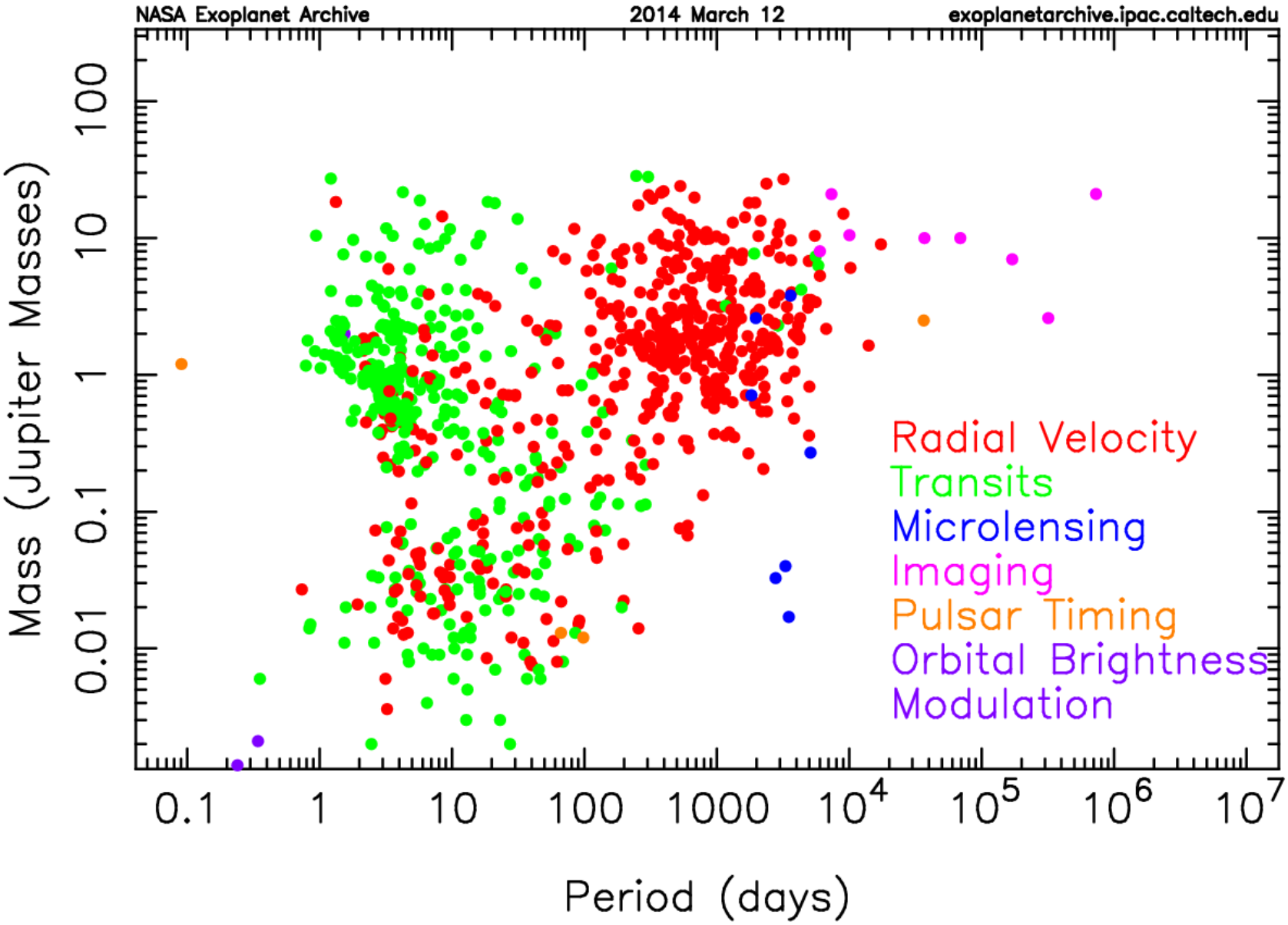


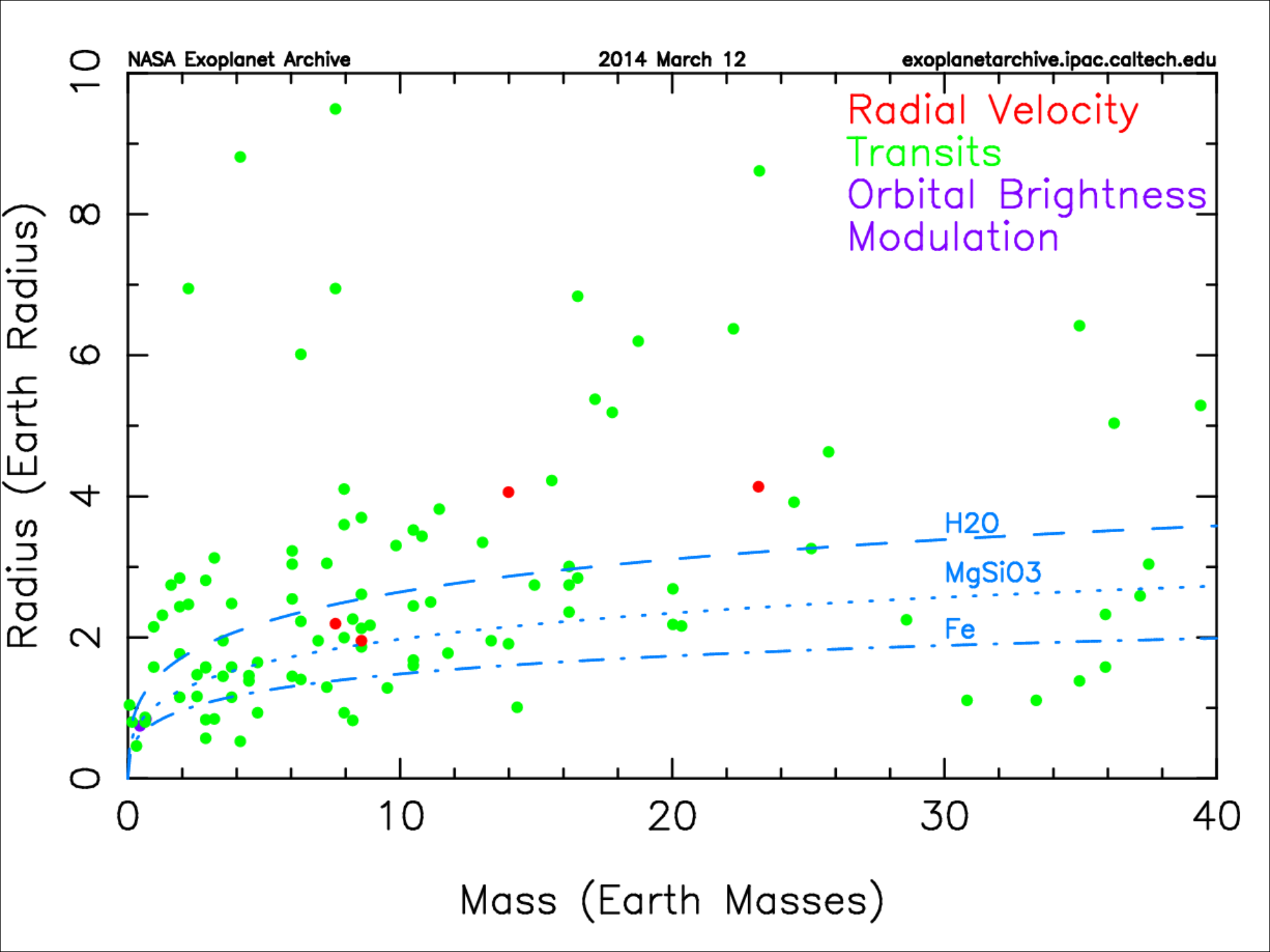
Image: NASA, ESA, A. Feild (STScI)

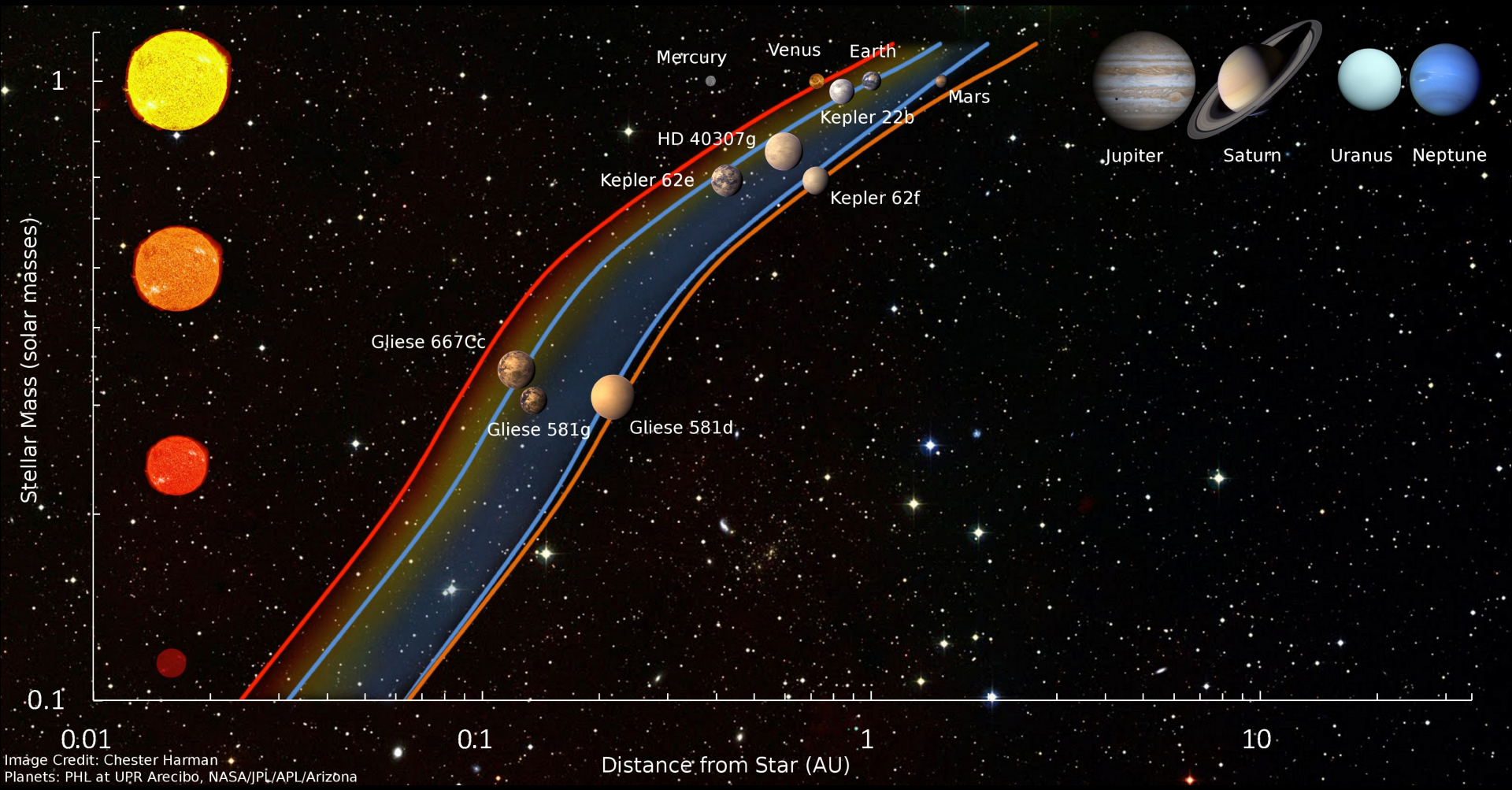

Kepler (NASA)
Lancio: 6/3/2009


Milky Way Galaxy
Kepler Search Space
3,000 light years
Sagittarius Arm
Sun
Orion Spur
Perseus Arm


NASA Exoplanet Archive
2014 March 12
exoplanetarchive.ipac.caltech.edu
Radial Velocity
Transits
Microlensing
Imaging
Pulsar Timing
Orbital Brightness
Modulation
Number of Detections
0
200
400
600
800
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Discovery Year


NASA Exoplanet Archive
2014 March 12
exoplanetarchive.ipac.caltech.edu
Mass (Jupiter Masses)
0.01
0.1
1
10
100
Period (days)
0.1
1
10
100
1000
10^4
10^5
10^6
10^7
Radial Velocity
Transits
Microlensing
Imaging
Pulsar Timing
Orbital Brightness Modulation

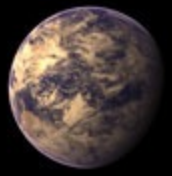

NASA Exoplanet Archive
2014 March 12
exoplanetarchive.ipac.caltech.edu
Radial Velocity
Transits
Orbital Brightness Modulation
H2O
MgSiO3
Fe
Radius (Earth Radius)
Mass (Earth Masses)
0
2
4
6
8
10
0
10
20
30
40


Mercury
Venus
Earth
Mars
Kepler 22b
HD 40307g
Kepler 62e
Kepler 62f
Gliese 667Cc
Gliese 581g
Gliese 581d
Jupiter
Saturn
Uranus
Neptune
1
0.1
Stellar Mass (solar masses)
0.01
0.1
1
10
Distance from Star (AU)
Image Credit: Chester Harman
Planets: PHL at UPR Arecibo, NASA/JPL/APL/Arizona

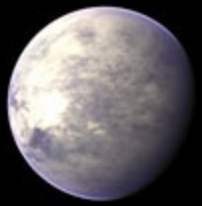
Potentially Habitable Exoplanets

Earth

Gliese 667C c



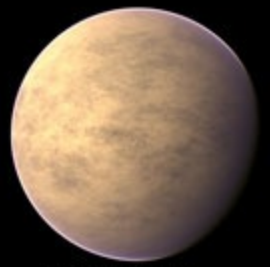
Kepler-62 e



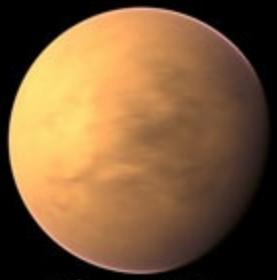
Tau Ceti e*

Gliese 581 g*

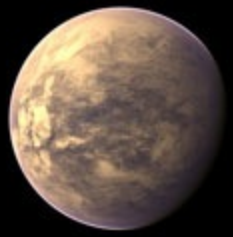
Gliese 667C f



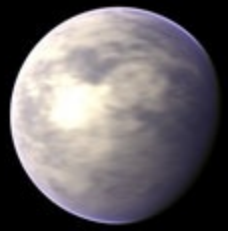
HD 40307 g



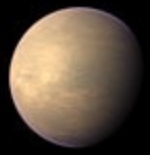
Gliese 163 c



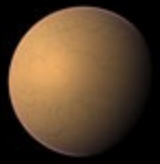
Kepler-61 b



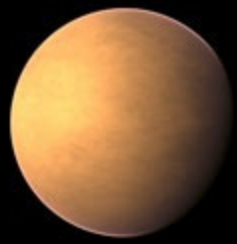
Kepler-22 b



Kepler-62 f



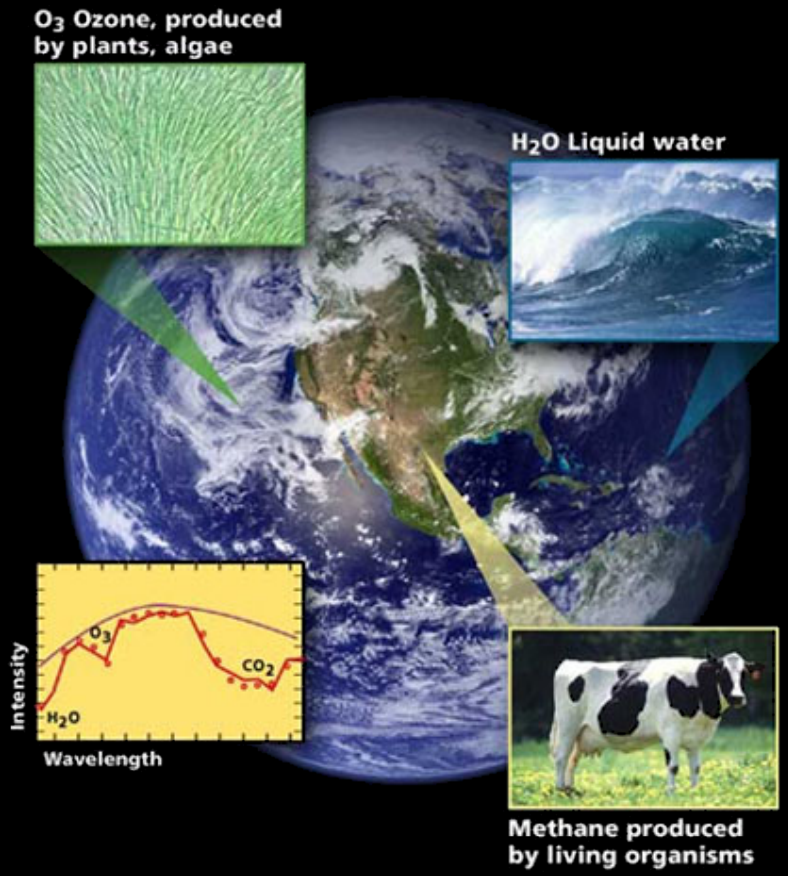
Gliese 667C e

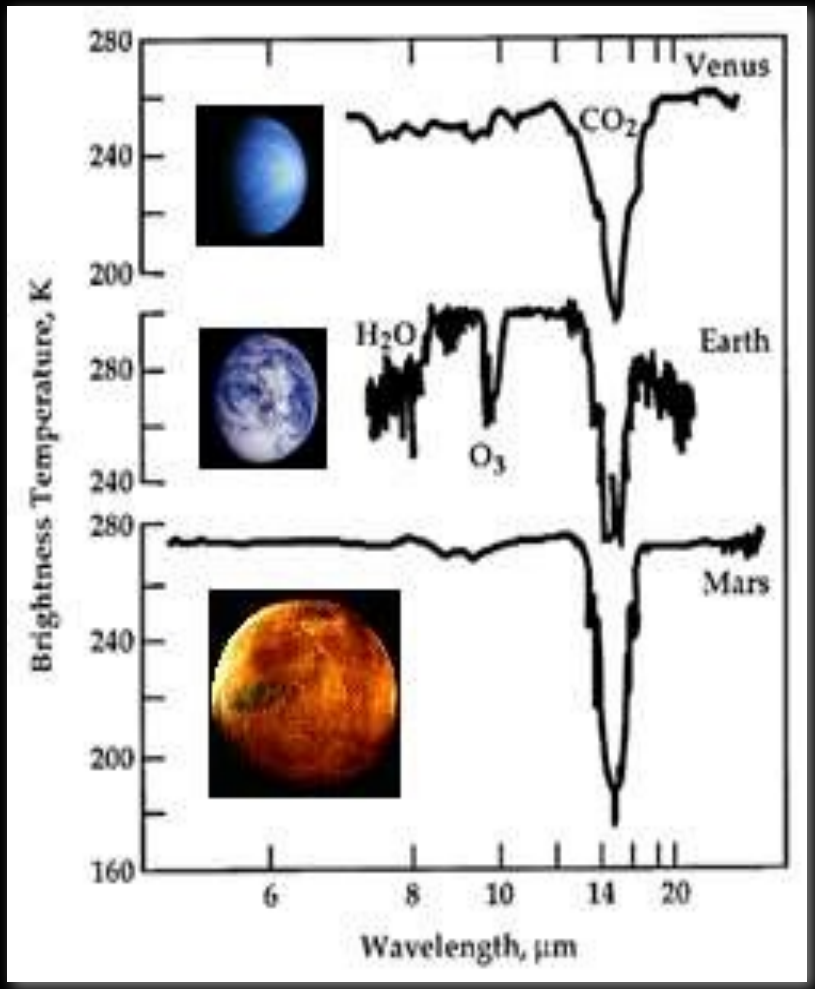


Gliese 581 d

*planet candidates

CREDIT: PHL @ UPR Arecibo (phl.upr.edu) December 5, 2013


O_3 Ozone, produced by plants, algae
H_2O Liquid water
Intensity
O_3
CO_2
H_2O
Wavelength
Methane produced by living organisms

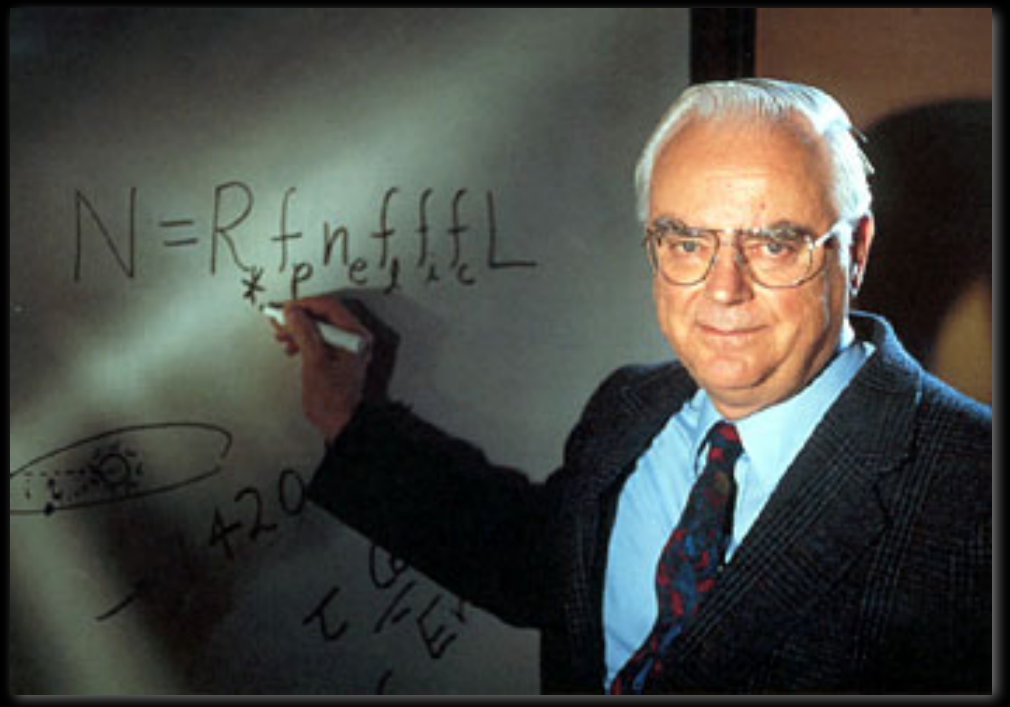

Venus
CO_2
Earth
H_2O
O_3
Mars
Brightness Temperature, K
280
240
200
280
240
280
240
200
160
6
8
10
14
20
Wavelength, μm

“Esistono due possibilità: siamo soli nell’Universo, oppure no. Entrambe sono spaventose.”

— Isaac Asimov


TIME
The Real Reagan
Showman Of Science
Astronomer Carl Sagan

Frank Drake, 1961



$$N = R_* \times f_p \times n_t \times f_v \times f_i \times f_c \times T$$

SEARCHING FOR INTERSTELLAR COMMUNICATIONS

By GIUSEPPE COCCONI* and PHILIP MORRISON†
Cornell University, Ithaca, New York

NO theories yet exist which enable a reliable estimate of the probabilities of (1) planet formation; (2) origin of life; (3) evolution of societies possessing advanced scientific capabilities. In the absence of such theories, our environment suggests that stars of the main sequence with a lifetime of many billions of years can possess planets, that of a small set of such planets two (Earth and very probably Mars) support life, that life on one such planet includes a society recently capable of considerable scientific investigation. The lifetime of such societies is not known; but it seems unwarranted to deny that among such societies some might maintain themselves for times very long compared to the time of human history, perhaps for times comparable with geological time. It follows, then, that near some star rather like the Sun there are civilizations with scientific interests and with technical possibilities much greater than those now available to us.

* Now on leave at CERN, Geneva.

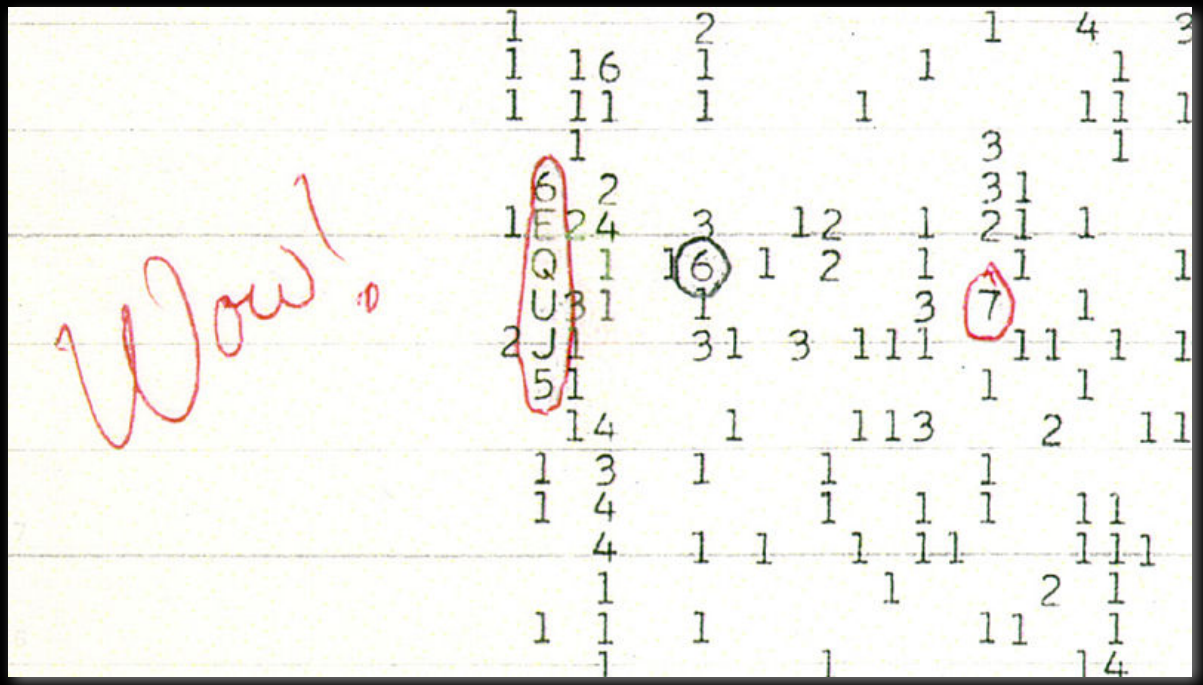
† Now on leave at the Imperial College of Science and Technology, London, S.W.7.

To the beings of such a society, our Sun must appear as a likely site for the evolution of a new society. It is highly probable that for a long time they will have been expecting the development of science near the Sun. We shall assume that long ago they established a channel of communication that would one day become known to us, and that they look forward patiently to the answering signals from the Sun which would make known to them that a new society has entered the community of intelligence. What sort of a channel would it be?

The Optimum Channel

Interstellar communication across the galactic plasma without dispersion in direction and flight-time is practical, so far as we know, only with electromagnetic waves.

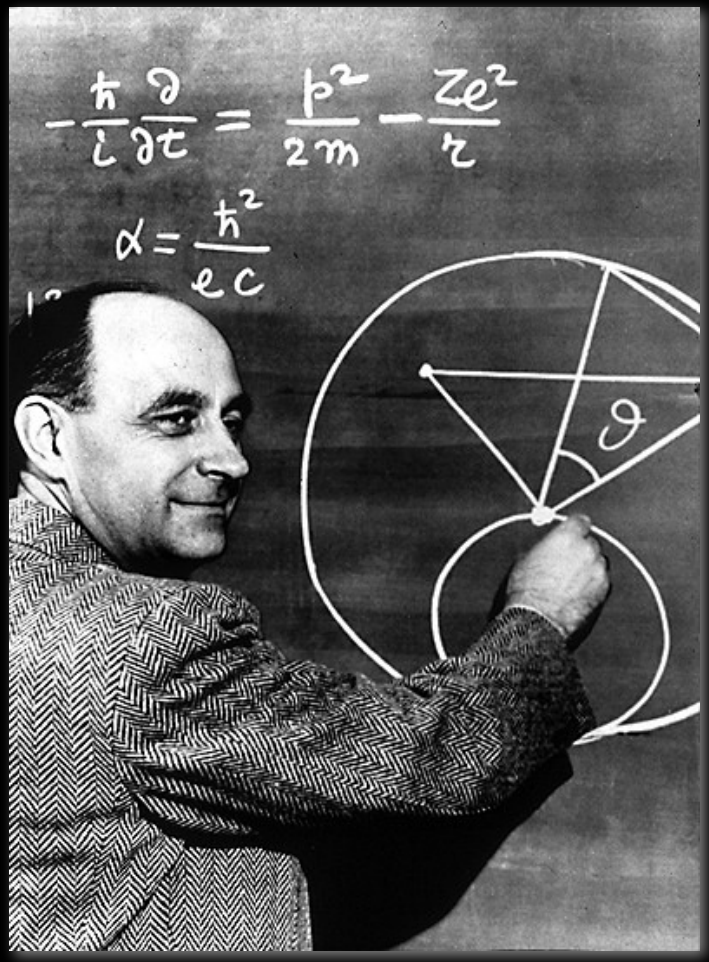
Since the object of those who operate the source is to find a newly evolved society, we may presume that the channel used will be one that places a minimum burden of frequency and angular discrimi-



Il grande silenzio

“Se esistono, allora dove sono?”

— Enrico Fermi, 1950



“La probabilità di successo è difficile da stimare: ma se non cerchiamo mai, la possibilità di successo è zero.”

— Giuseppe Cocconi e Philip Morrison, *“Searching for intestellar communications”*, Nature, 1959