# Search for a second genesis of life on other worlds in the Solar System

24 Oct 2016
CCST
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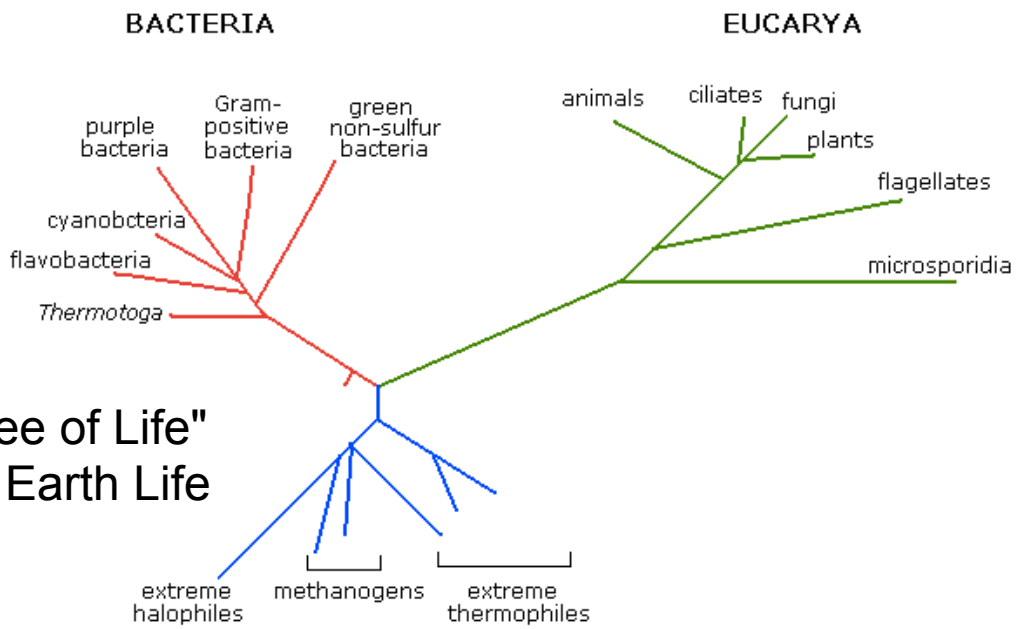
# The search for a second genesis of life

⇒ comparative biochemistry (life 2.0)

⇒ life is common in the universe (yeah!)

(by the zero-one-infinity rule)




From Woese, 1987

"The Tree of Life" defines Earth Life

Aliens: not on our tree of life

# Second Genesis:

How will we get our second example of Biochemistry

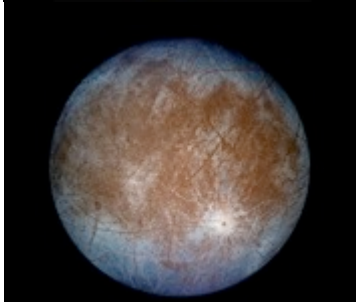
Listen for them to call

Make it in the laboratory

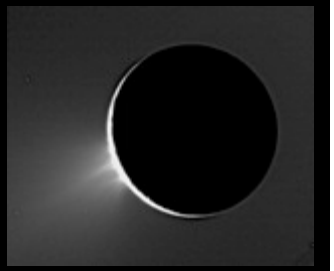
Find it on another world

# Where to look for life?

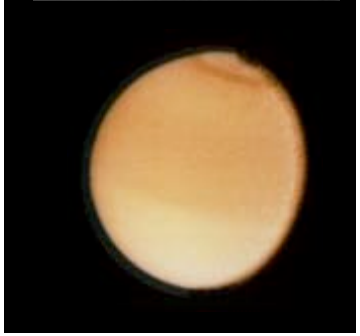
Mars ⋆⋆



Europa x
(moon of Jupiter)



Enceladus ★
(moon of Saturn)



Titan ?!
(moon of Saturn)

Mars is 1/10 the mass of Earth

No plate tectonics
Less gravity
No magnetic field

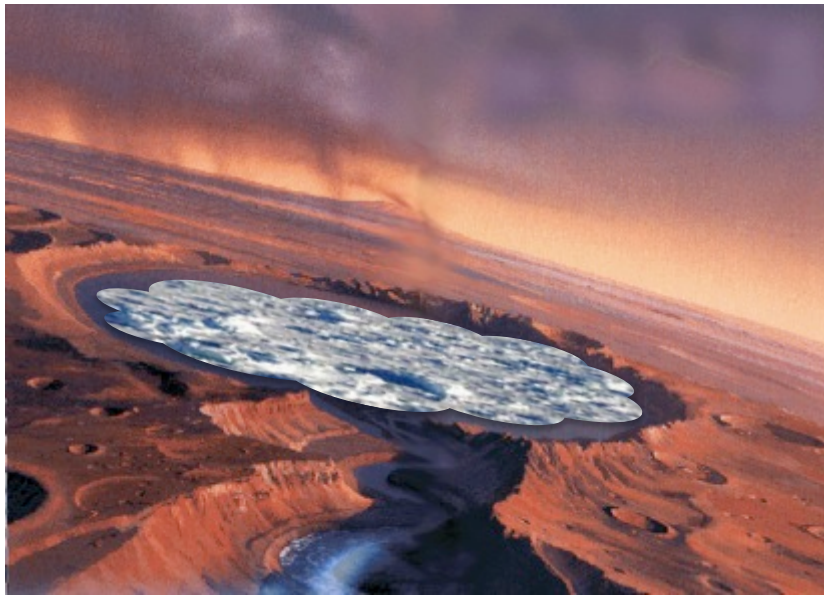
# Curiosity on Mars

## Landed 5 August 2012

# Yellowknife Bay, Mars

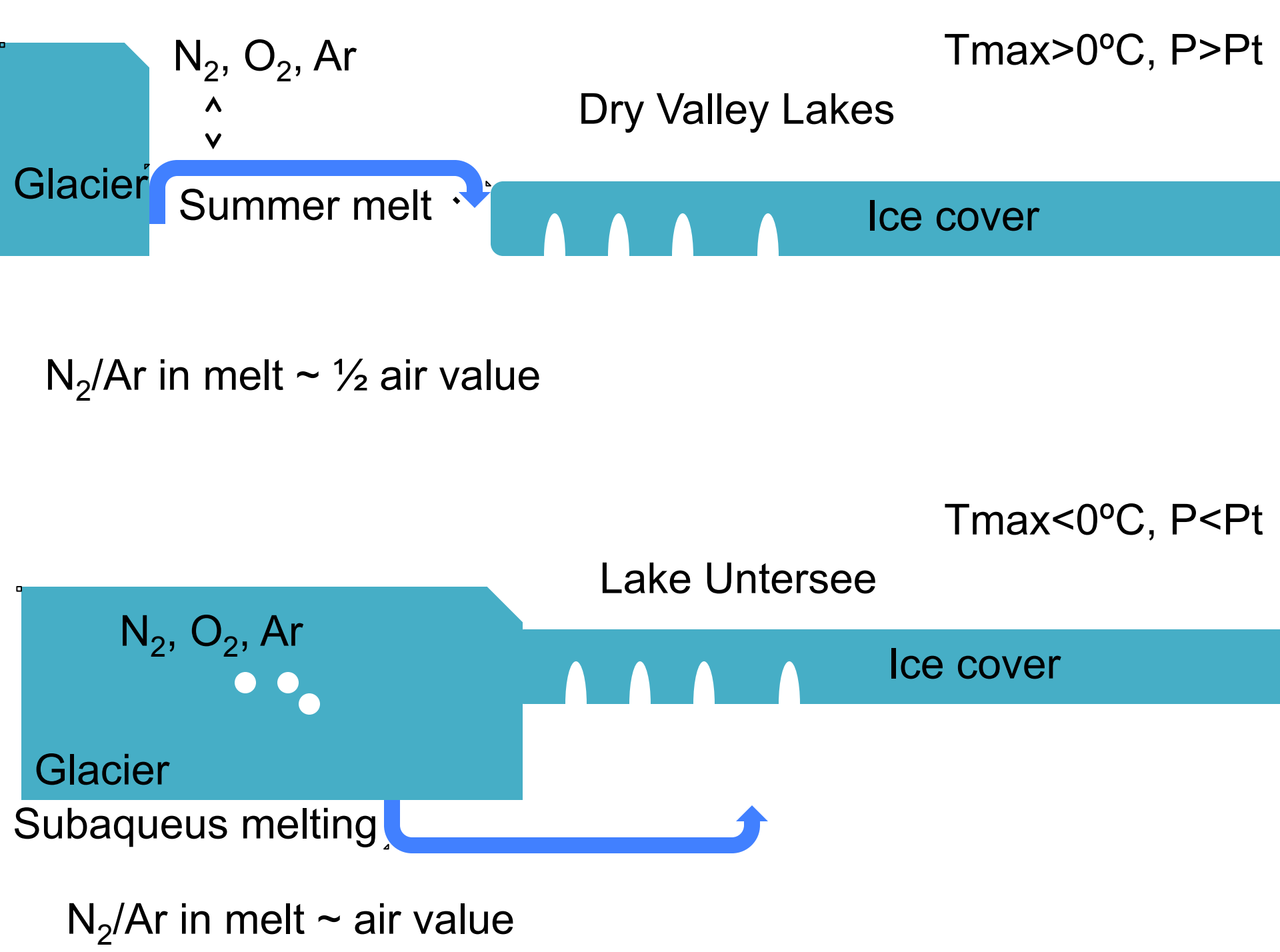
# Yellowknife Bay: An ideal site for astrobiology

- 3500 Myr ago; Impact forms Gale Crater
- Soon thereafter water deposits sediments. They harden and become compact and are buried
- Exposed 70 Myr ago by wind erosion of upper later



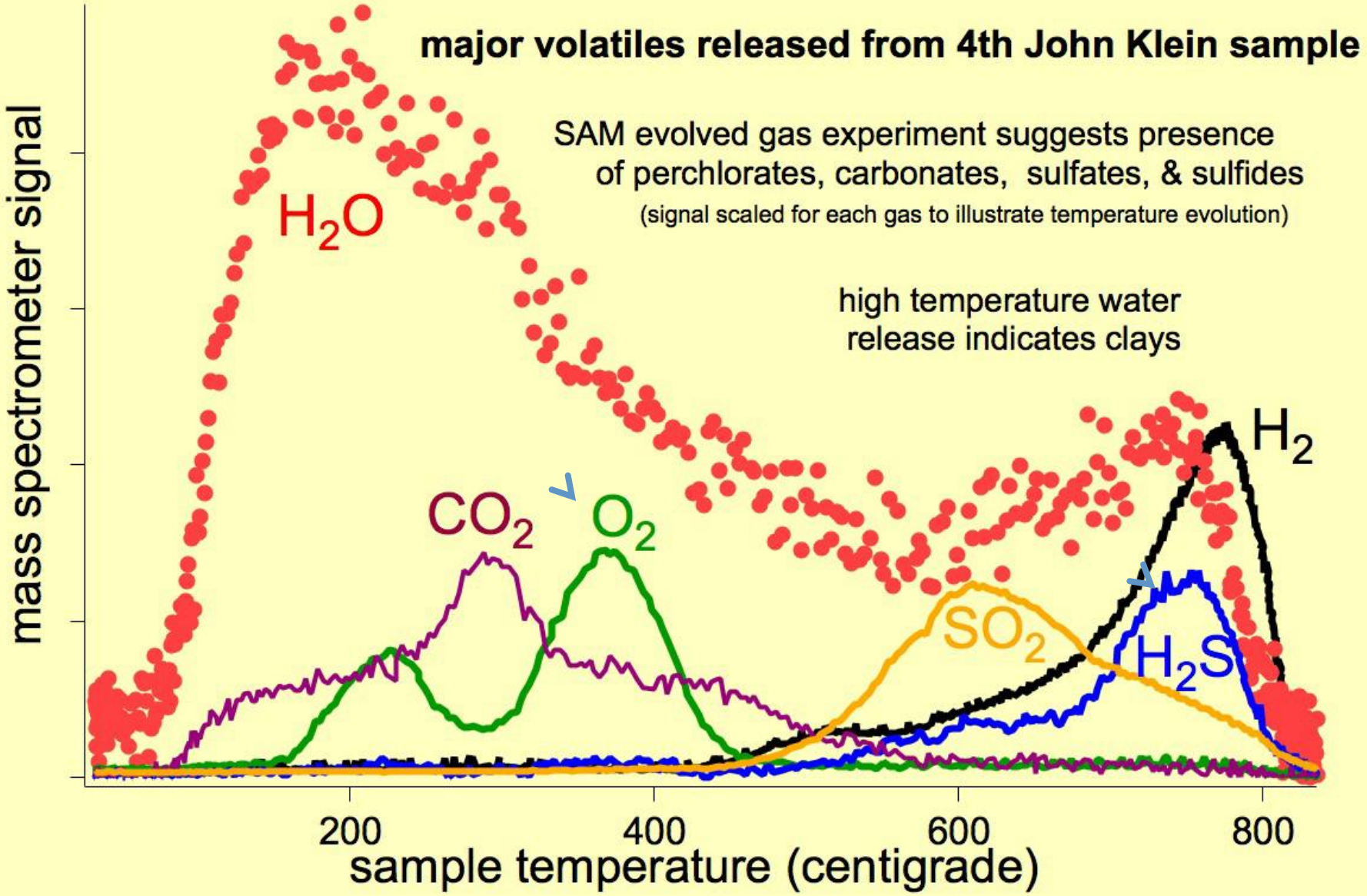

Lake Untersee, East Antarctica

On the bottom of an ice-covered lake. A world of only microscopic life making large mounds. Analogs for early Earth and Mars.

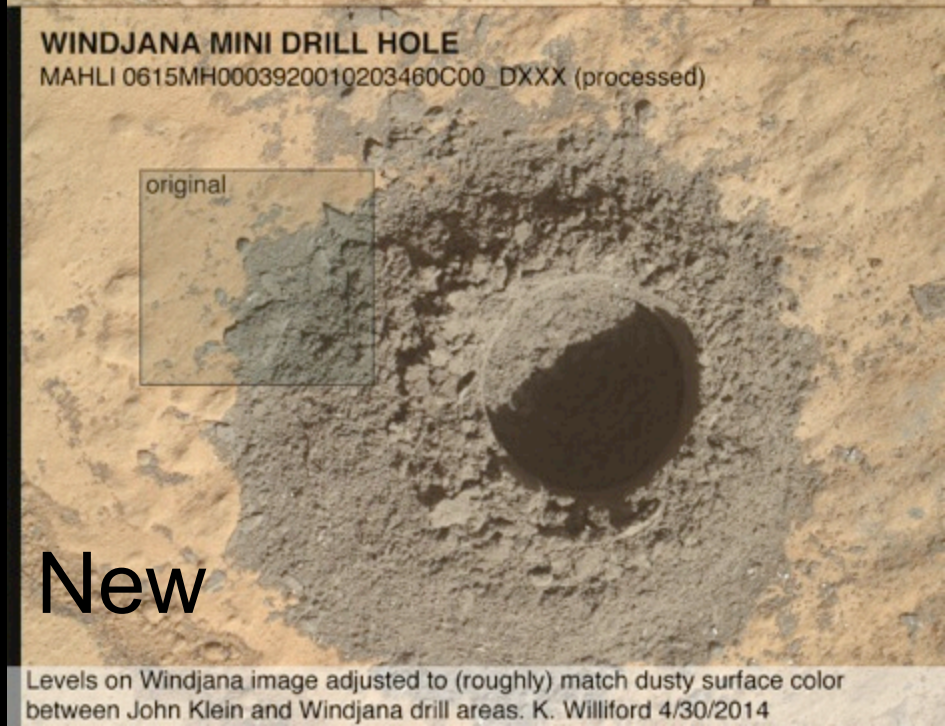

$N_2$, $O_2$, Ar
Tmax>0ºC, P>Pt
Dry Valley Lakes
Glacier
Summer melt
Ice cover
$N_2$/Ar in melt ~ ½ air value
Tmax<0ºC, P<Pt
Lake Untersee
$N_2$, $O_2$, Ar
Ice cover
Glacier
Subaqueus melting
$N_2$/Ar in melt ~ air value

## Curiosity Big Result #1 : Grey Mars

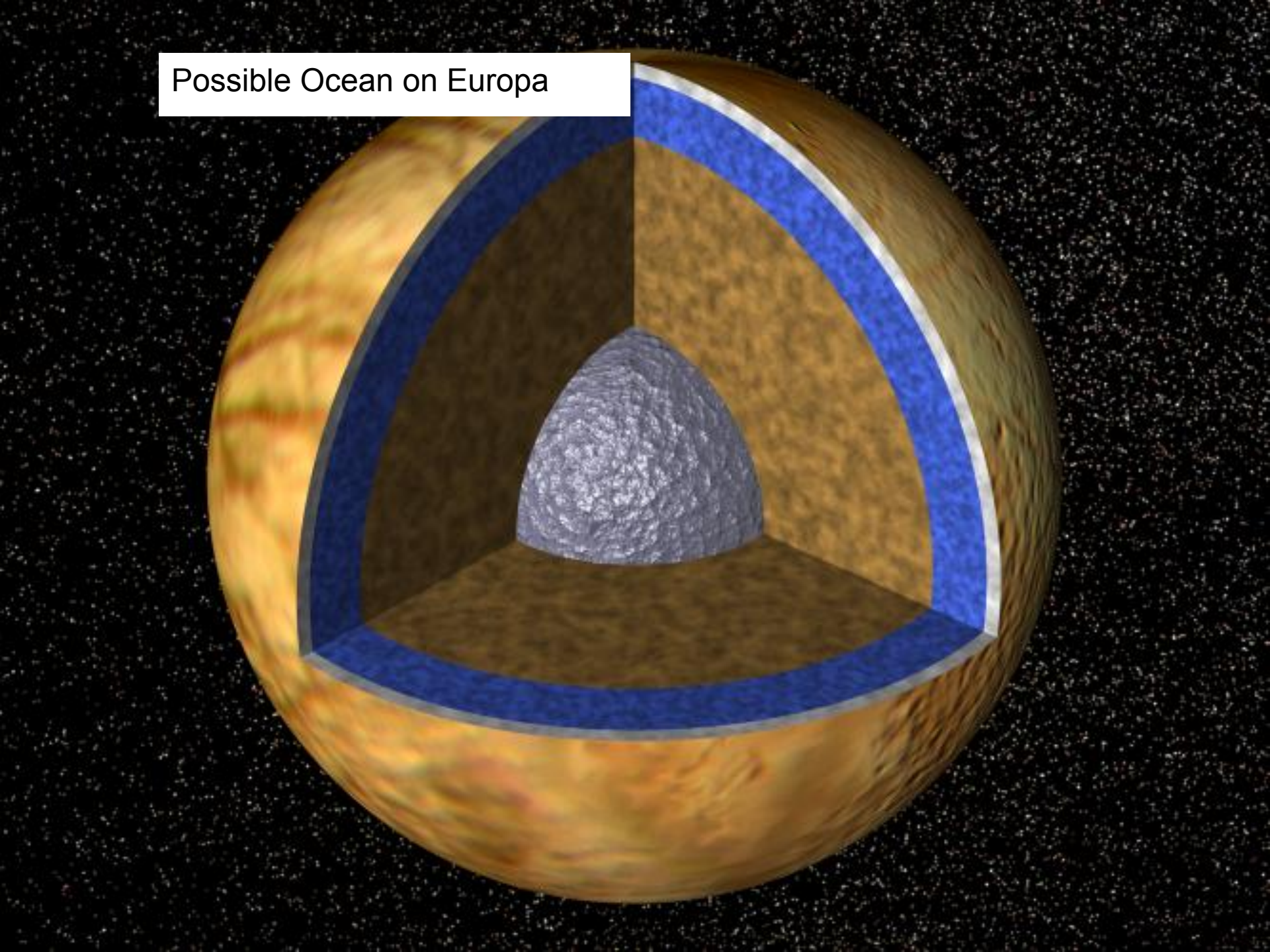

# $O_2$ and $H_2S$ and a small amount of organics



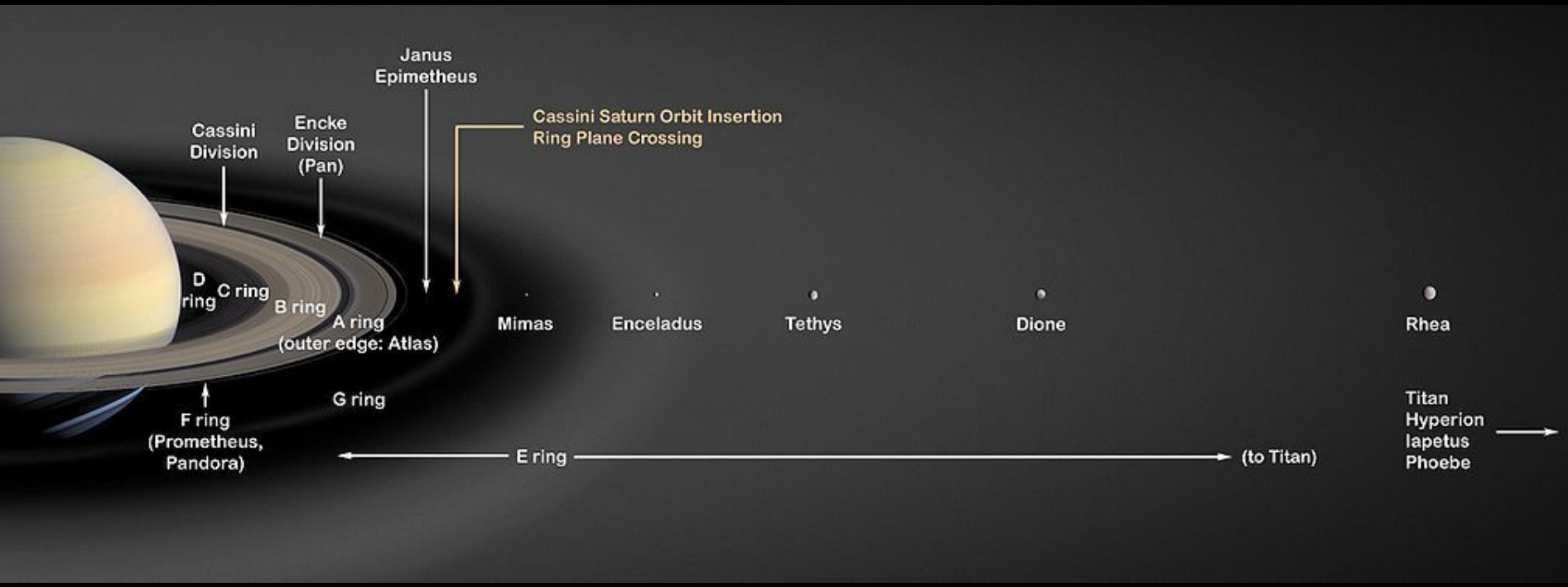
New drill hole and even darker material beneath.

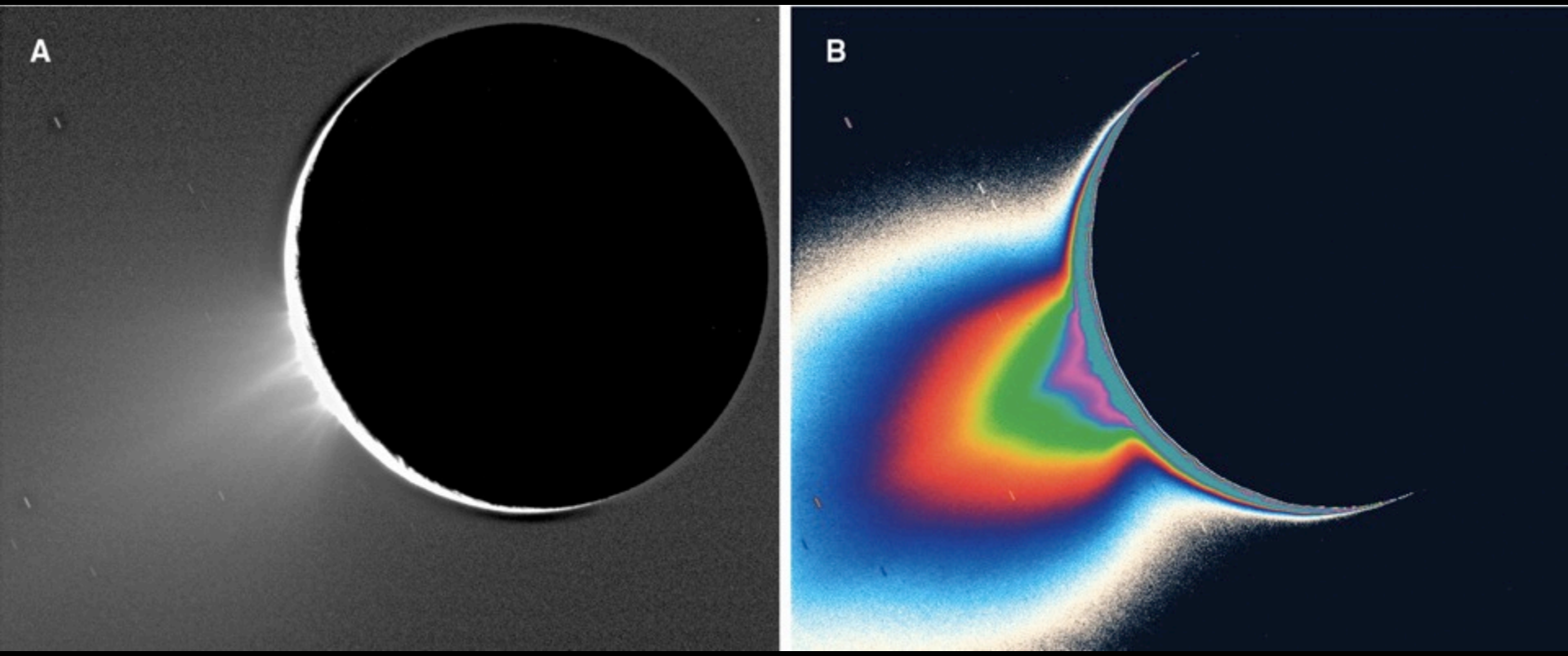

Levels on Windjana image adjusted to (roughly) match dusty surface color between John Klein and Windjana drill areas. K. Williford 4/30/2014

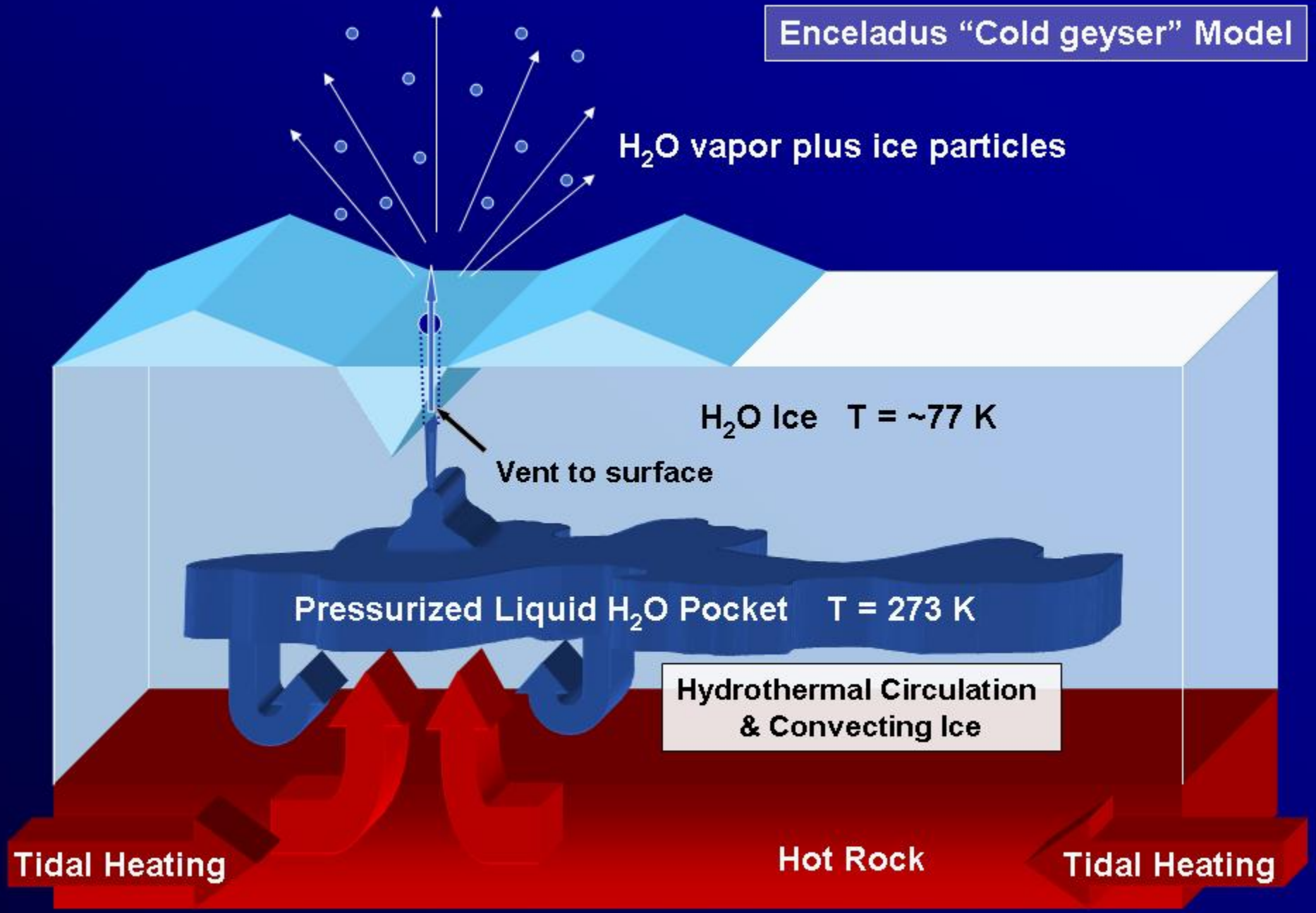

Possible Ocean on Europa

# Europa: Reaching the Ocean


Janus
Epimetheus
Cassini Saturn Orbit Insertion
Ring Plane Crossing
Cassini
Division
Encke
Division
(Pan)
D
ring
C ring
B ring
A ring
(outer edge: Atlas)
Mimas
Enceladus
Tethys
Dione
Rhea
G ring
F ring
(Prometheus,
Pandora)
E ring
(to Titan)
Titan
Hyperion
Iapetus
Phoebe

# Jets of $H_2O$ on Enceladus




Enceladus "Cold geyser" Model
$H_2O$ vapor plus ice particles
$H_2O$ Ice T = ~77 K
Vent to surface
Pressurized Liquid $H_2O$ Pocket T = 273 K
Hydrothermal Circulation & Convecting Ice
Tidal Heating
Hot Rock
Tidal Heating

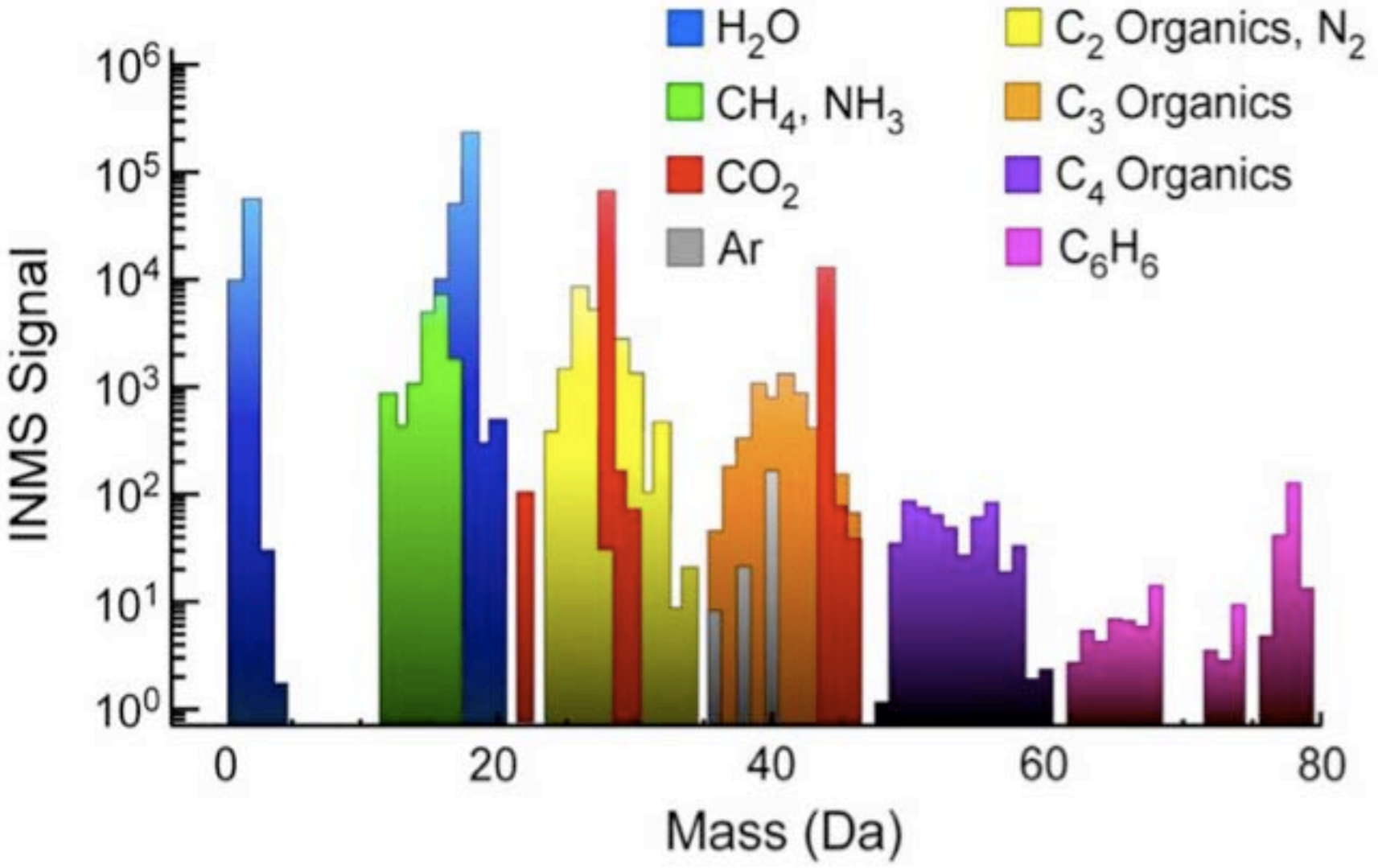



**Figure 22.18** Mass spectrum of the Enceladus plume from the October 9th 2008 flyby (Waite et al. 2009). The colors show contributions from various species and their breakdown products using the composition shown in Table 22.3.

# Examples of ecologically isolated microbial ecosystems (no $O_2$, no light, no organic input)

Only three examples are known:

Two are are based on $H_2$ from rock reactions
($H_2 + CO_2 \rightarrow CH_4 + H_2O$)

- Stevens, T.O. and J.P. McKinley 1995. Lithoautotrophic microbial ecosystems in deep basalt aquifers, Science 270, 450-454.
- Chapelle, F.H., K. O'Neill, P.M. Bradley, B.A. Methe, S.A. Ciufo, L.L. Knobel, and D.R. Lovley 2002. A hydrogen-based subsurface microbial community dominated by methanogens, Nature 415, 312-315.

One based on radioactive decay

- Lin, L.-H., et al. 2006. Long-Term Sustainability of a High-Energy, Low-Diversity Crustal Biome, Science 314, 479-482

# LIFE Life Investigation For Enceladus

P. Tsou H. Yano

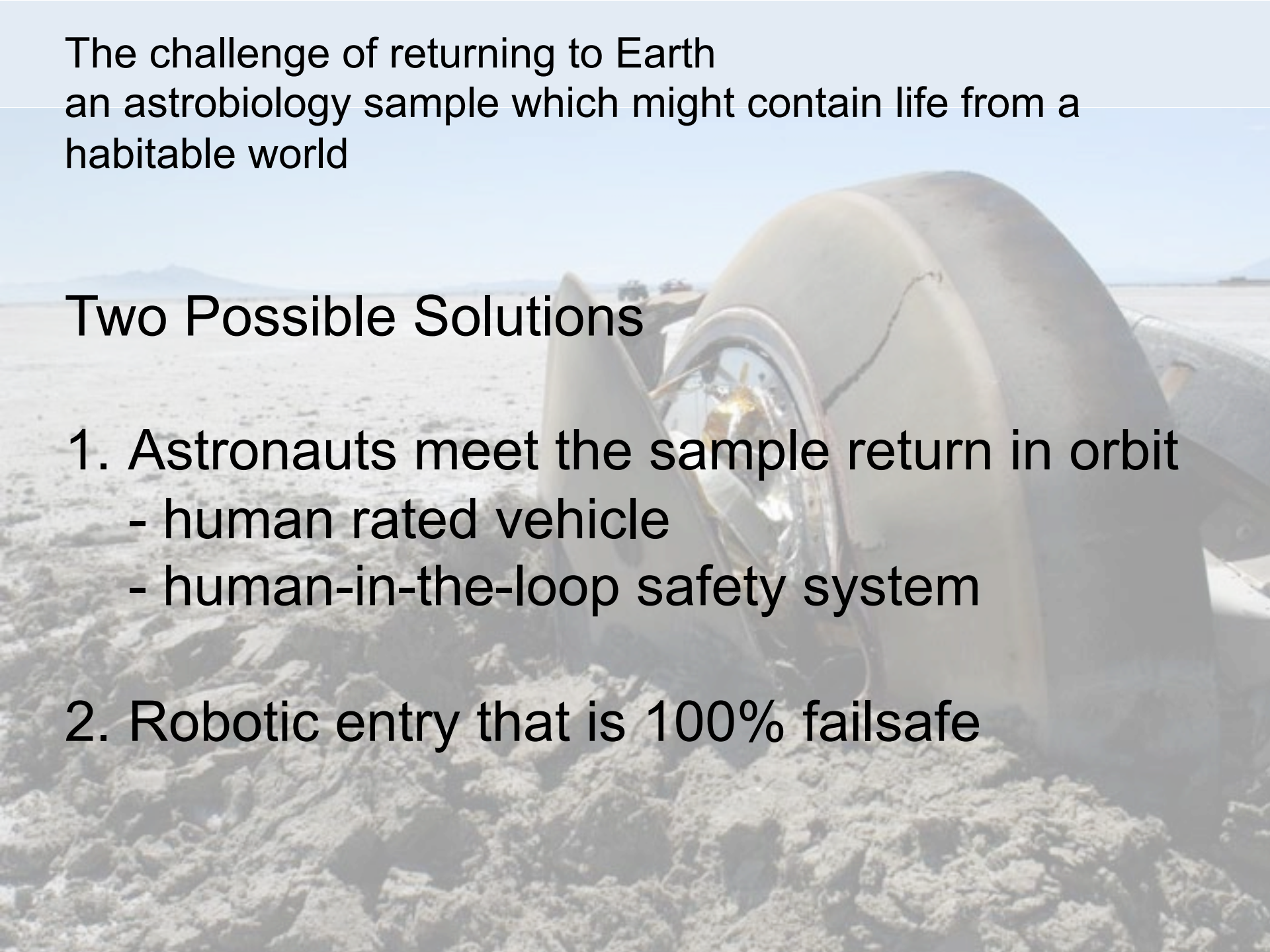
The Goal: A joint US-Japan mission to study the plume of Enceladus for organics and life and return a sample to Earth.

Heritage: Stardust, Hayabusa
Programmatic model: Cassini

To be proposed as a Discovery Mission

# The challenge of returning to Earth an astrobiology sample which might contain life from a habitable world

The challenge of returning to Earth
an astrobiology sample which might contain life from a habitable world



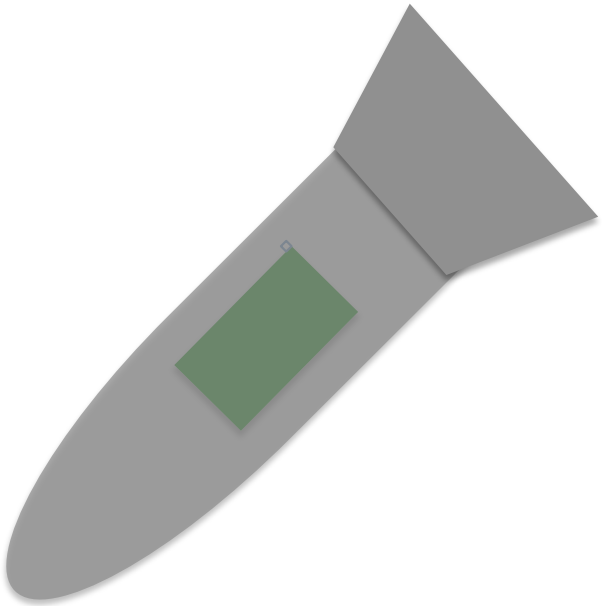
## Two Possible Solutions

1. Astronauts meet the sample return in orbit
   - human rated vehicle
   - human-in-the-loop safety system

2. Robotic entry that is 100% failsafe

# 100%  Failsafe entry system

1. Don’t move
2. Don’t think
3. Don’t make any decisions



- No parachute
- No deployable mechanisms
- Lands at terminal velocity
- Payload is designed to survive
- Like a meteorite (they survive landing)


Jamstec ship Chikyu
Mobile Bio containment facility

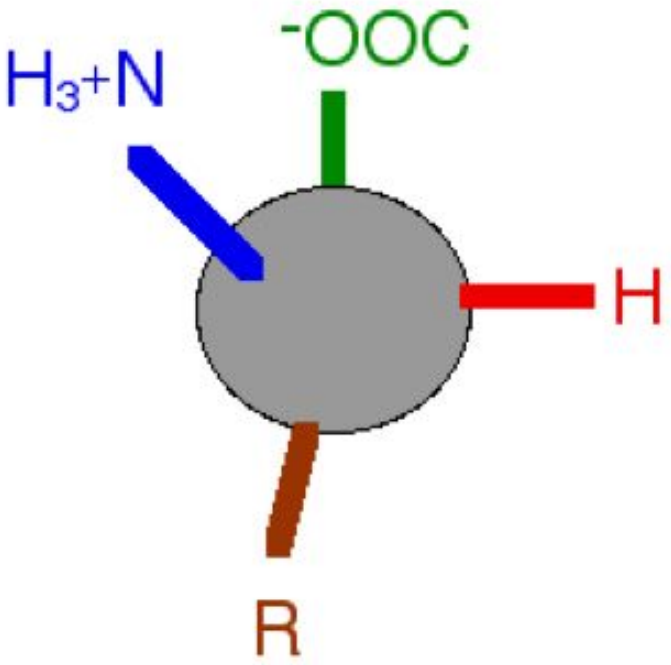

**T. A. T. Broth Base (M562)**

1. Control
2. Bacillus subtilis ATCC 6633
3. Pseudomonas aeruginosa ATCC 27853
4. Salmonella Typhi ATCC 6539
5. Staphylococcus aureus ATCC 6538
6. Candida albicans ATCC 10231

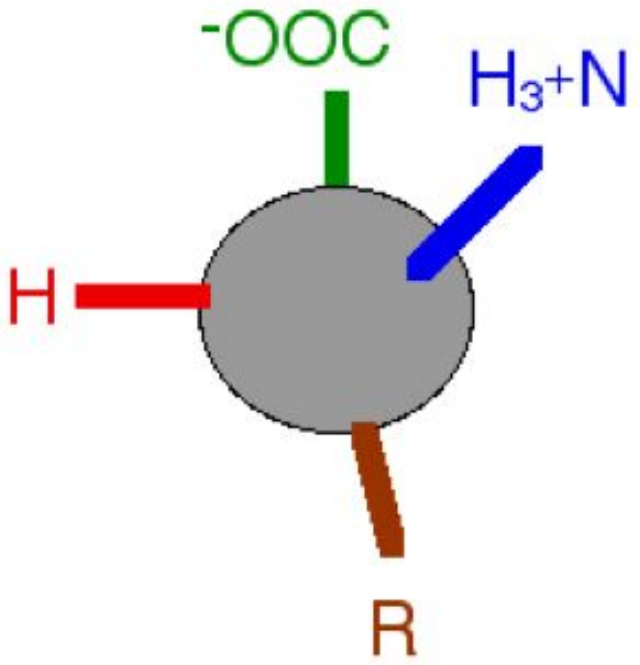
# Life Wanted: Dead or Alive

- The search for life* is **not** necessarily a search for something alive.
  - Not just microscopes for motion
  - Not just Viking-like metabolism experiments
- At the scale of microorganisms, structure is not convincing by itself
- The best evidence of life is dead
  - biomolecular structures

*[life: 1) a phenomenon, 2) a state variable, 3) a path integral]

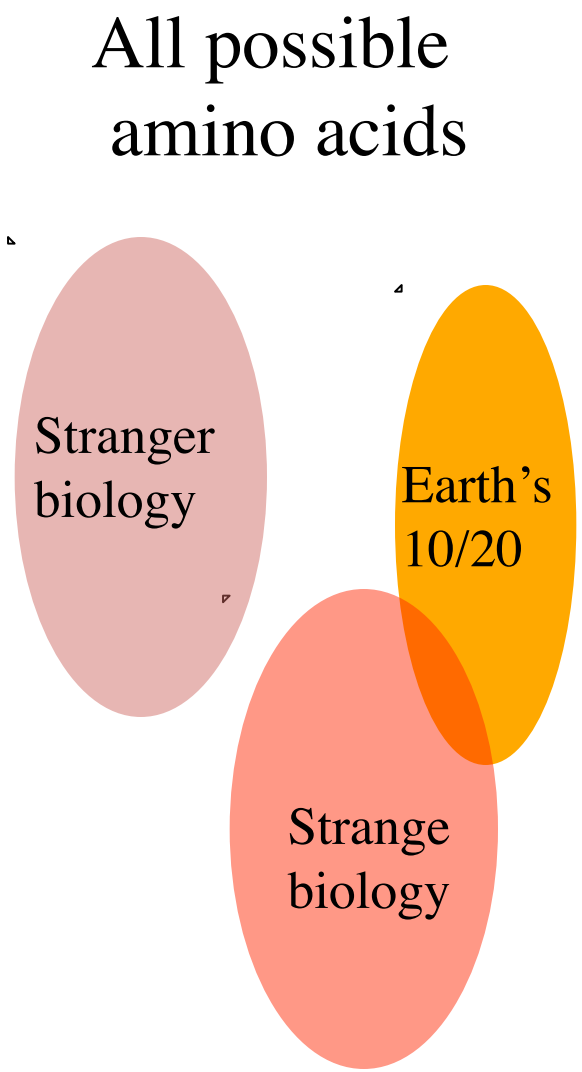



L - amino acids
used in proteins




D - amino acids
not in proteins

A specific proposal:

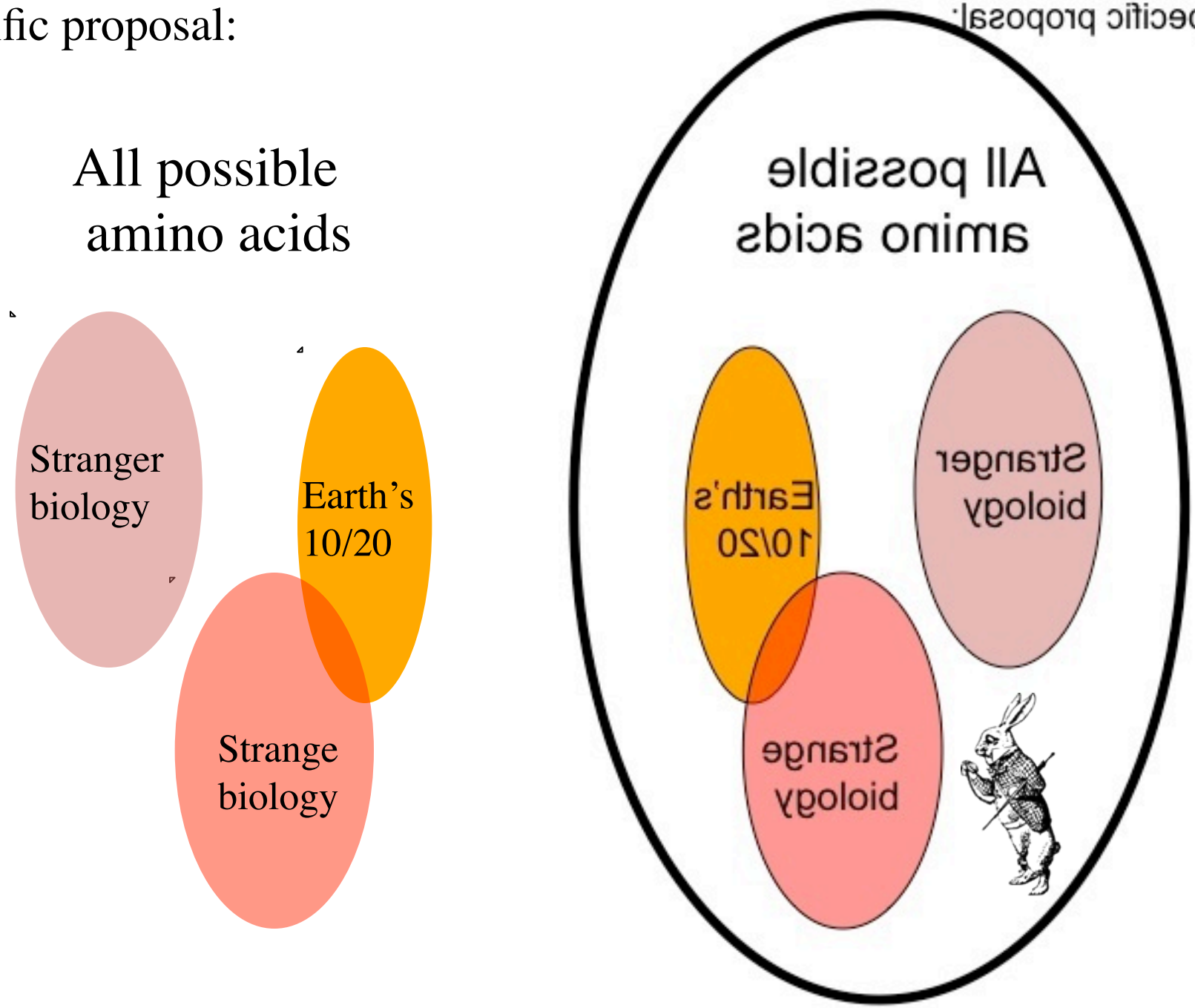



Strange biology is possible:

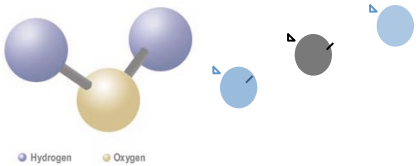
Alternative sets of 20 amino acids span the phase space of size, charge, and hydrophobicity properties and thus are plausible alternative construction sets for diverse proteins.

Philip, G. K., & Freeland, S. J. (2011). Did Evolution Select a Nonrandom "Alphabet" of Amino Acids?. Astrobiology, 11(3), 235-240.

A specific proposal:

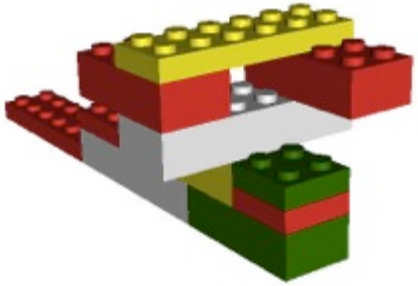


Atomic level



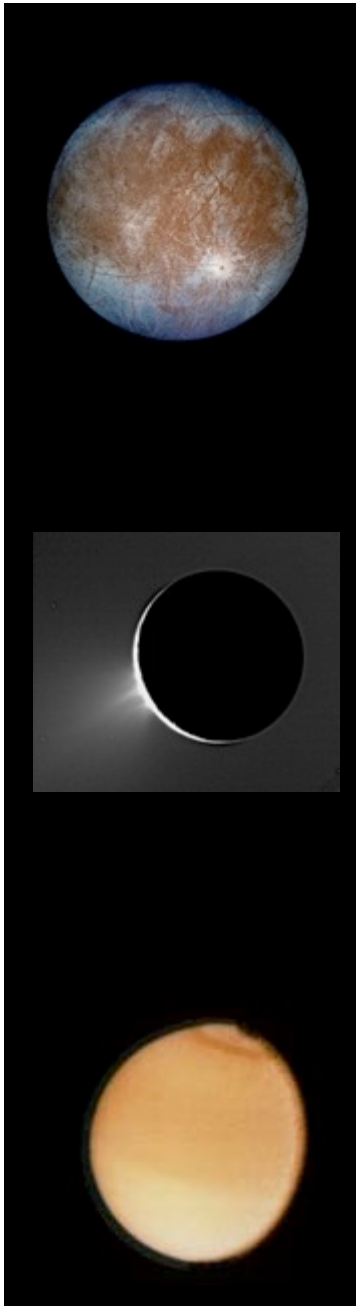

C=C=C $H_2O$

Biochemical level
(L amino acids, ATP)



Ecological level
(phototaxis, $CO_2$ uptake)

# Origin of Life



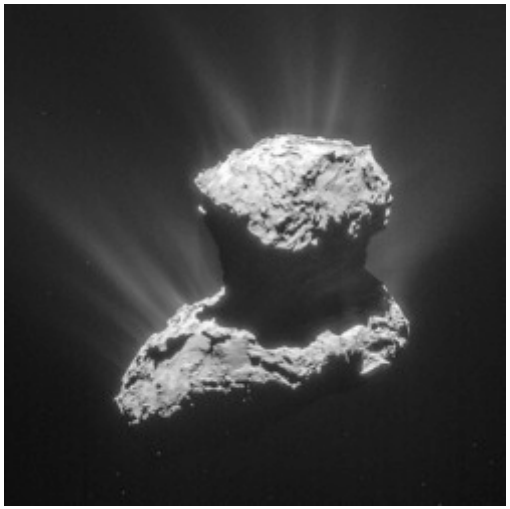
The only fact we have about the origin of life is that it happened more than 3.5 Gyr ago.

We do not know where, when, how it happened, or how long it took.

The view that it occurred on Earth and/or took a long time is not supported, or excluded, by any evidence.

Enceladus 100 Myr old is not necessarily bad news for the origin of life and may be good news for a second genesis.

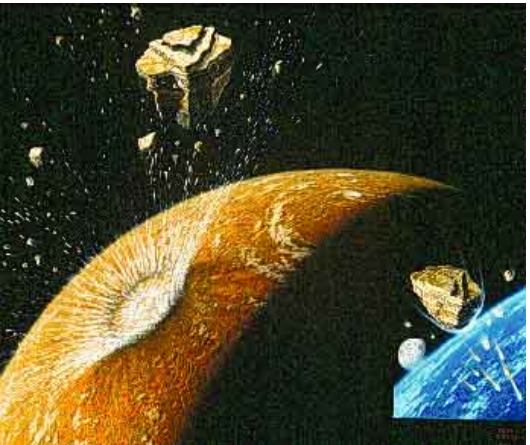
# From whence life on Earth?



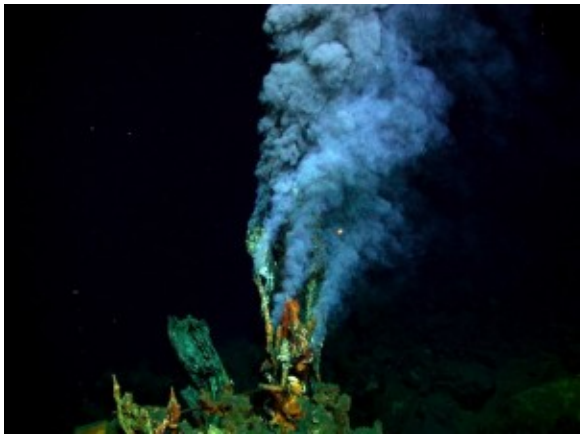
Stars via Comets

On the land

Mars via meteorites



From the sea



# Enceladus is a test between current models for the origin of life

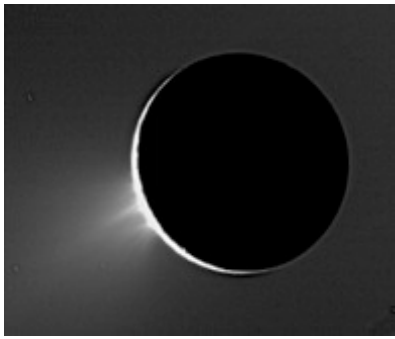
yes

Mike Russell: the origin of life occurred in a Lost City type vent, *Russell et al. "The drive to life on wet and icy worlds." Astrobiology 14.4 (2014): 308-343.*

no

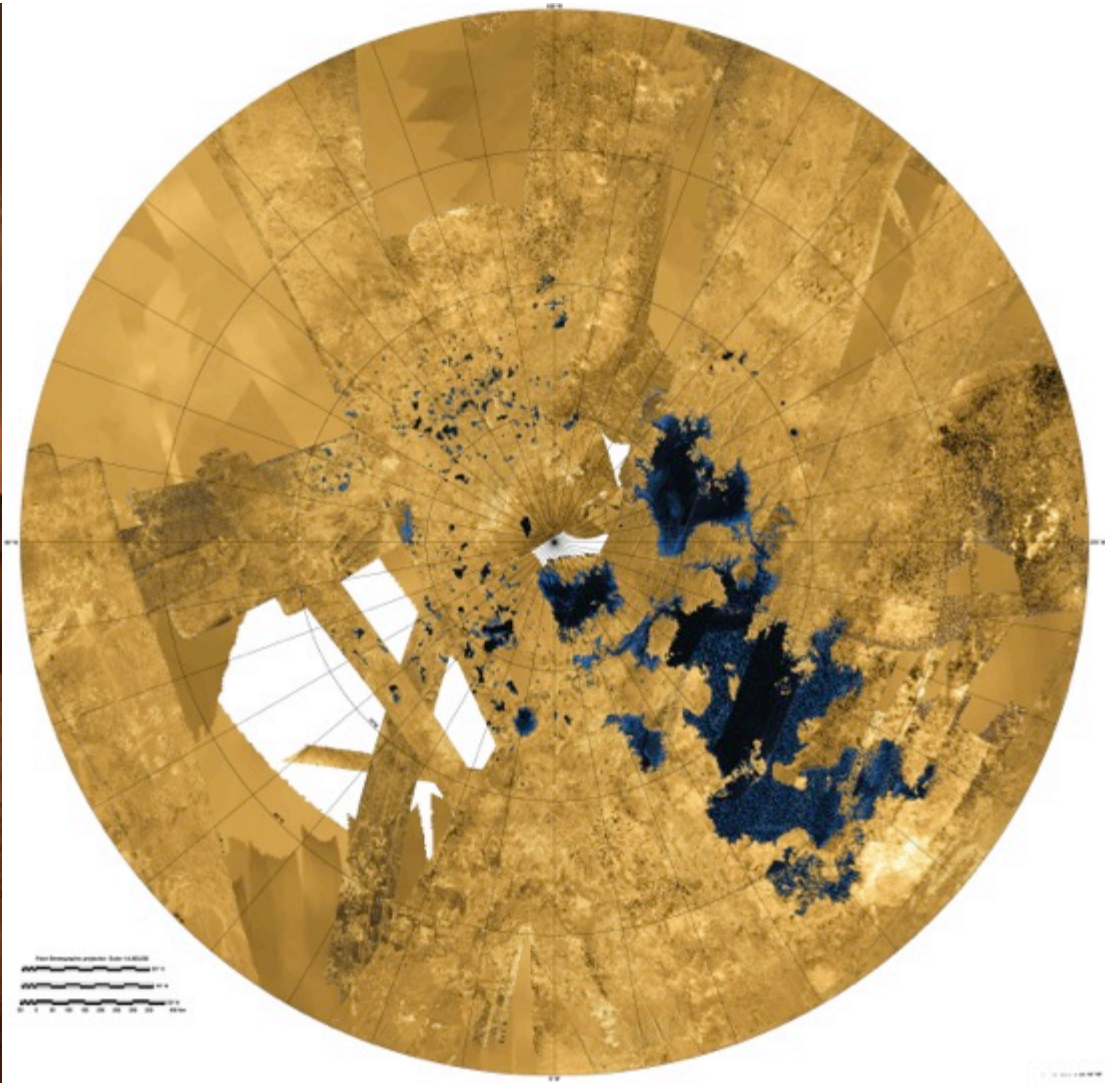
David Deamer: the origin of life occurred in a evaporate pond, *Deamer et al. "Self-assembly processes in the prebiotic environment." Philosophical Transactions of the Royal Society of London B: Biological Sciences 361.1474 (2006): 1809-1818.,*

# Origin of life and common life



| | | | |
|---|---|---|---|
| Earth-Mars Exchange: | Life1 | Life1 | Life2 |
| Comet source: | Life1 | Life1 | Life1 |
| On Land: | Life1 | Life2 | no |
| Sea vent : | Life1 | Life2 | Life3 |

# Titan: on the beach



# Could there be methane life on Titan? ☺

Table 1. Free Energies of Hydrogenation on Titan

| **Reaction** | **ΔG (kcal/mole)** |
|---|---|
| $C_2H_2 + 3H_2 = 2CH_4$ | 80 |
| $C_2H_6 + H_2 = 2CH_4$ | 15 |
| $R\text{-}CH_2 + H_2 = R + CH_4$ | 13 |
| Earth | |
| $CO_2 + H_2 = CH_4 + H_2O$ | >10 |

$$\Delta G = \Delta H - T\Delta S + RT \ln(Q)$$

McKay and Smith, Icarus, 2005

# Possibilities for Widespread Life on Titan

## Earth

Carbon based

Liquid $H_2O$

Life is widespread

Global effect ($O_2$, $CH_4$, $CO_2$)

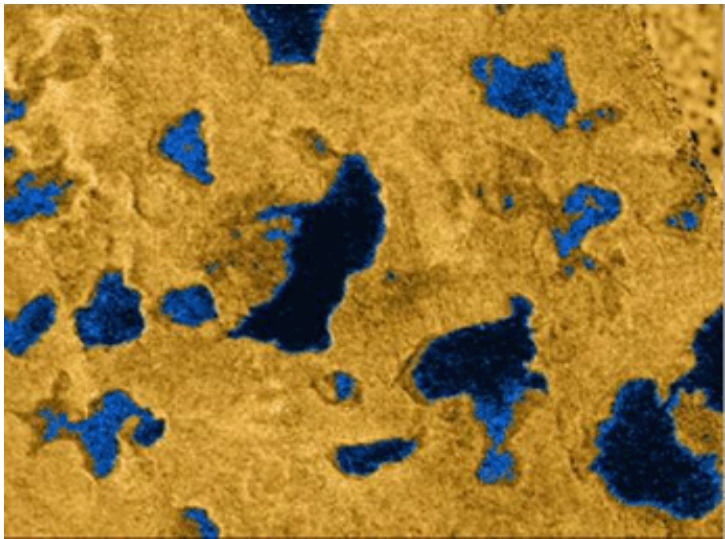
## Titan

Carbon based

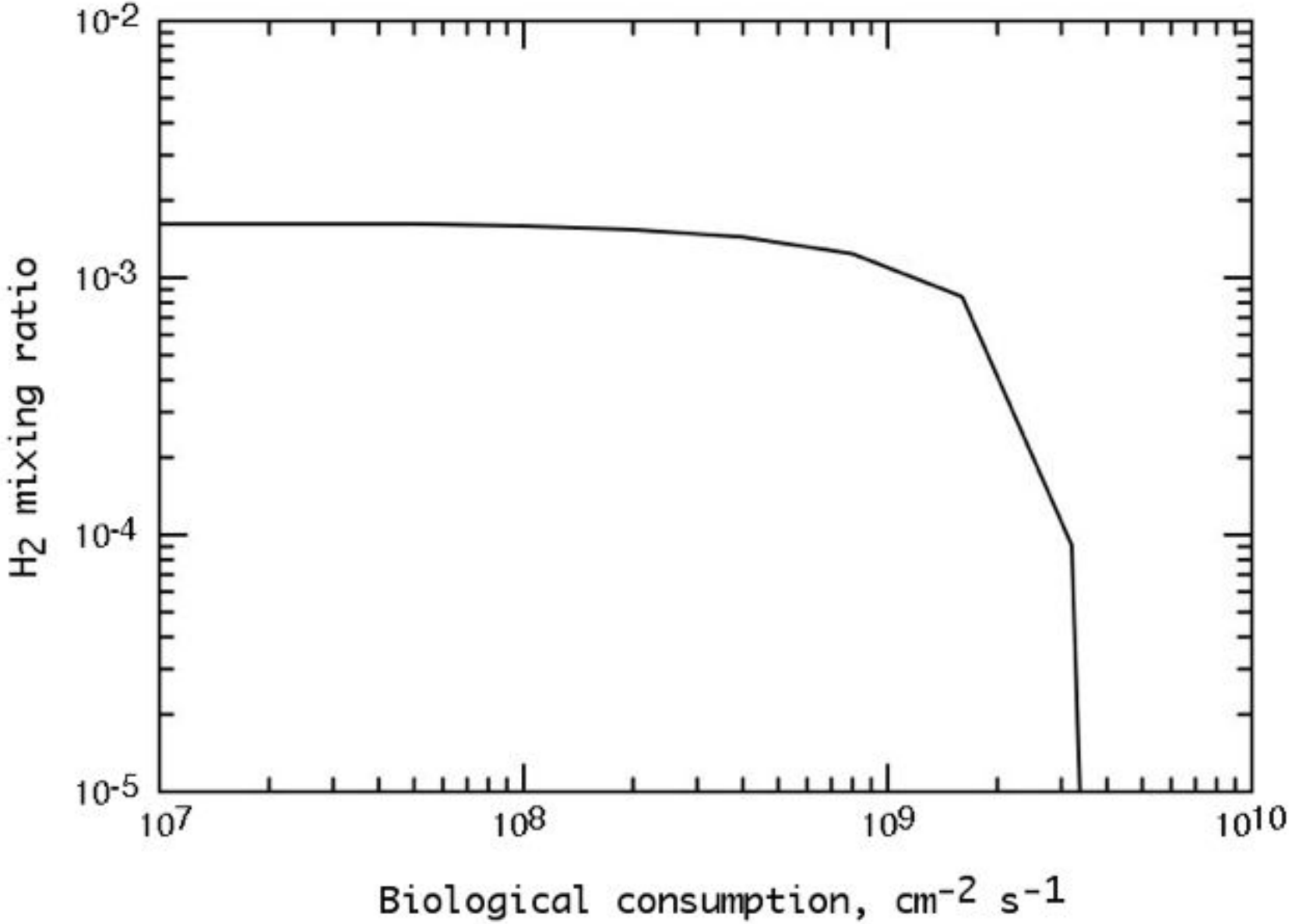
Liquid $CH_4$

Life??

Global effect ($H_2$)

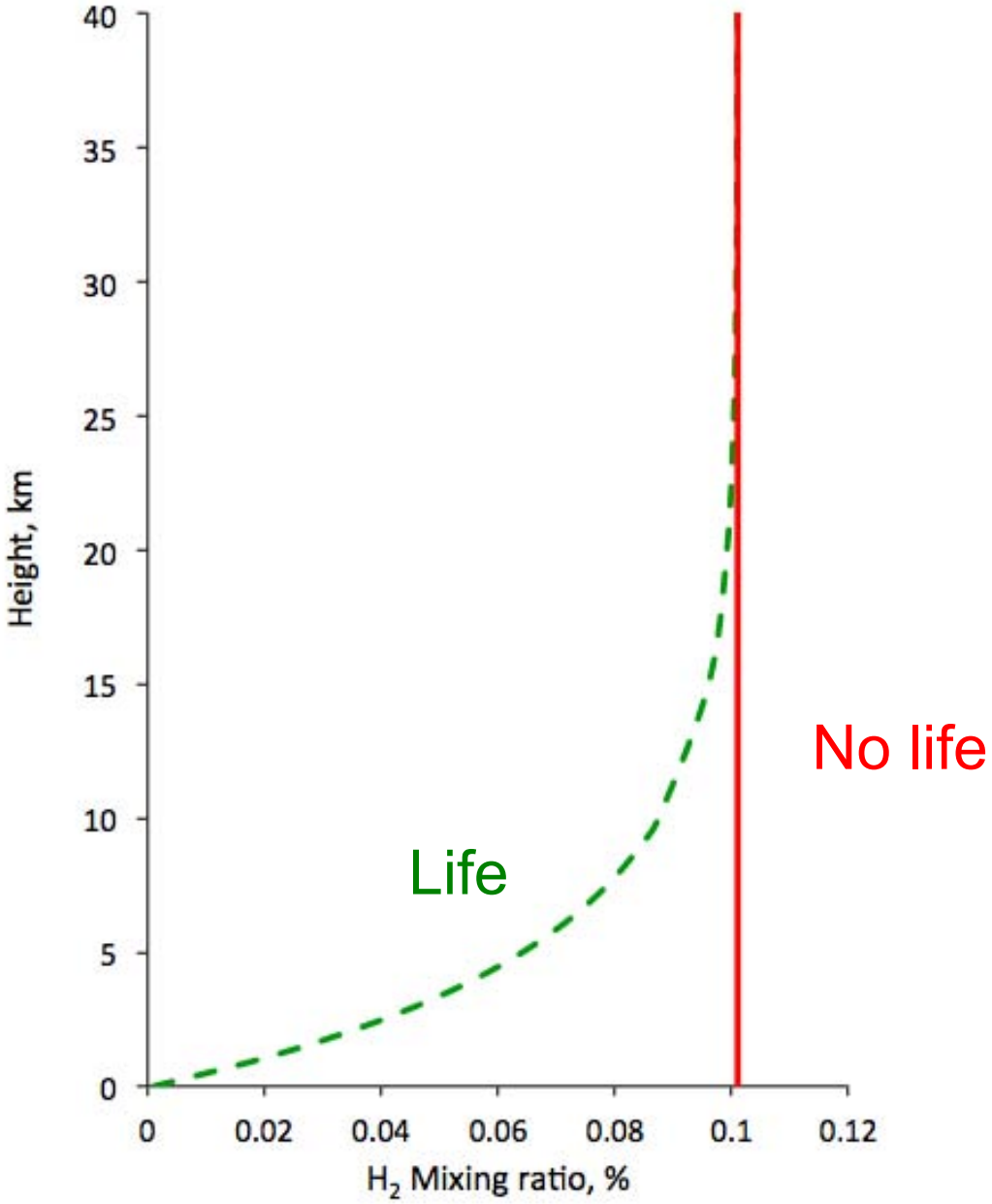


# $H_2$ consuming life on Titan would deplete $H_2$ at the surface




*McKay & Smith Icarus 2005*

# If there was life on Titan it would consume $H_2$ at the surface



# What will you do if you find a second genesis on Mars?

Unprepared for success!

# Moral Status of Alien Microbes (if we find them or if we make them)

- Now there are three sets: humans, life1, life2

- Microscopic organisms which score low moral status based on pain, complex behavior & communication would have high moral status as being the sole representatives of the set life2

# Immediate Recommendation: Biologically Reversible Exploration

The robotic and human exploration of Mars should be done in a way that is biologically reversible. We must be able to undo (‘ctrl Z’) our contamination of Mars if we discover a second genesis of life.