

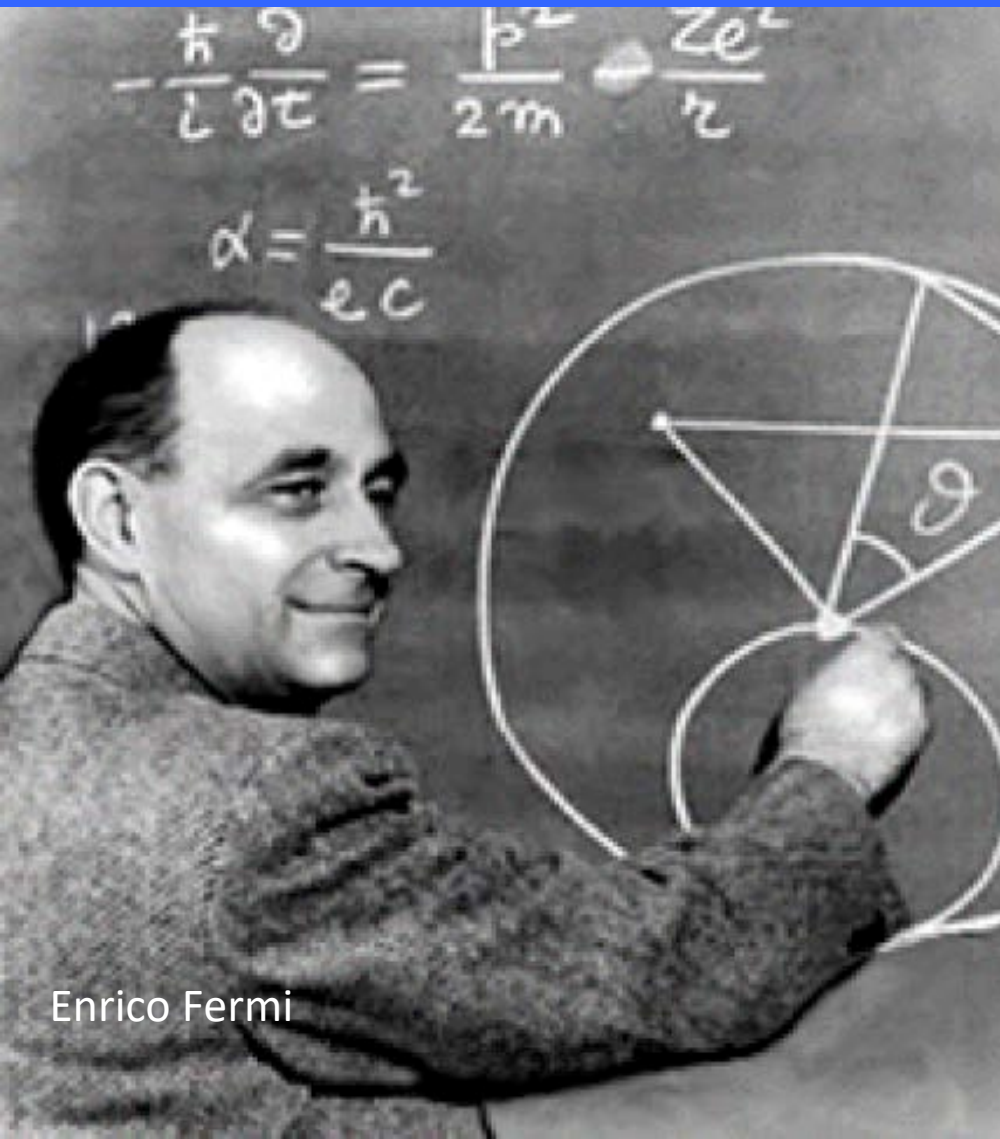
Where are they?

Joseph Silk

Gresham College

18 October 2017

At a luncheon , Fermi said.... “Don’t you ever wonder where everybody is?”we all knew he meant extra-terrestrials. He then followed up with a series of calculations on the probability of earthlike planets, the probability of life given an earth, the probability of humans given life, the likely rise and duration of high technology... He concluded that we ought to have been visited long ago and many times over.



Enrico Fermi

Los Alamos, 1951, in letter by Herbert York, 1984 (to Eric Jones)



There are billions of habitable planets in our Milky Way galaxy
The big questions: do any have life...or intelligent life?



*The Earth is the cradle of the mind but we
cannot live forever in a cradle*

Konstantin Tsiolkovsky 1911

How life began

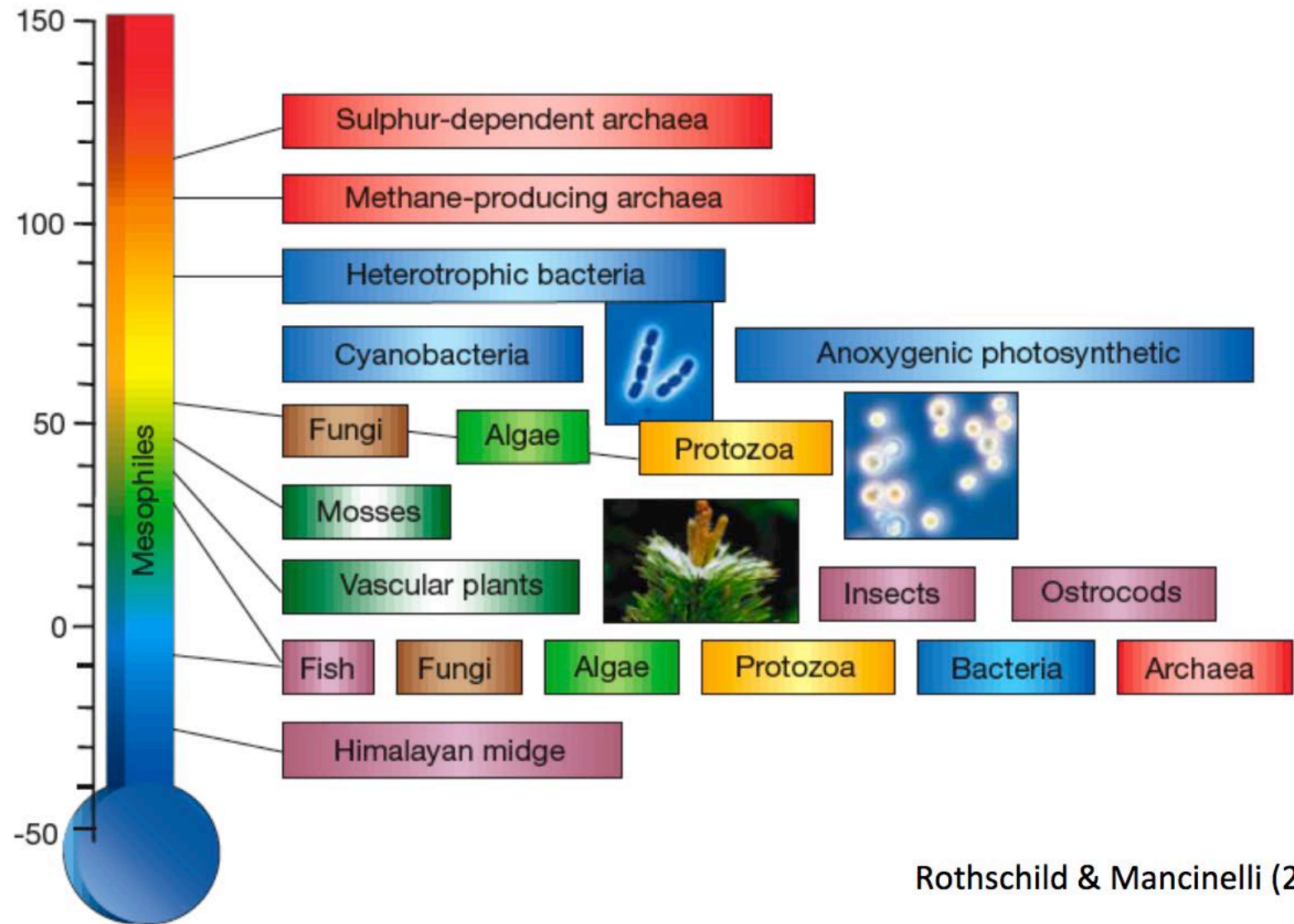


in some warm little pond, with all sorts of ammonia and phosphoric salts, light, heat, electricity, &c..... a protein compound was chemically formed ready to undergo still more complex changes...

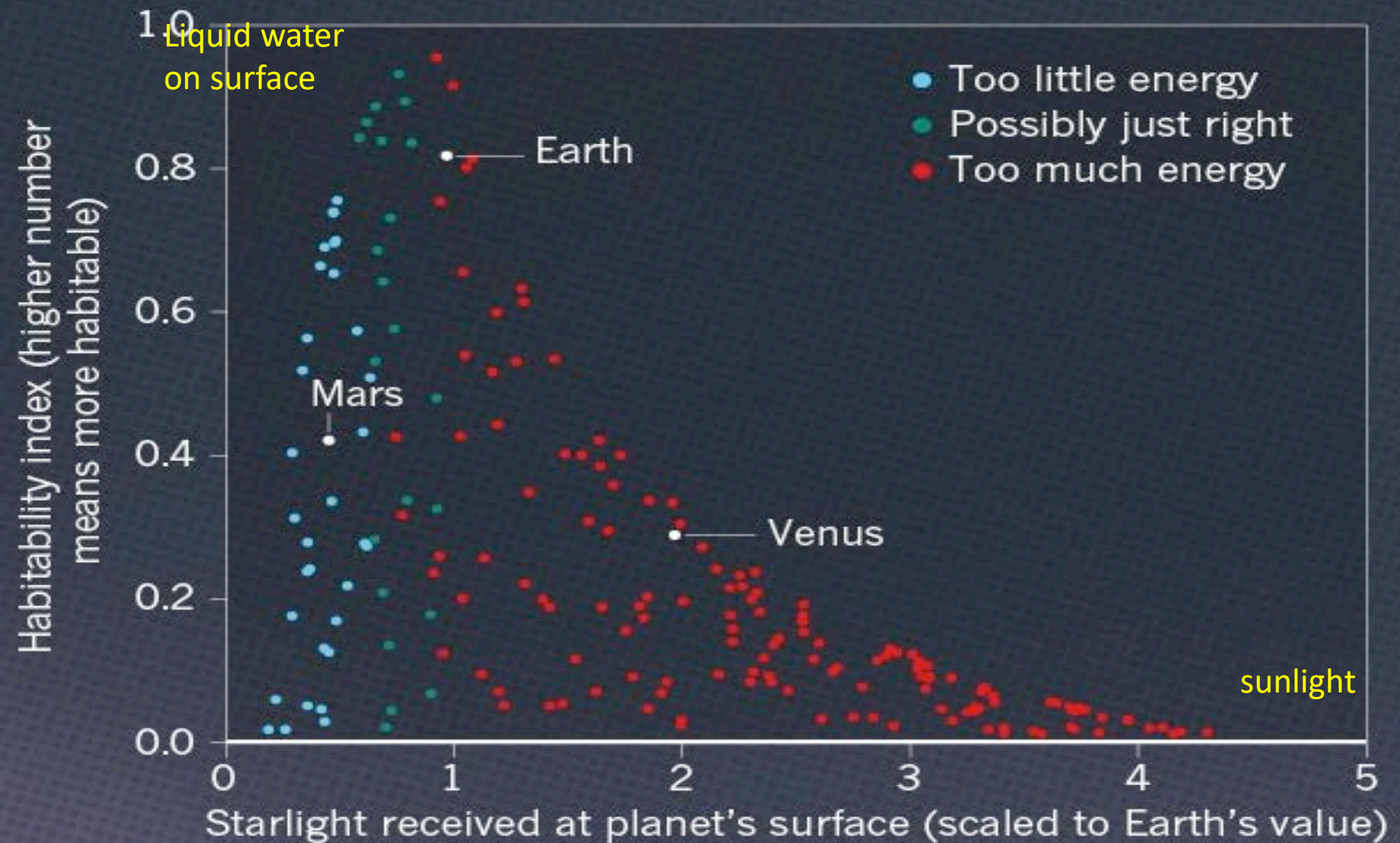
Charles Darwin, 1871

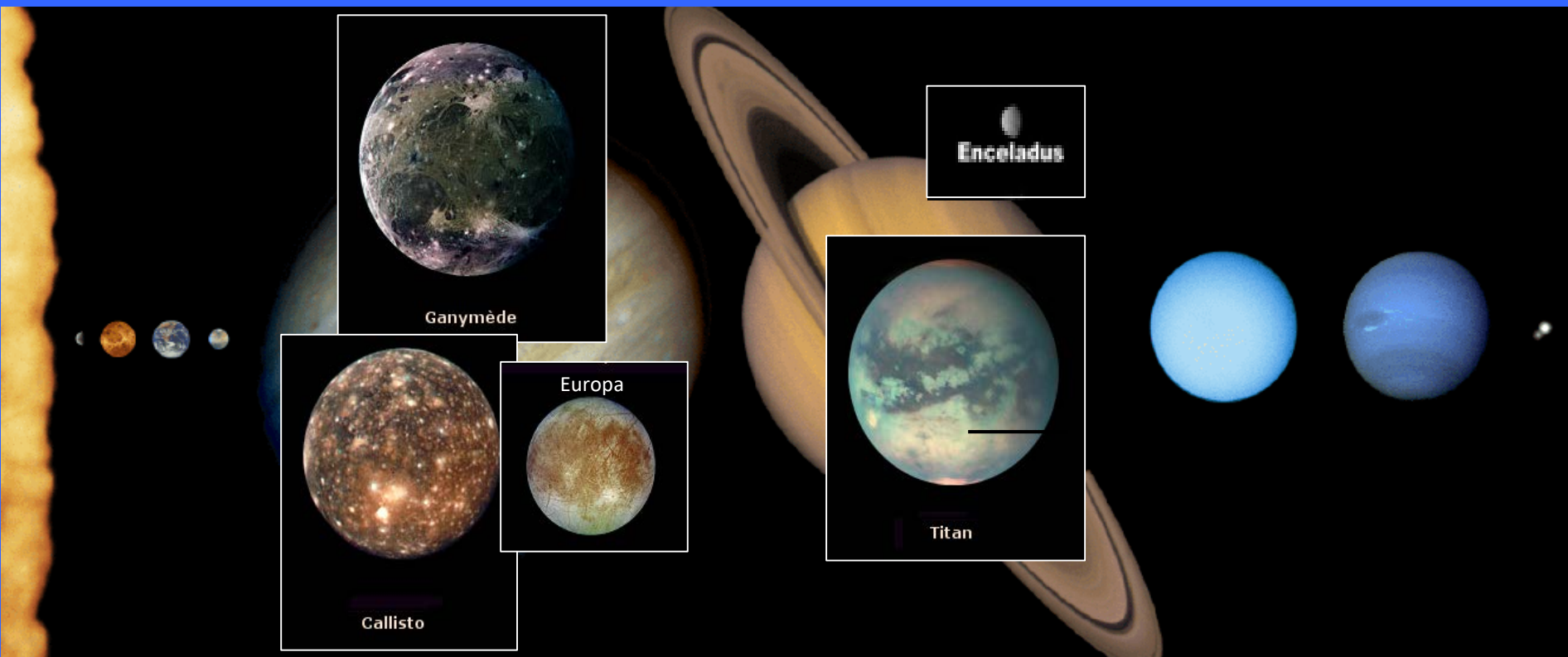
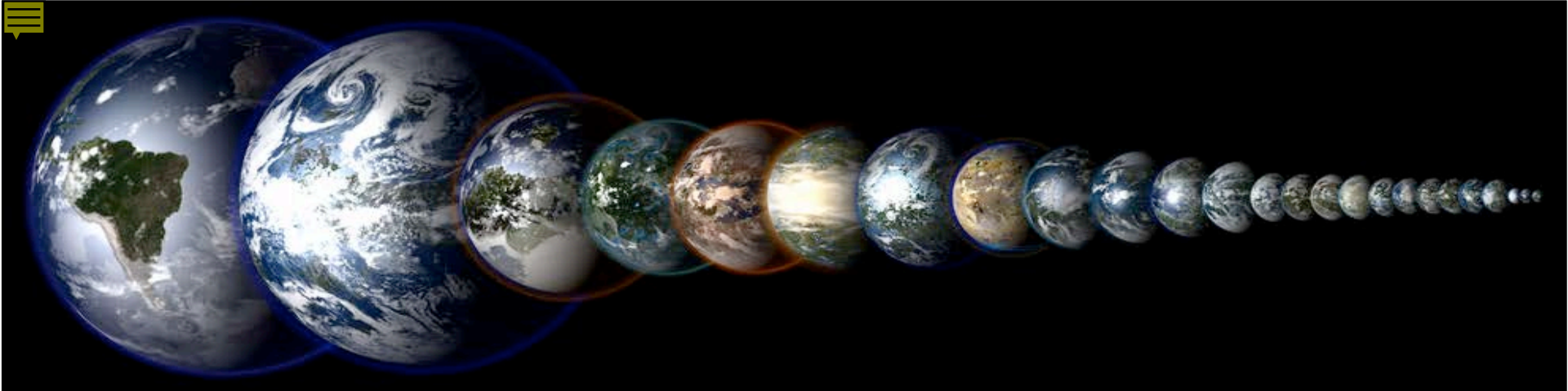


Life exists in extreme cold or heat



Ingredients of life: water, energy, organic material





Lets look nearby for traces of life.
Venus is bad. Mercury is worse.
The Moon, we've been there

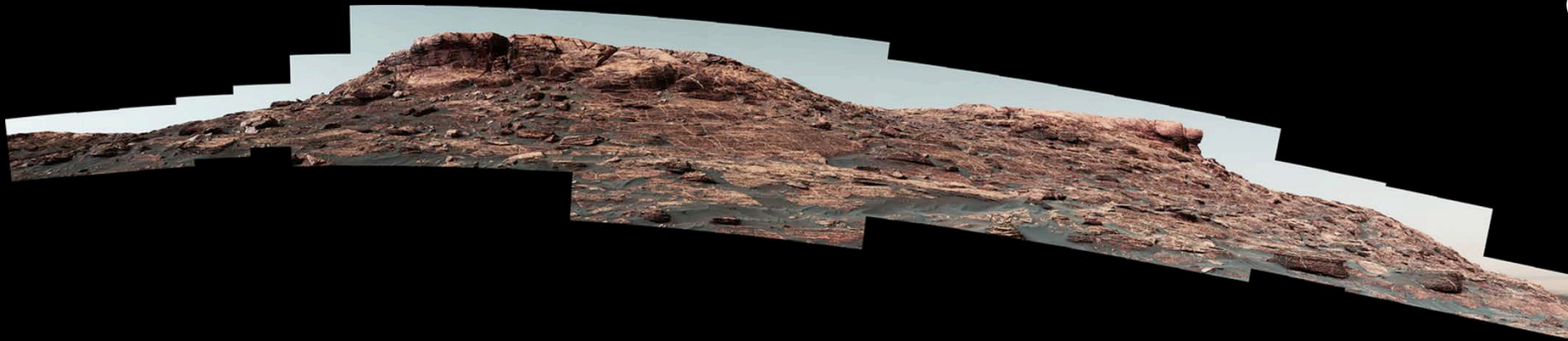
MARS

ENCELADUS

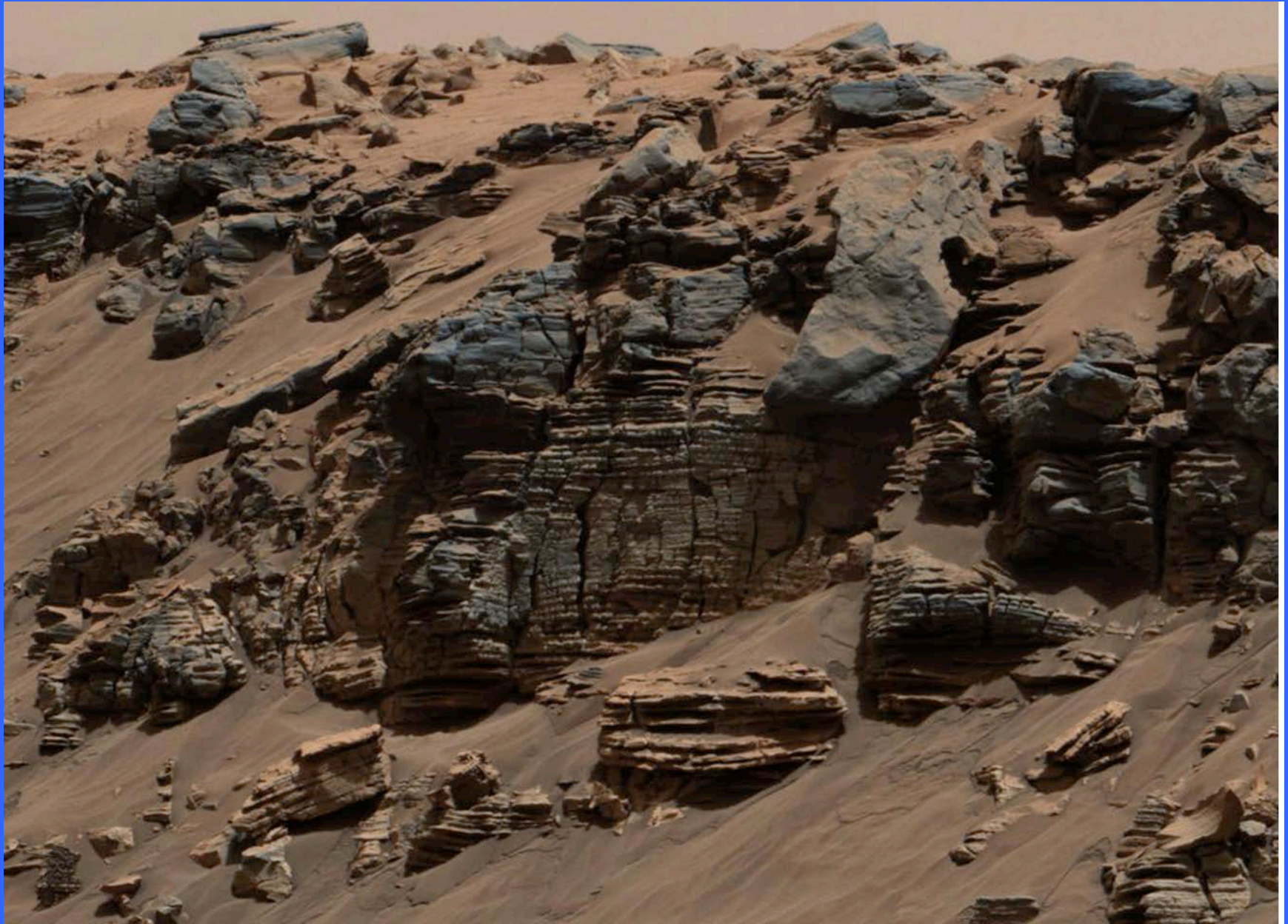
TITAN



Mars Rover Curiosity 2013-



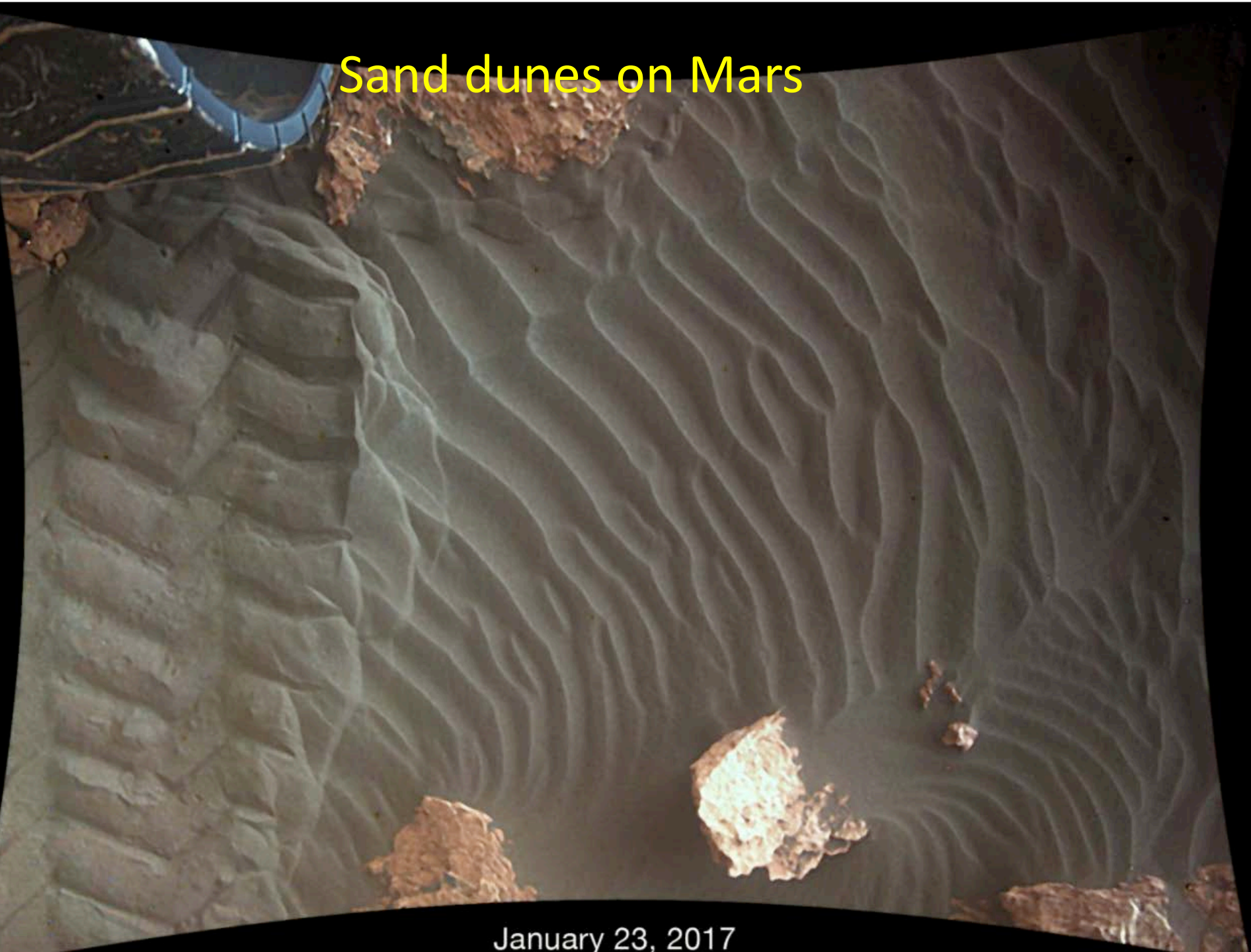
Rocky terrain on Mars



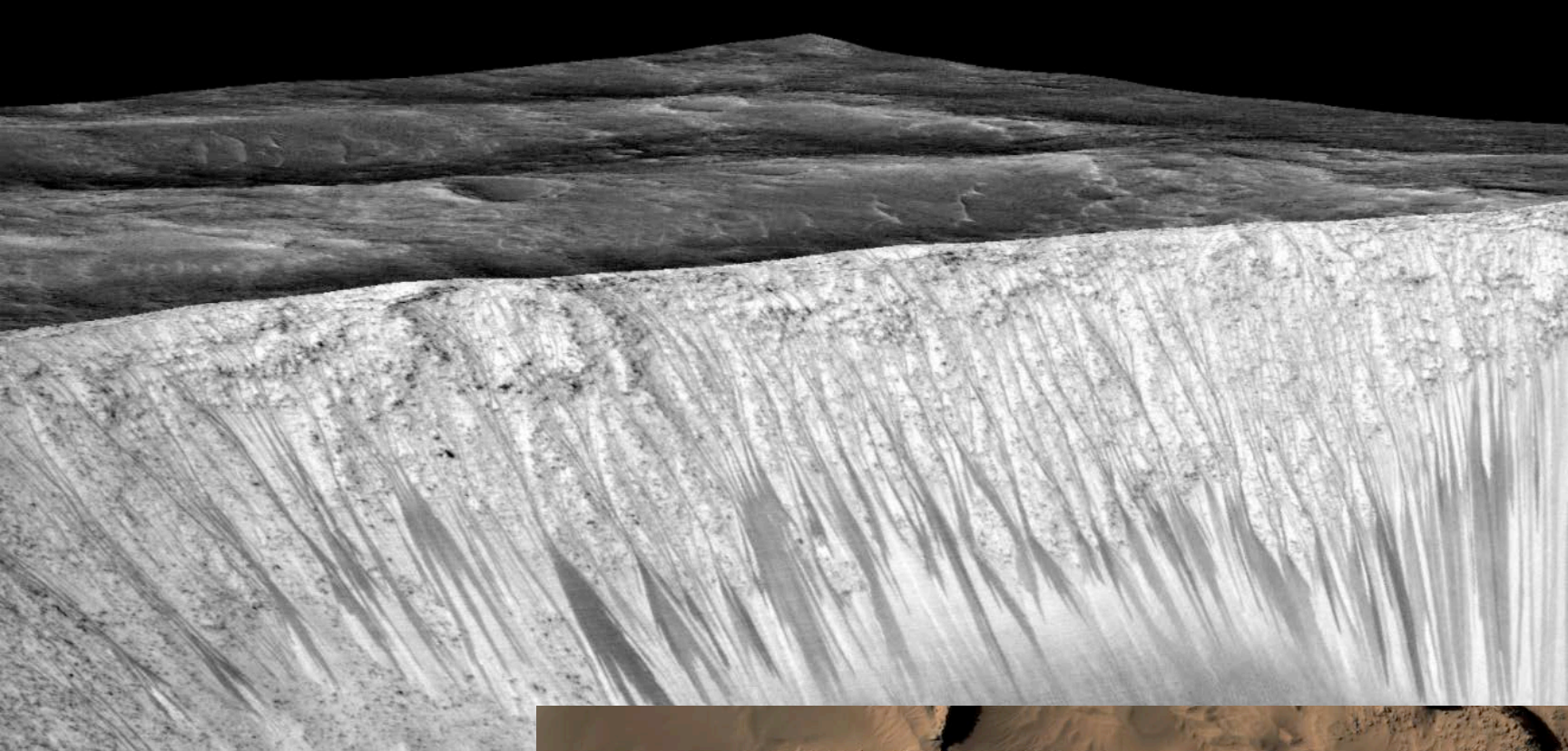
Valle de la Luna, Atacama Desert, Chile



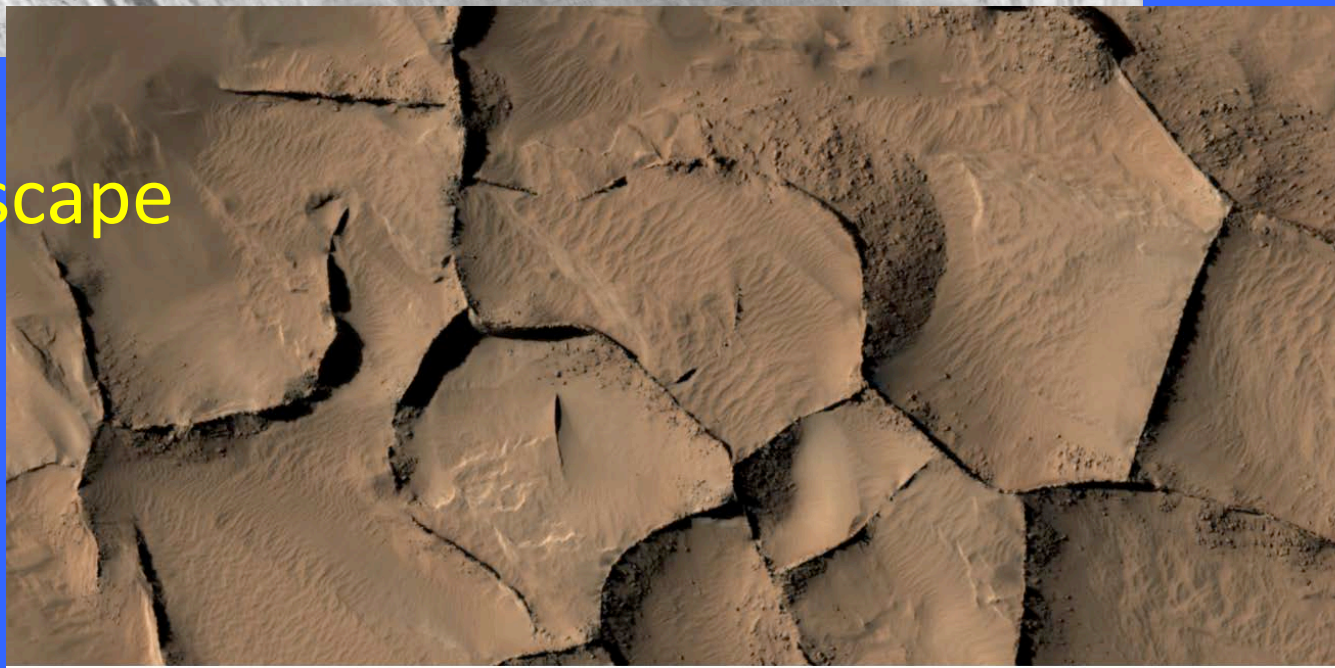
Sand dunes on Mars



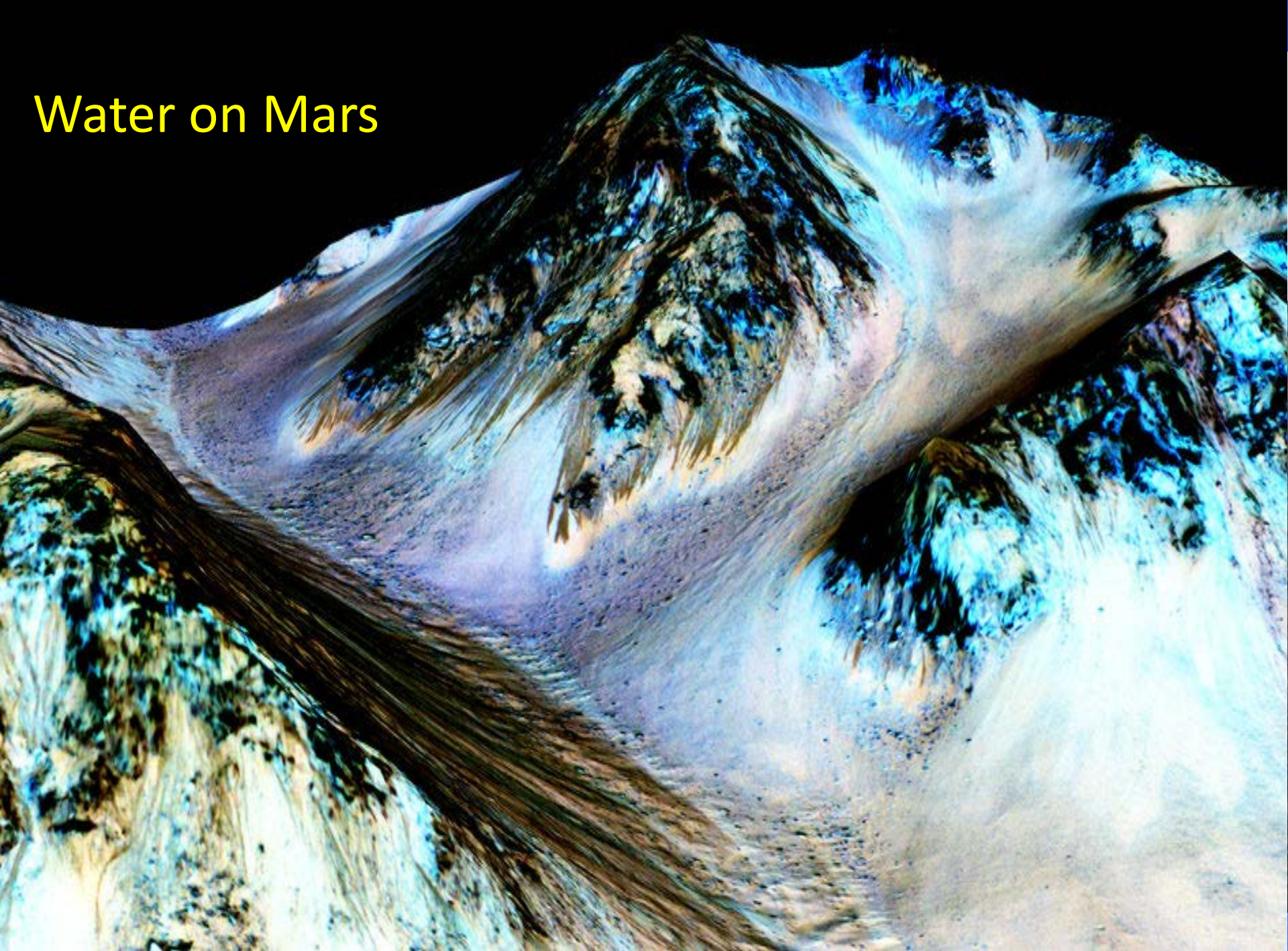
January 23, 2017



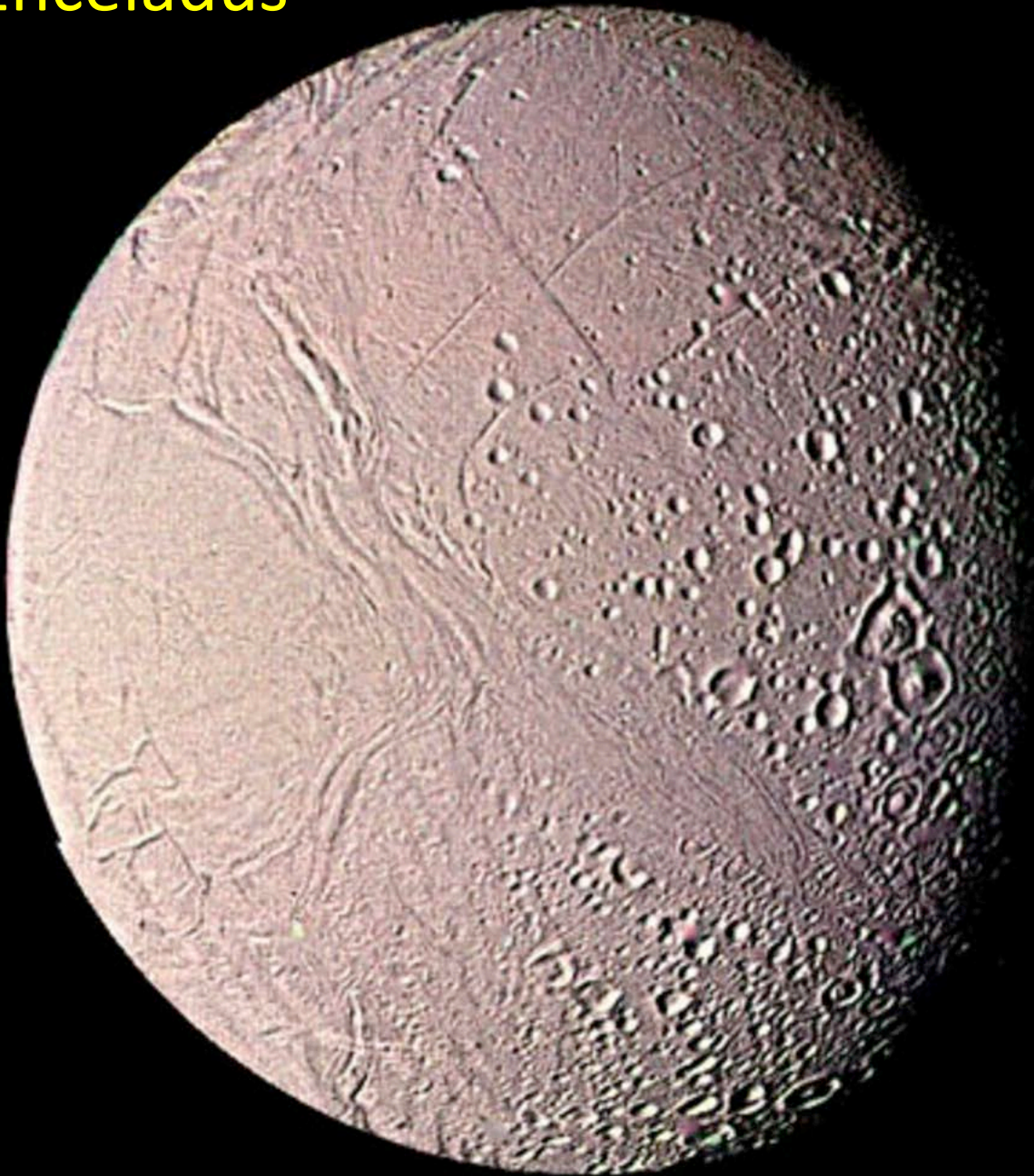
Martian landscape

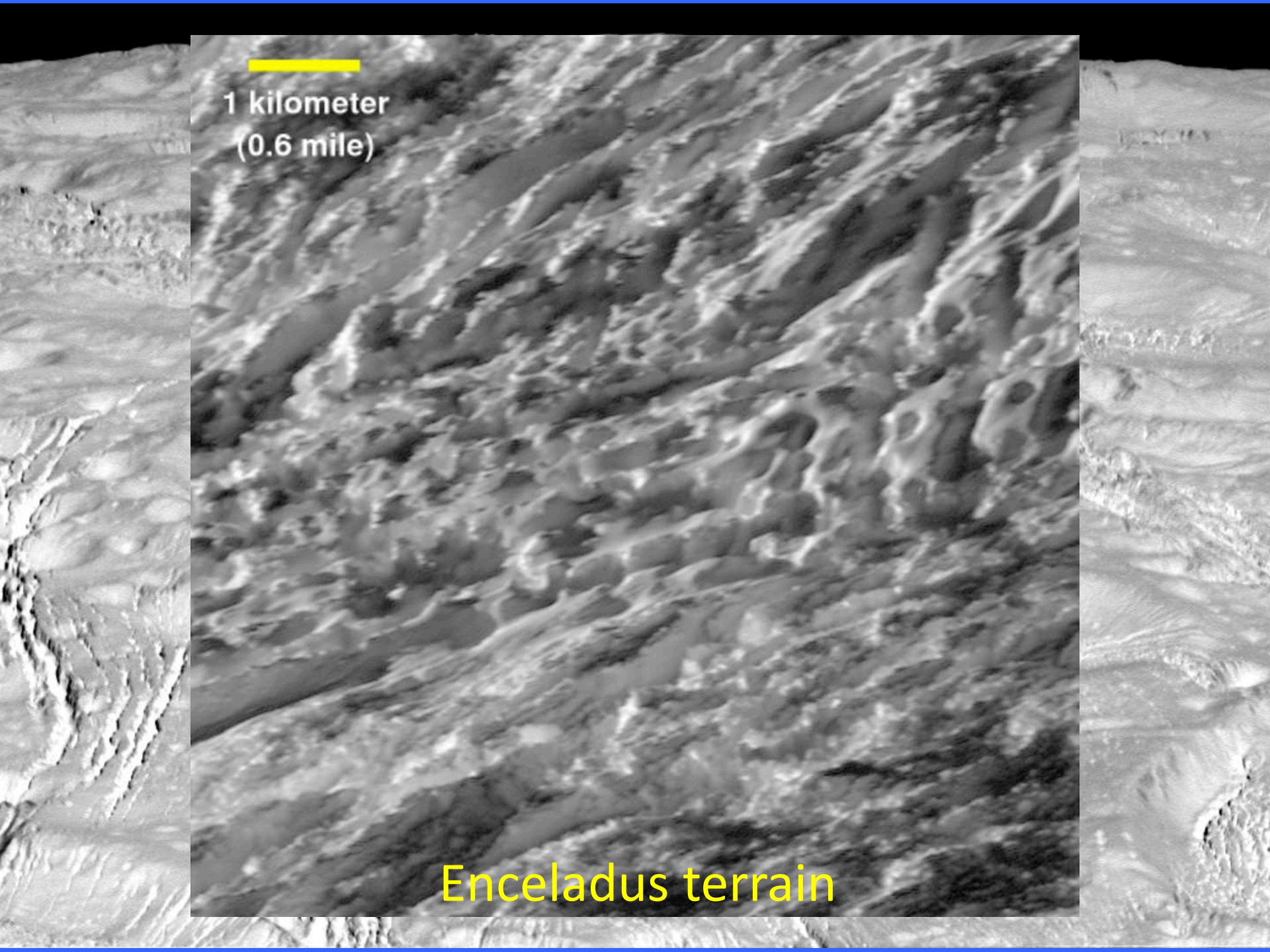


Water on Mars



Enceladus

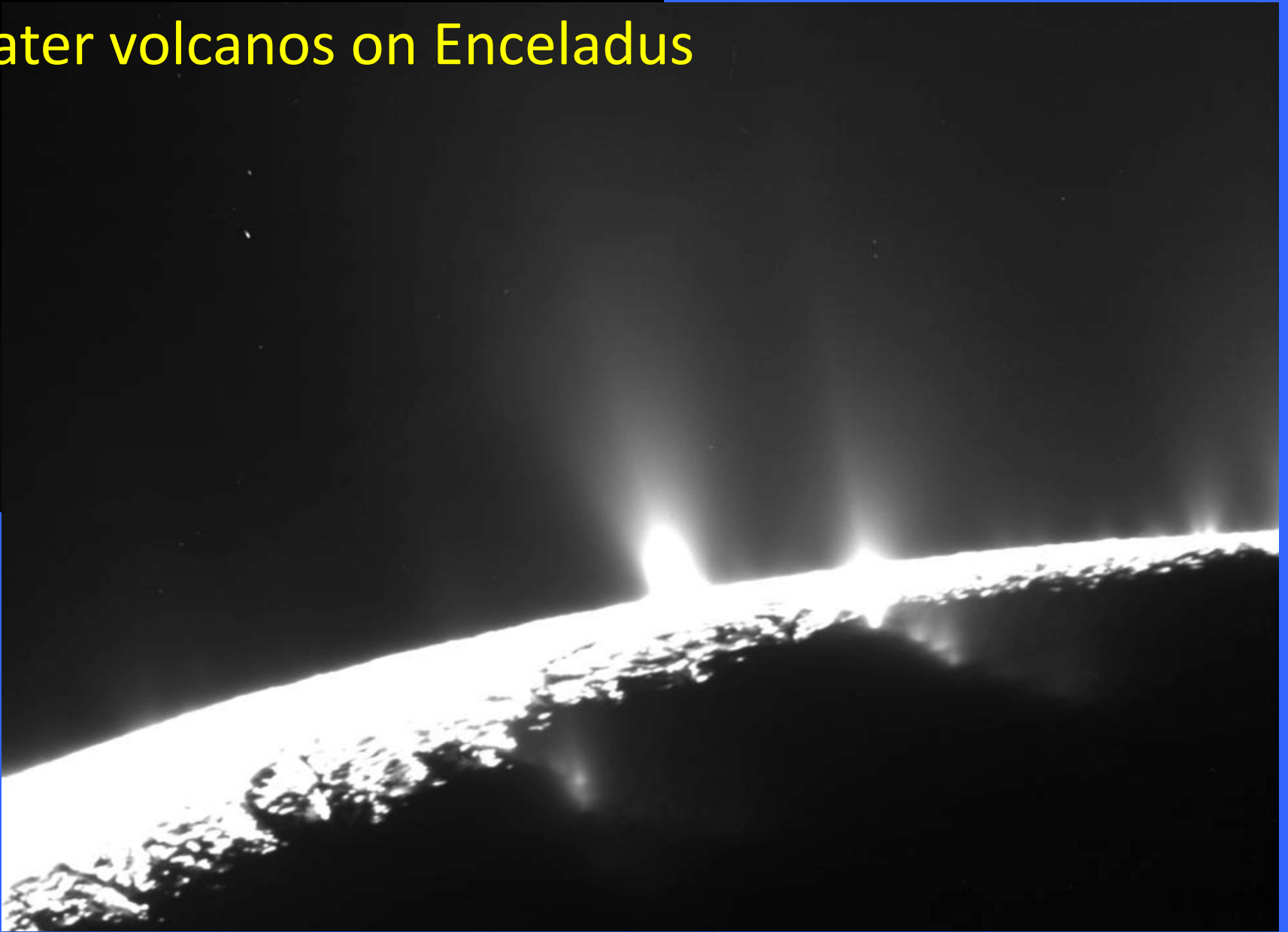




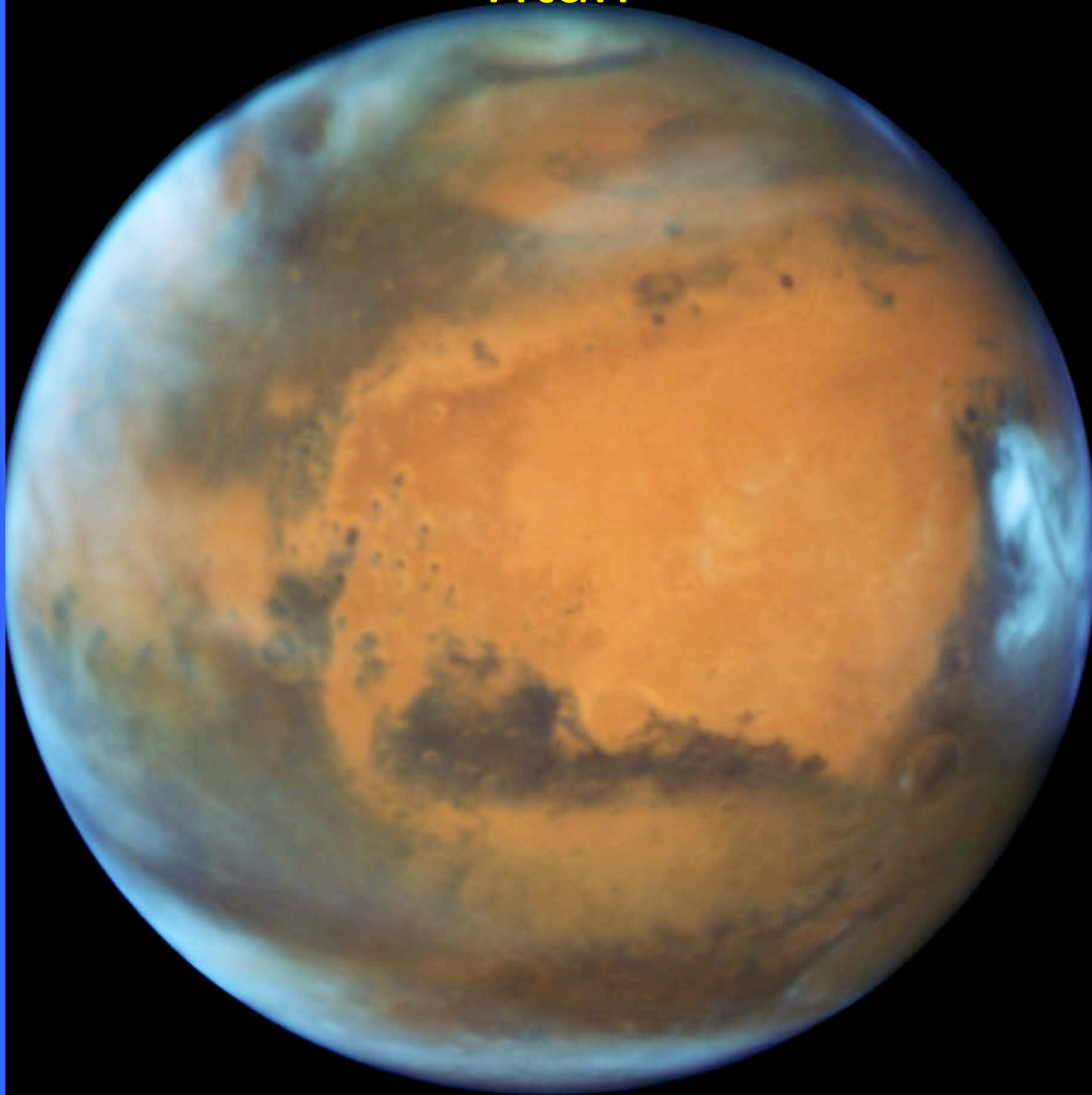
1 kilometer
(0.6 mile)

Enceladus terrain

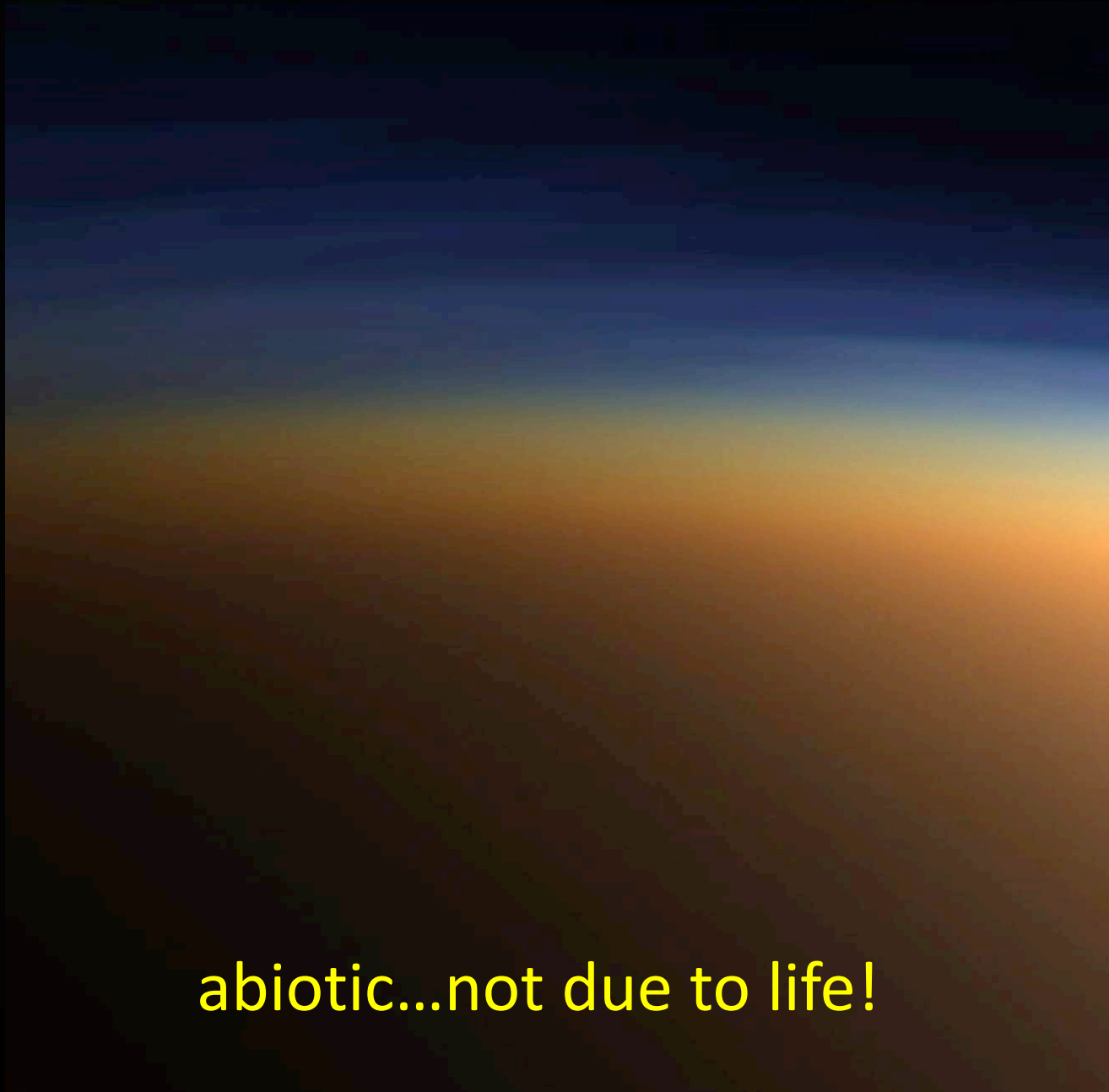
Water volcanos on Enceladus



Titan

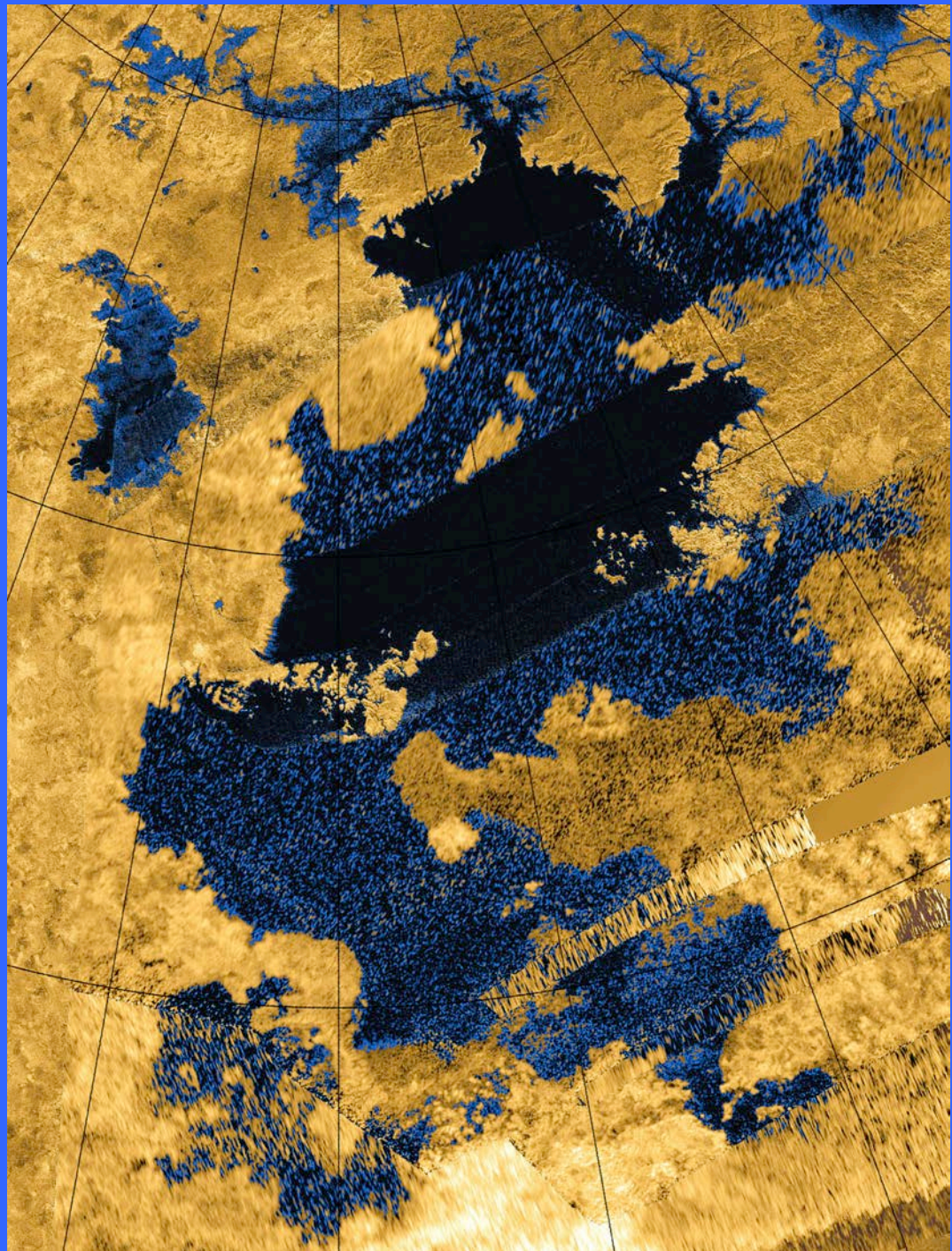


Methane haze on Titan



abiotic...not due to life!

Lakes on Titan

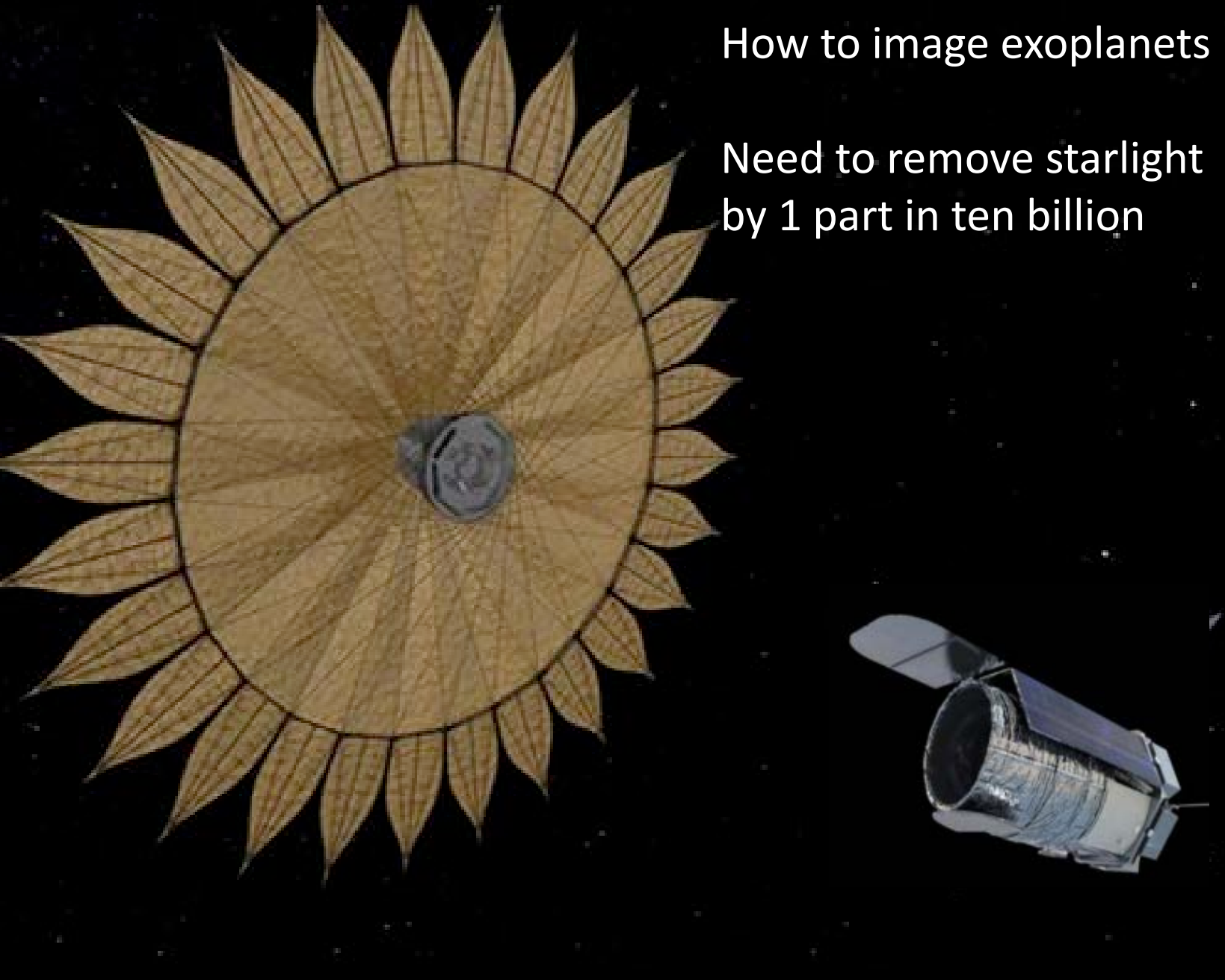


signatures of life

- We need to find exoplanets
- There are more exoplanets than stars
- But we'll settle for the nearest

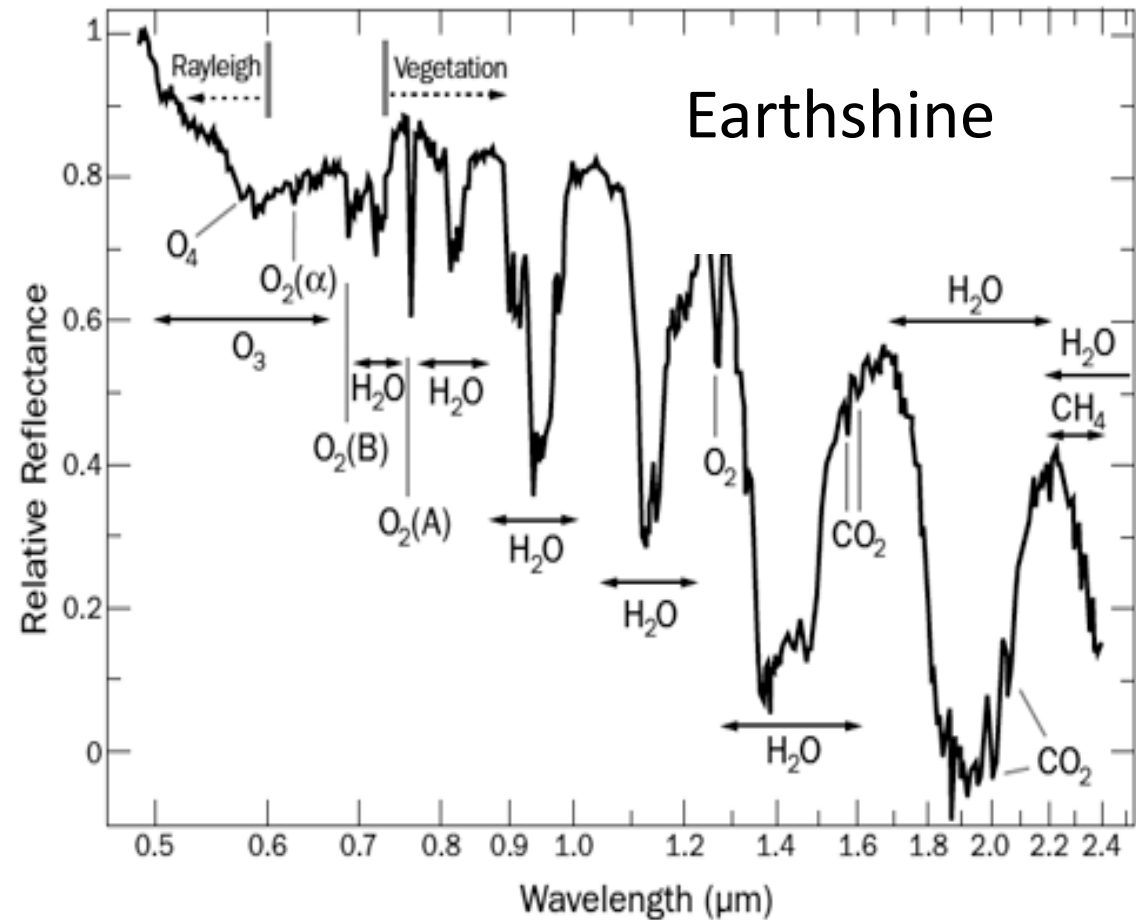
How to image exoplanets

Need to remove starlight
by 1 part in ten billion



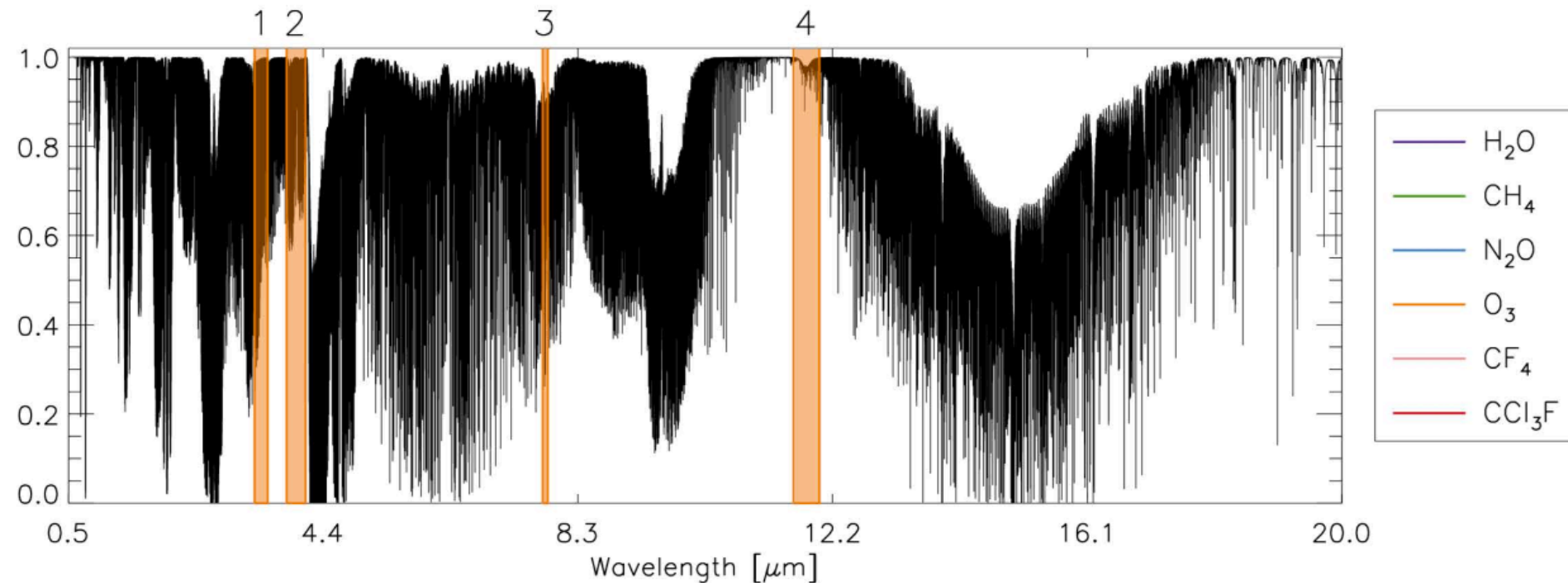
WFIRST with starshade ~ 2025

The red edge

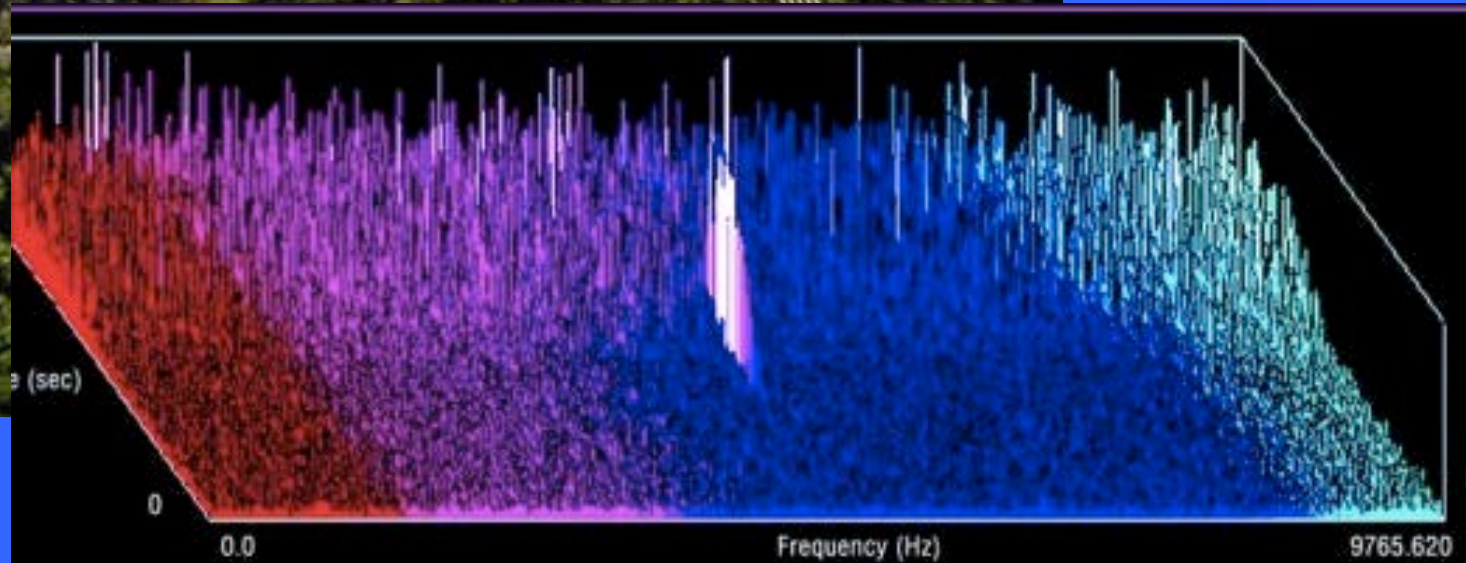


signatures of intelligent life

Industrial pollution

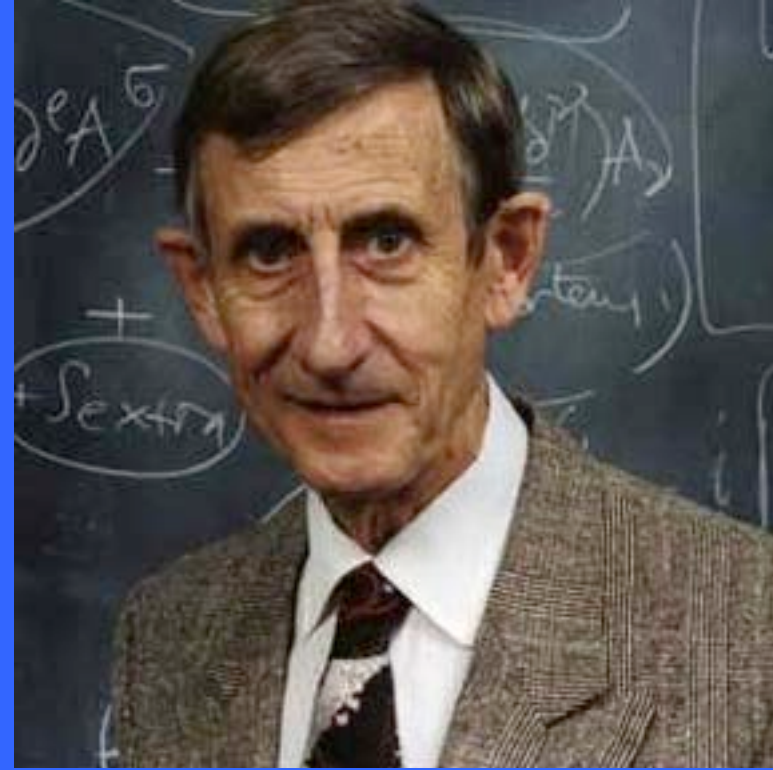


nuclear war



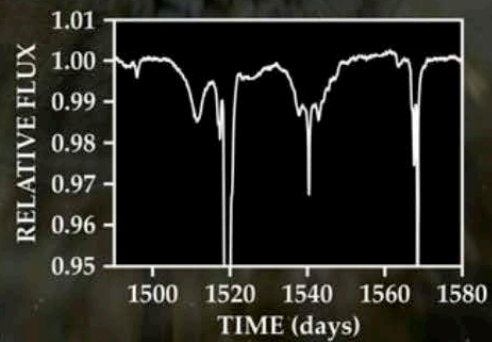
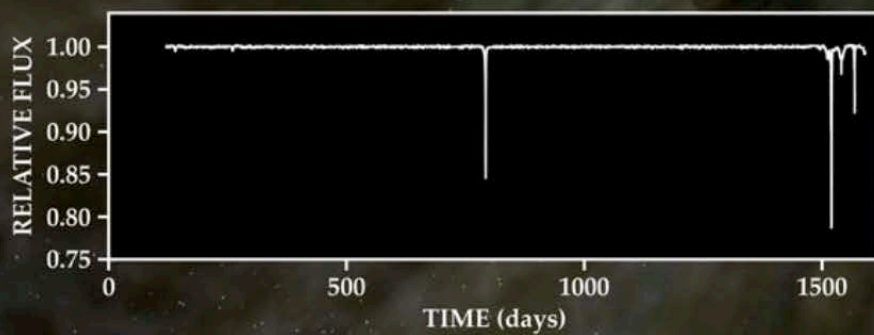
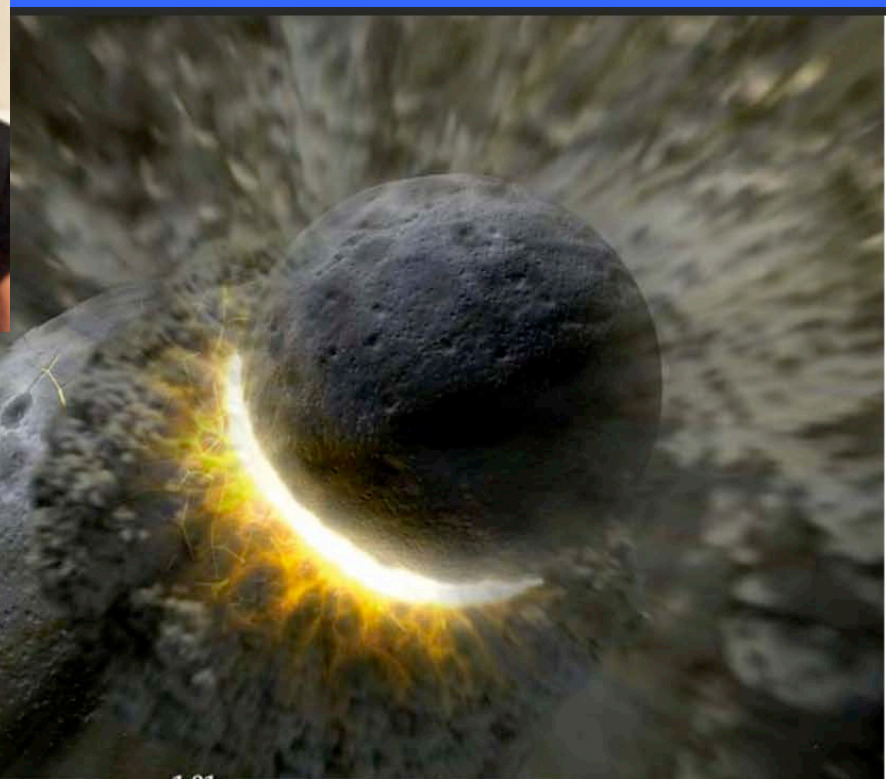
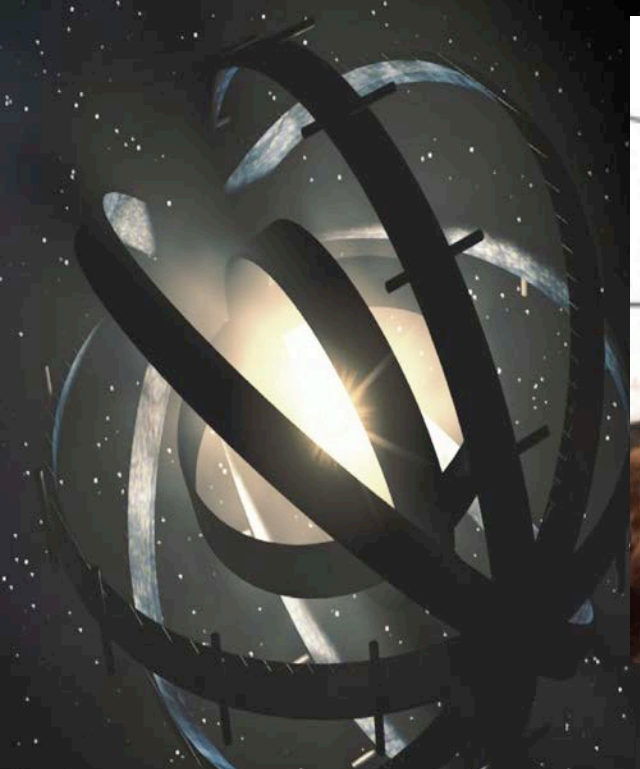
Project SETI

Dyson spheres:
artefacts of a
future civilization.
They must use
lots of energy
eg for transportation!



Search for Artificial Sources of Infrared Radiation

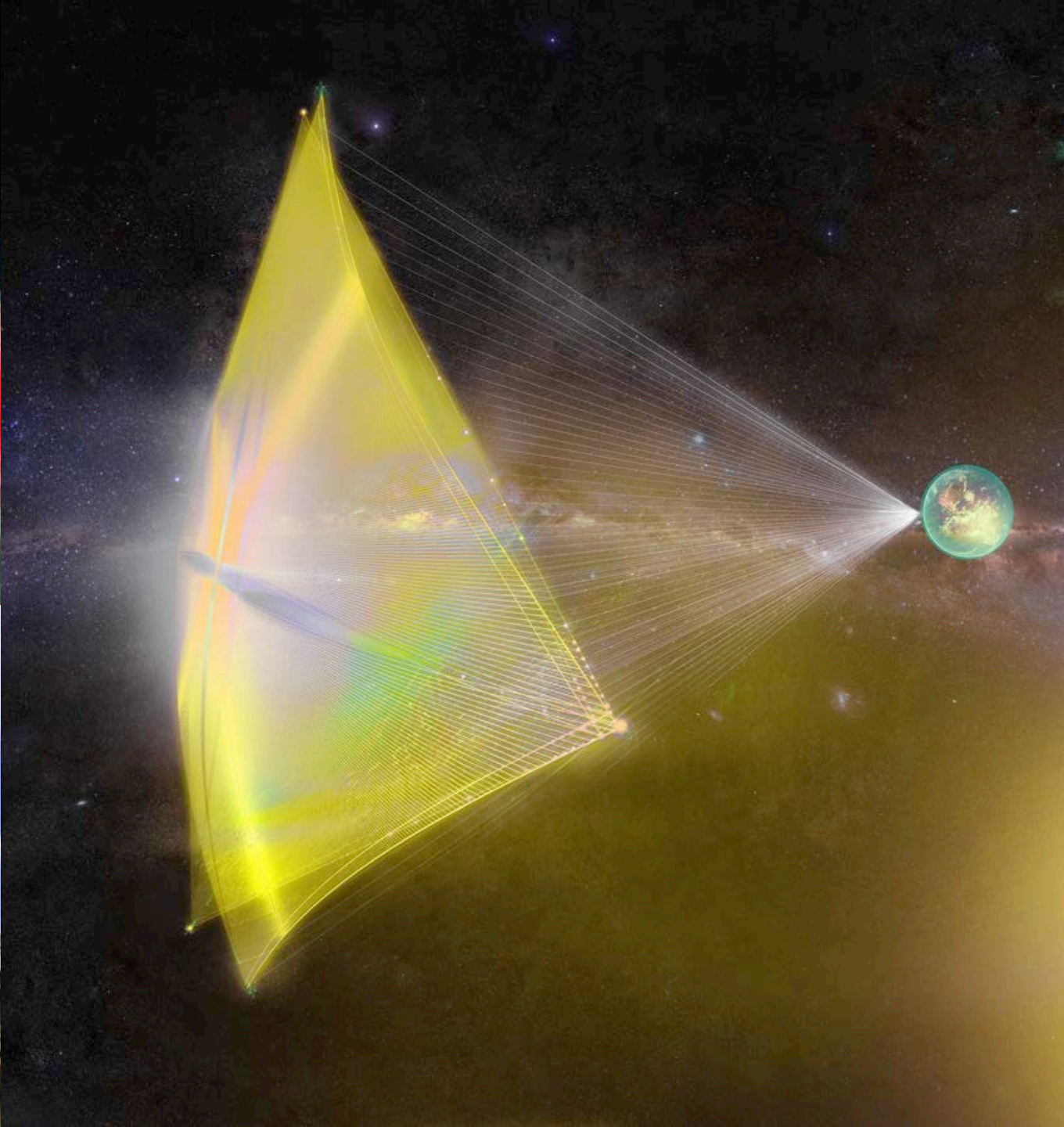
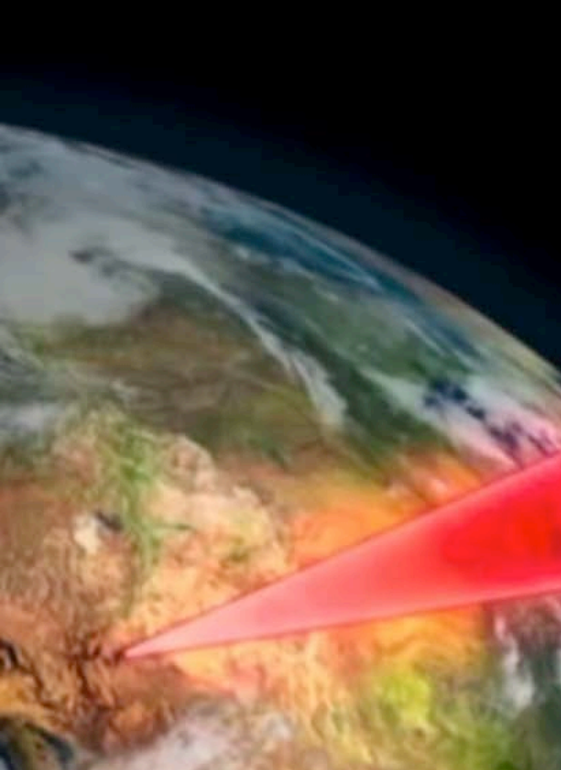
If extraterrestrial intelligent beings exist and have reached a high level of technical development, one by-product of their energy metabolism is likely to be the large-scale conversion of starlight into far-infrared radiation.



Project Breakthrough Starshot

launched by Yuri Milner in 2016





$$N = R_{*} \times f_p \times n_e \times f_e \times f_i \times f_c \times L$$

The number of technologically advanced civilizations in the Milky Way galaxy

The rate of formation of stars in the galaxy

The fraction of those stars with planetary systems

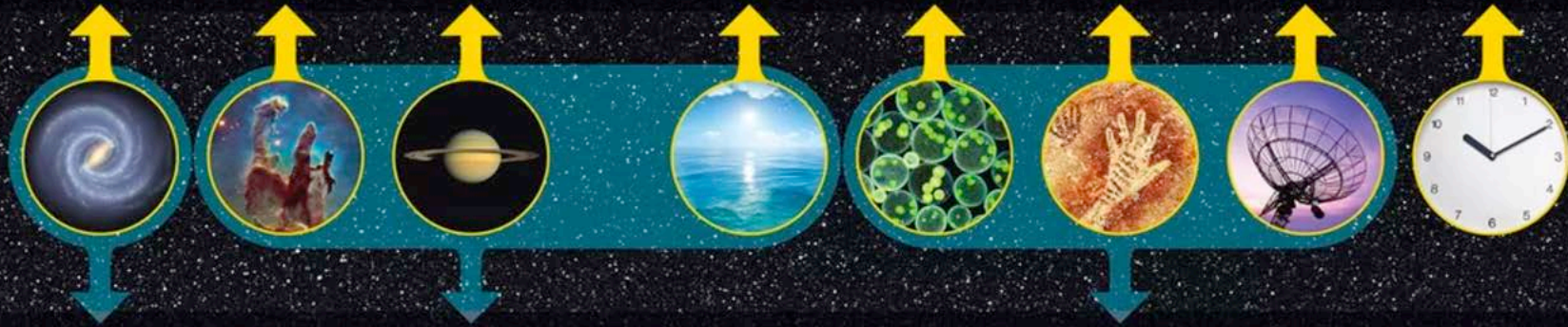
The number of planets, per solar system, with an environment suitable for life

The fraction of suitable planets on which life actually appears

The fraction of life-bearing planets on which intelligent life emerges

The fraction of civilizations that develop a technology that releases detectable signs of their existence into space

The length of time such civilizations release detectable signals into space



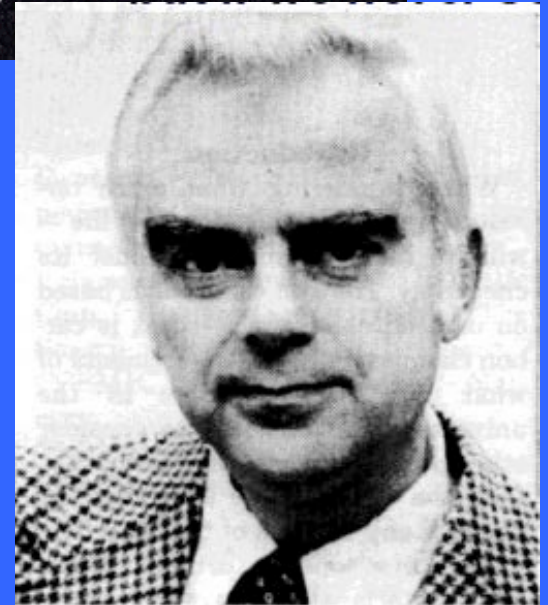
$$A = N_{ast} \times f_{bt}$$

The number of technological species that have formed over the history of the observable universe

The number of habitable planets in a given volume of the universe

The likelihood of a technological species arising on one of these planets

Largest uncertainty is duration of intelligent life

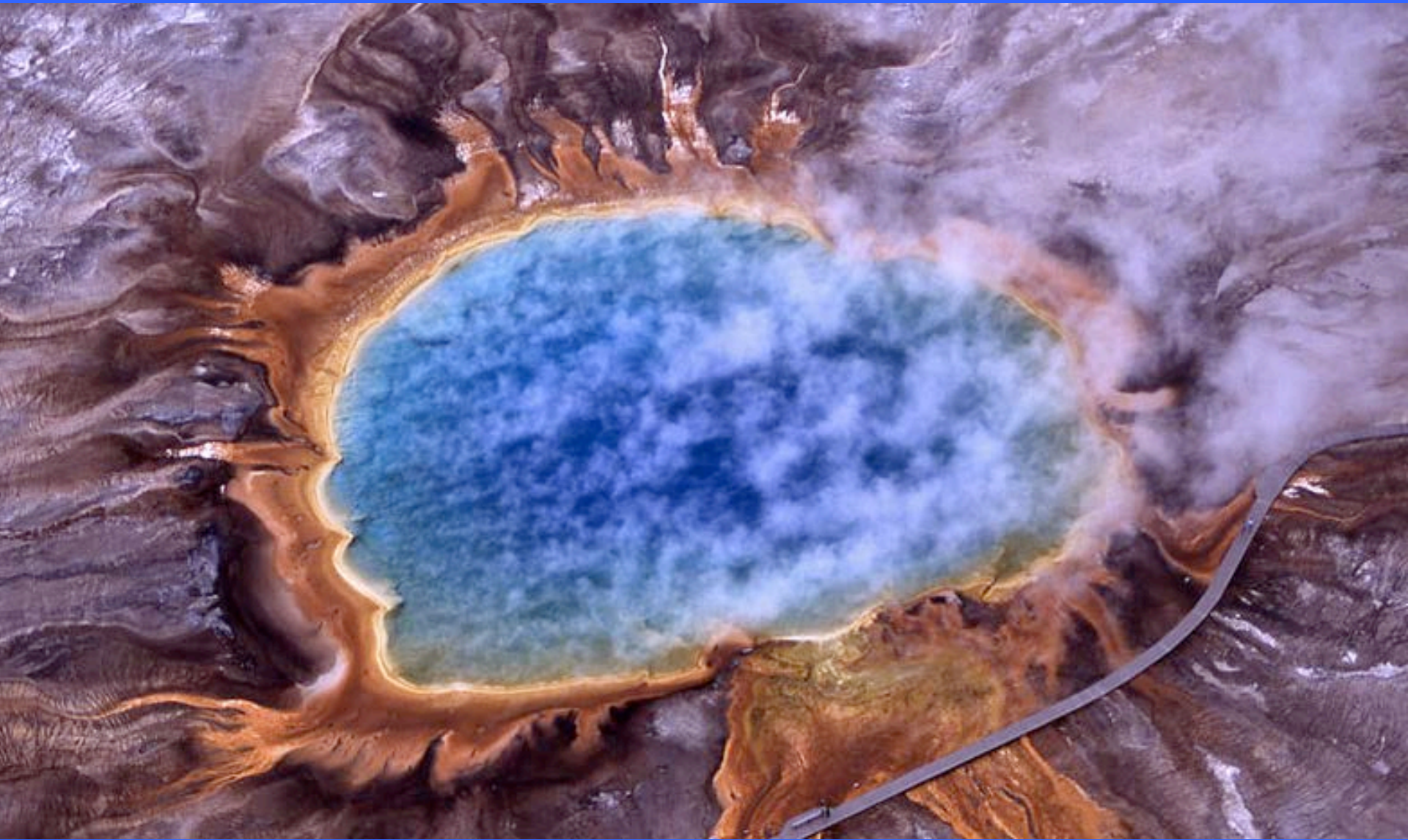


Life is fragile



Life is tenacious

Microbial life exists under extreme conditions



Humanity is very resilient

Suppose we destroy most of humanity in 5000 years by climate change or nuclear war or....

Back to the stone age.

But life should recover in 50000 years.

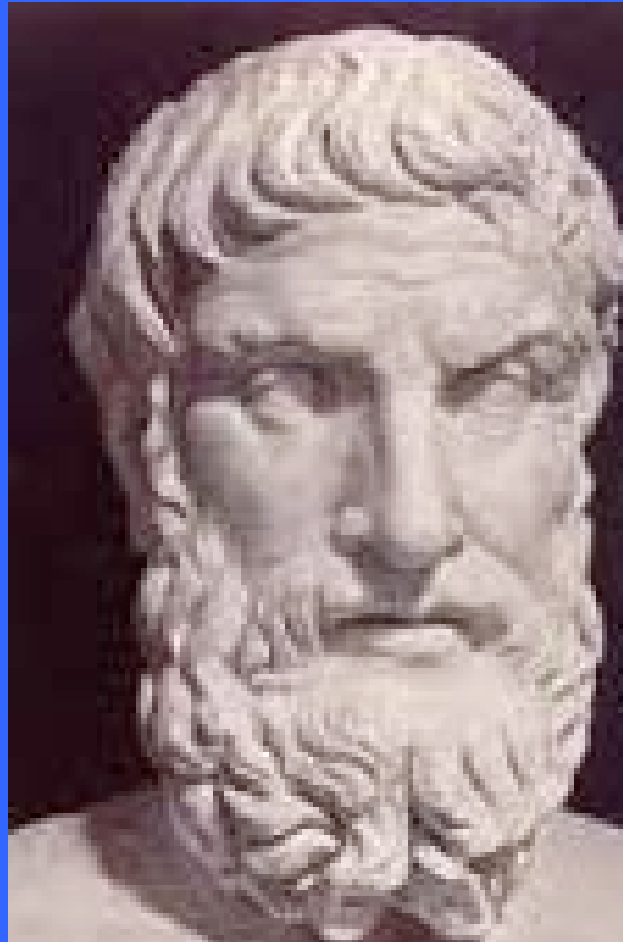
This just means we have to search 10 times harder to find signs of intelligent life elsewhere

The real problem: we don't know if life has a 10% chance of developing, or 0.0000000000000001%.
In the pessimistic case we are alone in the galaxy

There are no limits

It is in the highest degree unlikely that this earth and sky is the only one to have been created...Nothing in the Universe is the only one of its kind.

Lucretius, c. 50 BC.



Few will deny the profound importance, practical and philosophical, which the detection of interstellar communications would have. We therefore feel that a discriminating search for signals deserves a considerable effort. The probability of success is difficult to estimate; but if we never search, the chance of success is zero.

Giuseppe Cocconi and Philip Morrison 1959



Thank you!