ASTROBIOLOGY
Life in the Cosmic Context

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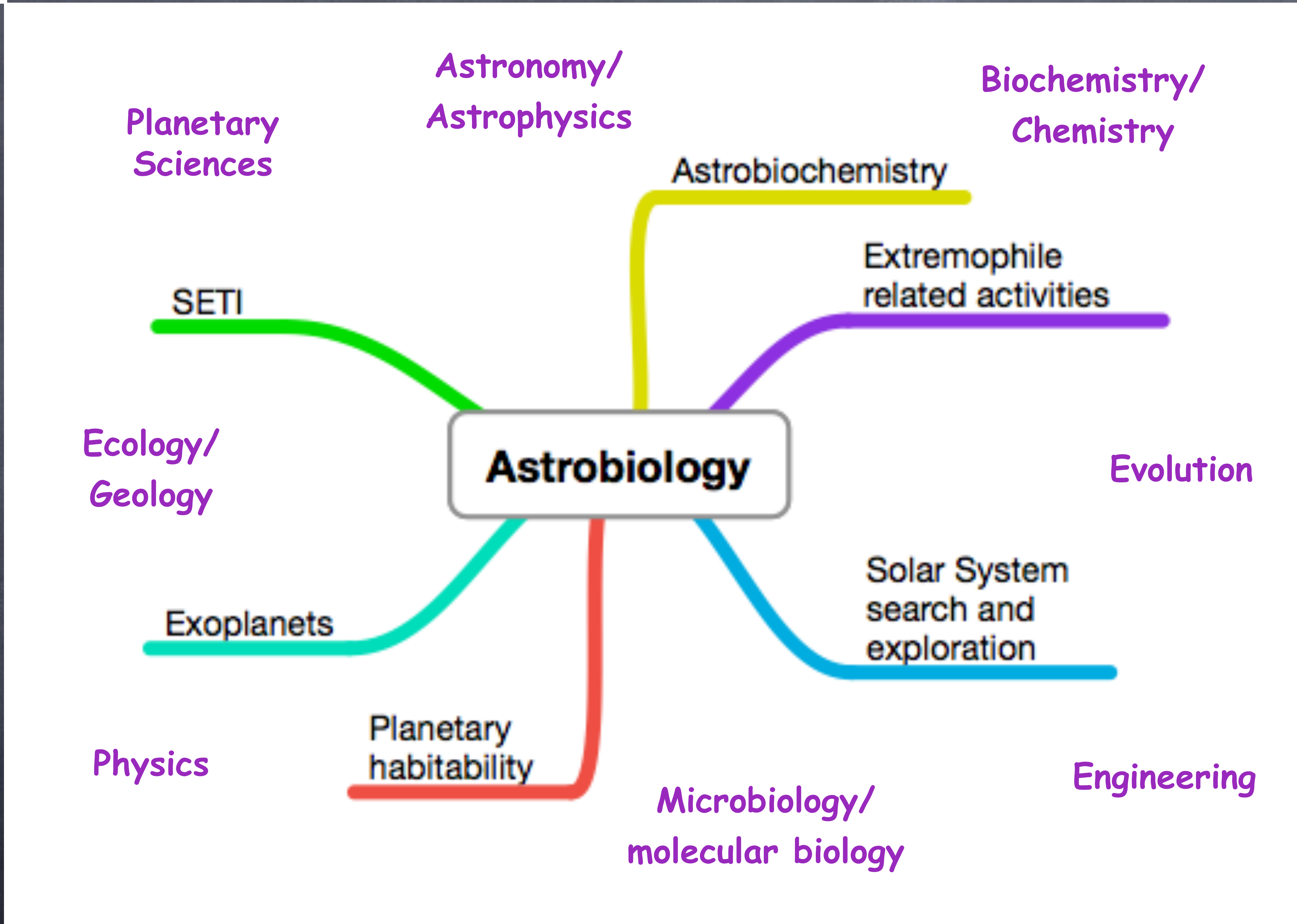
Plan of the talk

- Introduction
- Cosmological and astrophysical considerations
- Planetary habitability
- Extremophiles
- Search for life in the Solar System
- Exoplanets
- Biochemistry "elsewhere"
- The SETI program
- Summary



Multi and transdisciplinary by nature!

Fundamental questions for astrobiology

- How does life begin and evolve? Did it appear by chance or, once the Universe started, it would a cosmic imperative?
- Does life exist elsewhere in the Universe? Or is it formed and develops from local (Earthly) processes?
- What is the future of life on Earth and beyond? Are there realistic conditions outside our Solar System, for life - **AS WE KNOW IT** - to begin and evolve?

From "The Astrophysical Context of Life" (http://www.nap.edu/catalog/11316.html)

- **Astronomy provides the fundamental underpinnings for life: space and time.**
- **The Universe is filled with billions of galaxies, where there may be possible sites for the origin and evolution of life.**

How can we define life?

J. Schneider (astro-ph/9604131); Szostak et al. (Nature, 2001);
Bains (Astrobiology 2005), Bener (Astrobiology, 2013)

- Complex and diversified interactions with the environment
- System out of thermodynamical equilibrium
- Memory + reading/recovering mechanism
- **High information content and self-replication capability**

Working hipothesis...

- **Life is a "self-sustaining chemical system capable of Darwinian evolution (G.F.Joyce, 1994)**

How can we define life?

J. Schneider (astro-ph/9604131); Szostak et al. (Nature, 2001); Bains (Astrobiology 2005), Bener (Astrobiology, 2013)

Reading suggestion: "What is life". E. Schroedinger (1944). Check on Google Books!!!

WHAT is the relation between cosmology, astrophysics and the origin and evolution of life?

A Biophilic Universe

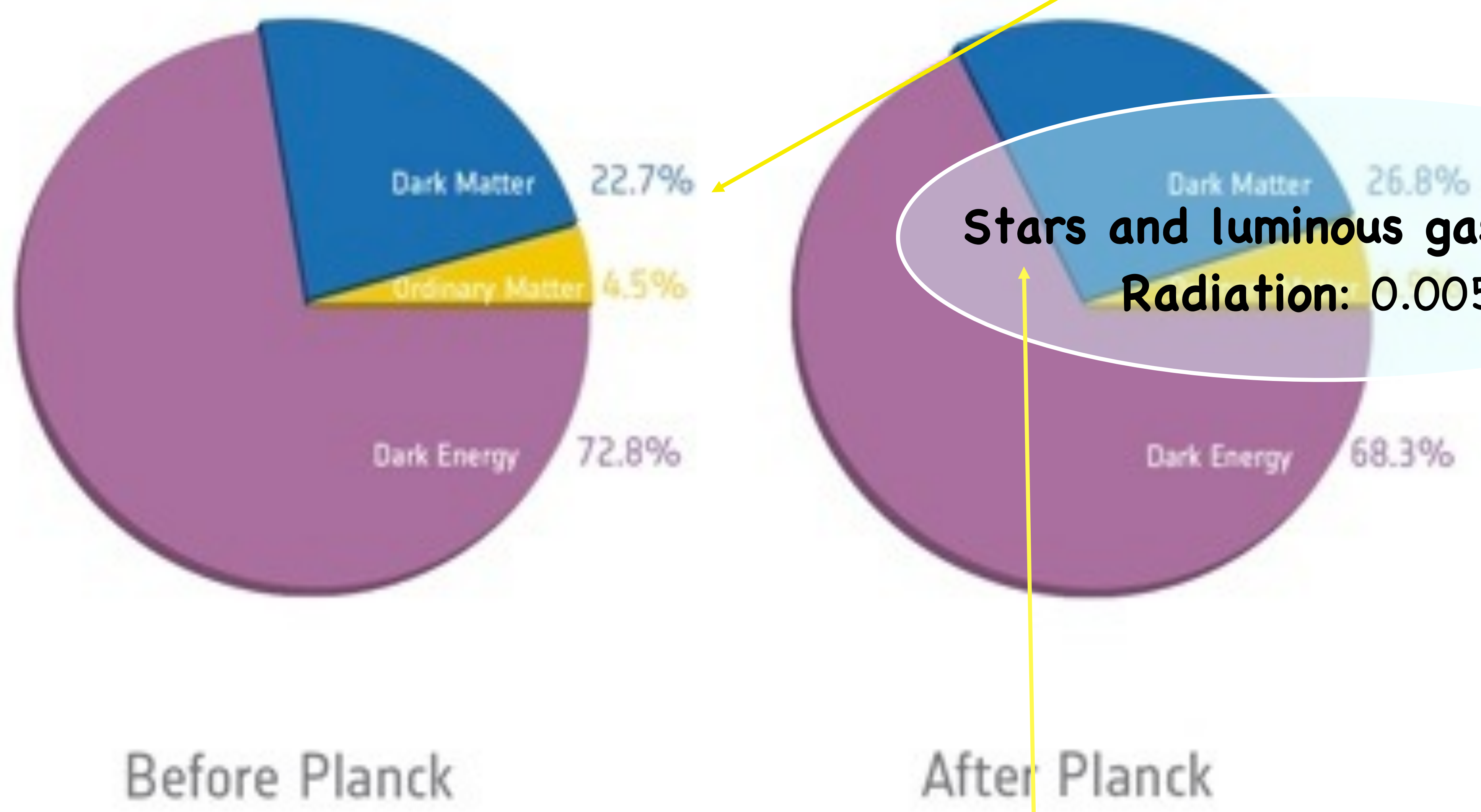
"A universe hospitable to life – what we may call a biophilic universe – has to be very special in many ways. The prerequisites for any life (long-lived stars, a period table of elements with complex chemistry, and so on) are sensitive to physical laws and could not have emerged from a Big Bang with a recipe that was even slightly different".

Martin Rees. "Our Cosmic Habitat" (2003)

A cosmological perspective to search of life in the Universe...

Planck results (2013)

$\Omega_b = 0.049\ \Omega_T$



Stars and luminous gas: ~ 0.9%
Radiation: 0.005%

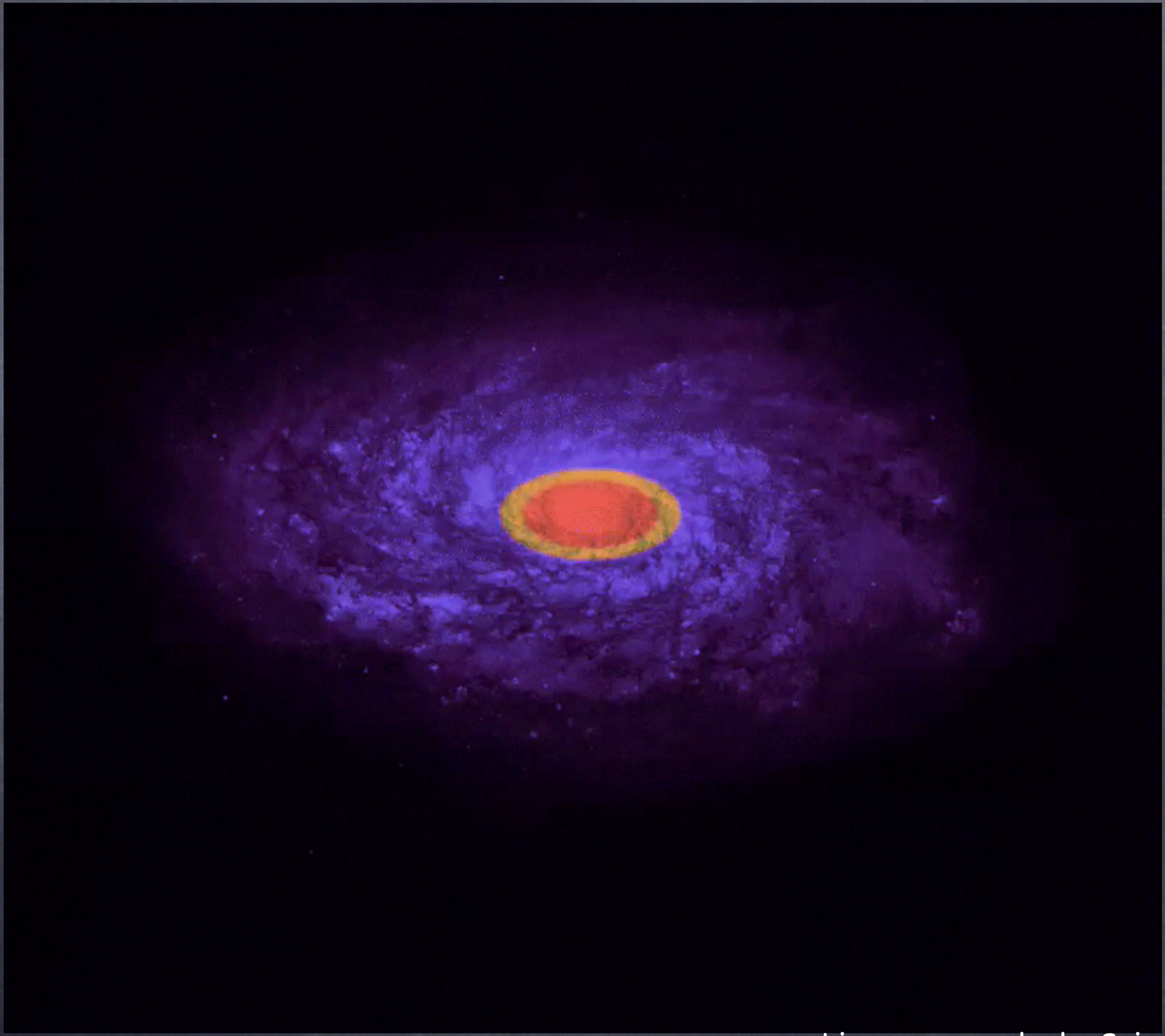
LET´S GIVE IT UP!

NOT!

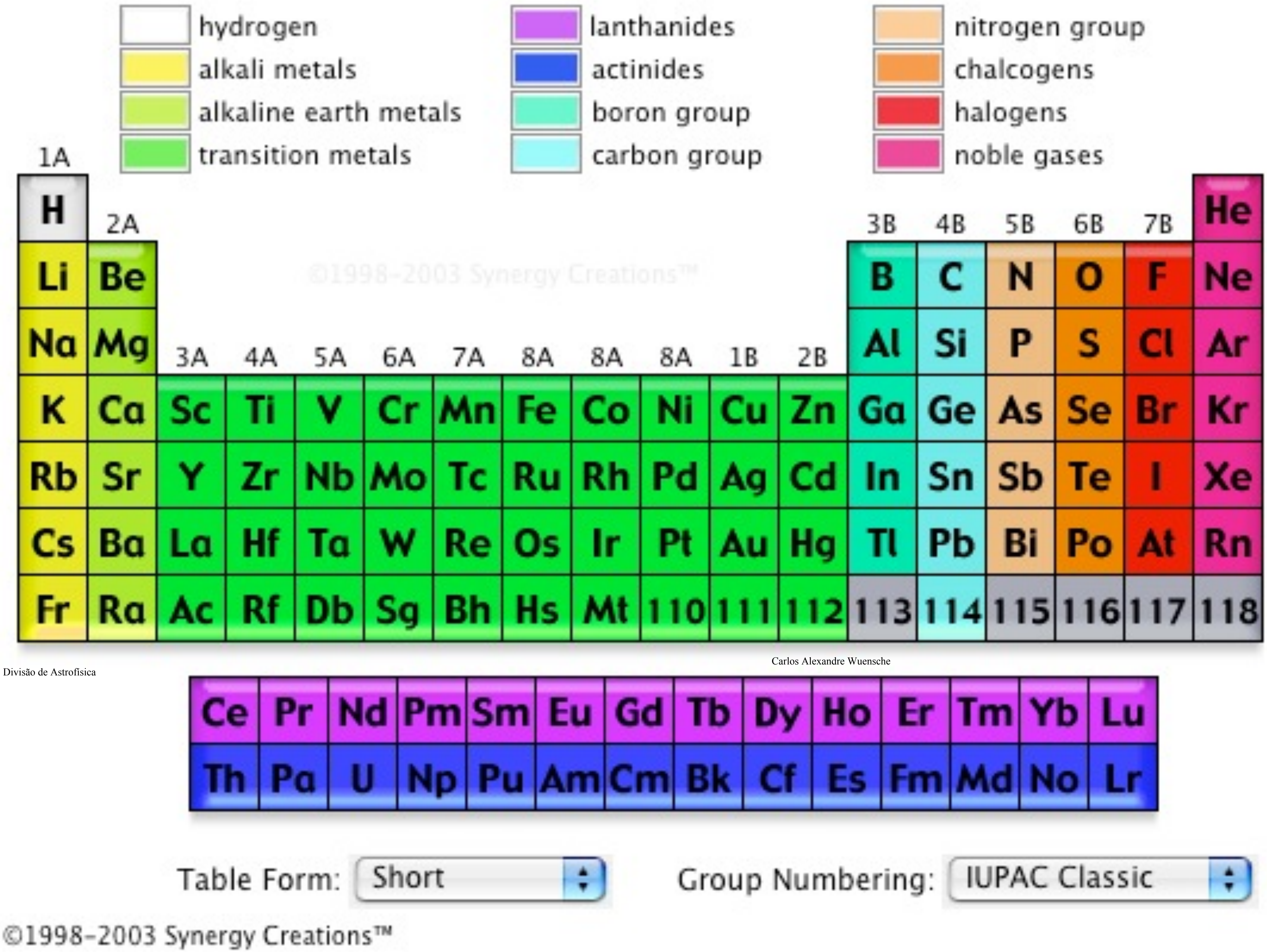
Galaxy Formation ⇒ Habitability

- Galaxies are natural "cells" from which the Universe is composed.
- Stars live in galaxies, and are responsible for the galactic chemical evolution.
- Necessary levels of chemical abundances and radiation fields needed for the rise of life **AS WE KNOW IT**
- Early galactic evolution:
  - starbursts ⇒ dust and molecules ⇒ complex chemistry.
- CNO synthesized by stars in early galaxies allow for the building blocks of organic chemistry to be present since the Universe was ~ 200 million years.

Is there a Galactic Habitable Zone?



Lineweaver et al., Science (2004)


hydrogen
alkali metals
alkaline earth metals
transition metals
lanthanides
actinides
boron group
carbon group
nitrogen group
chalcogens
halogens
noble gases
1A
2A
3A 4A 5A 6A 7A 8A 8A 8A 1B 2B
3B 4B 5B 6B 7B
H He
Li Be B C N O F Ne
Na Mg Al Si P S Cl Ar
K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr
Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe
Cs Ba La Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At Rn
Fr Ra Ac Rf Db Sg Bh Hs Mt 110 111 112 113 114 115 116 117 118
Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr
Table Form: Short
Group Numbering: IUPAC Classic
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The Astronomer's Periodic Table

(Ben McCall)

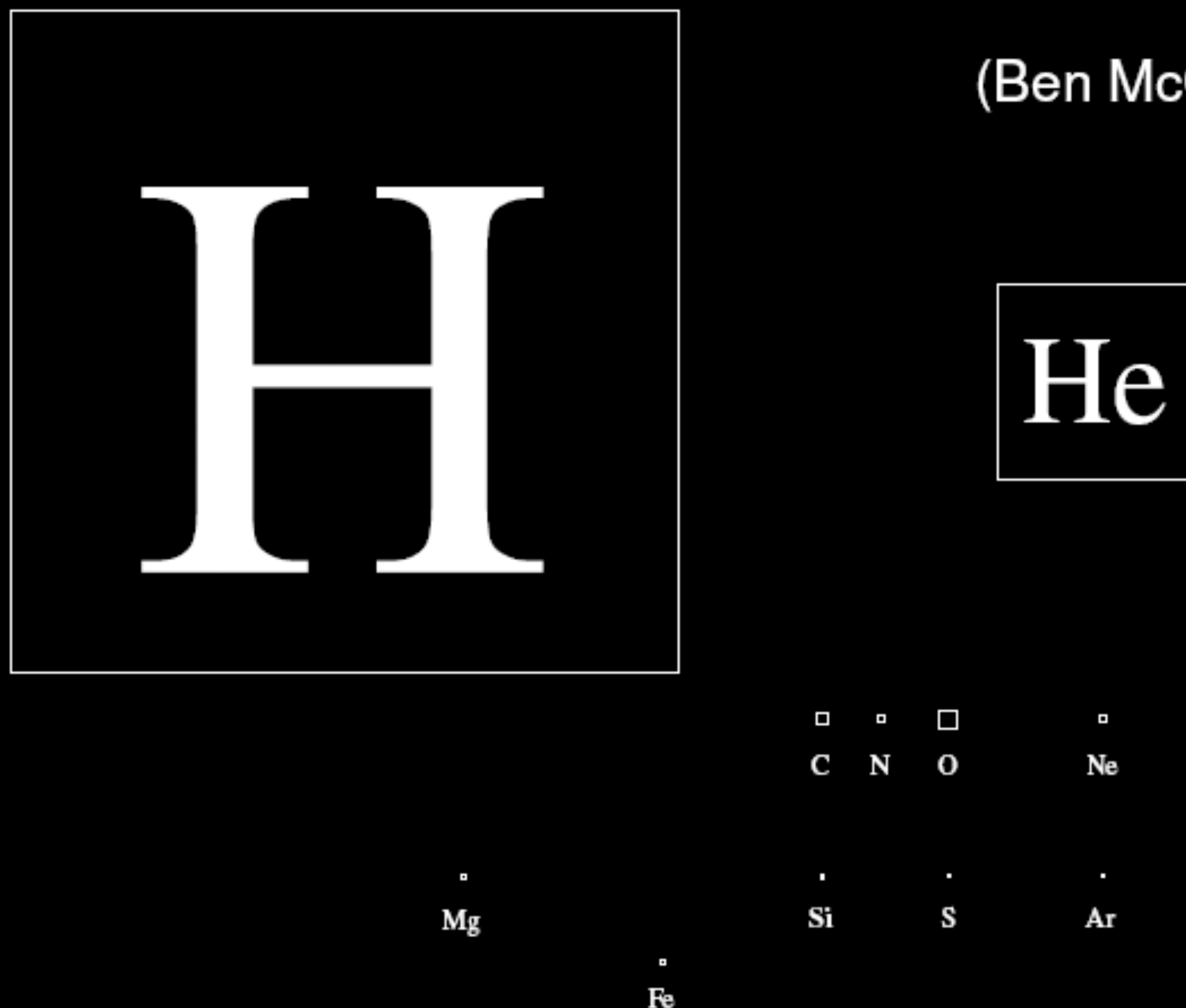


Image from Ben McCall

Molecules in the Interstellar Medium or Circumstellar Shells (as of 07/2013)

2 atoms	3 atoms	4 atoms	5 atoms	6 atoms	7 atoms	8 atoms	9 atoms	10 atoms	11 atoms	12 atoms	>12 atoms
H_2	C_3 *	c-C_3H	C_5 *	C_5H	C_6H	CH_3C_3N	CH_3C_4H	CH_3C_5N	HC_9N	c-C_6H_6 *	$HC_{11}N$
AlF	C_2H	l-C_3H	C_4H	l-H_2C_4	CH_2CHCN	HC(O)OCH_3	CH_3CH_2CN	$(CH_3)_2CO$	CH_3C_6H	$C_2H_5OCH_3$?	C_{60} * 2012
AlCl	C_2O	C_3N	C_4Si	C_2H_4*	CH_3C_2H	CH_3COOH	$(CH_3)_2O$	$(CH_2OH)_2$	C_2H_5OCHO	n-C_3H_7CN	C_{70} *
C_2**	C_2S	C_3O	l-C_3H_2	CH_3CN	HC_5N	C_7H	CH_3CH_2OH	CH_3CH_2CHO	$CH_3OC(O)CH_3$ 2013		
CH	CH_2	C_3S	c-C_3H_2	CH_3NC	CH_3CHO	C_6H_2	HC_7N				
CH^+	HCN	C_2H_2*	H_2CCN	CH_3OH	CH_3NH_2	CH_2OHCHO	C_8H				
CN	HCO	NH_3	CH_4 *	CH_3SH	c-C_2H_4O	l-HC_6H *	$CH_3C(O)NH_2$				
CO	HCO^+	HCCN	HC_3N	HC_3NH^+	H_2CCHOH	CH_2CHCHO (?)	C_8H^-				
CO^+	HCS^+	$HCNH^+$	HC_2NC	HC_2CHO	C_6H^-	CH_2CCHCN	C_3H_6				
CP	HOC^+	HNCO	HCOOH	NH_2CHO		H_2NCH_2CN					
SiC	H_2O	HNCS	H_2CNH	C_5N		CH_3CHNH 2013					
HCl	H_2S	$HOCO^+$	H_2C_2O	l-HC_4H *							
KCl	HNC	H_2CO	H_2NCN	l-HC_4N							
NH	HNO	H_2CN	HNC_3	c-H_2C_3O							
NO	MgCN	H_2CS	SiH_4 *	H_2CCNH (?)							
NS	MgNC	H_3O^+	H_2COH^+	C_5N^-							
NaCl	N_2H^+	c-SiC_3	C_4H^-	HNCHCN 2013							
OH	N_2O	CH_3 *	HC(O)CN								
PN	NaCN	C_3N^-	HNCNH 2012								
SO	OCS	PH_3 ?	CH_3O 2012								
SO^+	SO_2	HCNO	NH_4^+ 2013								
SiN	c-SiC_2	HOCN									
SiO	CO_2 *	HSCN									
SiS	NH_2	H_2O_2									
CS	H_3^+ *	C_3H^+ (?) 2012									
HF	H_2D^+, HD_2^+										
HD	SiCN										
FeO ?	AlNC										
O_2	SiNC										
CF^+	HCP										
SiH ?	CCP										
PO	AlOH										
AlO	H_2O^+										
OH^+	H_2Cl^+										
CN^-	KCN										
SH^+	FeCN										
SH 2012	HO_2 2012										
HCl^+ 2012	TiO_2 2013										
TiO 2012/13											

Acetic Acid

Ethanol

Glycine (CH2NH2COOH)

Benzene

The year most relevant to the detection (including isotopic species or vibrationally excited states) is given for recent results – the past two to three years.

As of July 2013, we recognize around **180 molecules** in the interstellar medium and circumstellar shells and **55 molecules** from extragalactic origin!!!

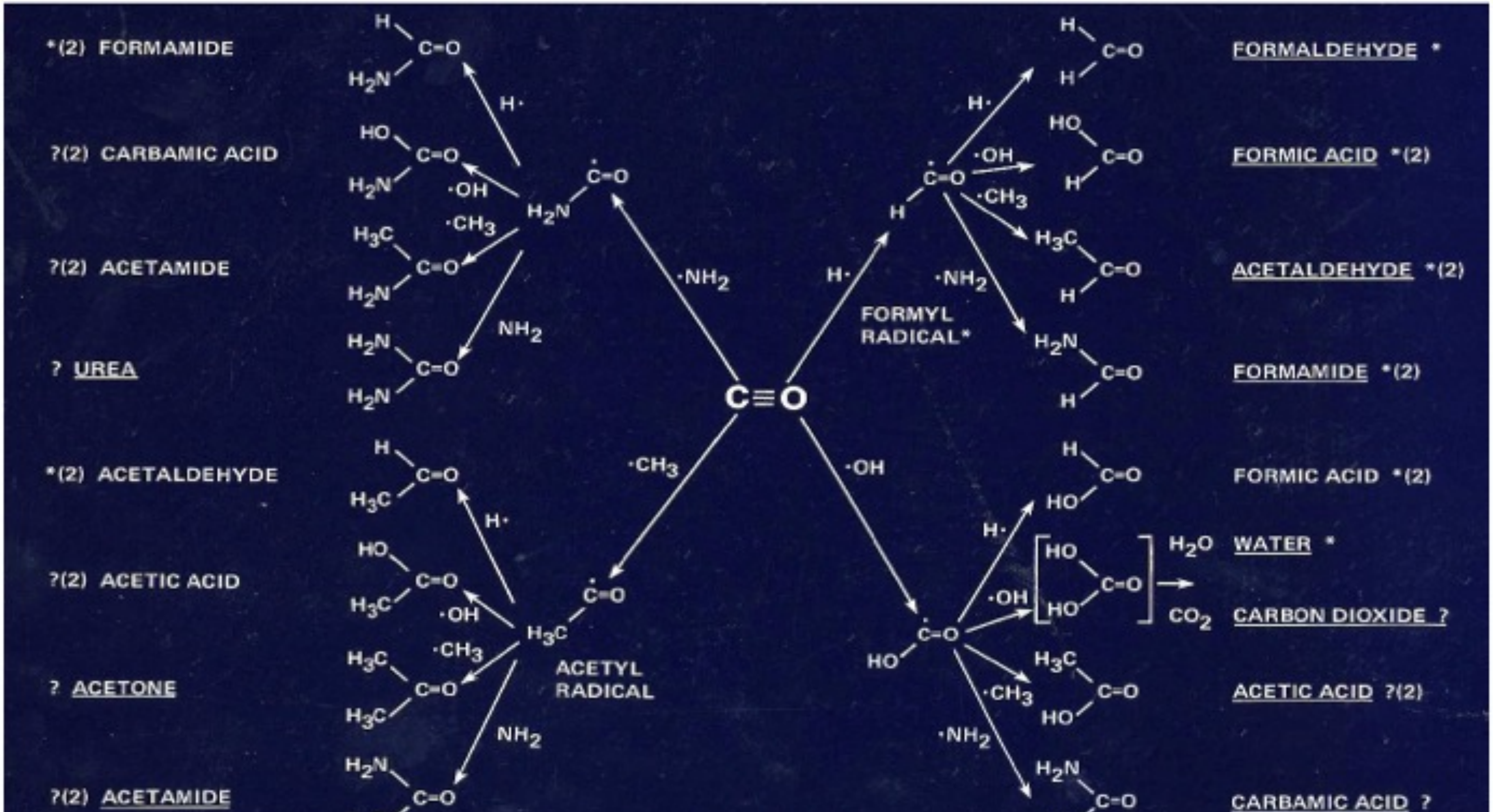
Source for molecules in space: astrochemistry.net and www.astro.uni-koeln.de/cdms/molecules

The LEGO® principle: the chemical building blocks are assembled towards complexity!!!!

- ☑20 aminoacids ⇒ all proteins
- ☑4 nucleobases ⇒ all DNA
- ☑acetate precursors (isopentenyl-pyrofosfate) ⇒ all lipids

On the chemical versatility of C

Combination of CO with H, OH, H2N & CH3 allows for a very "rich" chemistry



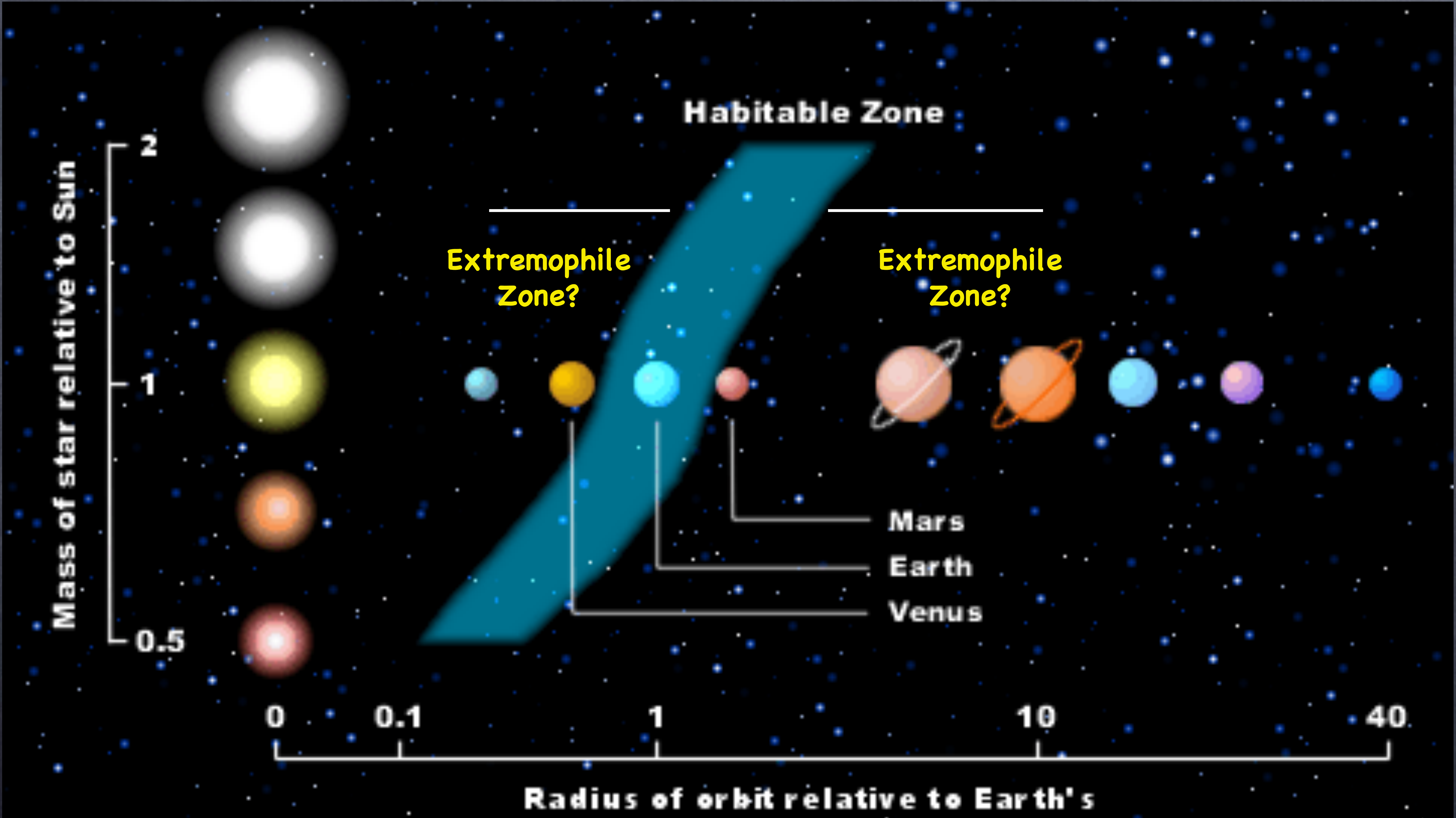
Chanrley, EAA lectures (2004)

But see Bains (Astrobiology, 4, 137 (2004)) for a different perspective

Why is our planet habitable? What's special about it?

Stellar Habitable Zone

Main requirement: liquid water!!!



Source: www.space.com

Comets

- Essential to understand the formation process and evolution of the Solar System
- Reservoir of pristine interstellar material?
- Possible suppliers of organic material necessary to trigger life formation on Earth

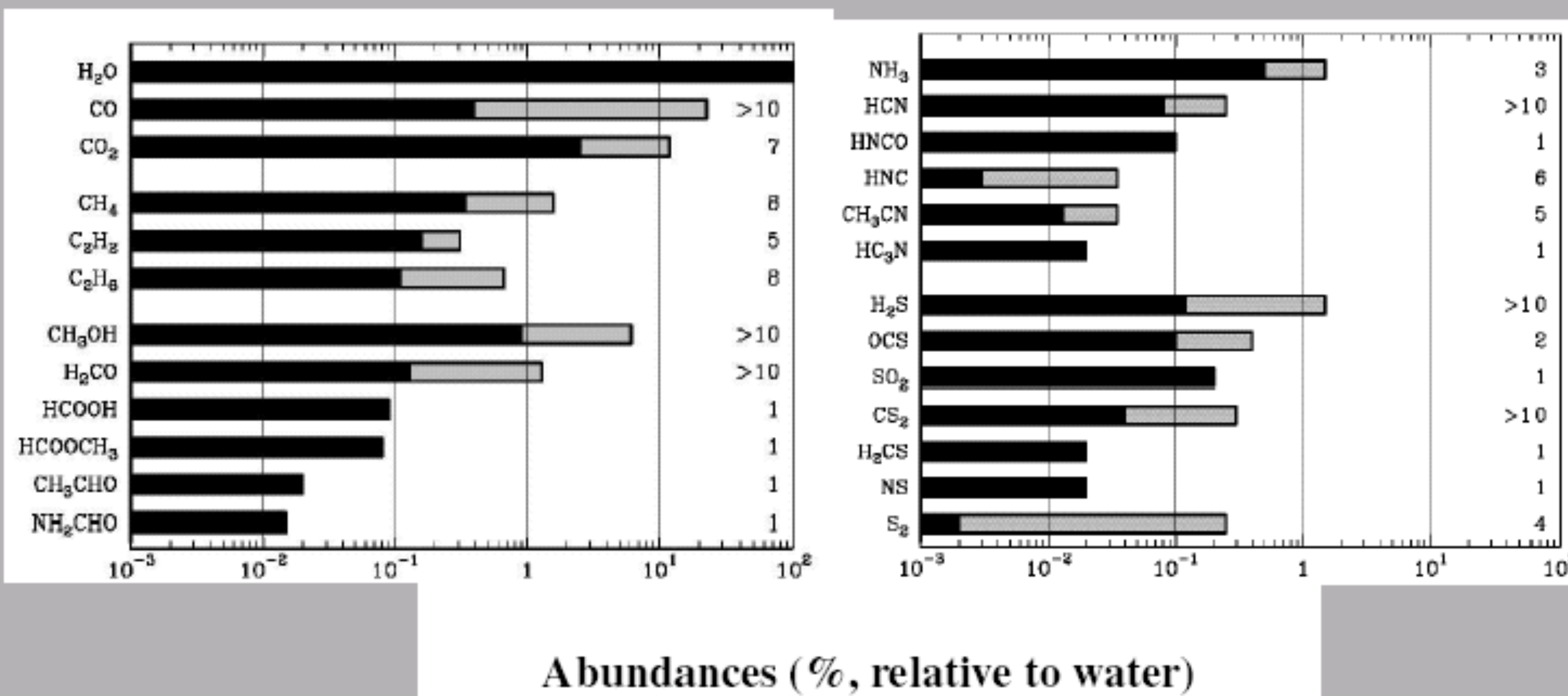
Asteroids

- Main source of meteorites
- Major interest in condrites: silicates, C-silicates, silicates with H2O
- Carbonated condrites are a source of aminoacids

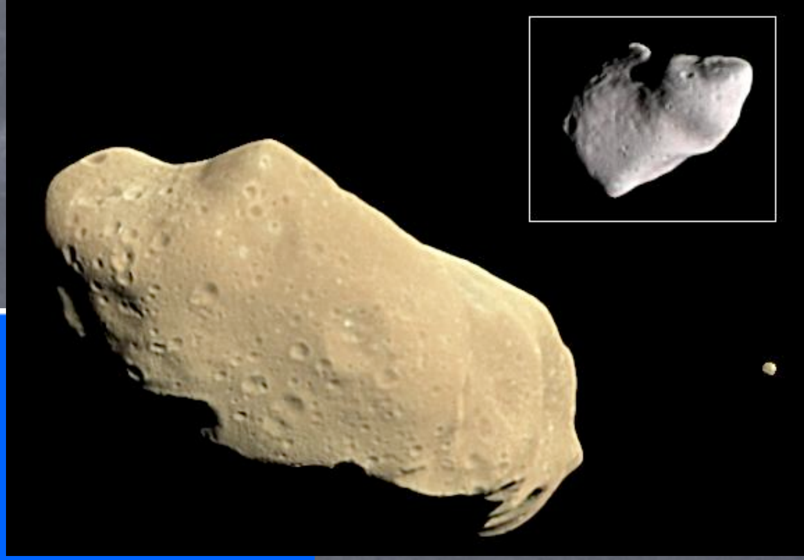
Important for formation (**organics deposition**) and annihilation (**mass extinction**) of life on Earth

Chemical Composition of Comets

(The grey bar indicates the range measured to date)



Bockelee-Morvan, Crovisier, Mumma, and Weaver (Comets II, 2003)



Organics Found in Meteorites

Total Carbon Content: > 3% (by weight); Soluble Fraction: < 30% of total C

COMPONENTS:

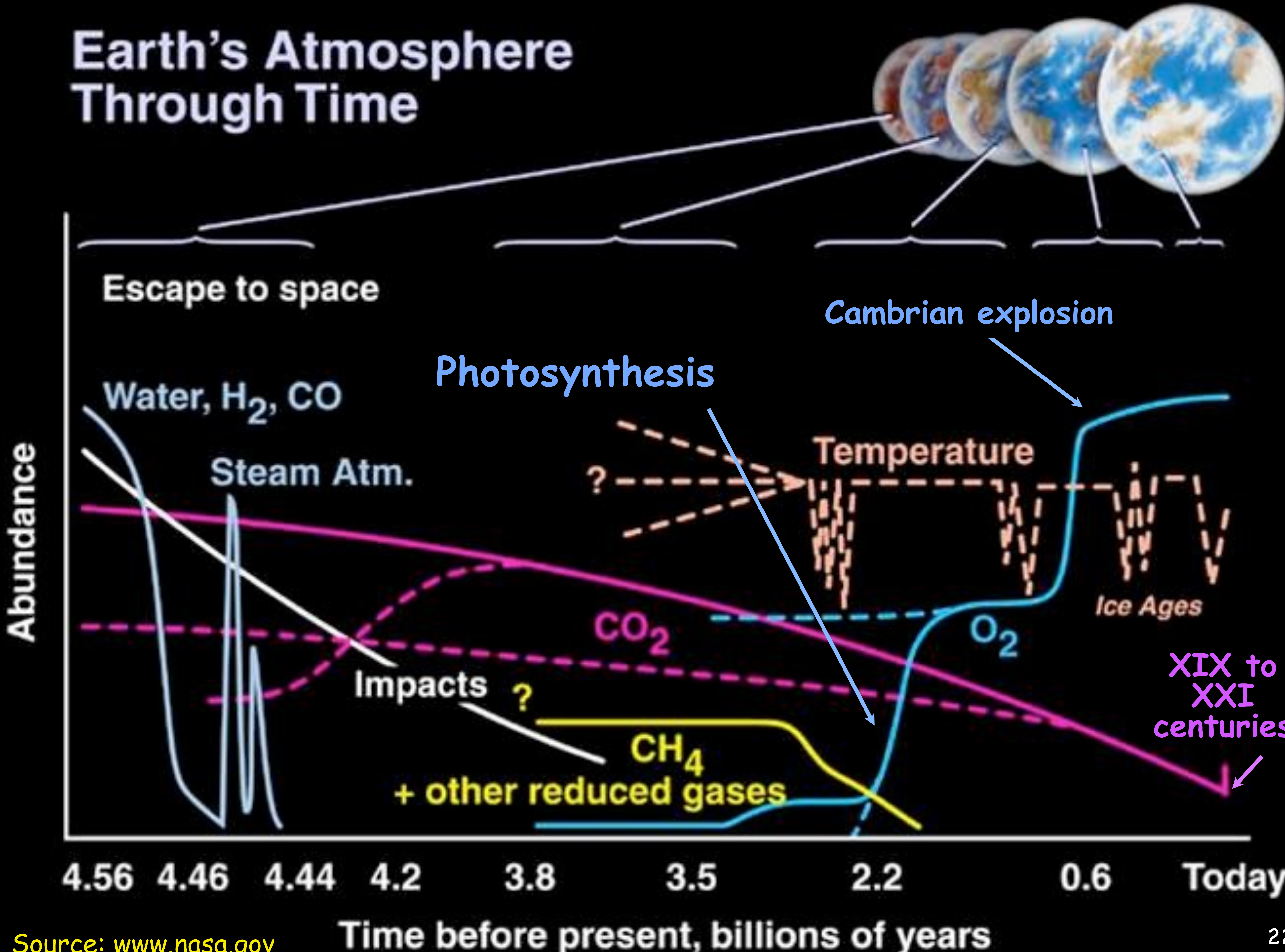
ACIDS:
- Amino acids
- Carboxylic acids
- Hydroxycarboxylic acids
- Dicarboxylic acids
- Hydroxydicarboxylic acids
- Sulfonic acids
- Phosphonic acids

HYDROCARBONS:
- non-volatile: aliphatic, aromatic (PAH), polar
- volatile

FULLERENES:
- C_{60}, C_{70}
- $He@C_{60}$
- Higher Fullerenes

OTHERS:
- N-Heterocycles
- Amides
- Amines
- Alcohols
- Carbonyl compounds

Chanrley, EAA lectures (2004)



Source: www.nasa.gov

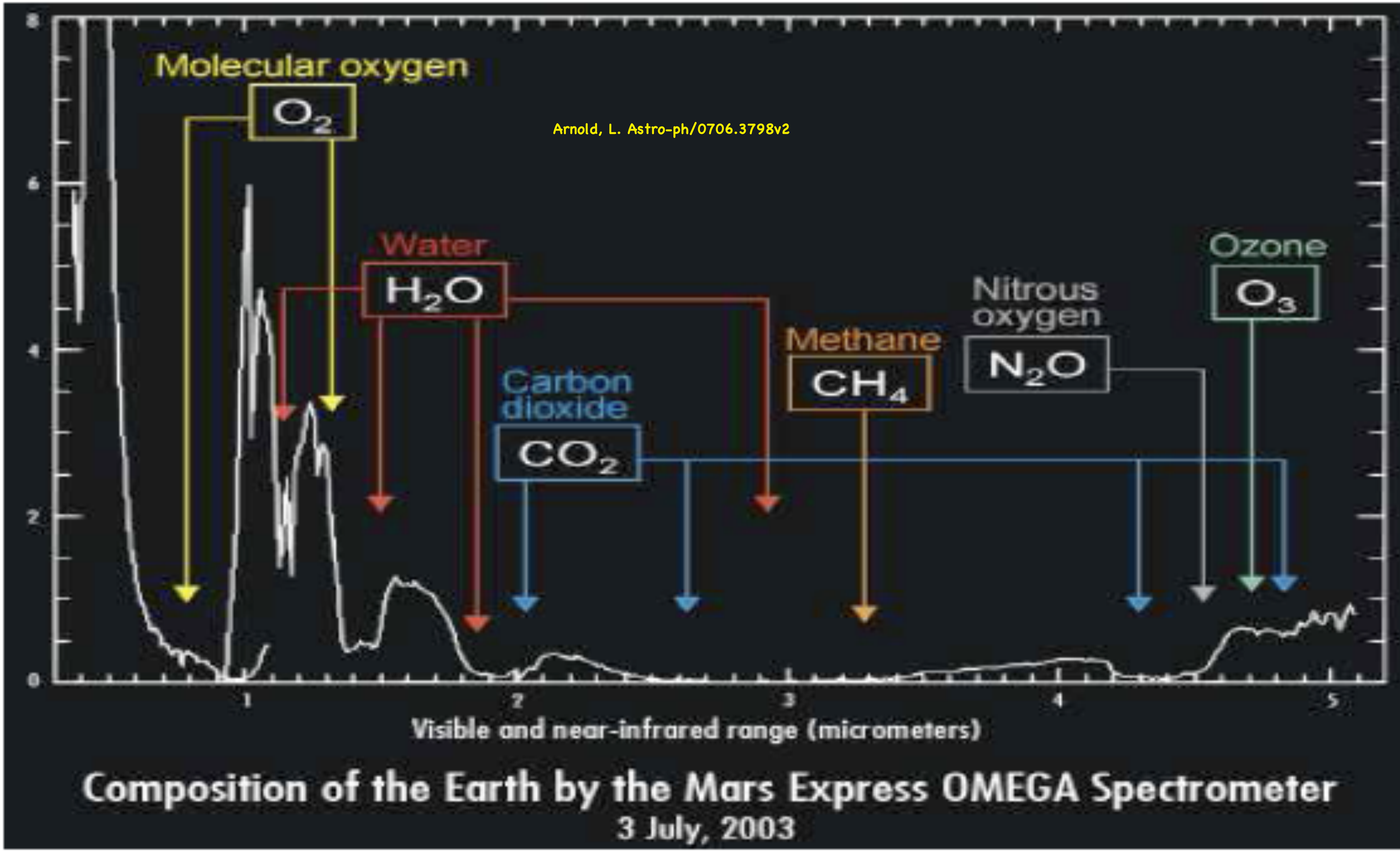
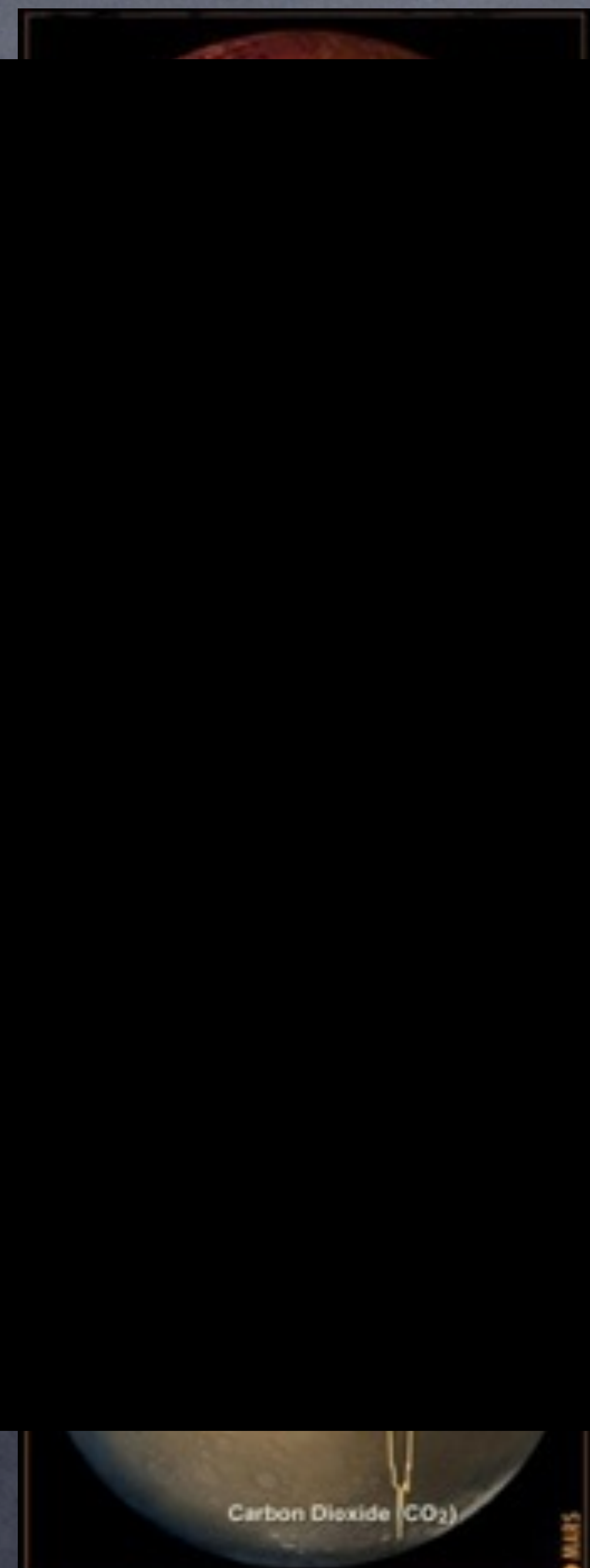


Fig. 2 Mars Express recorded the Earth spectrum with its OMEGA instrument in July 2003 while it was traveling to Mars. This picture illustrates how could look like an Earth-like extrasolar planet spectrum recorded with a high signal to noise ratio (figure adapted from http://mars.jpl.nasa.gov/express/newsroom/pressreleases/20030717a.html).

How can we detect life signatures remotely?



Source: http://science.nasa.gov

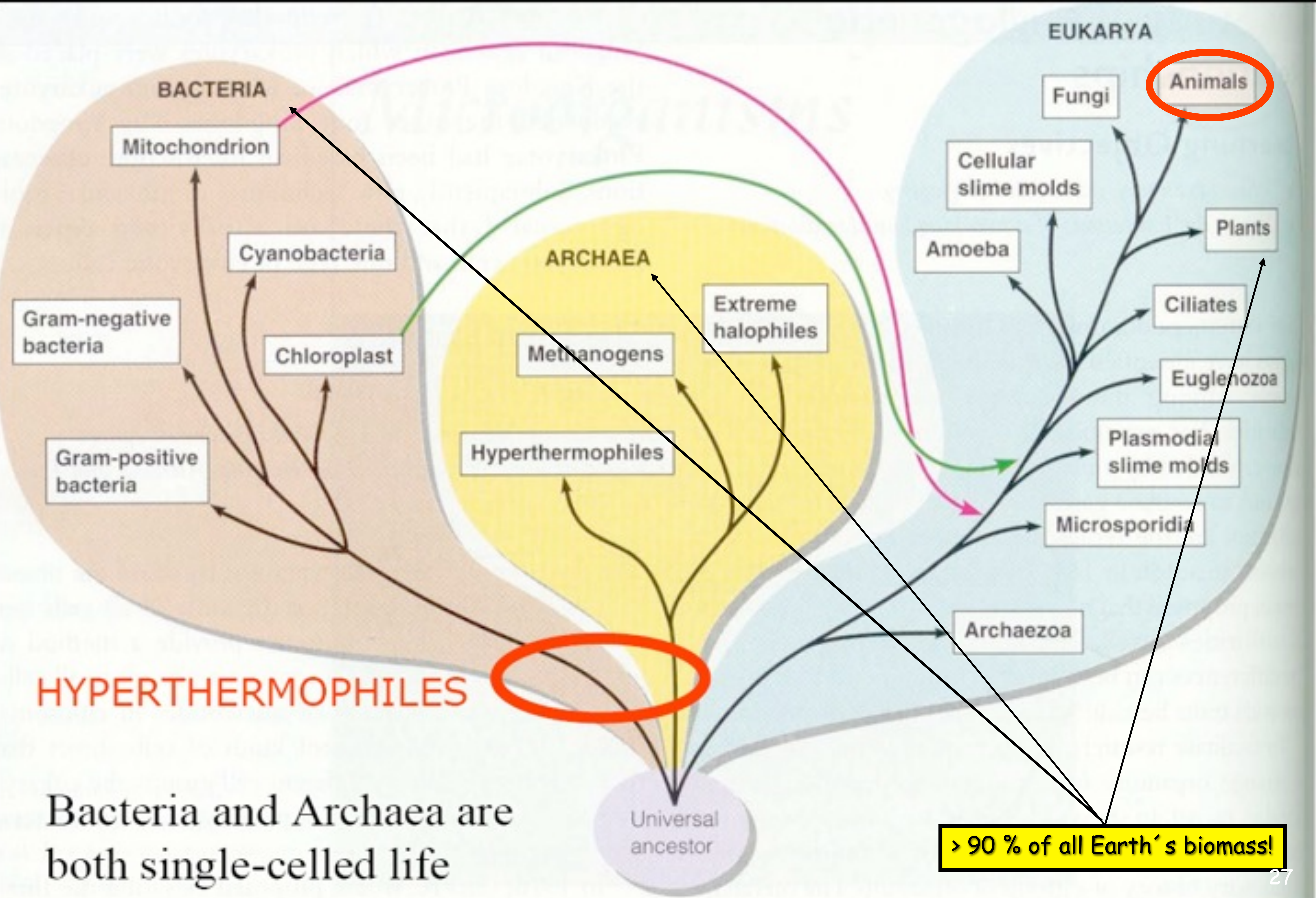
Habitability conditions (OUR recipe)

- **Water** on Earth's surface for, at least, 1 billion years
- Intense **meteorite bombardment** during Earth's formation (~ first 700 million years)
- **Resilience** to catastrophes during the first billion years

$$12\ H_2O + 6\ CO_2 \xrightarrow{\text{Light}} C_6H_{12}O_6 + 6\ O_2 + 6\ H_2O$$

MUCH MORE EFFICIENT THAN ANY OTHER PHOTOREACTION

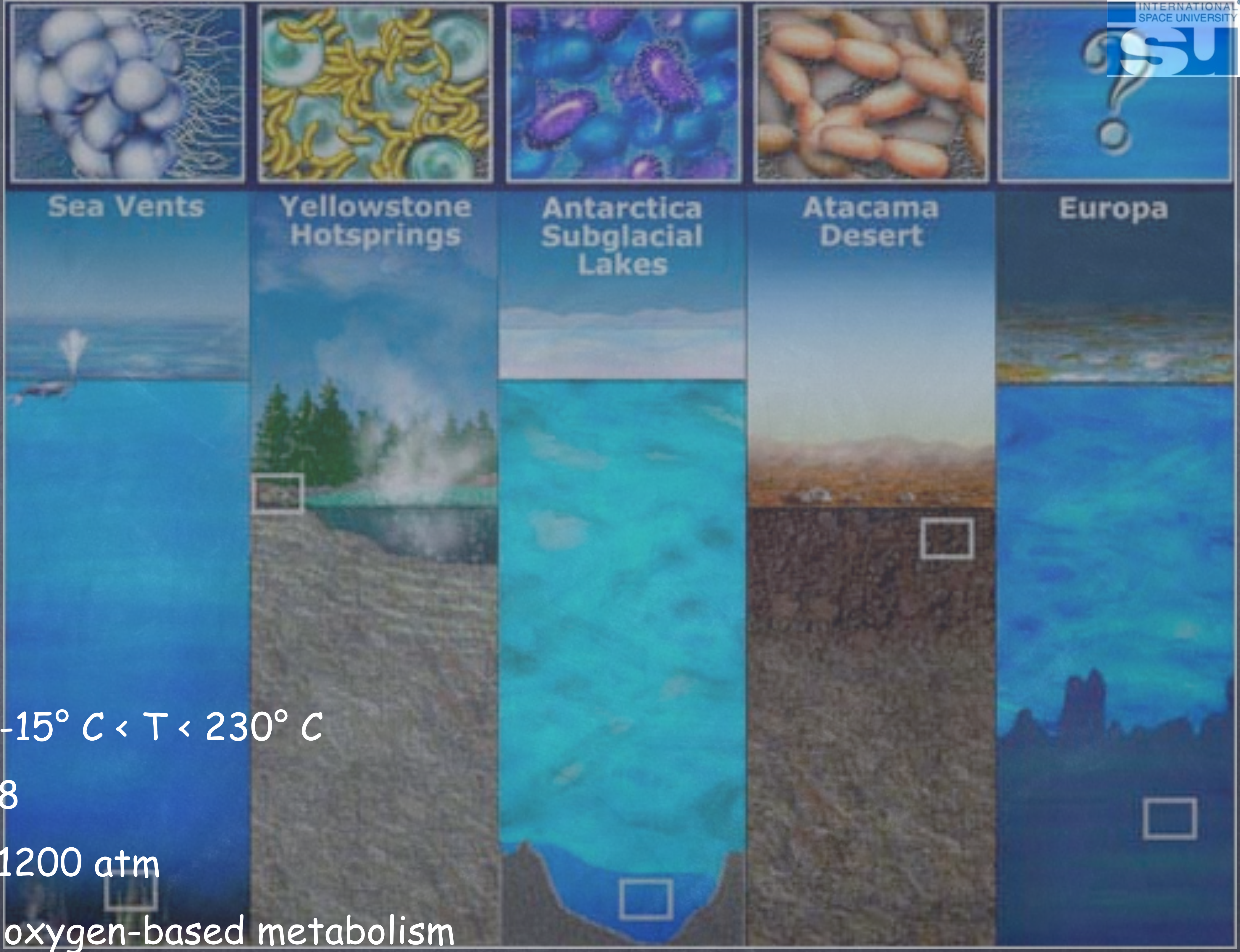
Extremophiles and the origin of life



Bacteria and Archaea are both single-celled life

Extremophiles

- We have more microbial cells (~ 1 trillion in the skin, 10 billion in the mouth and 100 trillion in the digestive tract) than human cells (10 trillion) in our OWN BODY.
- First life form on Earth, and the ONLY existing during the first 3 billion years was a microbium.
- There is more life "inside the ground" than on top of Earth's surface.
- Microbia can live in conditions which are EXTREMELY challenging.
- Most likely candidates to be an E.T.!!!



- Temperature: -15° C < T < 230° C
- 0.06 < pH < 12.8
- 0 < Pressure < 1200 atm
- No mandatory oxygen-based metabolism
- 20-40 million years of dormancy
- Capable of surviving and reproducing under radiation doses of 1000s of grays

The search for life in the Solar System: what has been done so far?

Searching for life

- Non-intelligent
  - Search for biotracers (and actual life forms) in the Solar System
  - Search for extrasolar planets
  - Search for biotracers in extrasolar planets
- Intelligent
  - Search for non-natural signals coming from another point in the Universe (SETI)

J. Tarter, Annual Review of Astronomy and Astrophysics, 39, 511-548 (2001)

Two classical strategies to search for life

- Follow the water!
- Follow abundant and available energy sources
    - Fundamental condition for habitability
    - Available energy allows for the reproduction of "chemical" states of very low probability (maybe ~ "life"???)
    - Identification of biotracers can be much more efficient (life is shaped by, and, at the same time, shapes the environment)

Ball. Nature, 427, 19 (2004)

Hoehler et al. Astrobiology, 7, 819 (2007)

Reading suggestion: "Vital dust". C. de Duve (1995). Check on Google Books!!!

Mars: explored since the 60's

- NASA(main missions)
  - Mars Rovers: Spirit/Opportunity (2003) / Curiosity (2012)
  - Mars Observer/Global Surveyor/Pathfinder: 92, 96 & 97
  - Viking, Mariner: 60s & 70s
- URSS (main missions)
  - Zond, Sputnik, Mars, Cosmos, Phobos: 60s to 80s
- ESA (after 2000)
  - Mars Express, Beagle, Rosetta

Water in Mars

nature International weekly journal of science

Access

To read this story in full you will need to login or make a payment (see right).

nature.com > Journal home > Table of Contents

Letter

Nature **454**, 305-309 (17 July 2008) | doi:10.1038/nature07097; Received 24 April 2008; A
2008; Published online 16 July 2008

Hydrated silicate minerals on Mars observed by the Mars Reconnaissance Orbiter CRISM instrument

John F. Mustard[1], S. L. Murchie[2], S. M. Pelkey[1], B. L. Ehlmann[1], R. E. Milliken[3], J. A. Grant[4], J.-P. Bibring[5], F. Poulet[5], J. Bishop[6], E. Noe Dobrea[3], L. Roach[1], F. Seelos[2], R. E. Arvidson[7], S. Wiseman[7], R. Green[3], C. Hash[8], D. Humm[2], E. Malaret[8], J. A. McGovern[2], K. Seelos[2], T. Clancy[9], R. Clark[10], D. D. Marais[6], N. Izenberg[2], A. Knudson[7], Y. Langevin[5], T. Martin[3], P. McGuire[7], R. Morris[11], M. Robinson[12], T. Roush[6], M. Smith[13], G. Swayze[9], H. Taylor[2], T. Titus[14] & M. Wolff[9]

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Phyllosilicates, a class of hydrous mineral first definitively identified on Mars by the OMEGA (Observatoire pour la Mineralogie, L'Eau, les Glaces et l'Activitié) instrument[1,2], preserve a record of the interaction of water with rocks on Mars. Global mapping showed that phyllosilicates are widespread but are apparently restricted to ancient terrains and a relatively narrow range of mineralogy (Fe/Mg and Al smectite clays). This was interpreted to indicate that phyllosilicate formation occurred during the Noachian (the earliest geological era of Mars), and that the conditions necessary for phyllosilicate formation (moderate to high pH and high water activity[3]) were specific to surface environments during the earliest era of Mars's history[4]. Here we report results from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM)[5] of phyllosilicate-rich regions. We expand the diversity of phyllosilicate mineralogy with the identification of kaolinite, chlorite and illite or muscovite, and a new class of hydrated silicate (hydrated silica). We observe diverse Fe/Mg-OH phyllosilicates and find that smectites such as nontronite and saponite are the most common, but chlorites are also present in some locations. Stratigraphic relationships in the Nili Fossae region show olivine-rich materials overlying phyllosilicate-bearing units, indicating the cessation of aqueous alteration before emplacement of the olivine-bearing unit. Hundreds of detections of Fe/Mg phyllosilicate in rims, ejecta and central peaks of craters in the southern highland Noachian cratered terrain indicate excavation of altered crust from depth. We also find phyllosilicate in sedimentary deposits clearly laid by water. These results point to a rich diversity of Noachian environments conducive to habitability.

Water in Mars

Live (Spirit & Opportunity) and remote sensing (Viking 1 & Pathfinder) observations

nature International weekly journal of science

Letter

Nature **459**, 401-404 (21 May 2009) | doi:10.1038/nature07978; Receiv
March 2009

Stability against freezing of aqueous solutions on early Mars

Alberto G. Fairén[1], Alfonso F. Davila[1], Luis Gago-Duport[2], Ricardo Amils[3,4] & Christopher P. McKay[1]

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2. Departamento de Geociencias Marinas, Universidad de Vigo, Lagoas Marcosende, Vigo 36200, Spain
3. Centro de Astrobiología, CSIC-INTA, Torrejón de Ardoz 28850, Madrid, Spain
4. Centro de Biología Molecular Severo Ochoa, CSIC-UAM, Cantoblanco 28049, Madrid, Spain

Correspondence to: Alberto G. Fairén[1] Correspondence and requests for materials should be addressed to A.G.F. (Email: alberto.g.fairen@nasa.gov).

Many features of the Martian landscape are thought to have been formed by liquid water flow[1, 2] and water-related mineralogies on the surface of Mars are widespread and abundant[3]. Several lines of evidence, however, suggest that Mars has been cold with mean global temperatures well below the freezing point of pure water[4]. Martian climate modellers[5, 6] considering a combination of greenhouse gases at a range of partial pressures find it challenging to simulate global mean Martian surface temperatures above 273 K, and local thermal sources[7, 8] cannot account for the widespread distribution of hydrated and evaporitic minerals throughout the Martian landscape[3]. Solutes could depress the melting point of water[9, 10] in a frozen Martian environment, providing a plausible solution to the early Mars climate paradox. Here we model the freezing and evaporation processes of Martian fluids with a composition resulting from the weathering of basalts, as reflected in the chemical compositions at Mars landing sites. Our results show that a significant fraction of weathering fluids loaded with Si, Fe, S, Mg, Ca, Cl, Na, K and Al remain in the liquid state at temperatures well below 273 K. We tested our model by analysing the mineralogies yielded by the evolution of the solutions: the resulting mineral assemblages are analogous to those actually identified on the Martian surface. This stability against freezing of Martian fluids can explain saline liquid water activity on the surface of Mars at mean global temperatures well below 273 K.

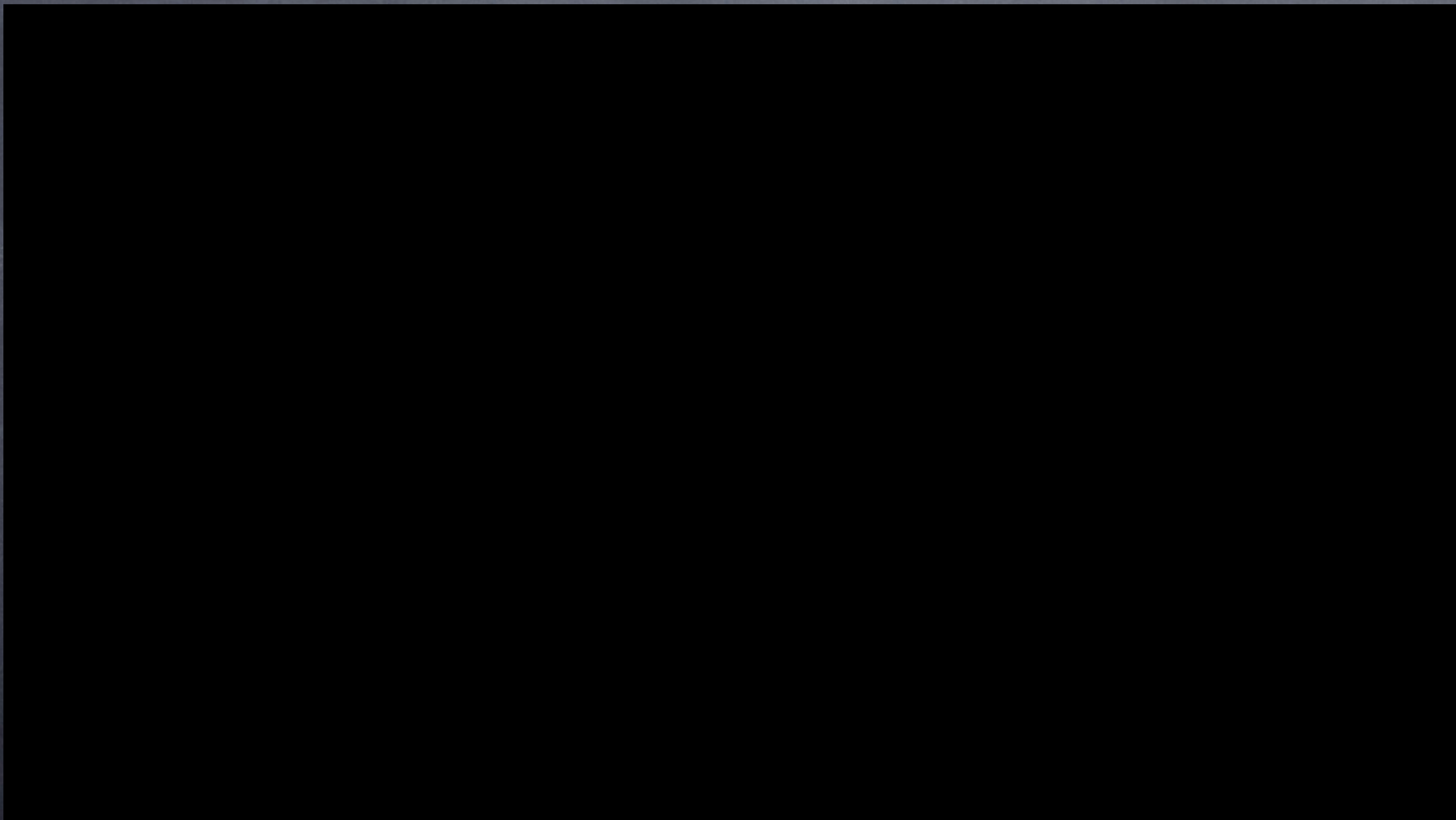
And the existence of methane?

- Detected after a number of (Martian...) years studying Mars atmosphere (Jan 15, 2009).
- Impossible to exist for long time spans, due to the atmospheric conditions of Mars
- Geological or biological (recent) origin
- Levels comparable to those emitted by oil explorations on Earth

How is it produced?

Source: science.nasa.gov

Where and what is produced?

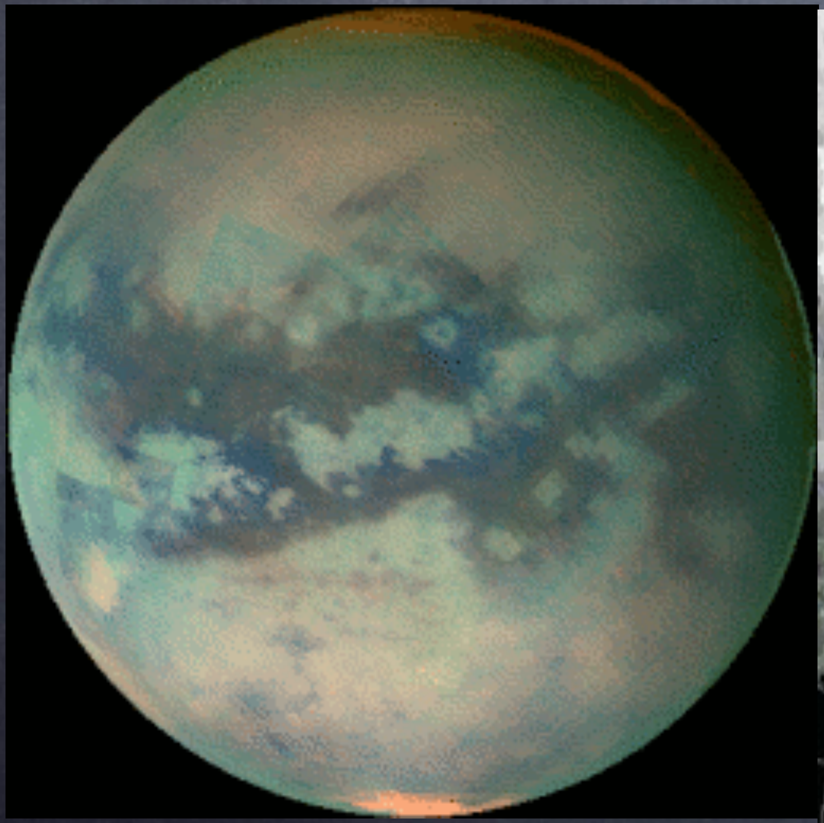


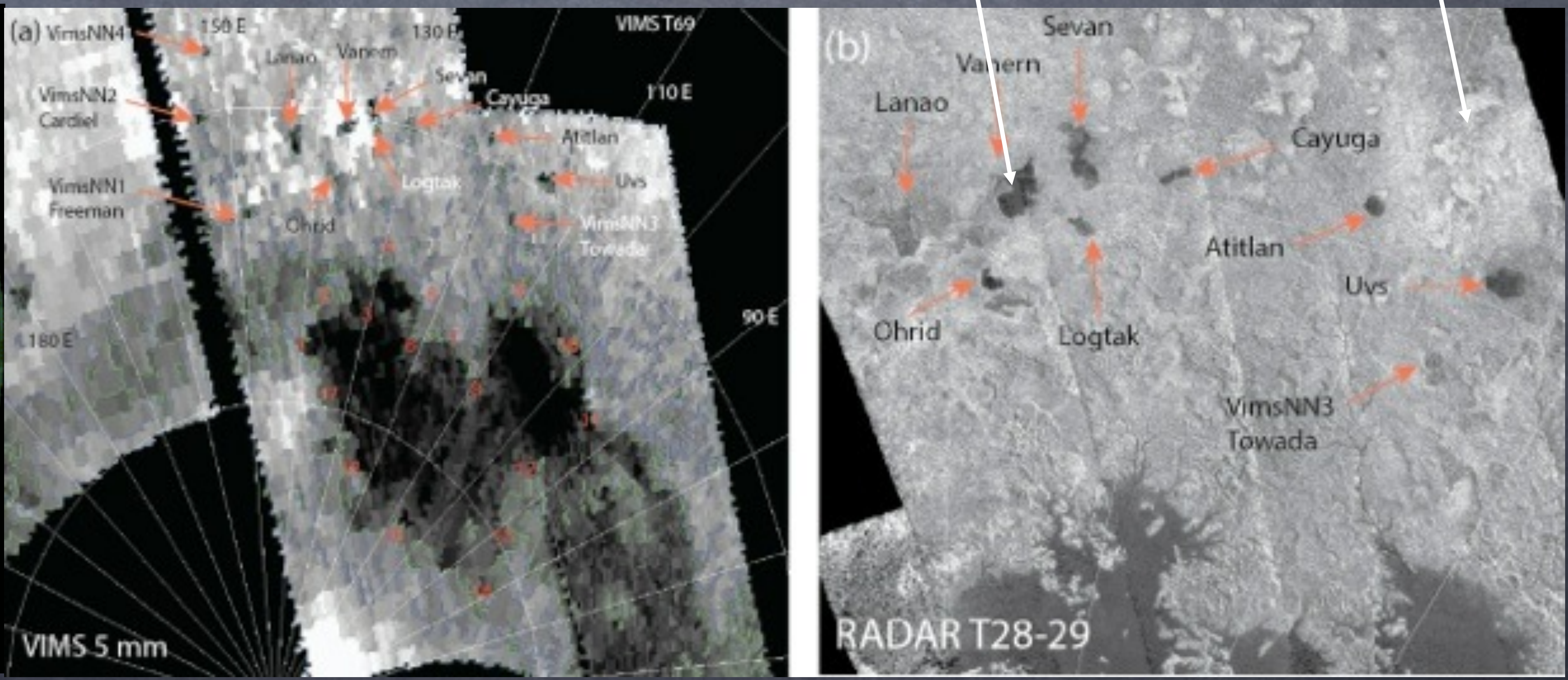
Source: science.nasa.gov

Titan – Saturn's moon

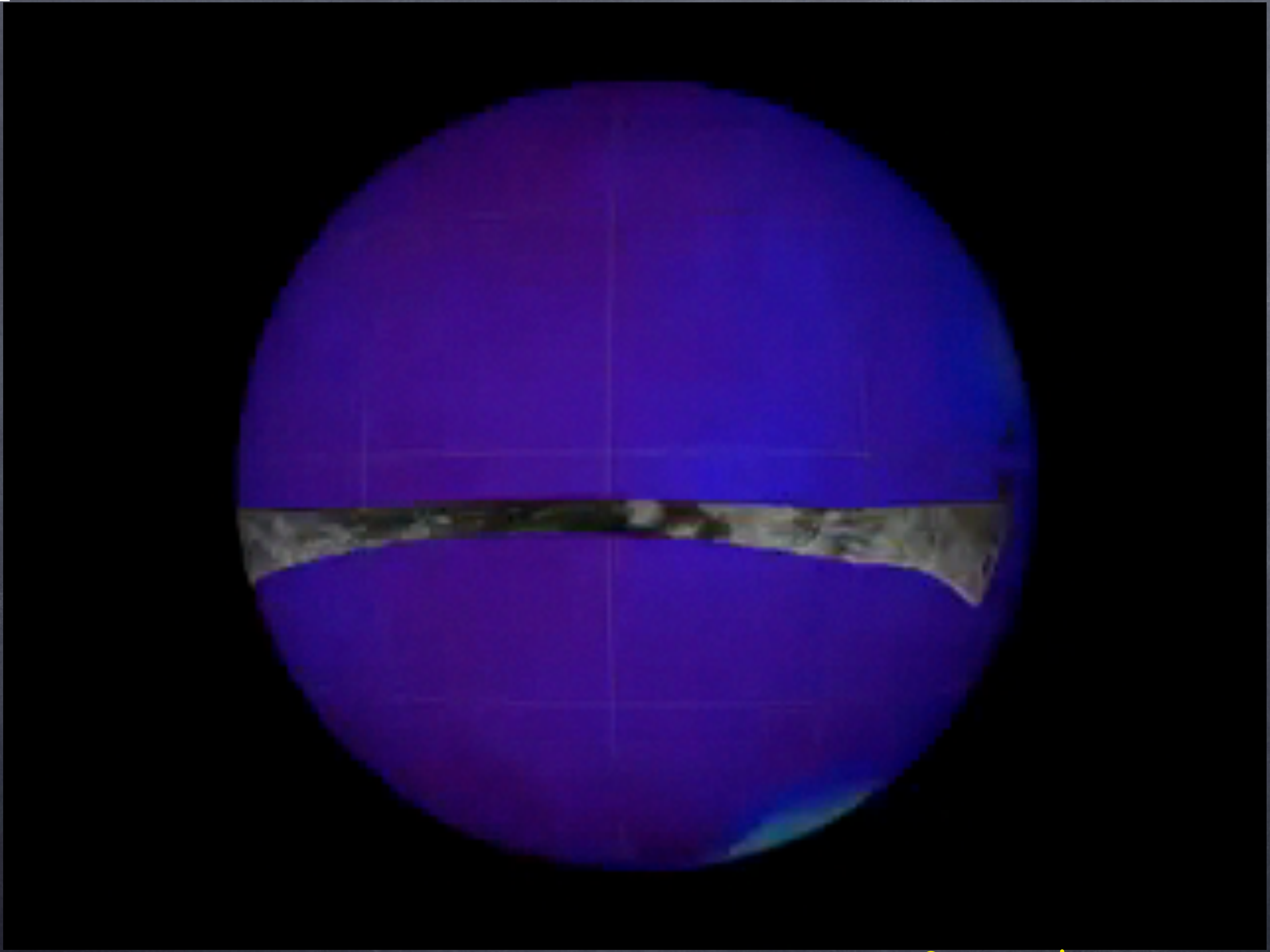
An Earth-like "continental" landscape: lakes and elevations

- Atmosphere very distinct from Earth's (containing N and CH_4)
- Larger than the Moon or Mercury
- Hostile environment (T ~ -180° C)
- Liquids: methane/ethane





Source: http://photojournal.jpl.nasa.gov/catalog/PIA16844



Source: science.nasa.gov

Other potential targets for "in-situ" exploration

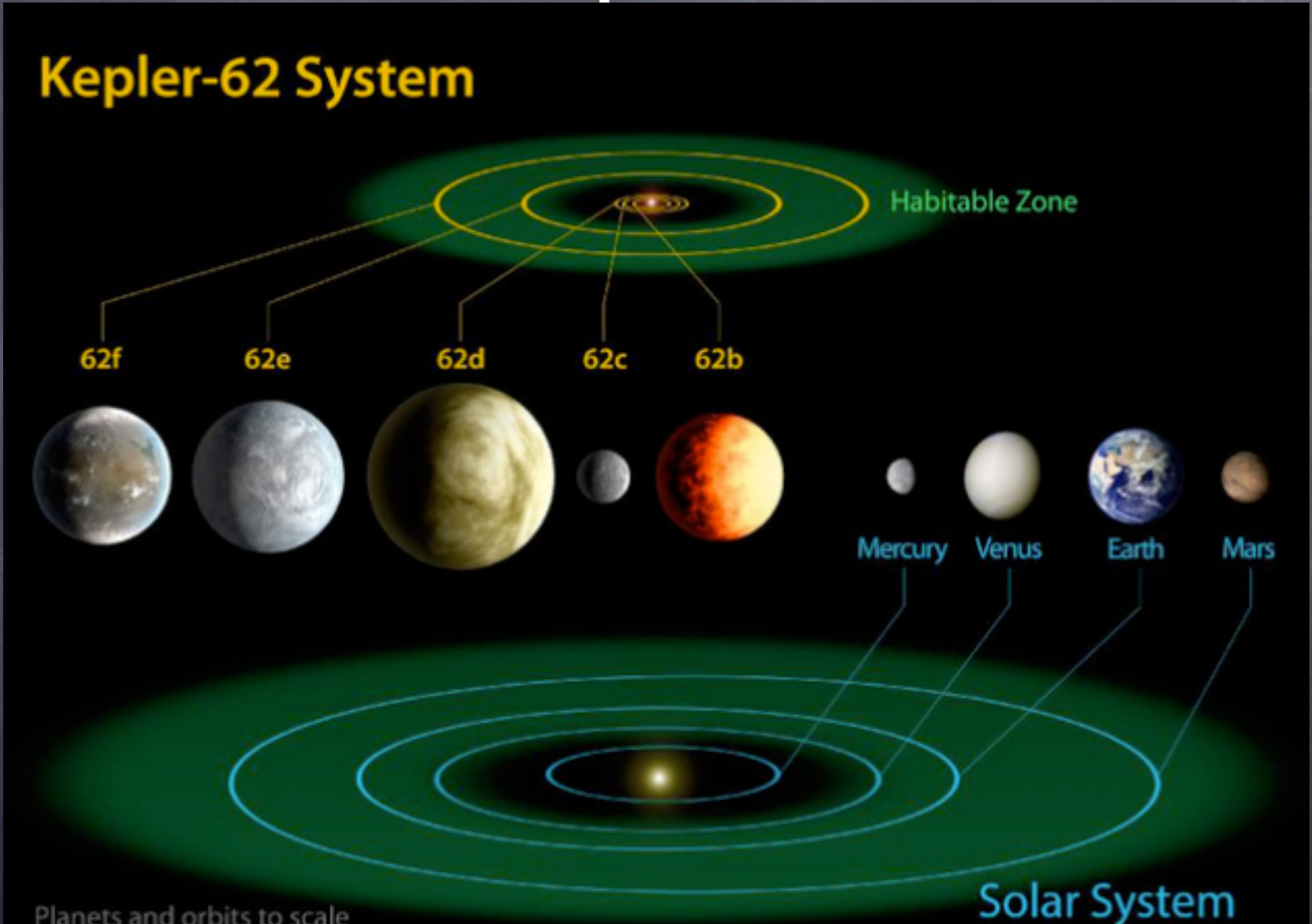
- Europa & Ganimedes (Jupiter)
- Enceladus (Saturn)
- **And there we stop, at least for the next decades...**
- A journey to the closest star, Alpha Centauri, at 4.5 light-years (42.5 trillion km), would take, onboard the Space Shuttle, about 173.500 years, navigating at 28000 km/h. This speed is enough to allow an astronaut to fly around the Earth Equator in 1.5h or to arrive at the Moon in about 13 h!!!!

Extrasolar planets (a.k.a. exoplanets): they are REALLY out there!

The exoplanet zoo

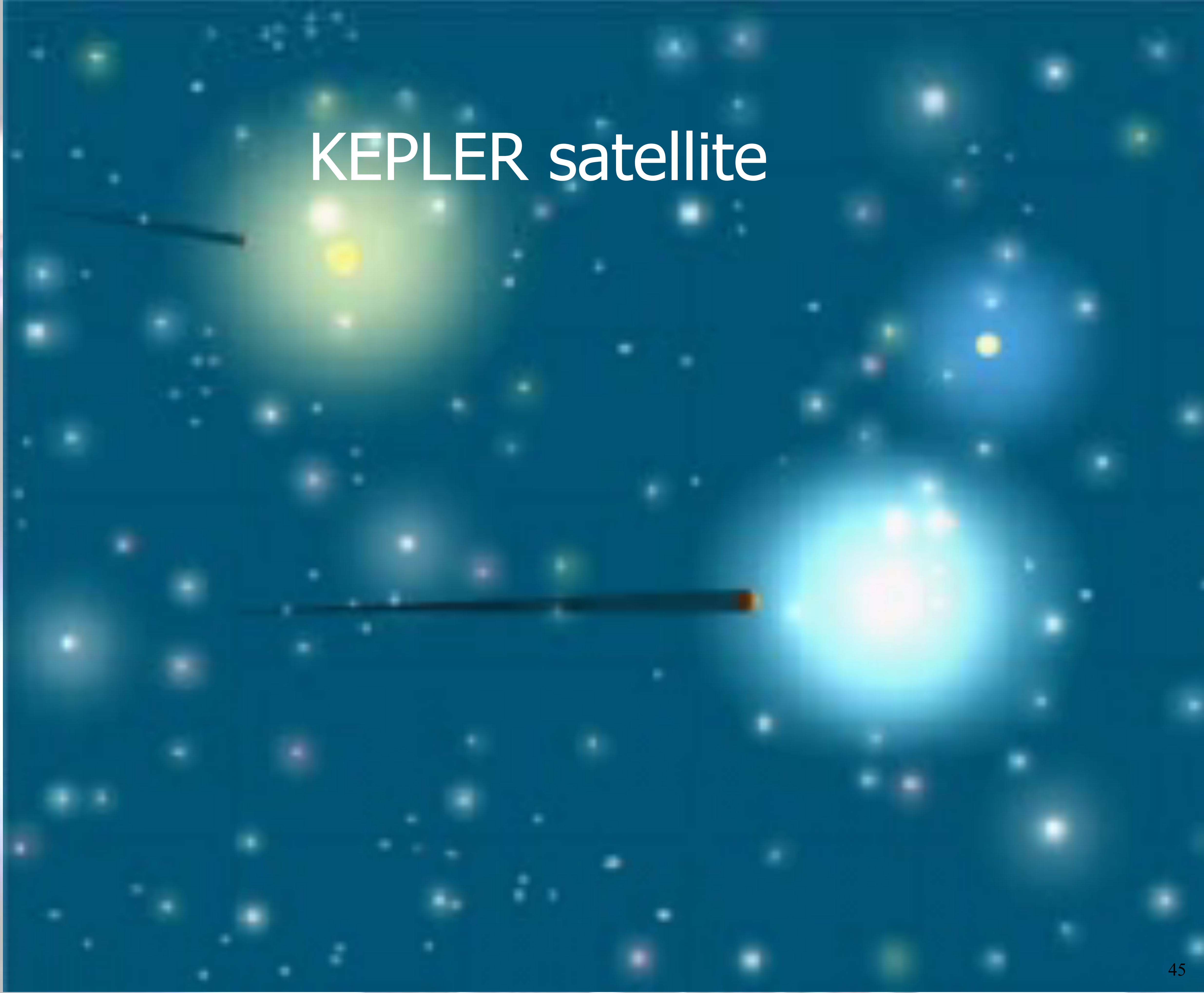
- Please refer to http://exoplanet.eu/catalog.php
- Last access: July 17, 2013
  - **708 planetary systems**
  - **919 planets**
  - **142 multiple planet systems**
  - **Recent discovery of 3 more Earth-like planets by Kepler satellite (1.4, 1.7 and 1.9 times the size of Earth) at Kepler 62 and Kepler 69 systems**

The exoplanet zoo

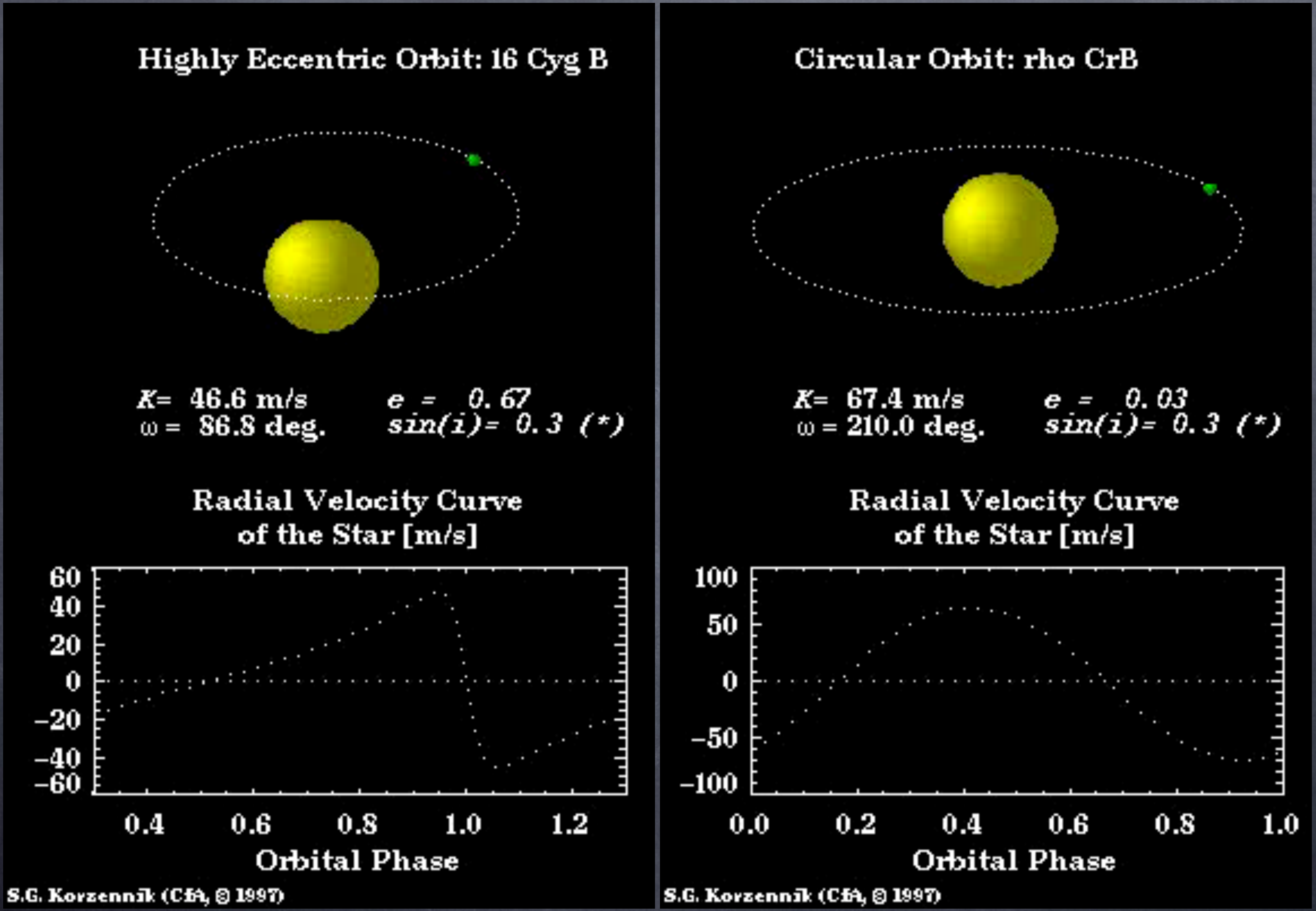


Borucki et al. Science, 340, 6132, pp. 587-590 (3 May 2013)

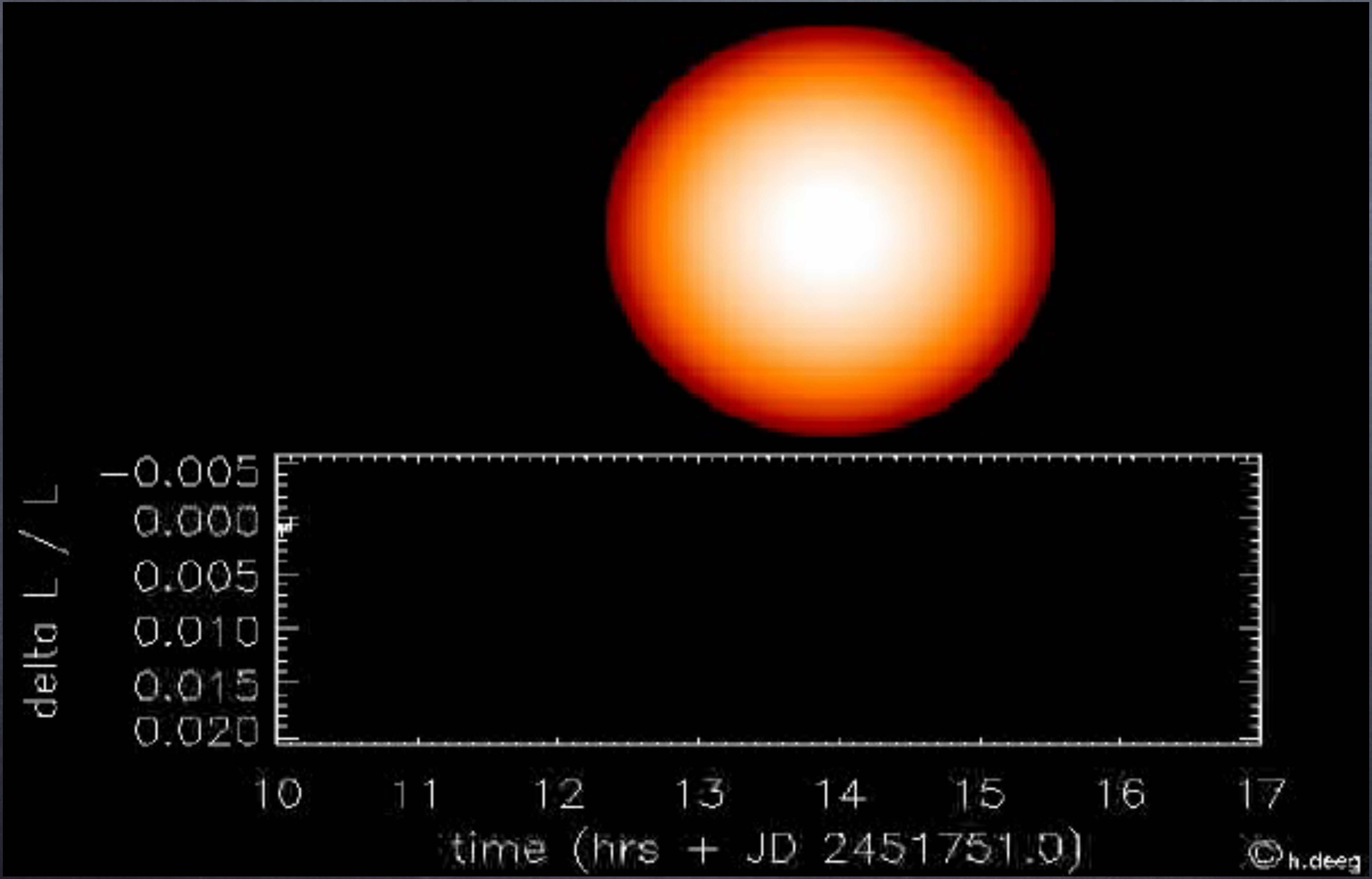
KEPLER satellite



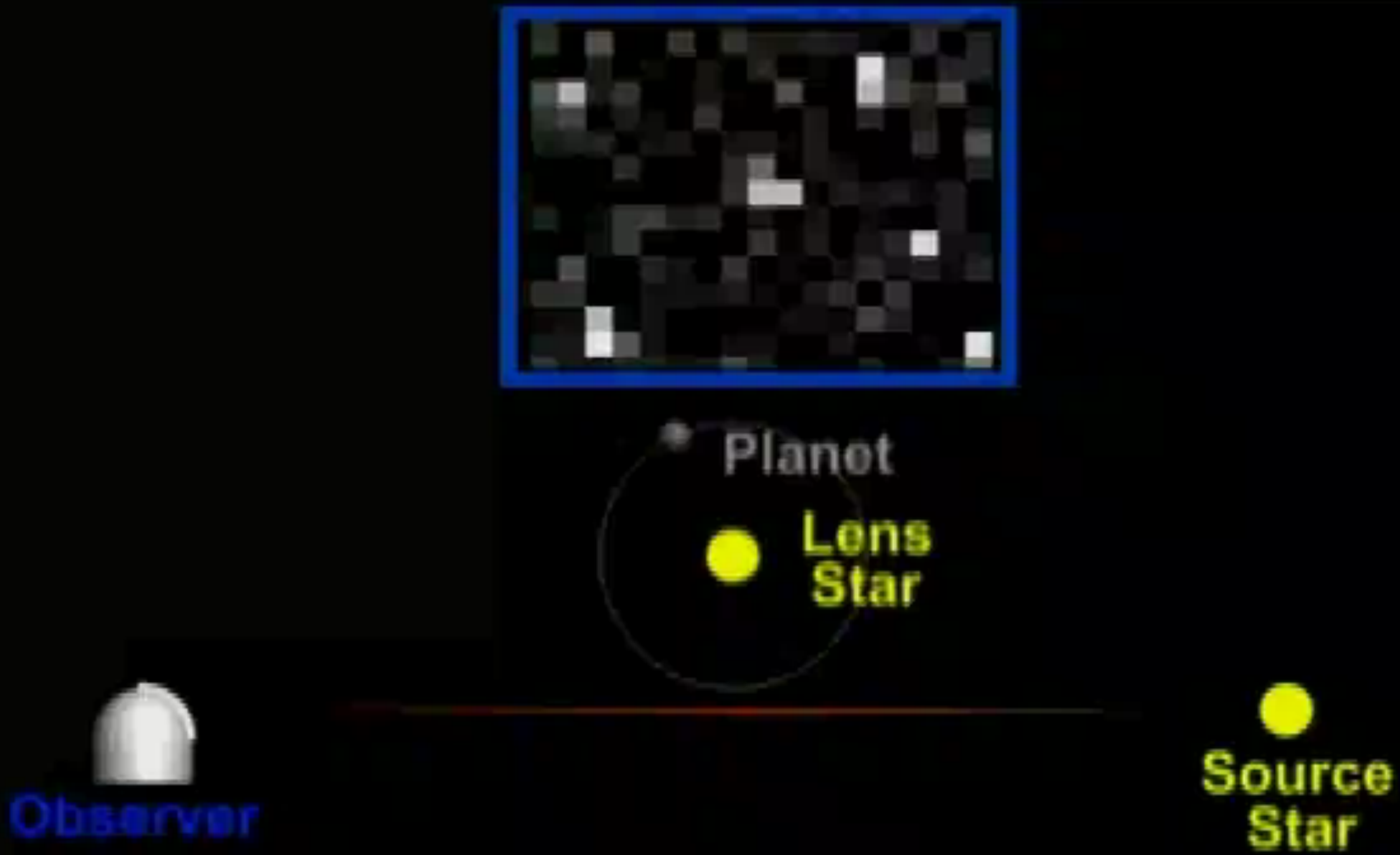
Extrasolar planets detection method



Extrasolar planets detection mehtod



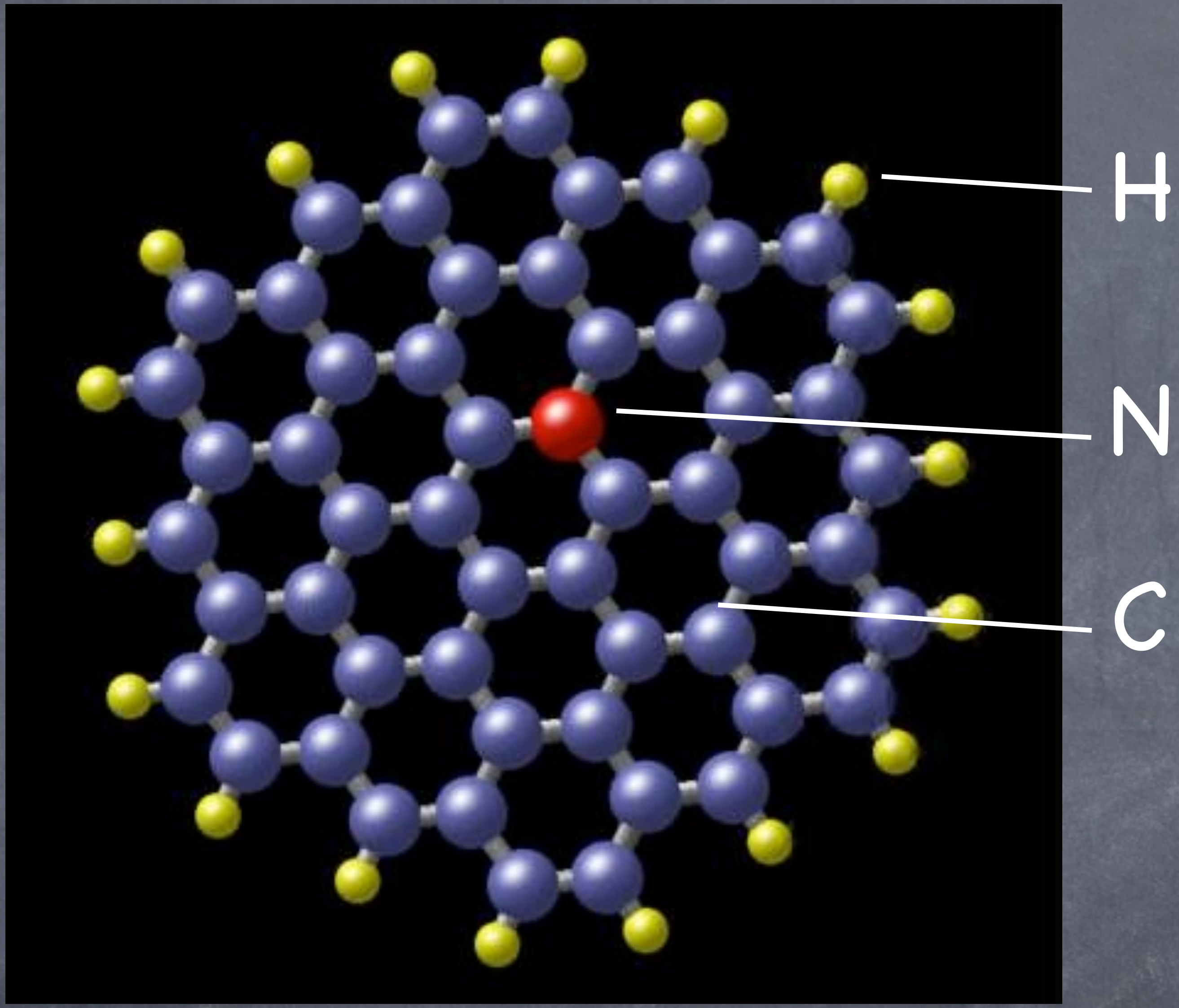
Extrasolar planets detection mehtod



The chemistry elsewhere in the Universe

Detection of a PANH in the IR band

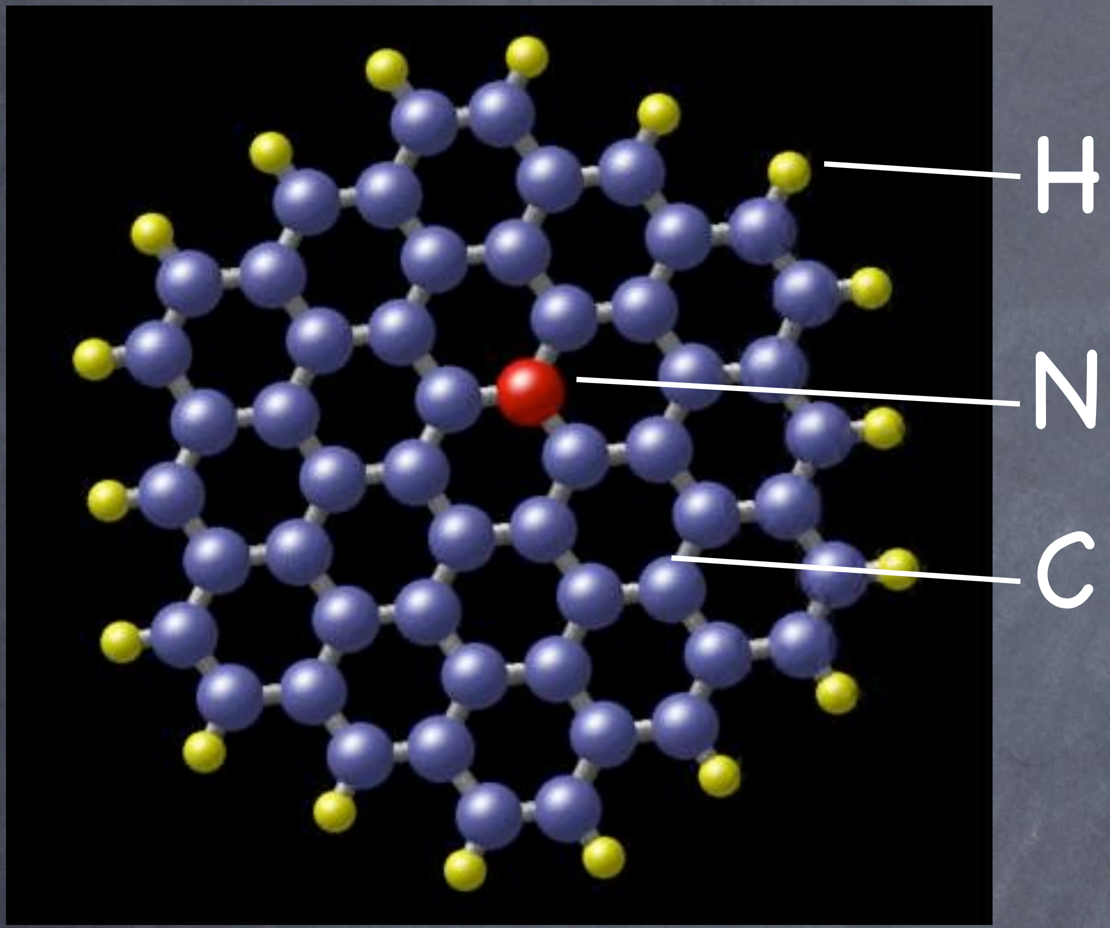
Hudgins et al. ApJ, 2005

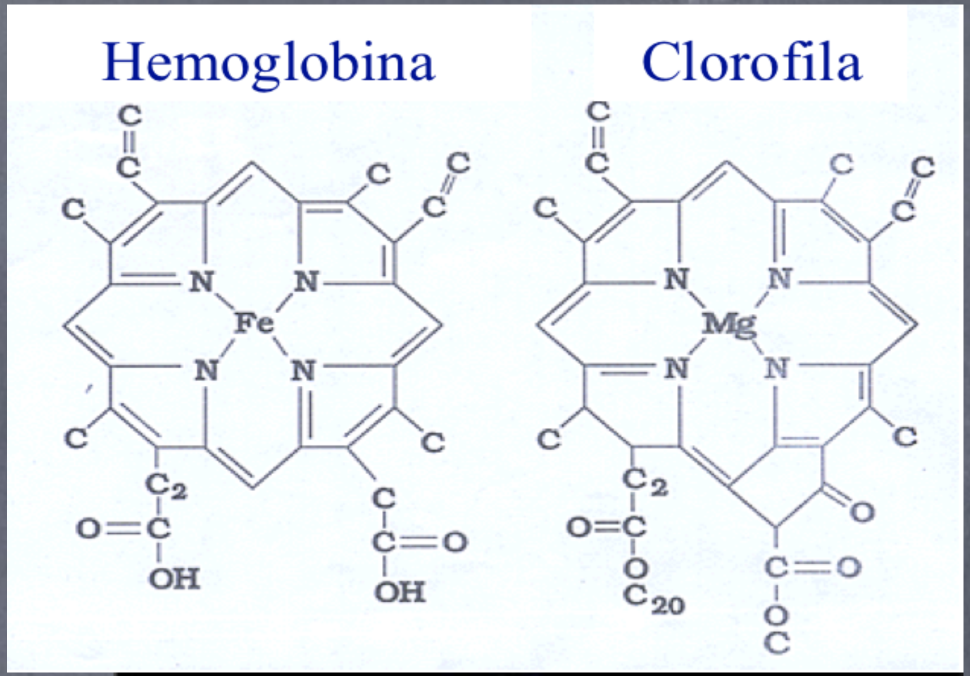


- PANH - Polycyclic Aromatic Nitrogen Hydrocarbons
- Detected by the Spitzer satellite in other galaxies, as well as in ours
- First evidence of an interesting prebiotic compound in space
- Presence of N is important in biologically relevant compounds (clorophyl and hemoglobin)

Detection of a PANH in the IR band

Hudgins et al. ApJ, 2005





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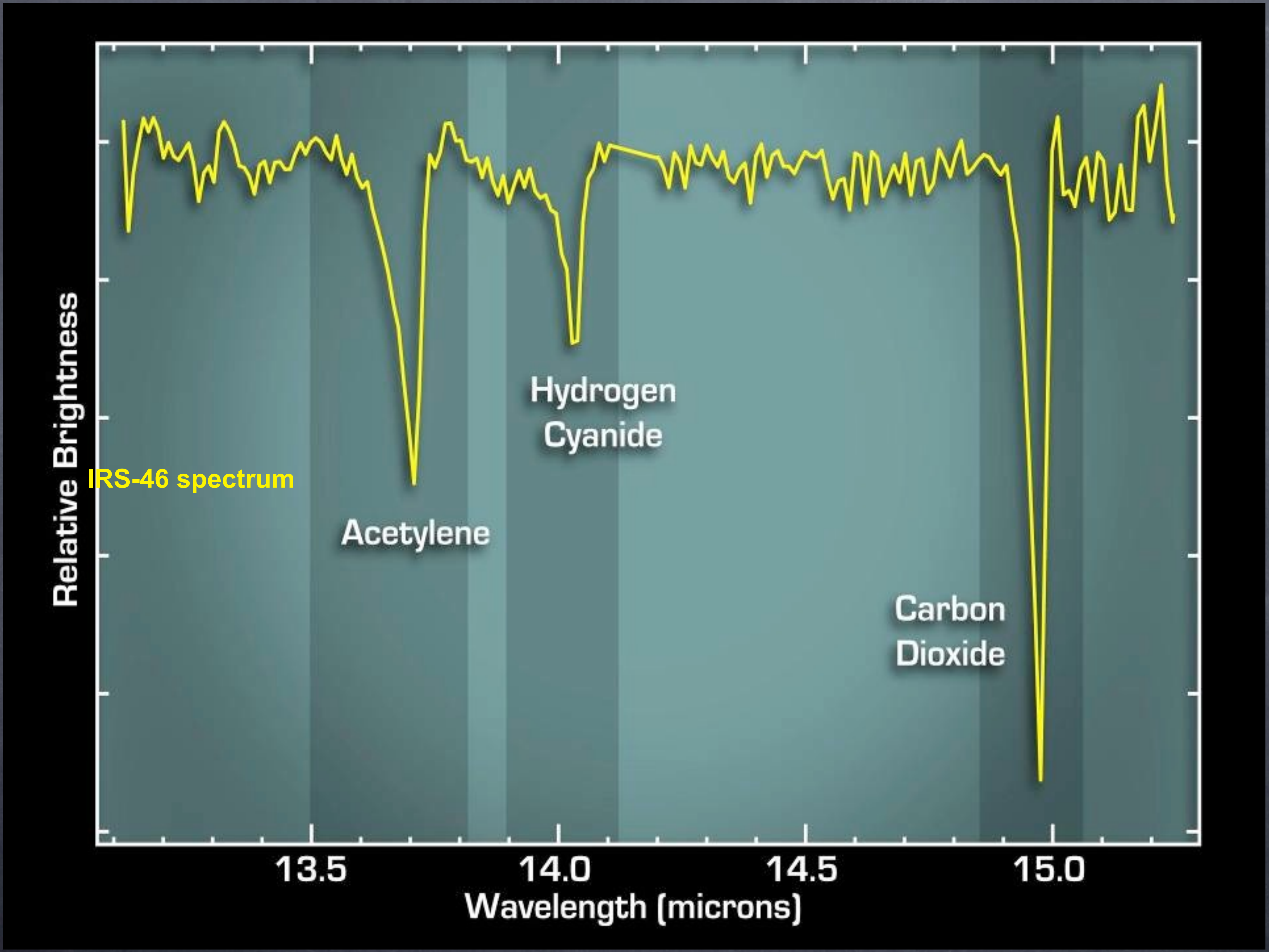
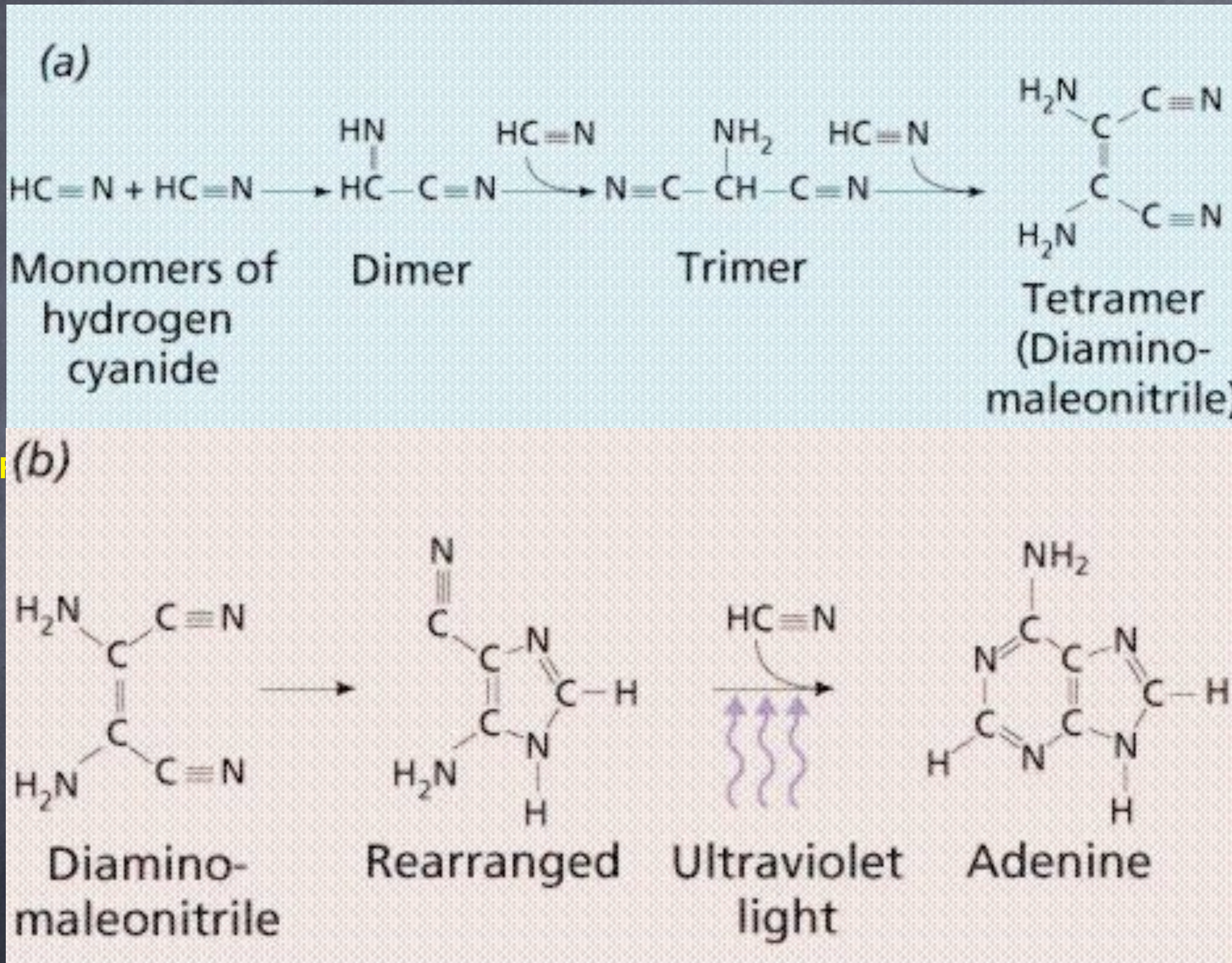
http://www.nasa.gov/lb/vision/universe/starsgalaxies/spitzer-20051220.html





Saladino et al. Current Organic Chemistry, 8, 15, 1425-1443 (October 2004)

Science News

Share Blog Cite

Two Highly Complex Organic Molecules Detected In Space

ScienceDaily (Apr. 22, 2009) — Scientists from the Max Planck Institute for Radio Astronomy (MPIfR) in Bonn, Germany, Cornell University, USA, and the University of Cologne, Germany, have detected two of the most complex molecules yet discovered in interstellar space: ethyl formate and n-propyl cyanide.

See Also:

Space & Time
- Astrophysics
- Space Telescopes
- Astronomy

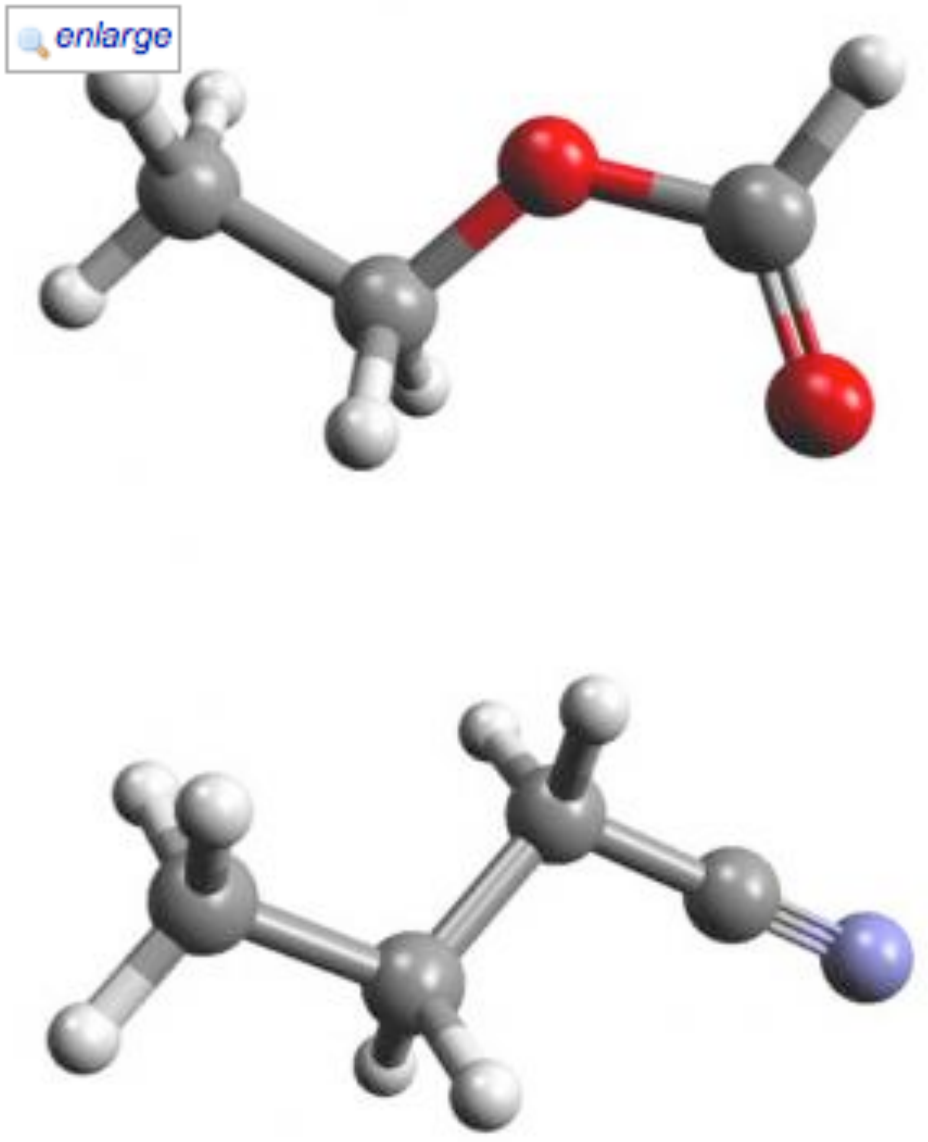
Matter & Energy
- Organic Chemistry
- Chemistry
- Nature of Water

Reference
- Molecule
- Interstellar medium
- Spectroscopy
- Radio telescope

Their computational models of interstellar chemistry also indicate that yet larger organic molecules may be present -- including the so-far elusive amino acids, which are essential for life.

The results will be presented at the European Week of Astronomy and Space Science at the University of Hertfordshire on Tuesday 21st April.

The IRAM 30 m telescope in Spain was used to detect emission from molecules in the star-forming region Sagittarius B2, close to the center of our galaxy. The two new molecules were detected in a hot, dense cloud of gas known as the "Large Molecule Heimat", which contains a luminous newly-formed star. Large, organic molecules of many different sorts have been detected in this cloud in the past, including alcohols, aldehydes, and acids. The new molecules ethyl formate (C_2H_5OCHO) and n-propyl cyanide (C_3H_7CN) represent two different classes of molecule -- esters and alkyl



Two new highly complex organic molecules detected in space. Top: Ethyl formate (C2H5OCHO). Bottom: n-Propyl cyanide (C3H7CN). Colour code of the atomic constituents of both molecules: hydrogen (H): white, carbon (C): grey, oxygen (O): red and nitrogen (N): blue. (Credit: Oliver Baum, University of Cologne)

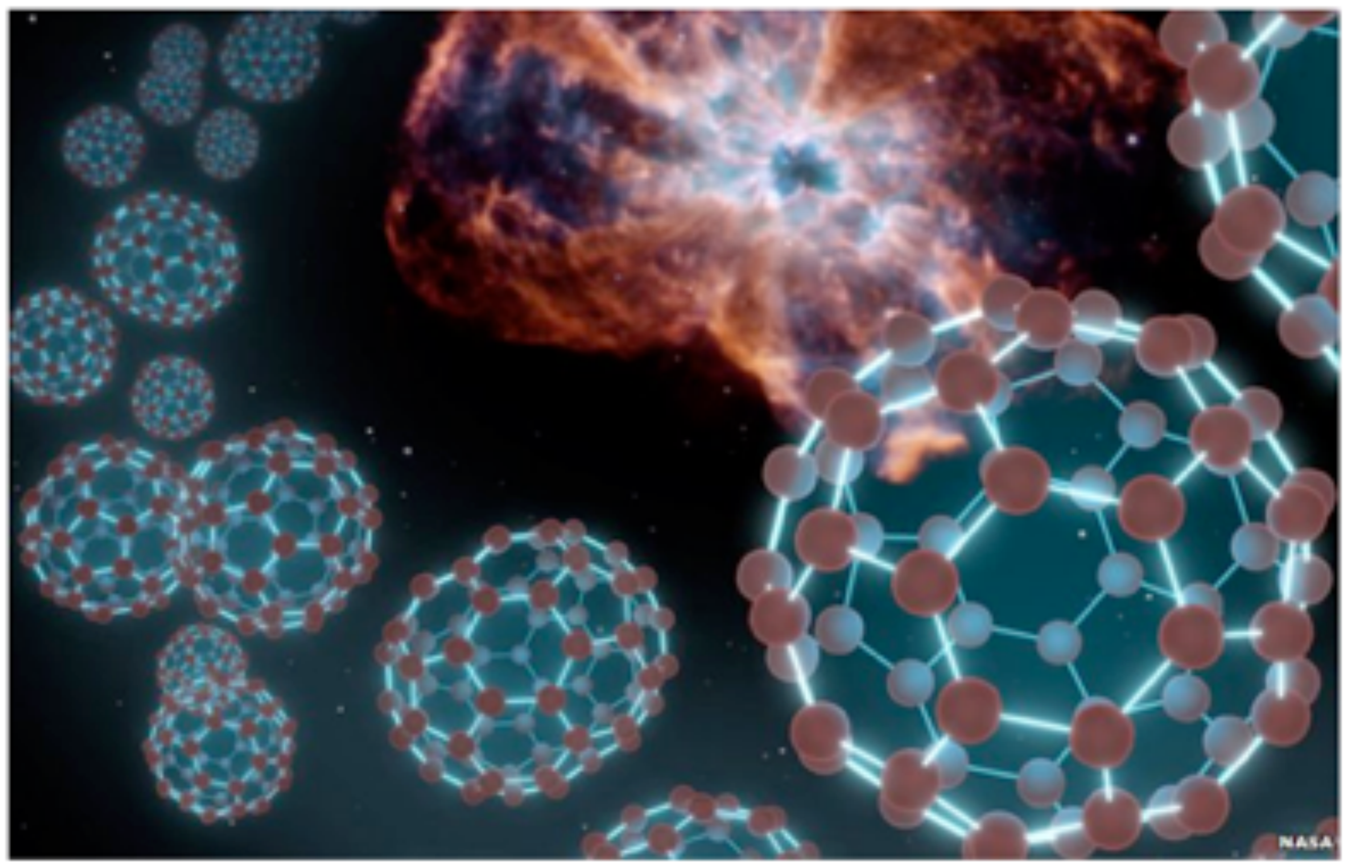
NEWS SCIENCE & ENVIRONMENT

Home | UK | Africa | Asia-Pac | Europe | Latin America | Mid-East | South Asia | US & Canada | Busines
Video

Grafene and C70 detected around planetary nebulae (2011 Aug 15) in the infrared band by the Spitzer satellite in the Magellanic Clouds

Stars reveal carbon 'spaceballs'

By Victoria Gill
Science reporter, BBC News



The football-shaped molecules are the largest molecules ever found in space

Scientists have detected the largest molecules ever seen in space, in a cloud of cosmic dust surrounding a distant star.

The football-shaped carbon molecules are known as buckyballs, and were only discovered on Earth 25 years ago when they were made in a laboratory.

Prebiotic biochemical compounds are common in the Universe and the necessary energy sources have been available "for eons of time"

Abundant amounts of "building blocks"

X

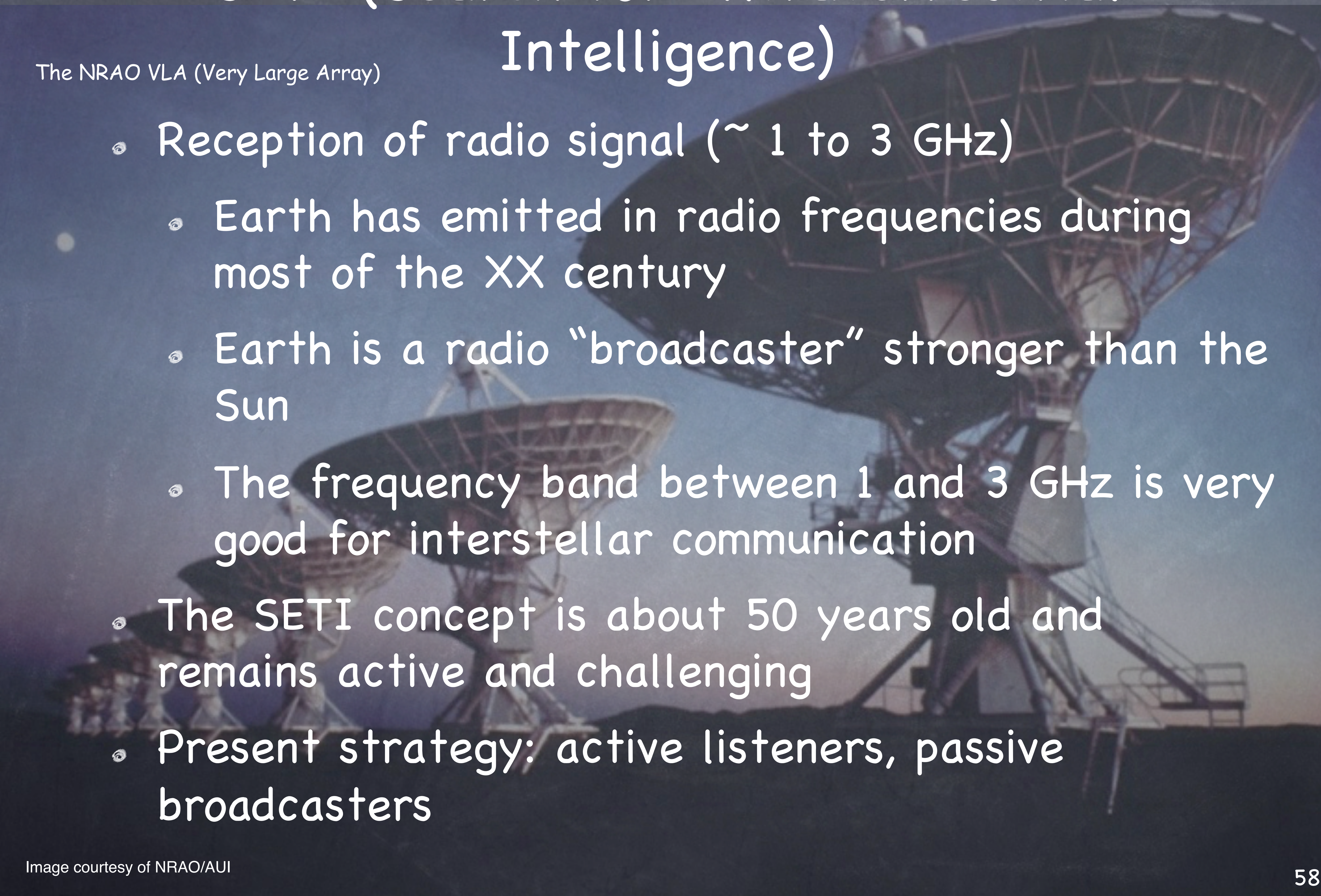
Almost zero probability (1^{100}) of random molecular self-assembly

However, once appearing on Earth, life was not extinguished later, "evolving" since then!

The **S**arch for **E**xtra**T**errestrial **I**ntelligence: **SETI**

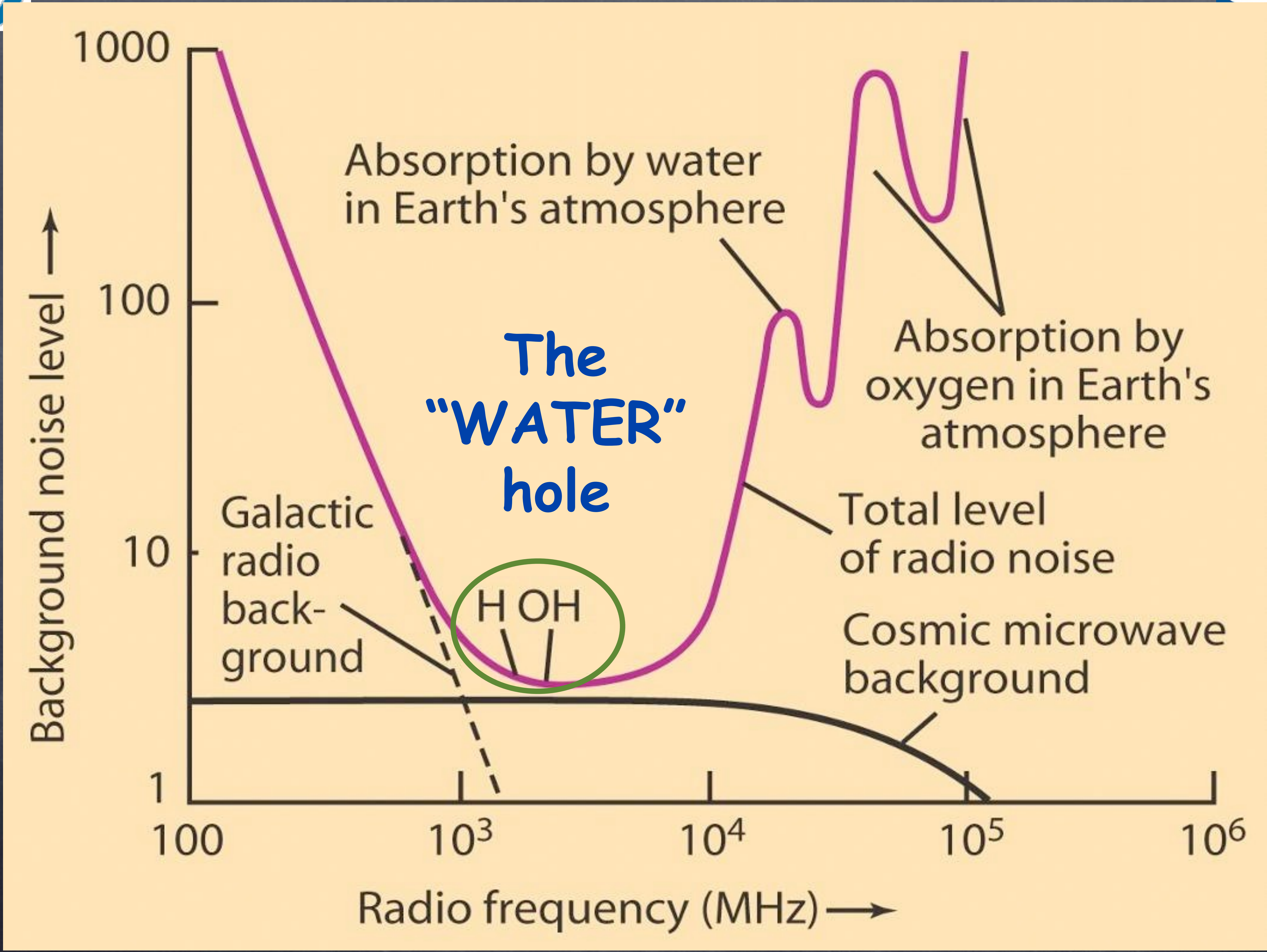
SETI (Search for Extraterrestrial Intelligence)

The NRAO VLA (Very Large Array)



- Reception of radio signal (~ 1 to 3 GHz)
  - Earth has emitted in radio frequencies during most of the XX century
  - Earth is a radio "broadcaster" stronger than the Sun
  - The frequency band between 1 and 3 GHz is very good for interstellar communication
- The SETI concept is about 50 years old and remains active and challenging
- Present strategy: active listeners, passive broadcasters

Image courtesy of NRAO/AUI



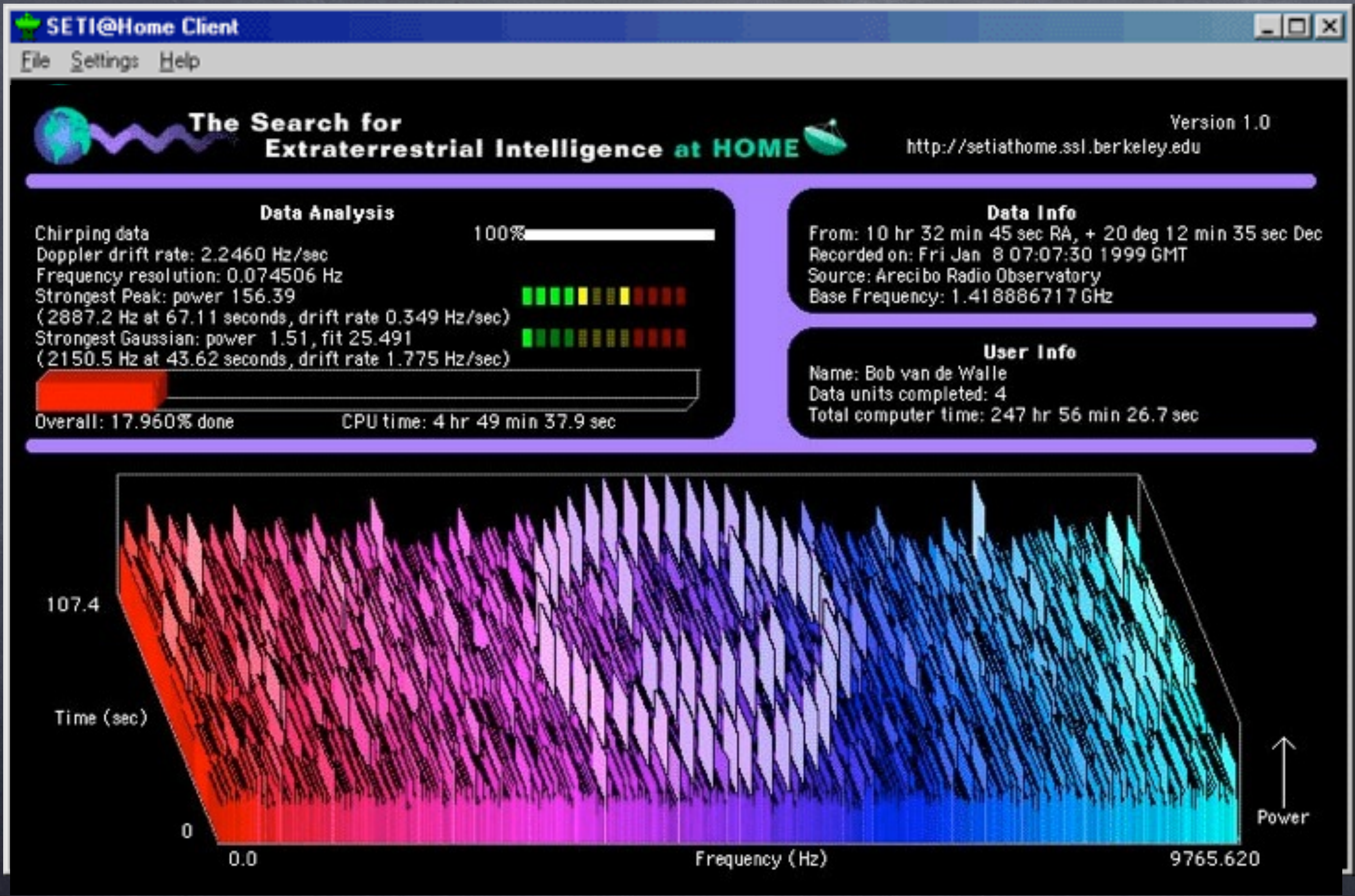
1000
100
10
1
Background noise level
Absorption by water in Earth's atmosphere
Absorption by oxygen in Earth's atmosphere
The "WATER" hole
H OH
Galactic radio back- ground
Total level of radio noise
Cosmic microwave background
100
10^3
10^4
10^5
10^6
Radio frequency (MHz)

Your account

SETI@HOME

HOME | PARTICIPATE | ABOUT | COMMUNITY | ACCOUNT | STATISTICS

Account information	
Name	Carlos Alexandre Wuensche
Email address	ca.wuensche@inpe.br
URL	http://www.das.inpe.br/~alex
Country	Brazil
Postal code	12227-210
SETI@home member since	25 May 1999
Change	email address · password · other account info
User ID *Used in community functions*	1352239
Account keys	View
Preferences	
When and how BOINC uses your computer	Computing preferences
Message boards and private messages	Community preferences
Preferences for this project	SETI@home preferences
Computing and credit	
Total credit	232,843
Recent average credit	1.53
SETI@home classic workunits	1,147
SETI@home classic CPU time	5,532 hours
Pending credit	View
Computers on this account	View
Tasks	View
Cross-project statistics	Free-DC BOINCstats


SETI@Home Client
File Settings Help
The Search for Extraterrestrial Intelligence at HOME
Version 1.0
http://setiathome.ssl.berkeley.edu
Data Analysis
Chirping data
100%
Doppler drift rate: 2.2460 Hz/sec
Frequency resolution: 0.074506 Hz
Strongest Peak: power 156.39
(2887.2 Hz at 67.11 seconds, drift rate 0.349 Hz/sec)
Strongest Gaussian: power 1.51, fit 25.491
(2150.5 Hz at 43.62 seconds, drift rate 1.775 Hz/sec)
Overall: 17.960% done
CPU time: 4 hr 49 min 37.9 sec
Data Info
From: 10 hr 32 min 45 sec RA, + 20 deg 12 min 35 sec Dec
Recorded on: Fri Jan 8 07:07:30 1999 GMT
Source: Arecibo Radio Observatory
Base Frequency: 1.418886717 GHz
User Info
Name: Bob van de Walle
Data units completed: 4
Total computer time: 247 hr 56 min 26.7 sec
107.4
Time (sec)
0
0.0
Frequency (Hz)
9765.620
Power

SETI results

- From the technical point of view, it is presently possible to detect signals with equivalent power of a TV station at 1 l.y., a militar radar at 300 l.y. or a planetary radar like Arecibo at 3000 l.y.
- Ongoing SETI projects: SETI@home, Serendip, IR excess, JPL/SETI spectrometer, Optical SETI (as of late 2012)
- Since early 60s, there were ~ 100 science projects related to SETI, but with no significant results so far
- Huge volume to explore and relatively low sensitivity of the instruments (needed to be 10^5 times better)
- The Allen Telescope Array: present & future for radio SETI (350 antennas operating between 1 GHz and 10 GHz, with state-of-the-art receiver technology, but everything else "off-the_shelf")

Summary

Results from the last 20 years

- Chemical elements and basic astrophysical/astrochemical conditions for life (as we know it) to emerge seem to be a common ground in the Universe
- Life in extreme environmental conditions exist on Earth and may survive in space, under proper conditions
- We are quickly reaching 1000 exoplanets and some similar in size to our Earth
- The search for signals from an extraterrestrial intelligence has not shown any confirmed positive results, after almost 50 years

Perspectives

- Radiotelescopes, satellites and space missions will continue searching for evidence of biotracers on planets and satellites in our solar system
- The same is valid for extraterrestrial planets and signs of intelligent life in nearby stars
- Extremophiles are, by far, our best bet for ETs (as of now)
- Although it can be very challenging, we can do the exercise of imagining life based upon other processes other than our "biochemistry model" (Bains, Astrobiology, 4, 137 (2004)) to open our eyes for forms of life **"AS WE DO NOT KNOW IT".**


Shake-speare's sonnets
edited with analytic commentary by Stephen Booth
Canon triplex à 6 Voc.
per J. S. Bach
THANK YOU!

Mars surface

Comparison between polygons photographed by Phoenix on Mars...

... and as photographed (in false color) from Mars orbit...

... with patterned ground on Devon Island in the Canadian Arctic, on Earth.

The chemical complexity of life

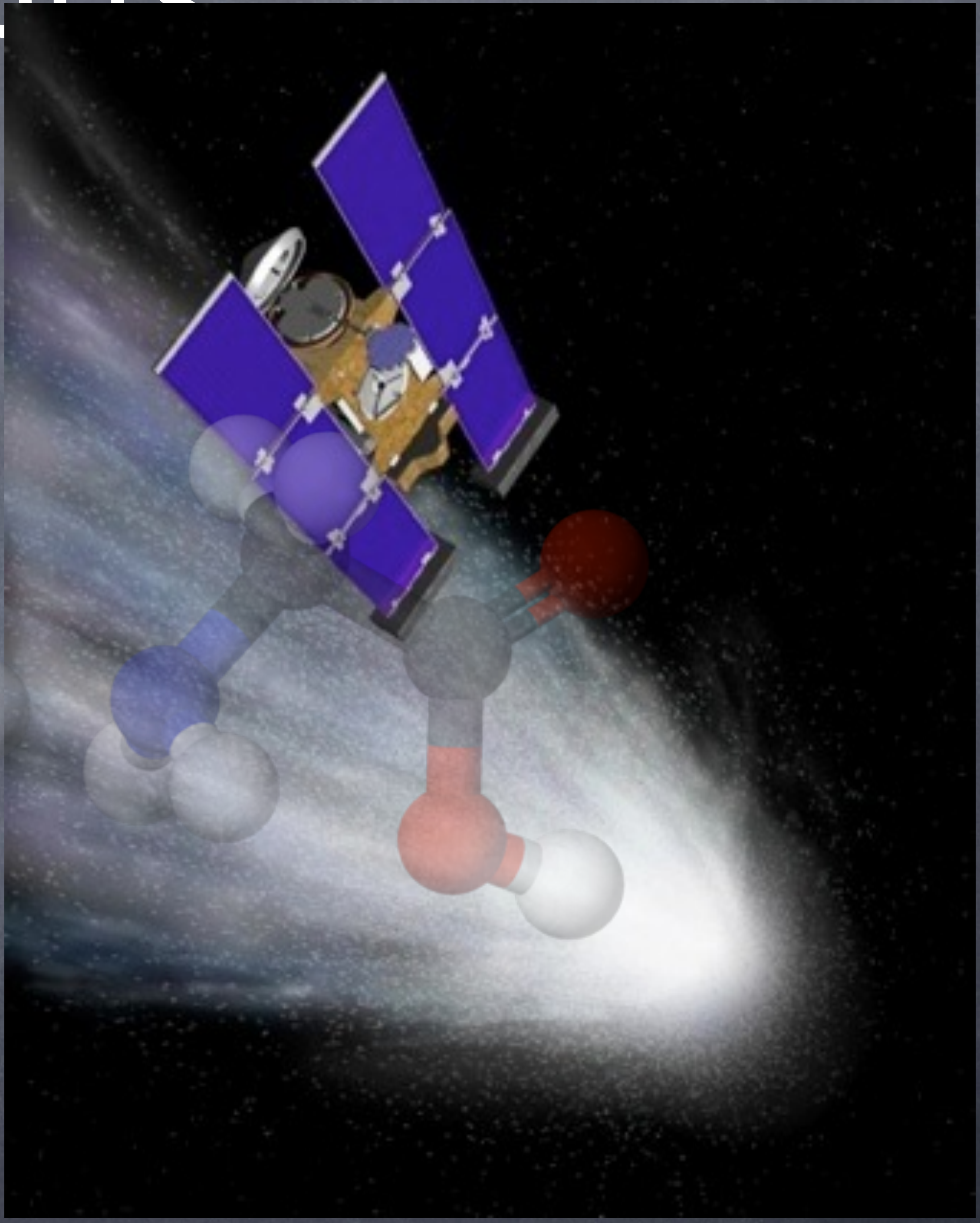
- Life building blocks:
  - Hydrogen (H)
  - Carbon (C)
  - Nitrogen (N)
  - Oxygen (O)
  - Sulfur (S)
  - Iron (Fe)
  - Magnesium (Mg)
  - Phospor (P)

They are used to build aminoacids, sugars and nucleotides which, on their turn, are assembled to create the organic polymers necessary for life as we know it: polysaccharids, proteins e nucleic acids

Important class for membrane formation: **lipids**

Stardust results

- Glycin (NH_2CH_2COOH) found in the gaseuous and dust region surrounding the cold core around Wild-2 comet
- Measurements: 2004
- Result: Aug 19, 2009
- Previously also (possibly) found in star-forming regions
- The smallest (simplest) life aminoacid used in life forms.

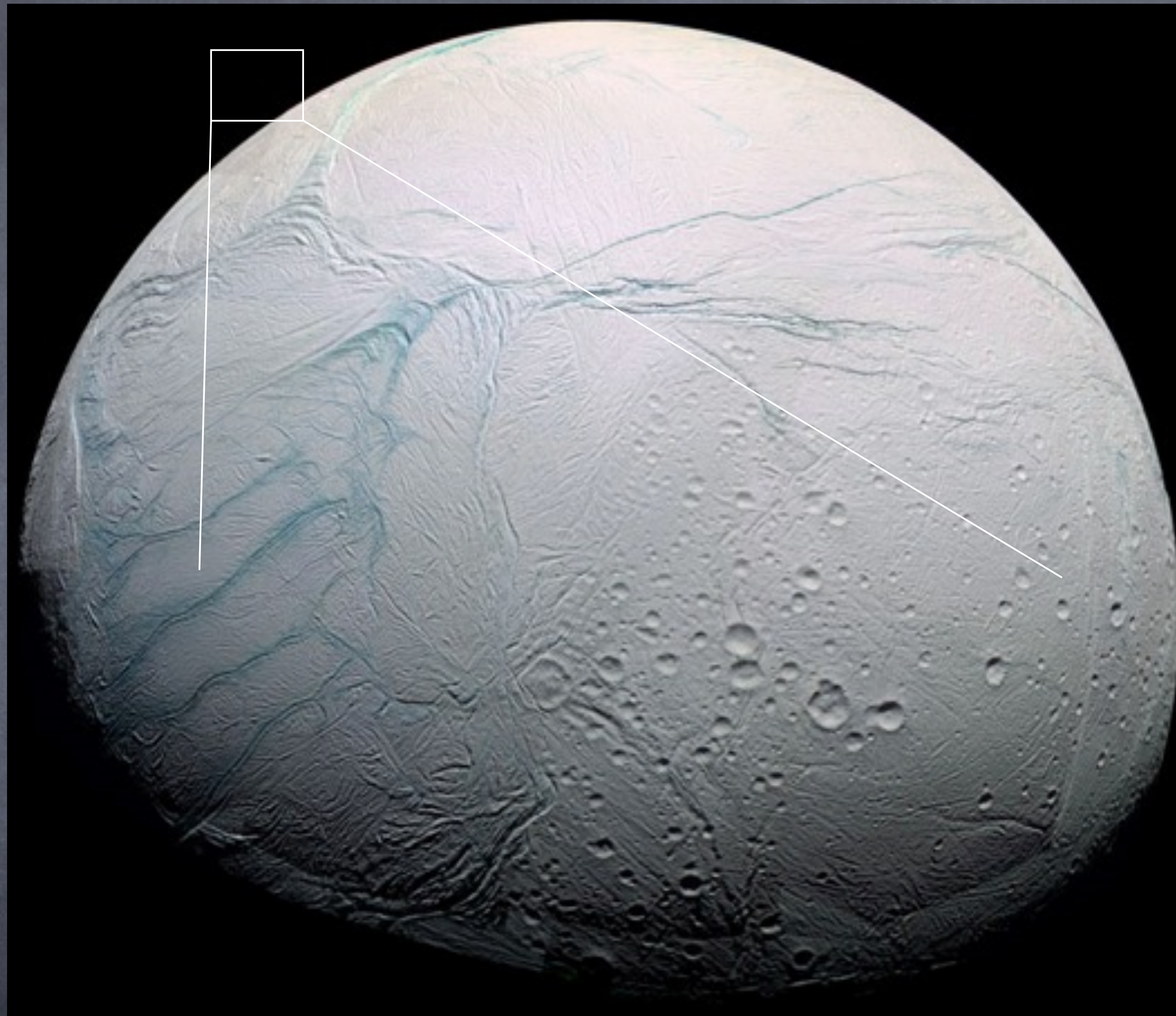


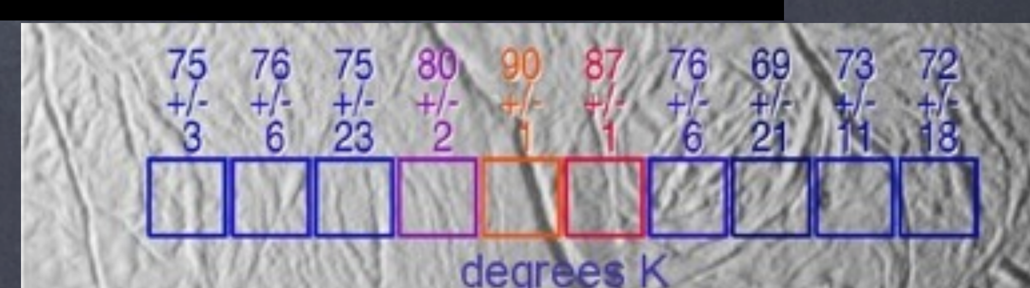
http://stardust.jpl.nasa.gov/

The timeline for habitability on Earth

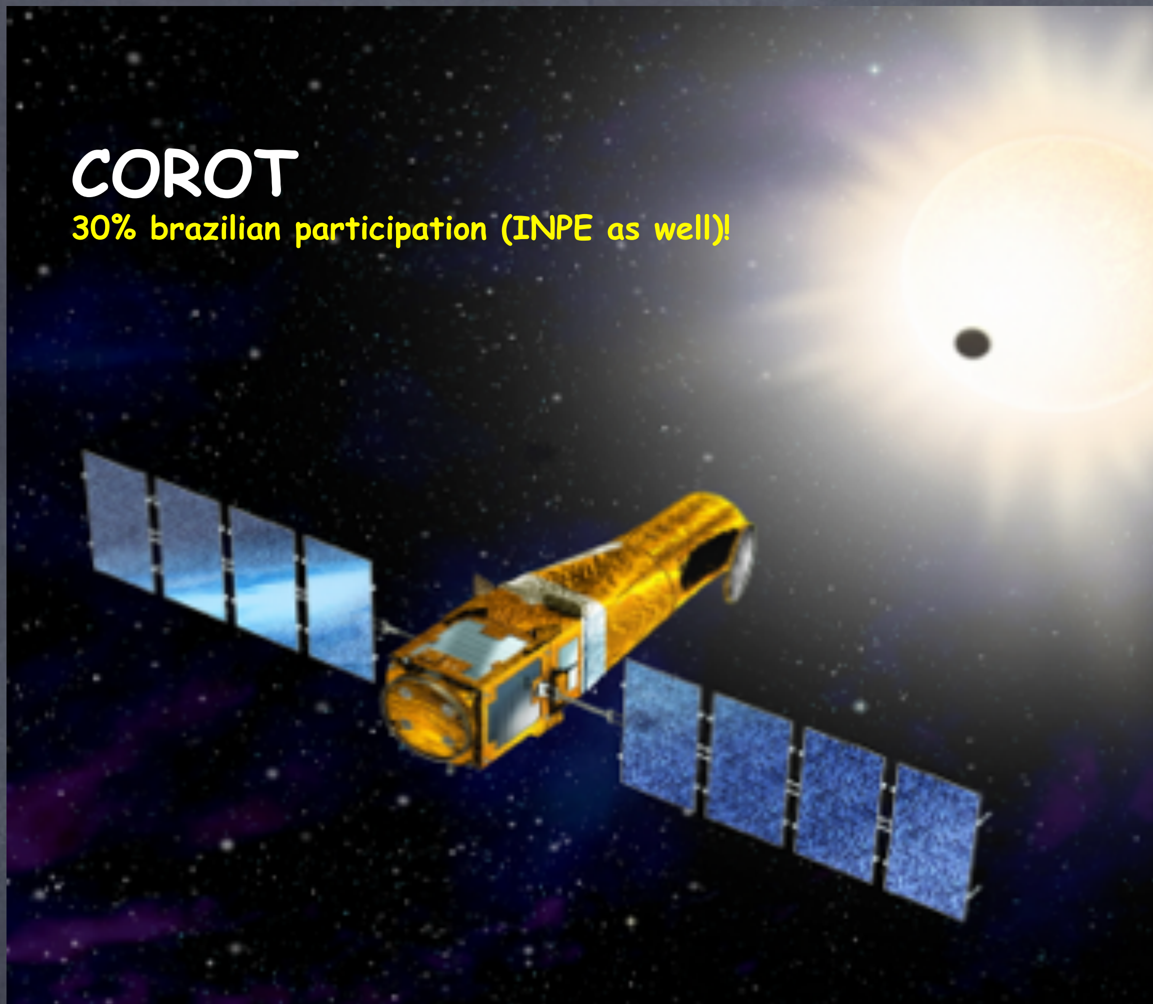
- Liquid water allowed microbes to originate and evolve
- Plate tectonics replenished CO_2 for life to persist
- Earth's magnetic field shielded atmospheric gases from (except H, He)
- Microbes produced O_2, CH_4 ⇒ CH4 then O_2 dominated
- Ozone layer formed ~ 2.3 billion years
- Simple algae, fungi developed
- More O_2 and animals @ 600 million years
- Human ancestors @ 2 million years
- ISU 2013...

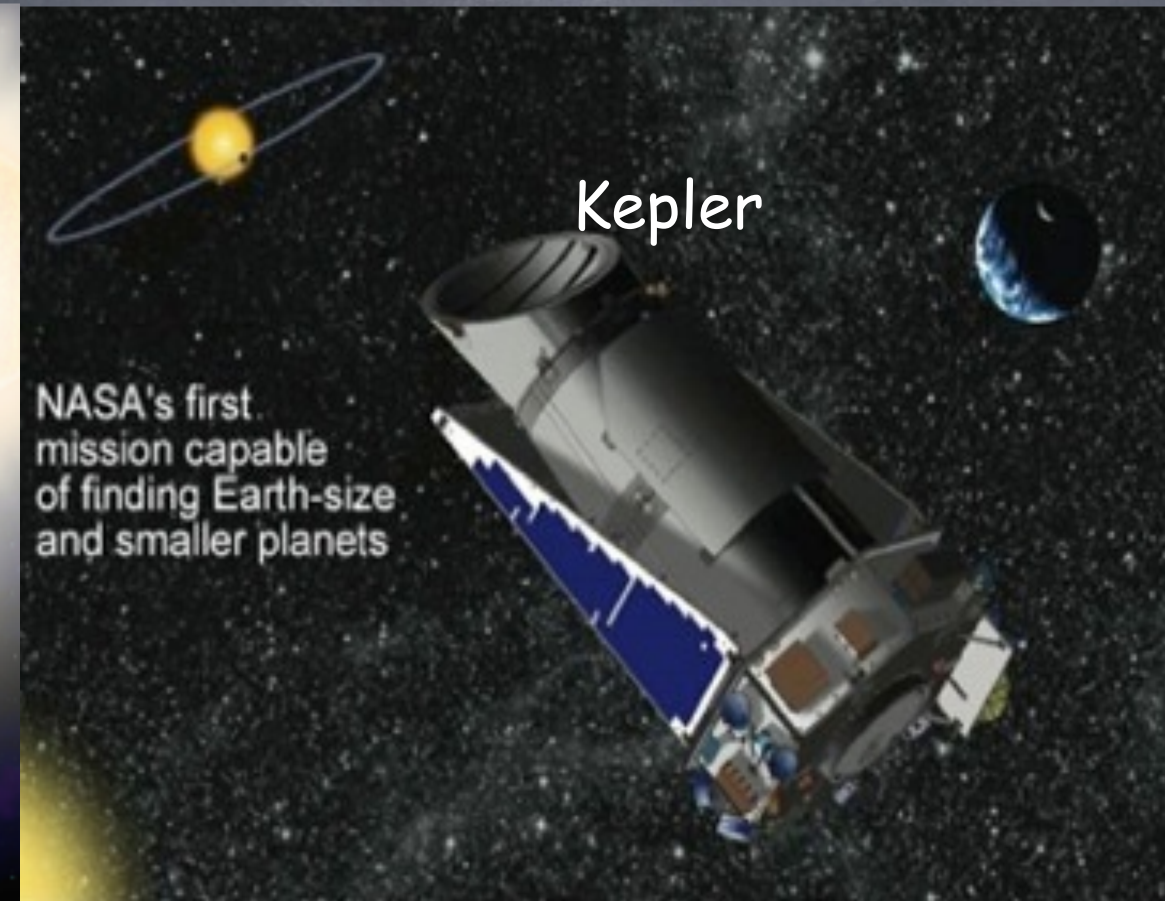
Likely region for water ejection from Enceladus surface





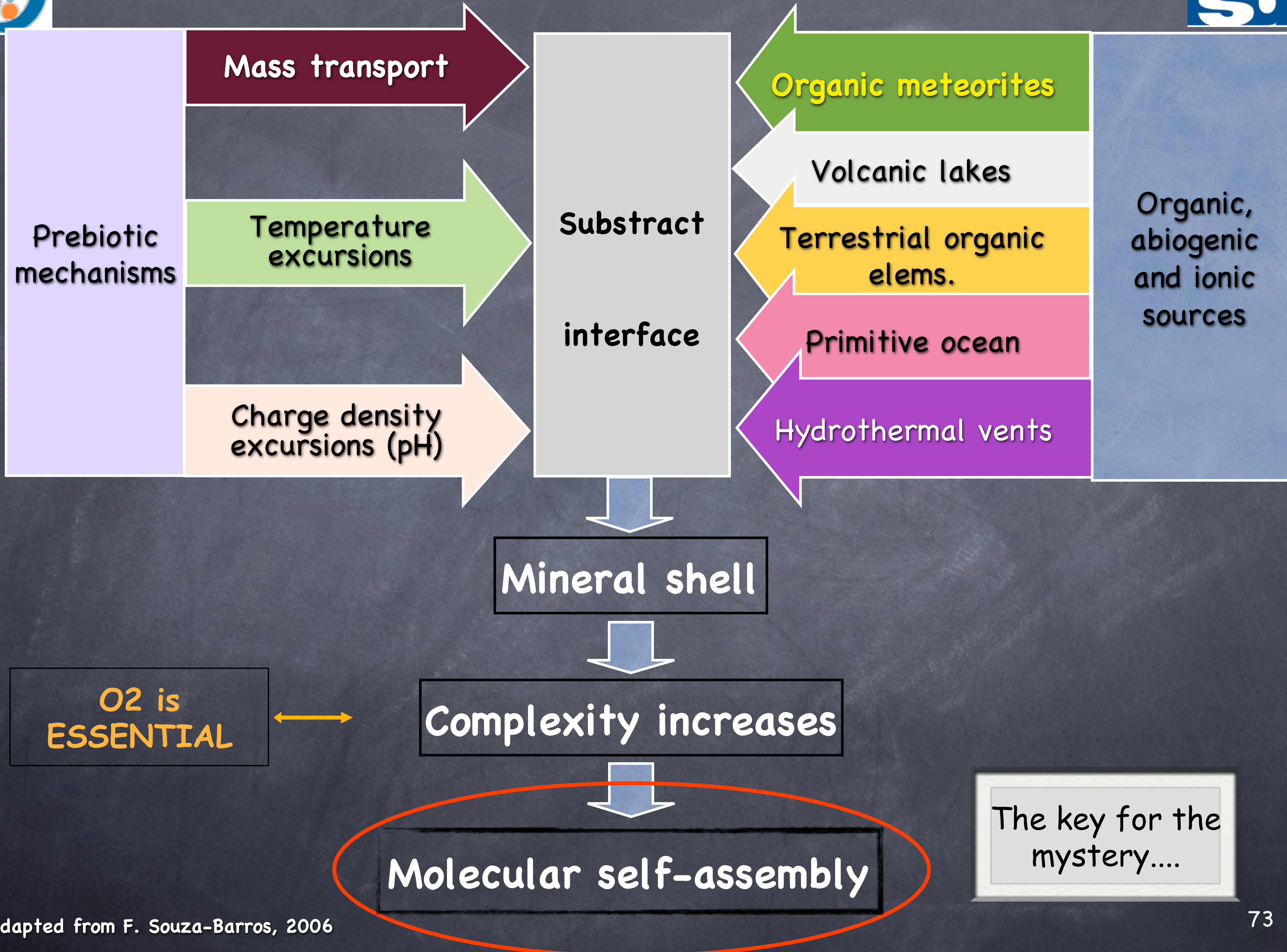
http://science.nasa.gov/headlines/y2006/09mar_enceladus.htm


COROT
30% brazilian participation (INPE as well)!


Kepler
NASA's first
mission capable
of finding Earth-size
and smaller planets

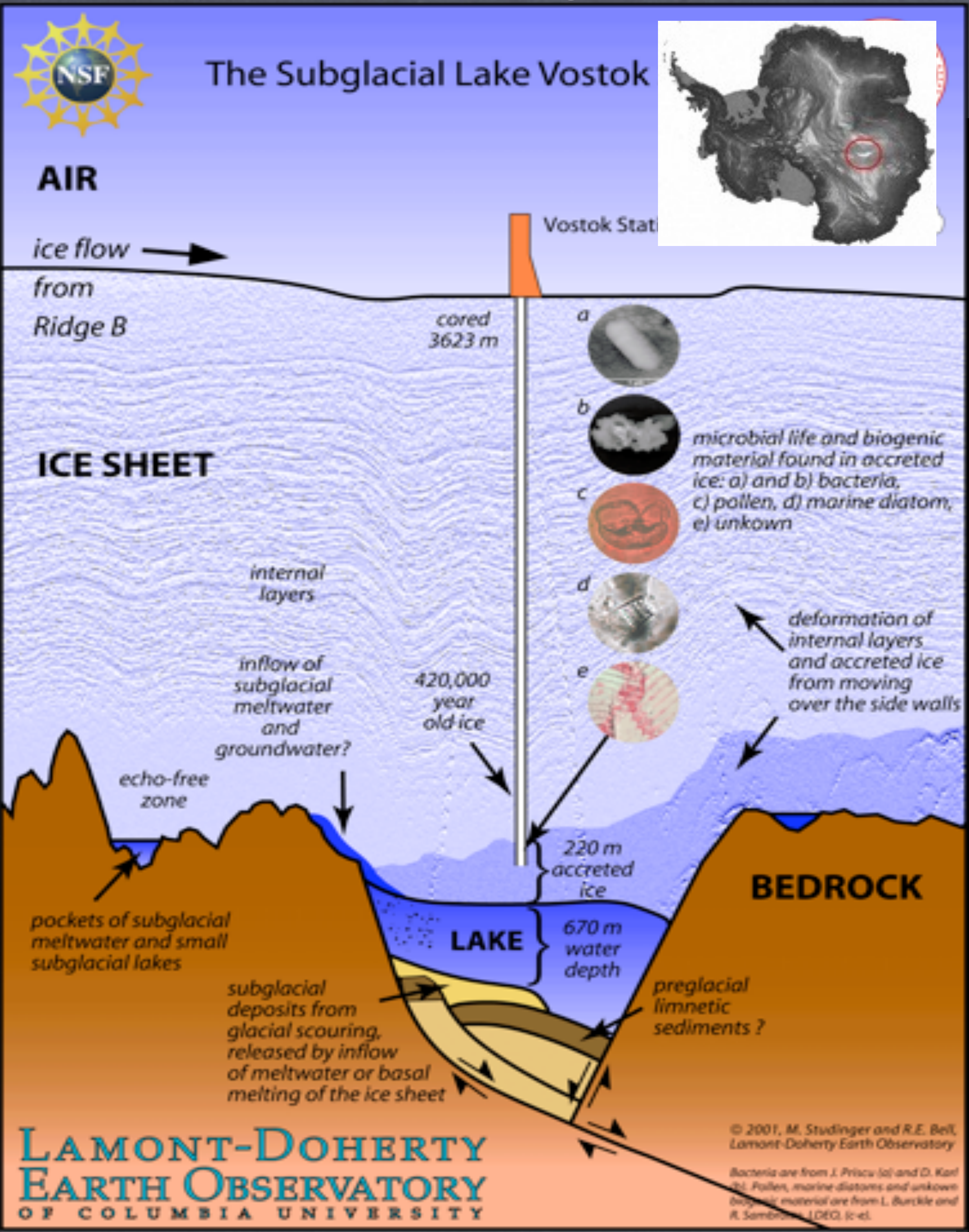

TPF (Terrestrial Planet Finder)


Darwin

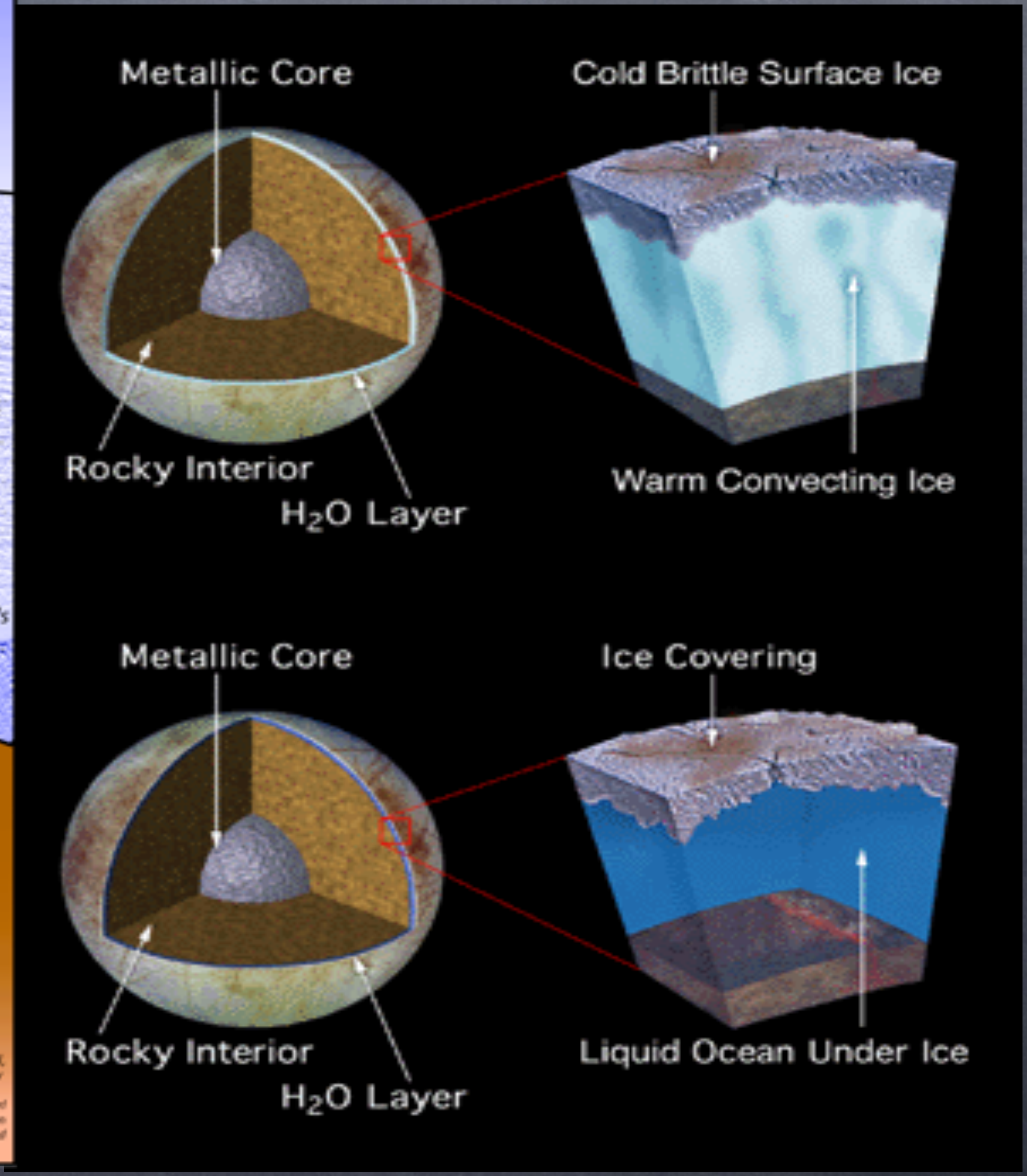


Adapted from F. Souza-Barros, 2006

Life in subglacial systems



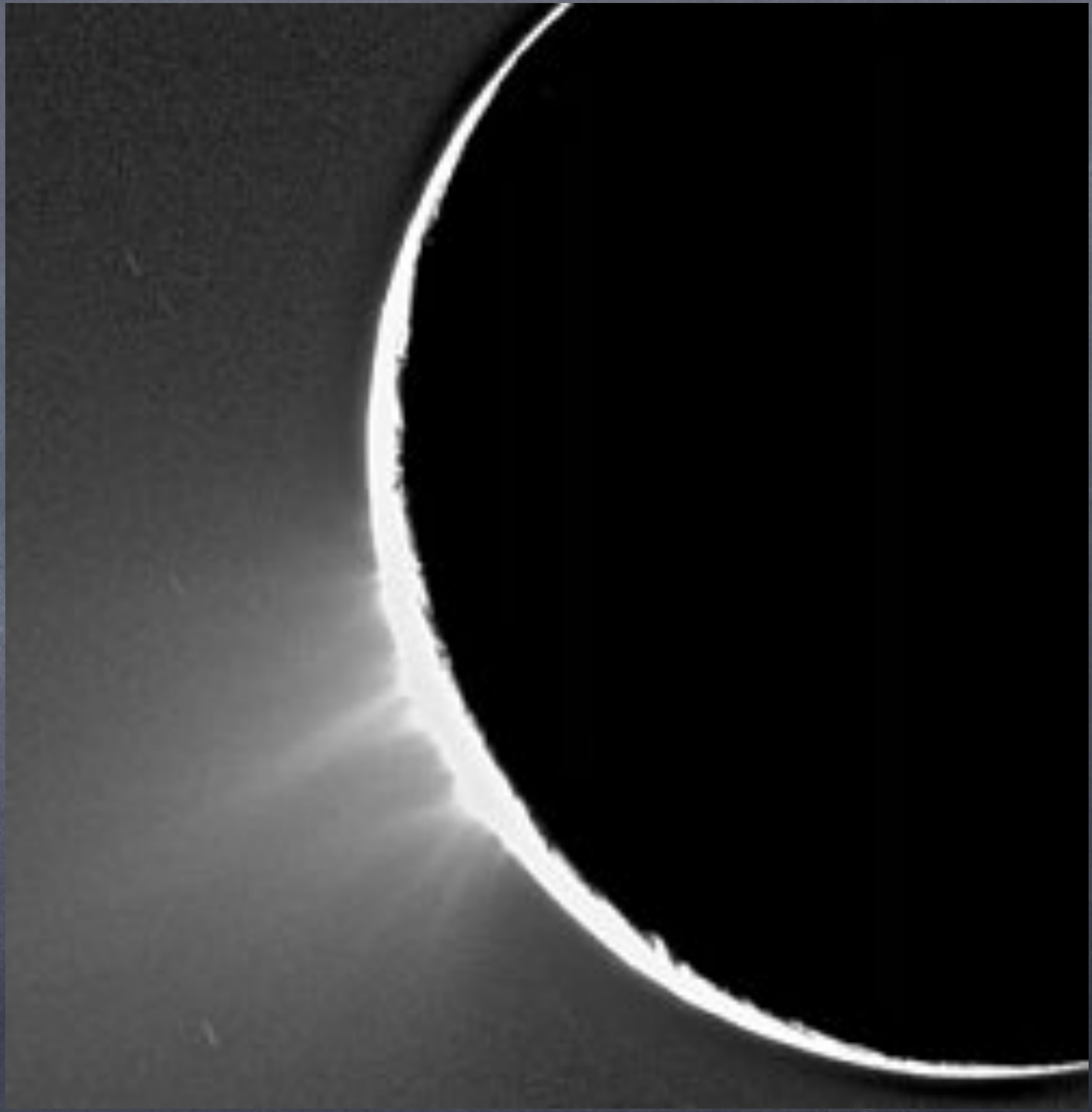
Europa



Water in Enceladus?

- Cassini observations indicate the existence of liquid water coming from an eruption (Nasa News, March 09, 2006).

- Presence of vulcanism



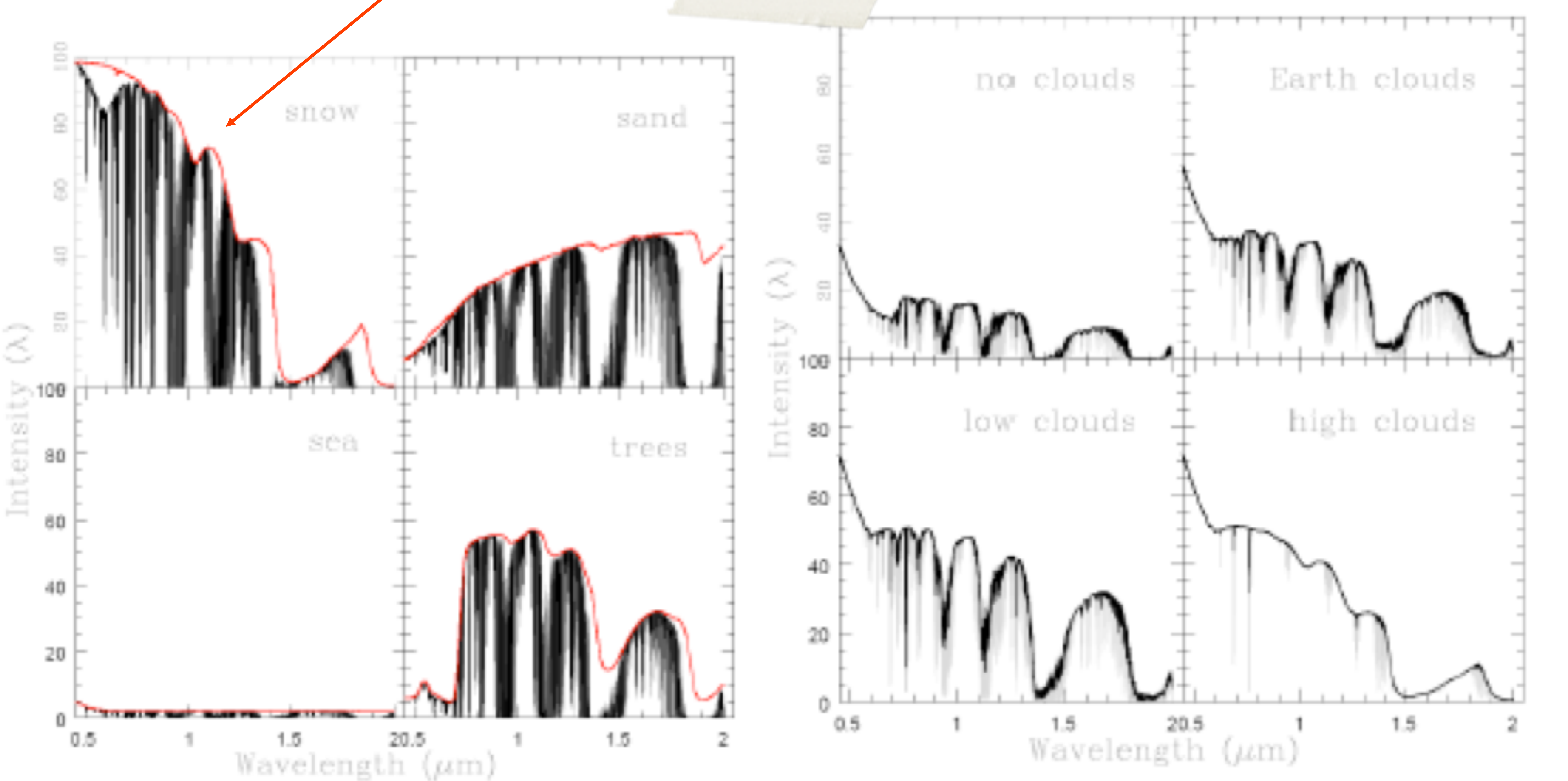
http://science.nasa.gov/headlines/y2006/09mar_enceladus.htm

The astronomical search for the origins

LIFE!!!! But not necessarily intelligent...

The effects of clouds on Earth's spectrum

Albedo

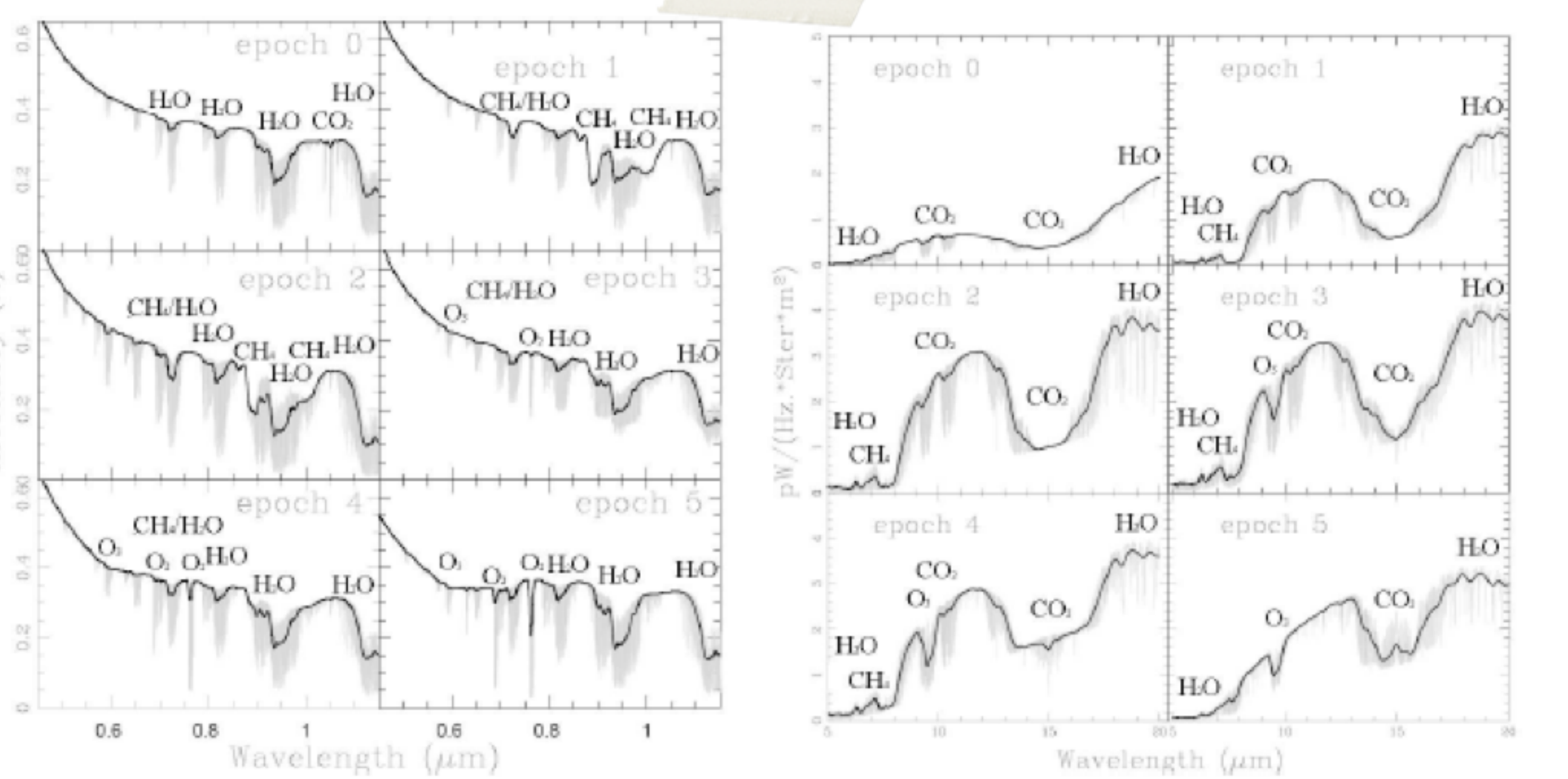


Kaltenneger et al., astro-ph/0512053

Kaltenneger et al., astro-ph/0512053

Optical

Infrared

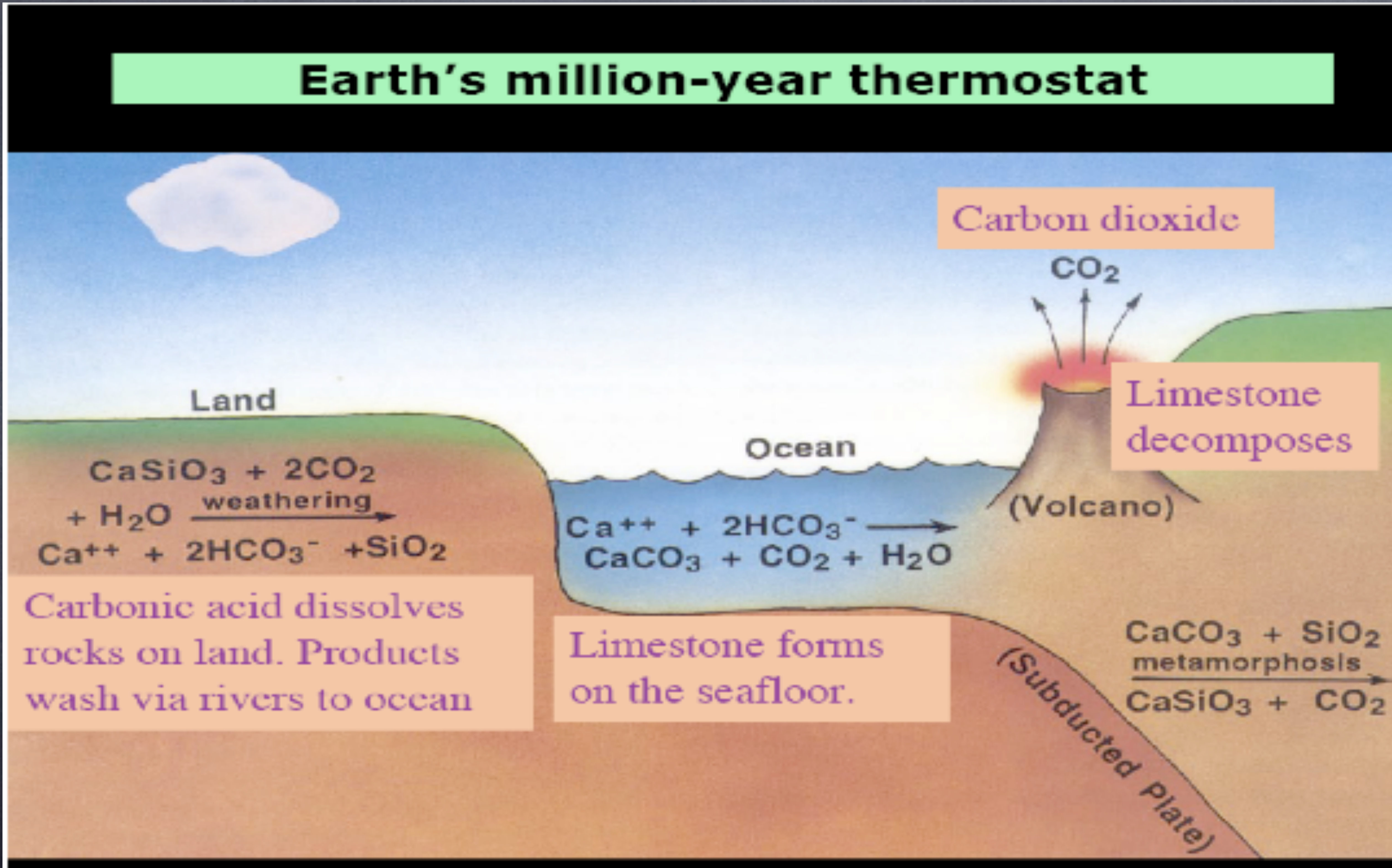


Epoch 0: 3,9 Gyears, rich in CO2

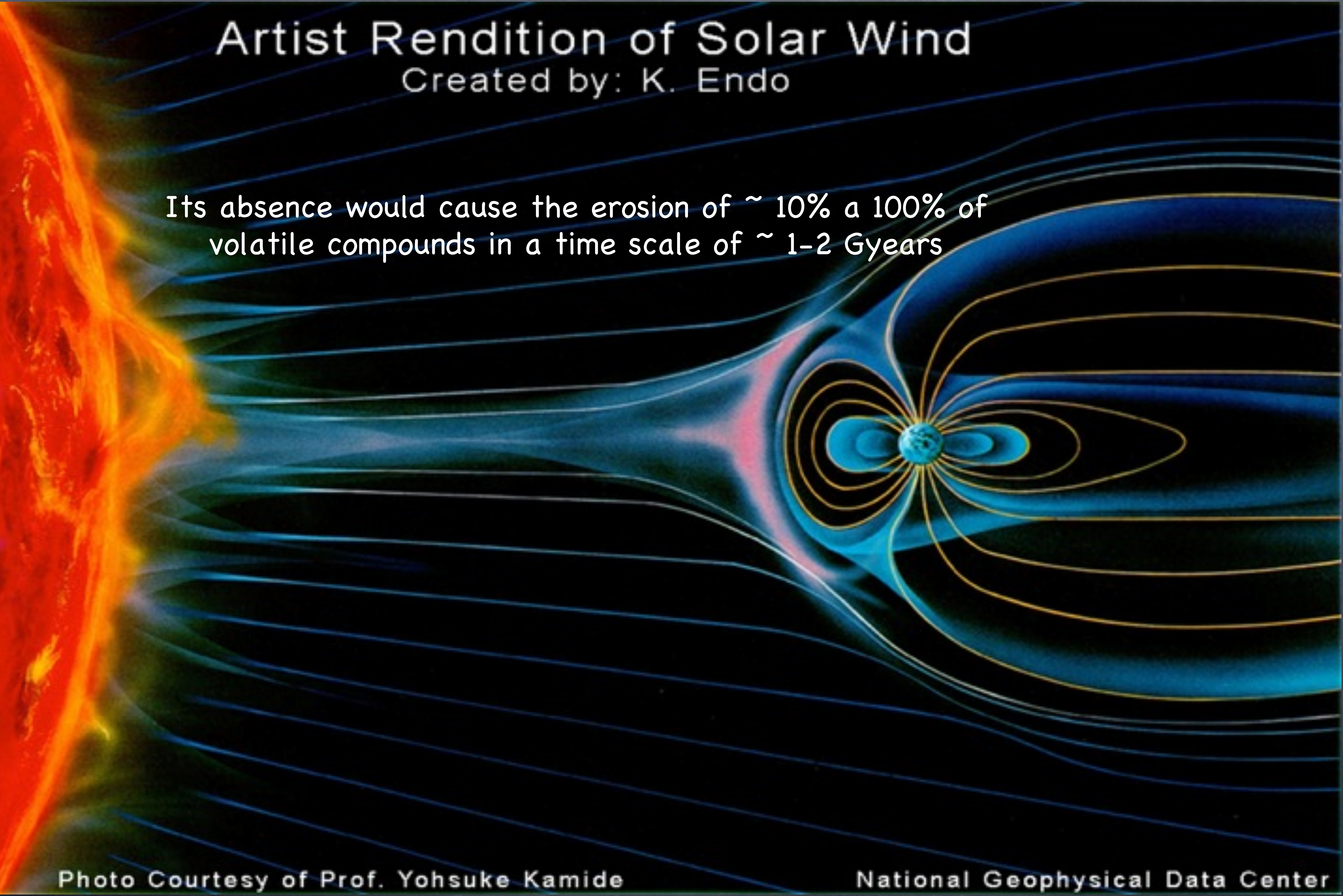
Epoch 5: today, rich in O2

Epoch 3: ~ 2 Gyears, Rich in CO2/CH4

Cycle Carbon compounds - Silicates



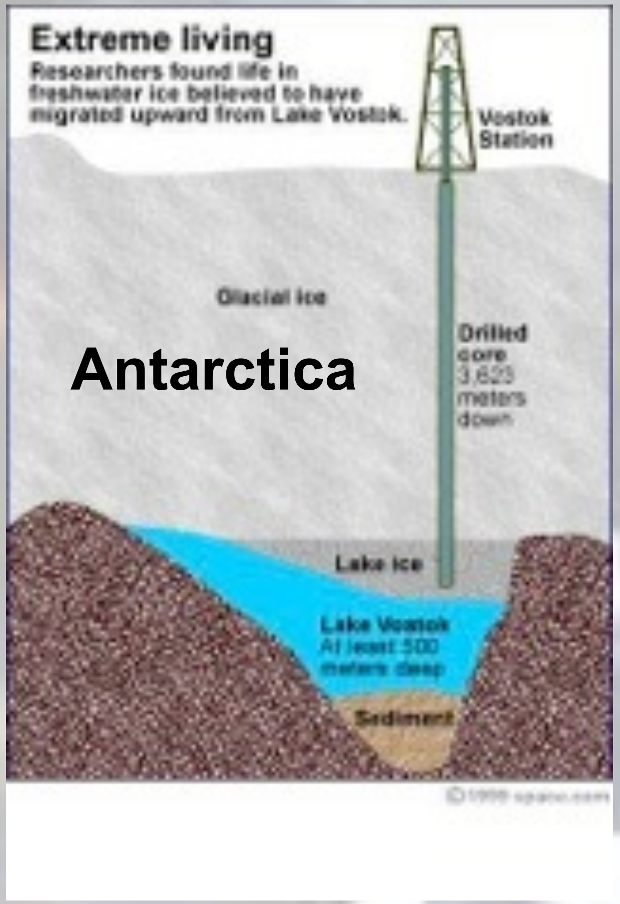
Magnetic fields

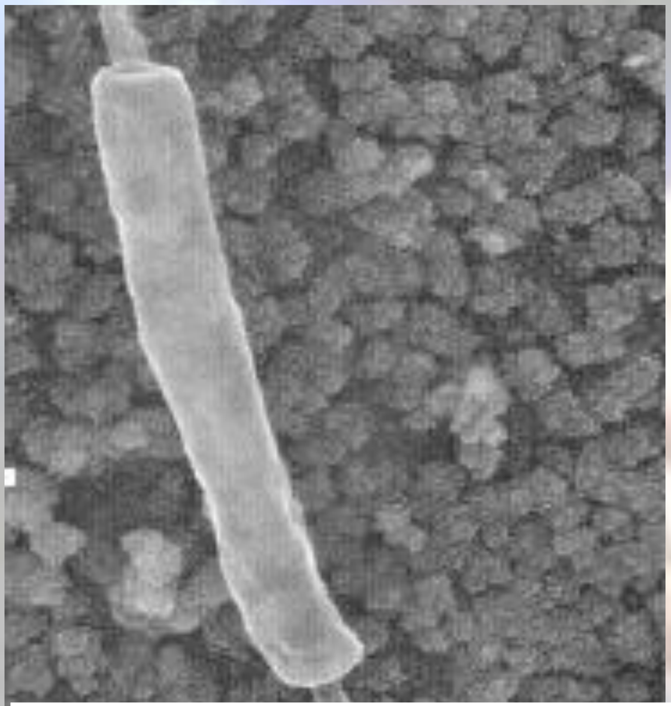


Its absence would cause the erosion of ~ 10% a 100% of volatile compounds in a time scale of ~ 1-2 Gyears

Extremophiles' survival chart

Hidrotermal vents

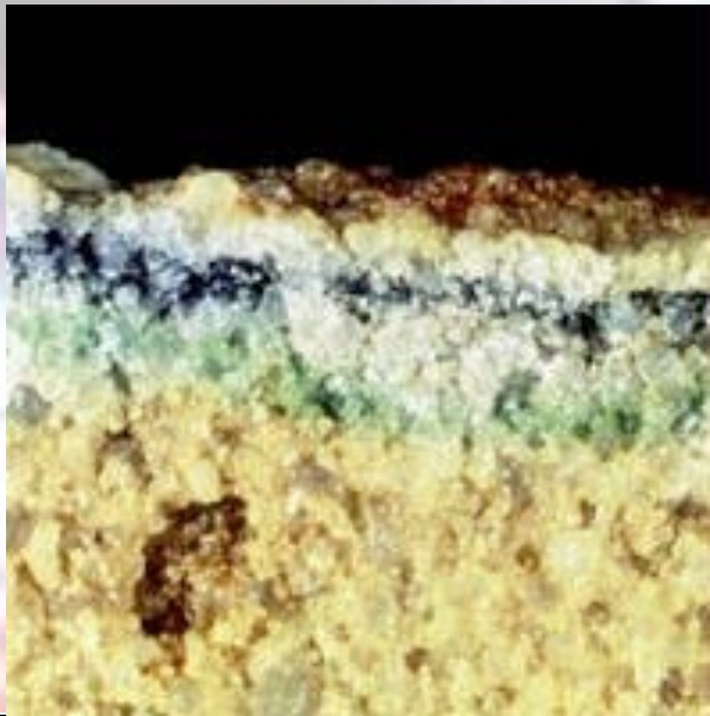




Thermophile bacteria

Hot geisers and volcans

Criptoendoliths



nature

Vol 454 | 28 August 2008 | doi:10.1038/nature07268

ARTICLES

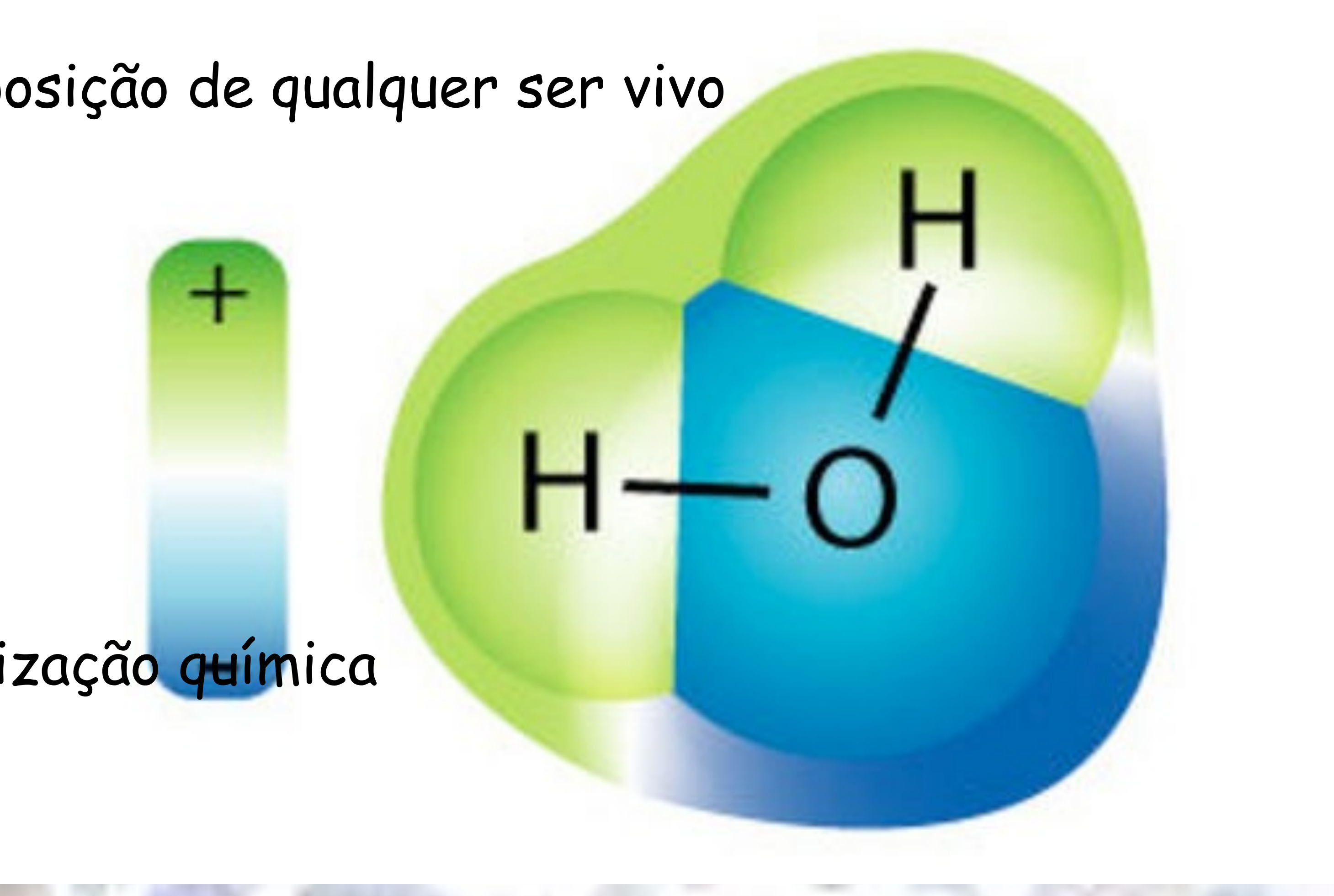
Major viral impact on the functioning of benthic deep-sea ecosystems

Roberto Danovaro[1], Antonio Dell'Anno[1], Cinzia Corinaldesi[1], Mirko Magagnini[1], Rachel Noble[2], Christian Tamburini[3] & Markus Weinbauer[4]

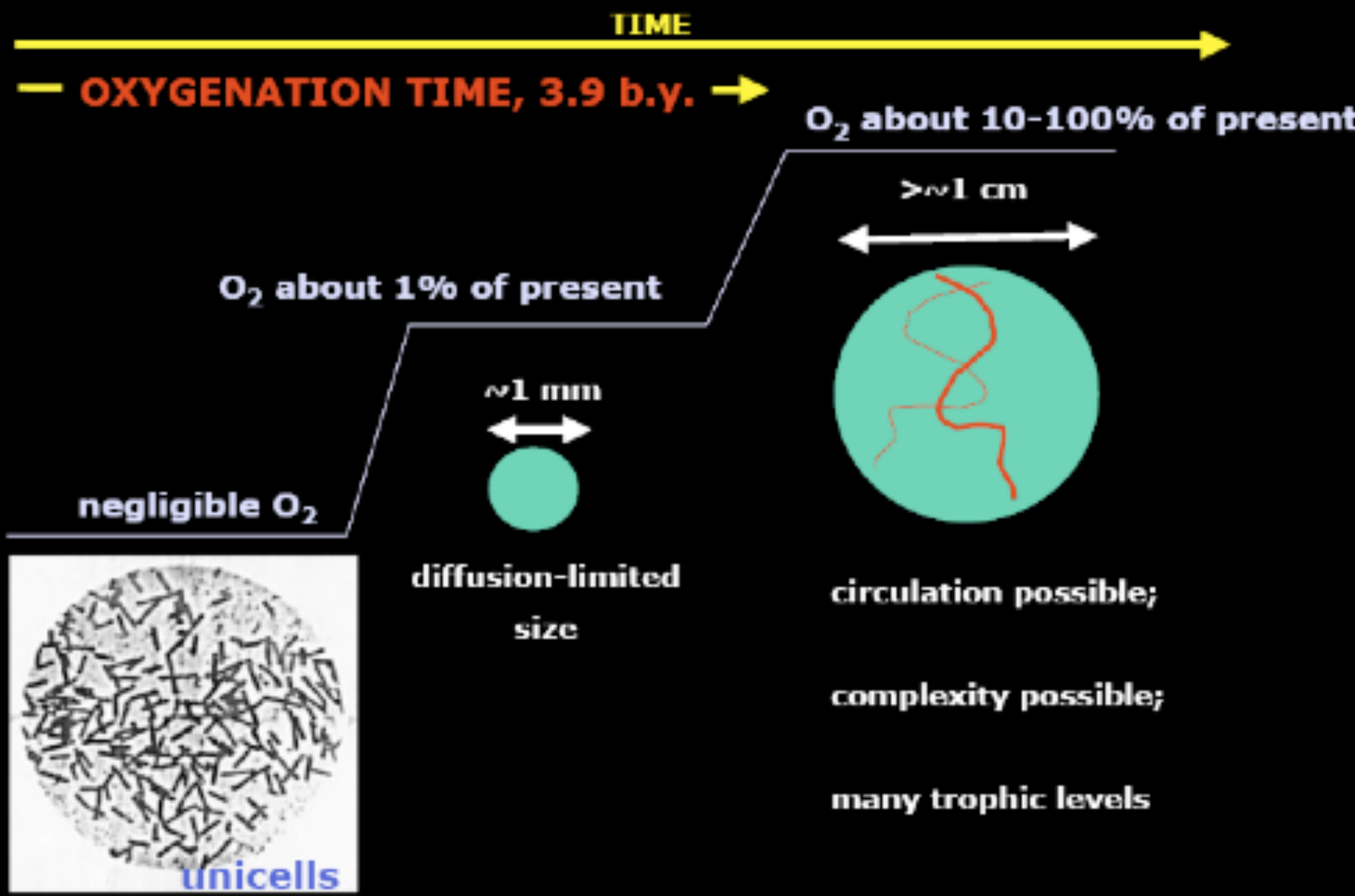
Viruses are the most abundant biological organisms of the world's oceans. Viral infections are a substantial source of mortality in a range of organisms—including autotrophic and heterotrophic plankton—but their impact on the deep ocean and benthic biosphere is completely unknown. Here we report that viral production in deep-sea benthic ecosystems worldwide is extremely high, and that viral infections are responsible for the abatement of 80% of prokaryotic heterotrophic production. Virus-induced prokaryotic mortality increases with increasing water depth, and beneath a depth of 1,000 m nearly all of the prokaryotic heterotrophic production is transformed into organic detritus. The viral shunt, releasing on a global scale ~0.37–0.63 gigatonnes of carbon per year, is an essential source of labile organic detritus in the deep-sea ecosystems. This process sustains a high prokaryotic biomass and provides an important contribution to prokaryotic metabolism, allowing the system to cope with the severe organic resource limitation of deep-sea ecosystems. Our results indicate that viruses have an important role in global biogeochemical cycles, in deep-sea metabolism and the overall functioning of the largest ecosystem of our biosphere.

Propriedades e papel da água

- Líquido de maior estabilidade química
- Aproximadamente 75% da composição de qualquer ser vivo
- Alto calor específico
- Pontes de Hidrogênio
- Mundo hidrofílico induz a organização química



Oxygen and the size of life

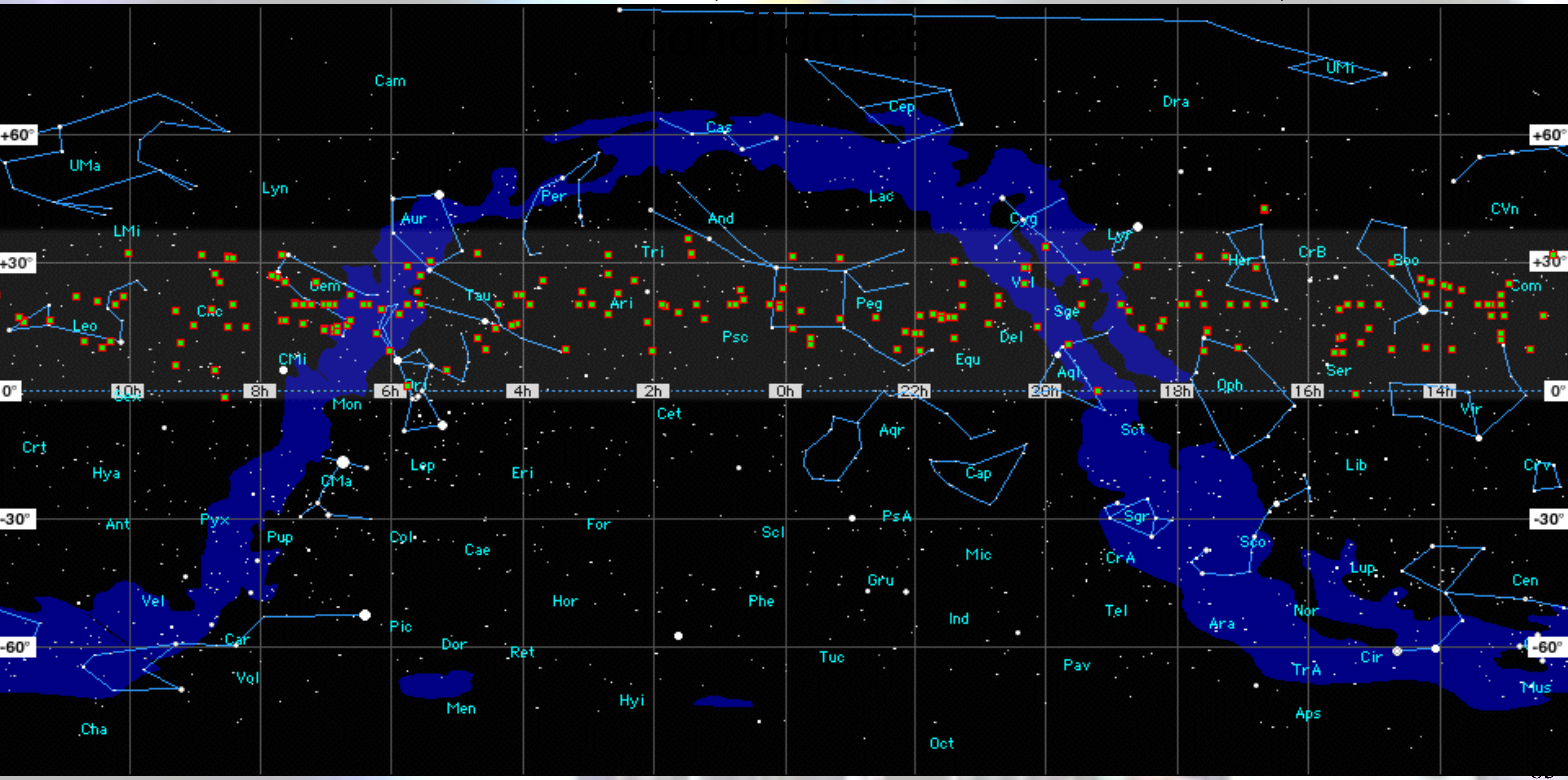


From David Catling (U. Washington,

http://www.planetary.org/stellarcountdown/sky_map.html

Most promising candidates from SETI@home

The blue area marks the Galactic plane (aka Milky Way) Yellow squares mark the position of the most promising candidates



We still do not kno

- the origin of life was an accident or a common fact in the Universe
- if there is any clear relation between complex life and intelligence

Food for thought, based upon current evidences:

- If the origin of life happened by chance, we are probably alone in the Universe, **even if "terrestrial" planets are common**
- Even if the origin of live is an universal mechanism

Planet Detection Methods

Michael Perryman, Rep. Prog. Phys., 2000, 63, 1209 (updated November 2004)

[corrections or suggestions please to michael.perryman@esa.int]