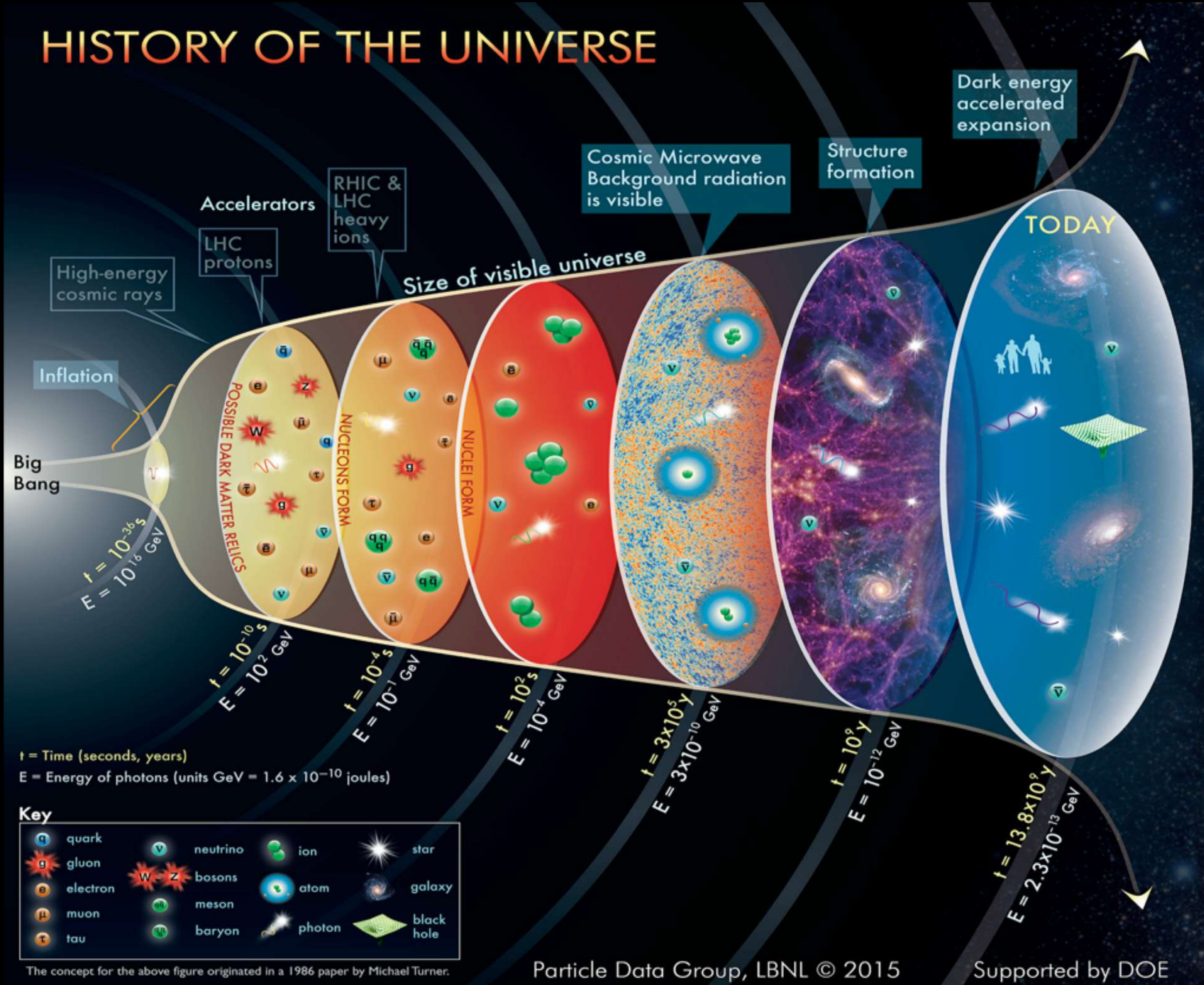
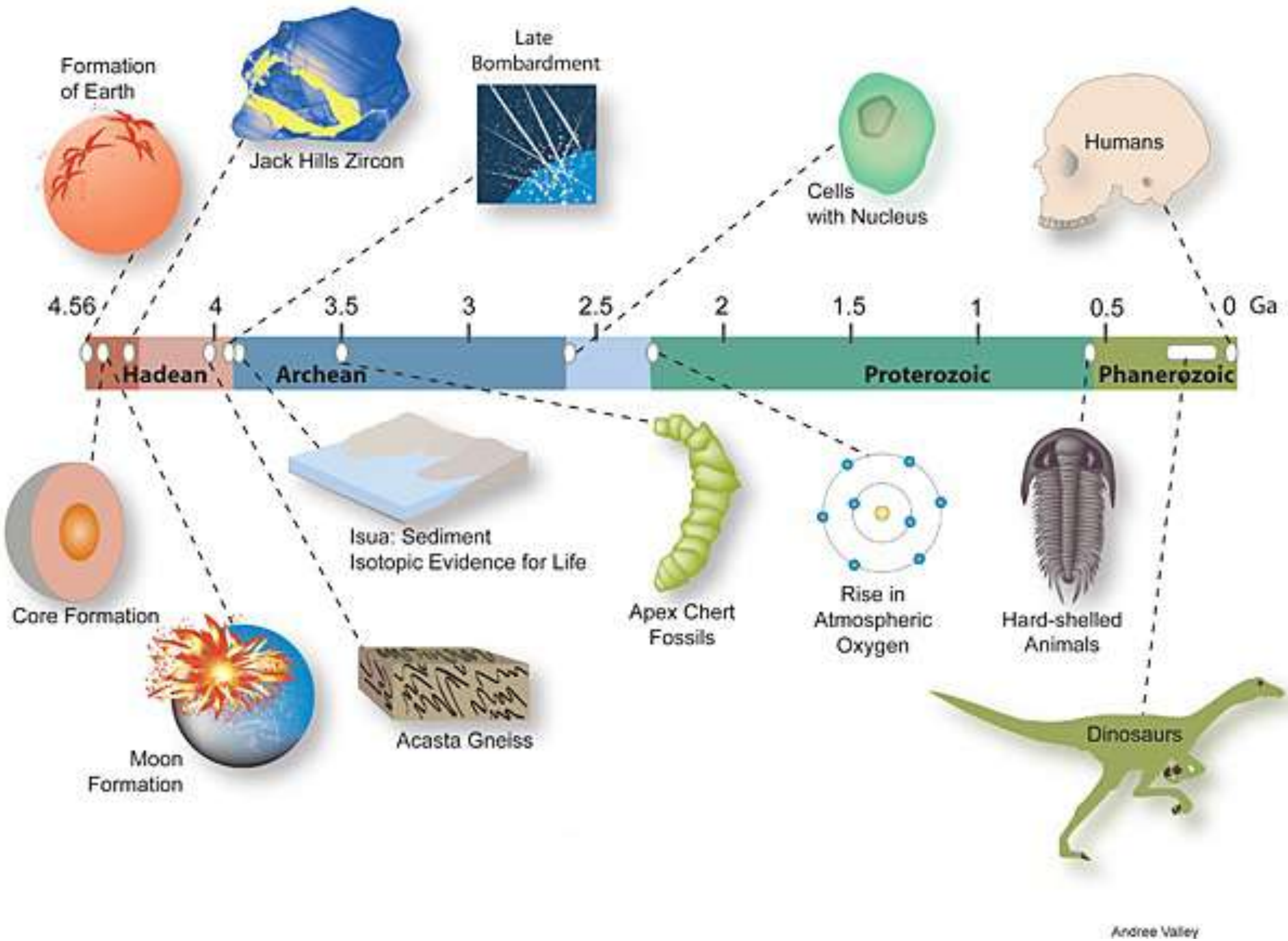
Where is everybody? Searching for life in the Universe

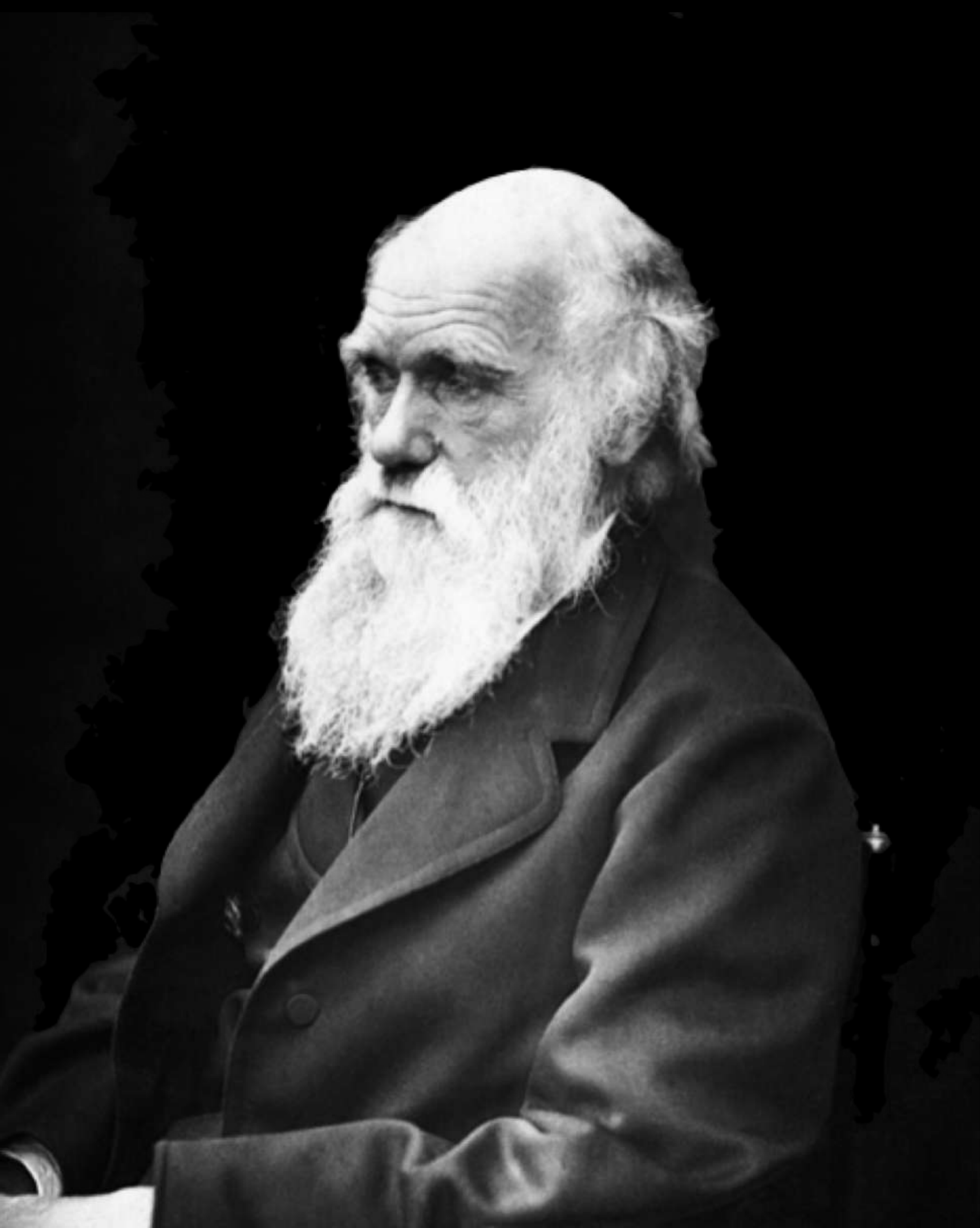
Amedeo Balbi

Dipartimento di Fisica,
Università di Roma
«Tor Vergata»


HISTORY OF THE UNIVERSE
Dark energy accelerated expansion
Cosmic Microwave Background radiation is visible
Structure formation
Accelerators
RHIC & LHC heavy ions
LHC protons
High-energy cosmic rays
Inflation
Size of visible universe
TODAY
Big Bang
POSSIBLE DARK MATTER RELICS
NUCLEONS FORM
NUCLEI FORM
t = 10^-36 s
E = 10^16 GeV
t = 10^-10 s
E = 10^2 GeV
t = 10^-4 s
E = 10^-1 GeV
t = 10^2 s
E = 10^-4 GeV
t = 3x10^5 y
E = 3x10^-10 GeV
t = 10^9 y
E = 10^-12 GeV
t = 13.8x10^9 y
E = 2.3x10^-13 GeV
t = Time (seconds, years)
E = Energy of photons (units GeV = 1.6 x 10^-10 joules)
Key
quark
gluon
electron
muon
tau
neutrino
bosons
meson
baryon
ion
atom
photon
star
galaxy
black hole
The concept for the above figure originated in a 1986 paper by Michael Turner.
Particle Data Group, LBNL © 2015
Supported by DOE



Formation of Earth
Jack Hills Zircon
Late Bombardment
Cells with Nucleus
Humans
4.56
4
3.5
3
2.5
2
1.5
1
0.5
0 Ga
Hadean
Archean
Proterozoic
Phanerozoic
Core Formation
Moon Formation
Isua: Sediment Isotopic Evidence for Life
Acasta Gneiss
Apex Chert Fossils
Rise in Atmospheric Oxygen
Hard-shelled Animals
Dinosaurs
Andree Valley

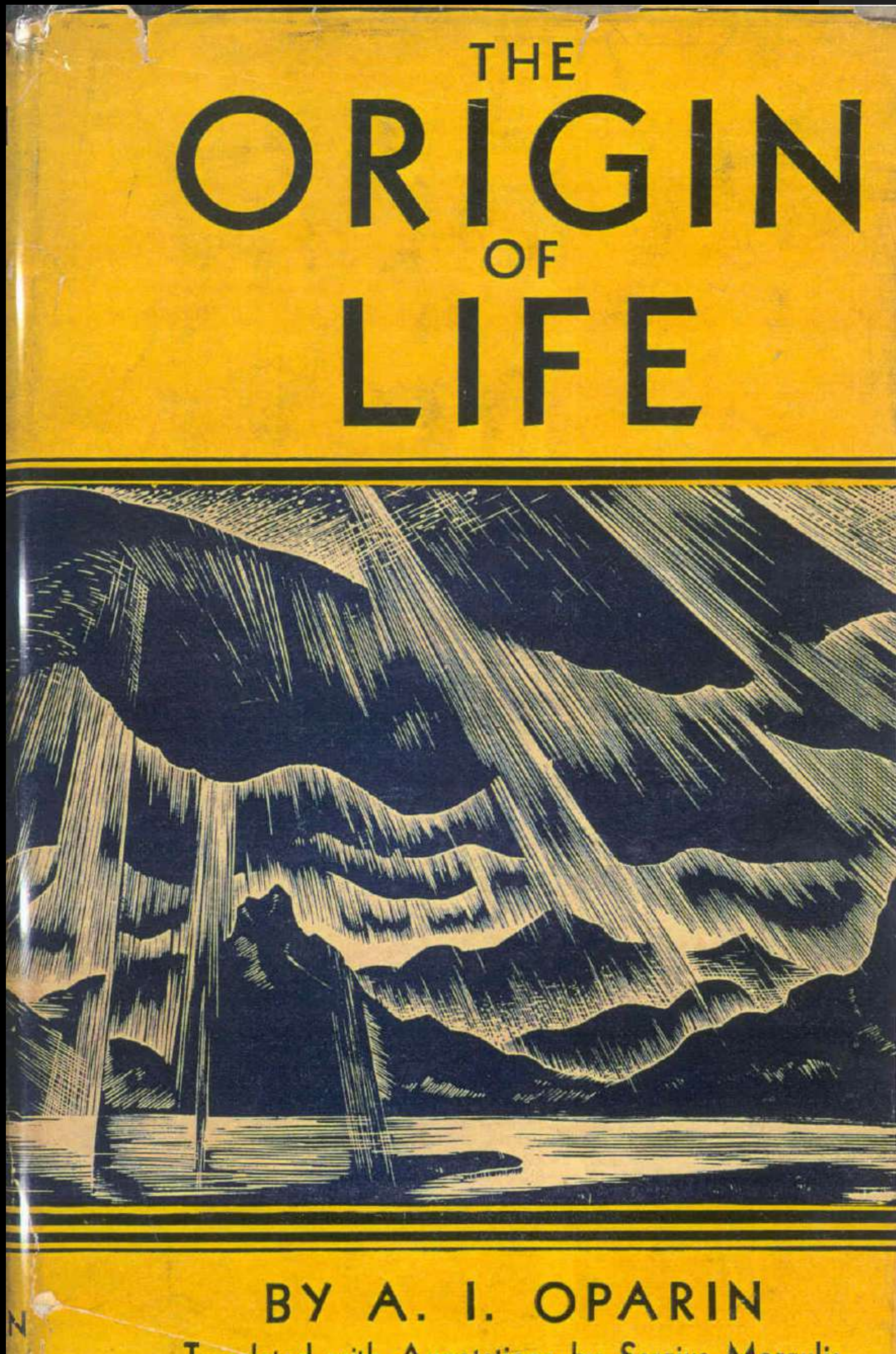


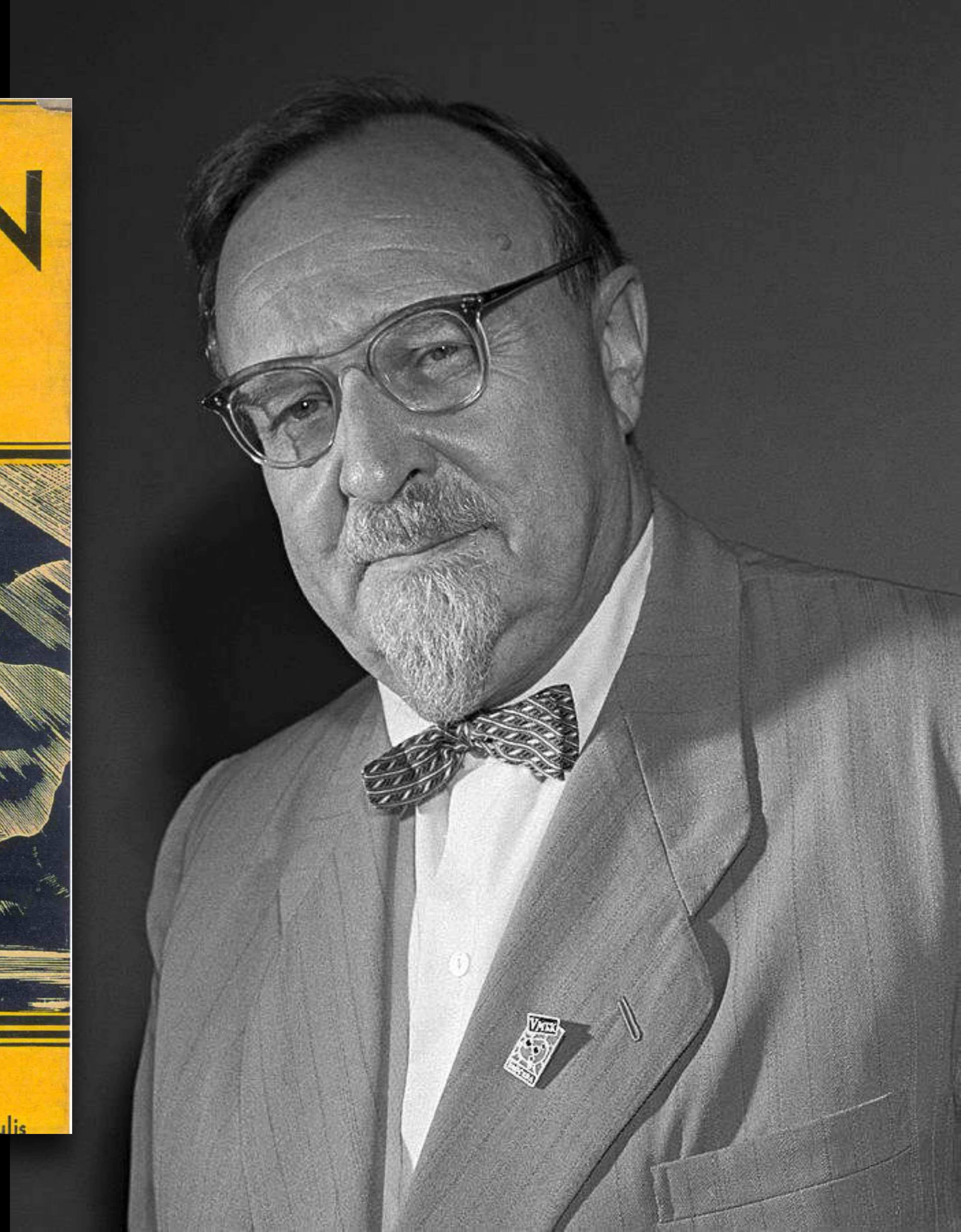
“It is mere rubbish, thinking at present of the origin of life.”

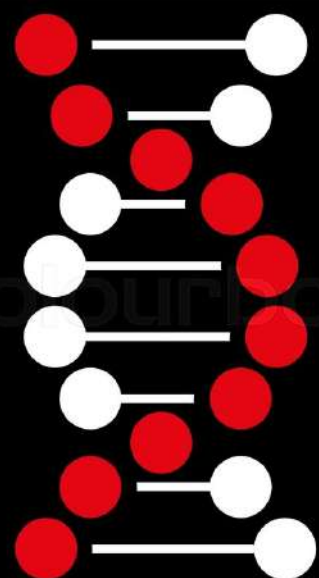
— Charles Darwin, letter to Joseph Hooker (1863)

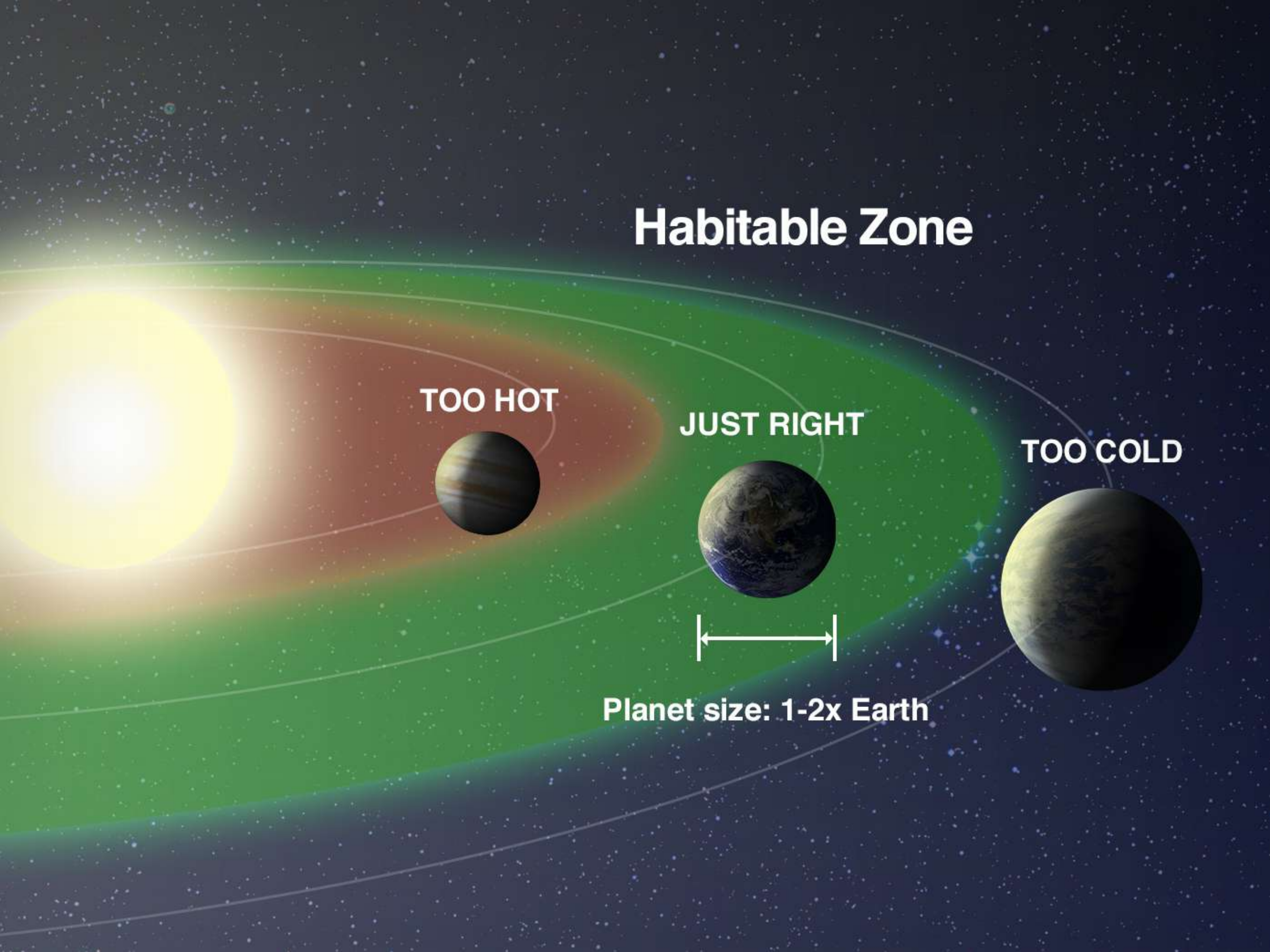
“[...] in some warm little pond, with all sorts of ammonia and phosphoric salts, light, heat, electricity, etc., [...]”

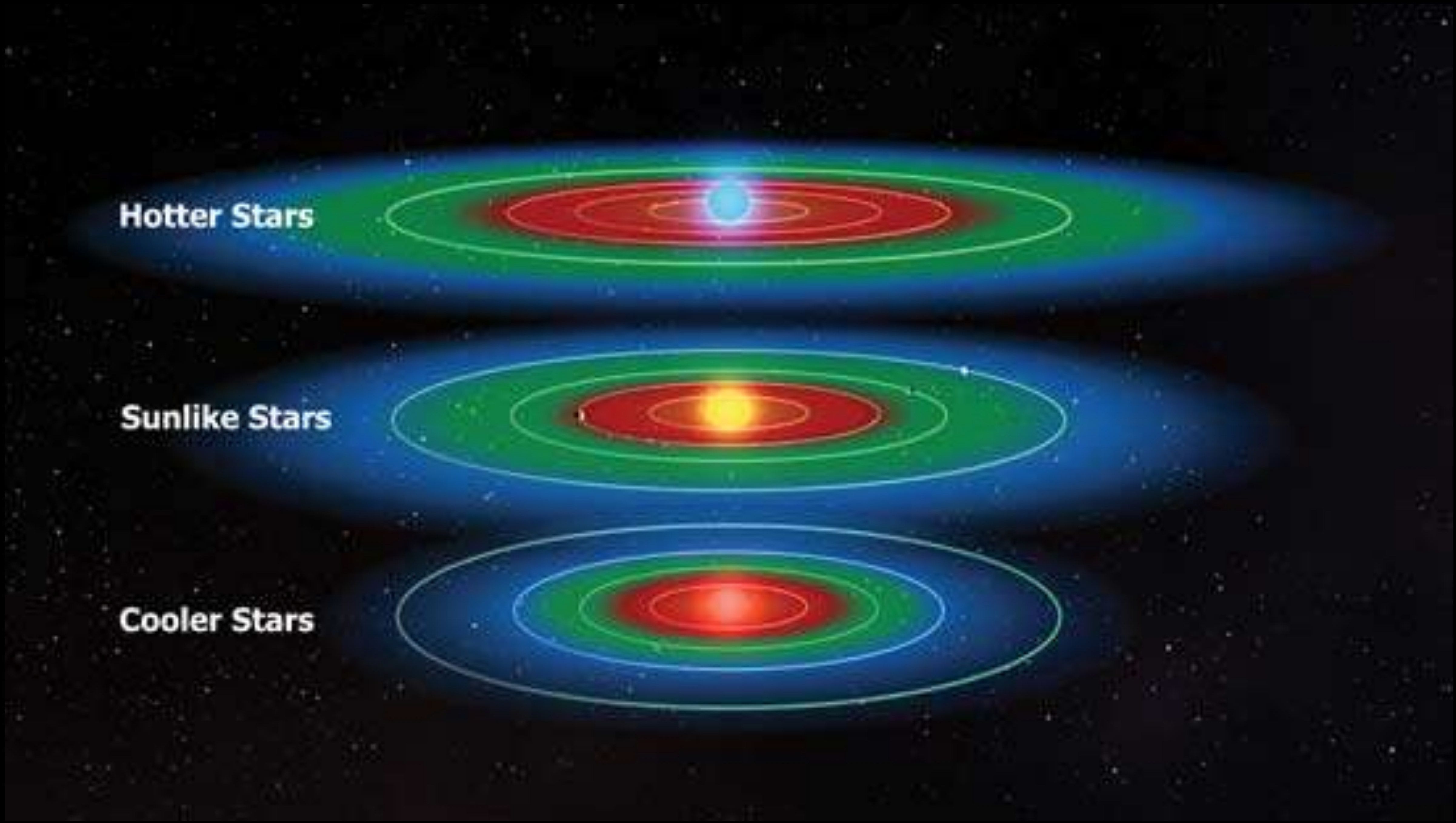
— Charles Darwin, letter to Joseph Hooker (1871)


THE
ORIGIN
OF
LIFE
BY A. I. OPARIN
Translated with Annotations by Sergius Morgulis

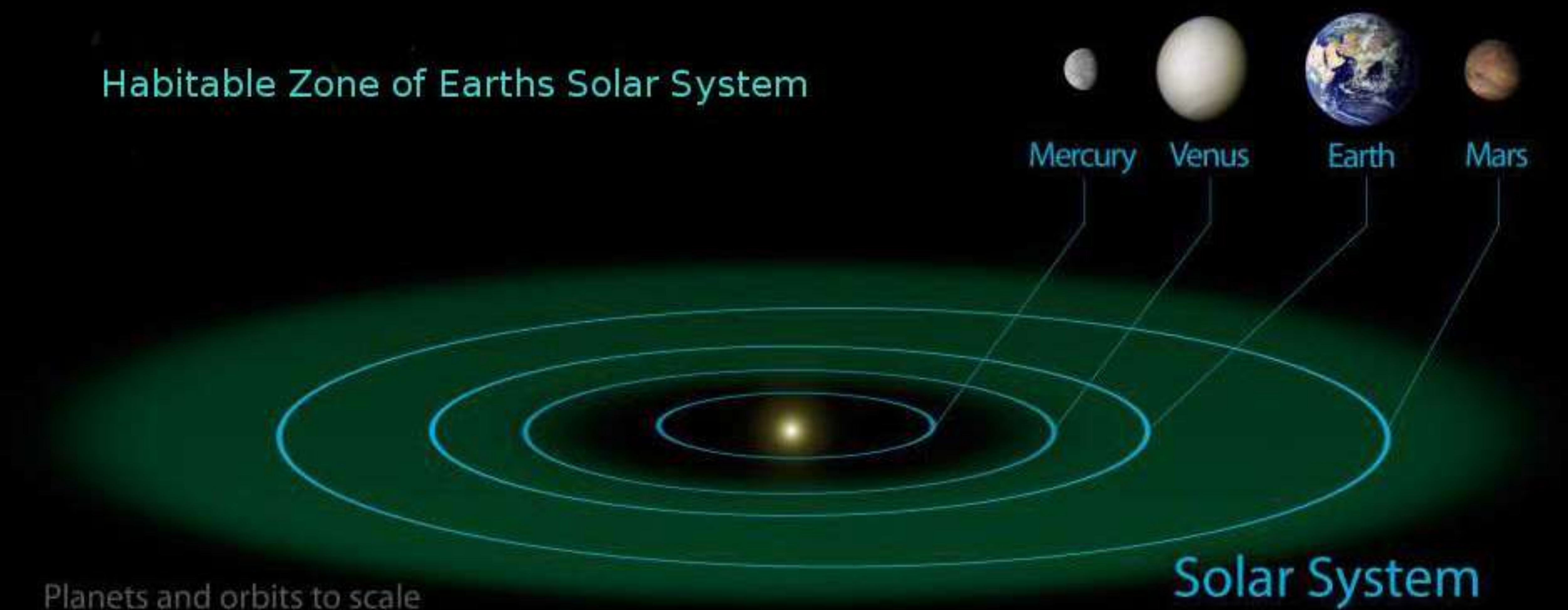





Habitable Zone
TOO HOT
JUST RIGHT
TOO COLD
Planet size: 1-2x Earth


Hotter Stars
Sunlike Stars
Cooler Stars

Habitable Zone of Earths Solar System

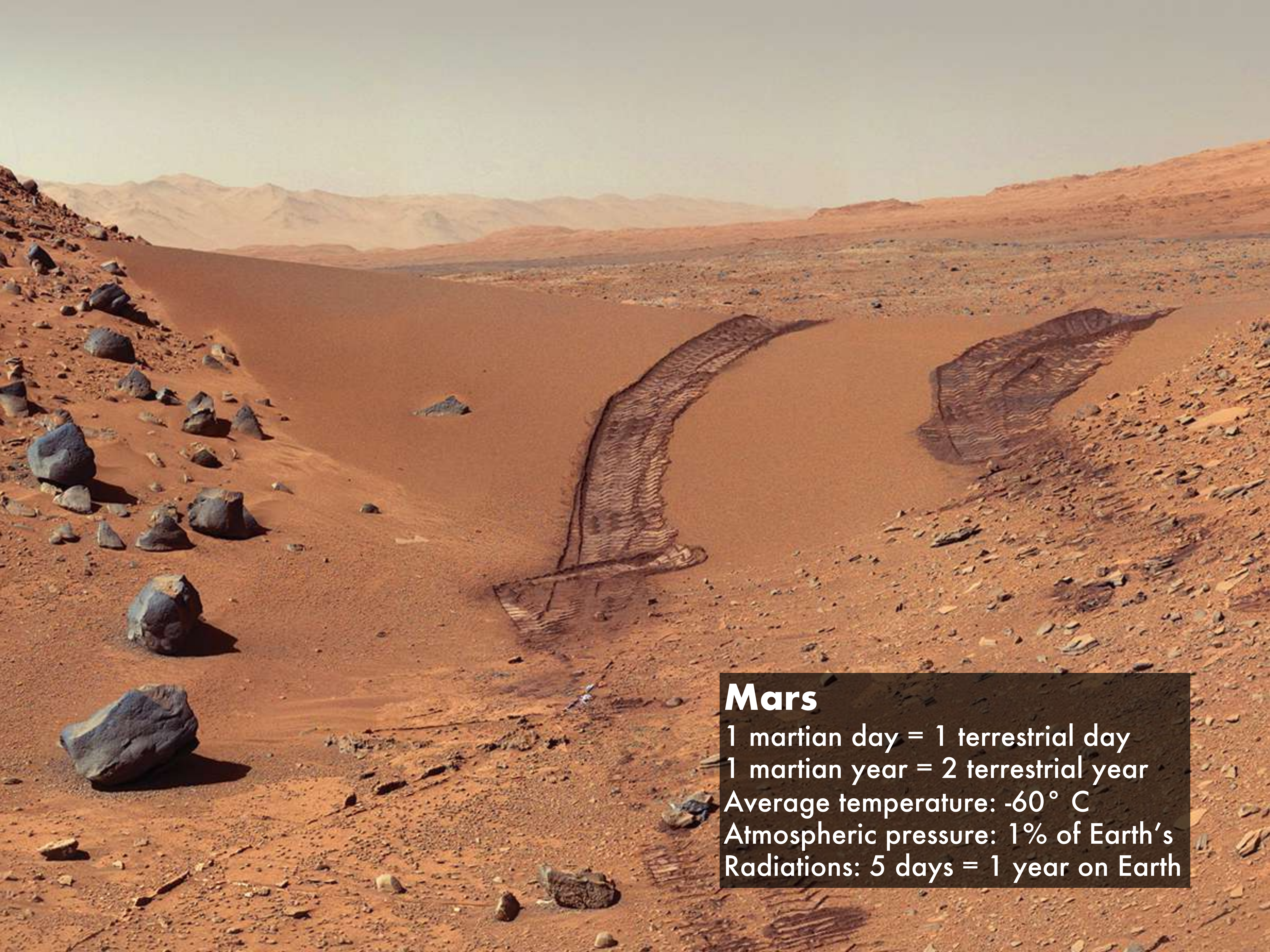


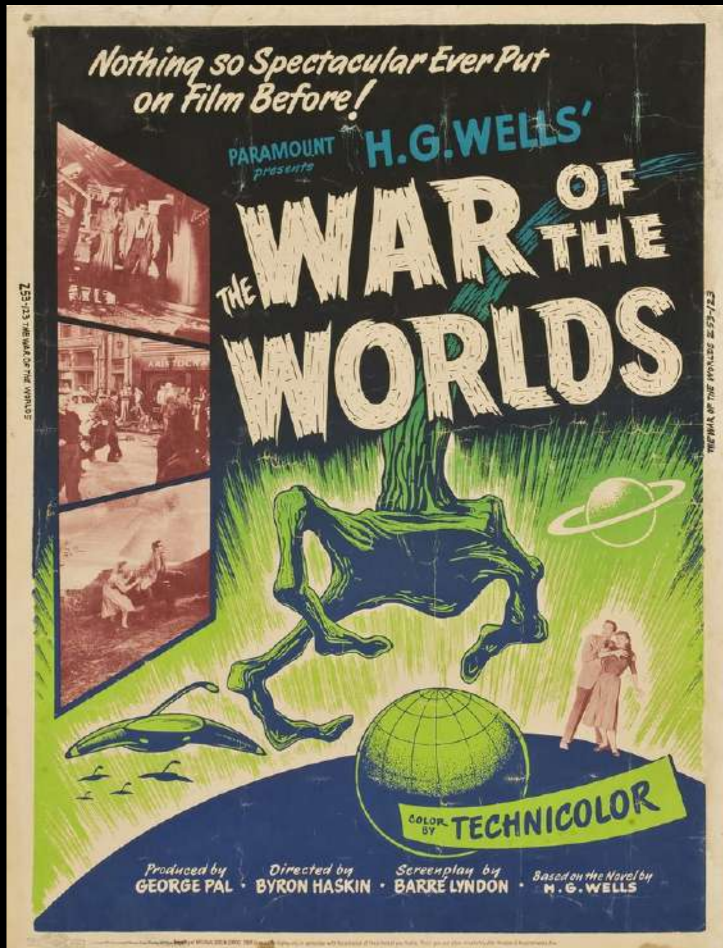
Venus

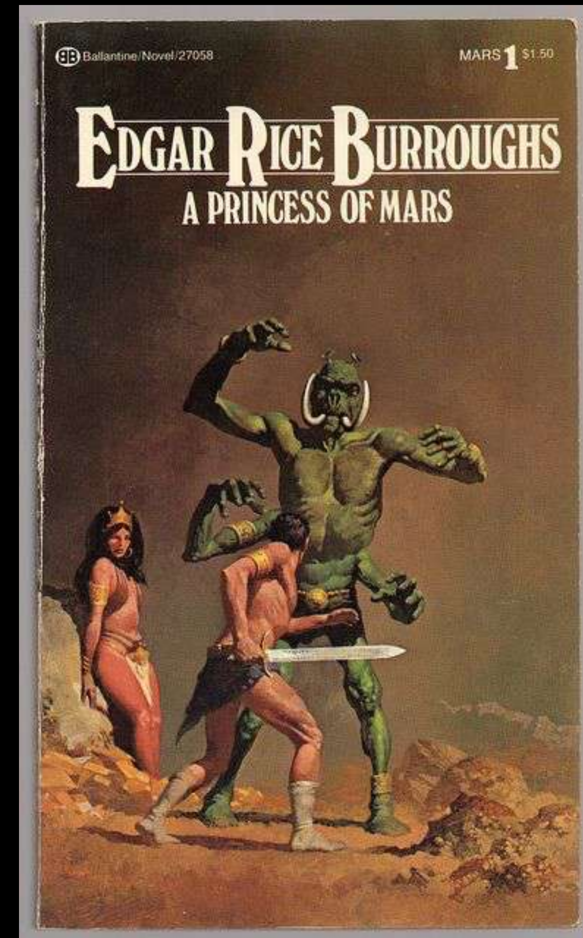
Earth

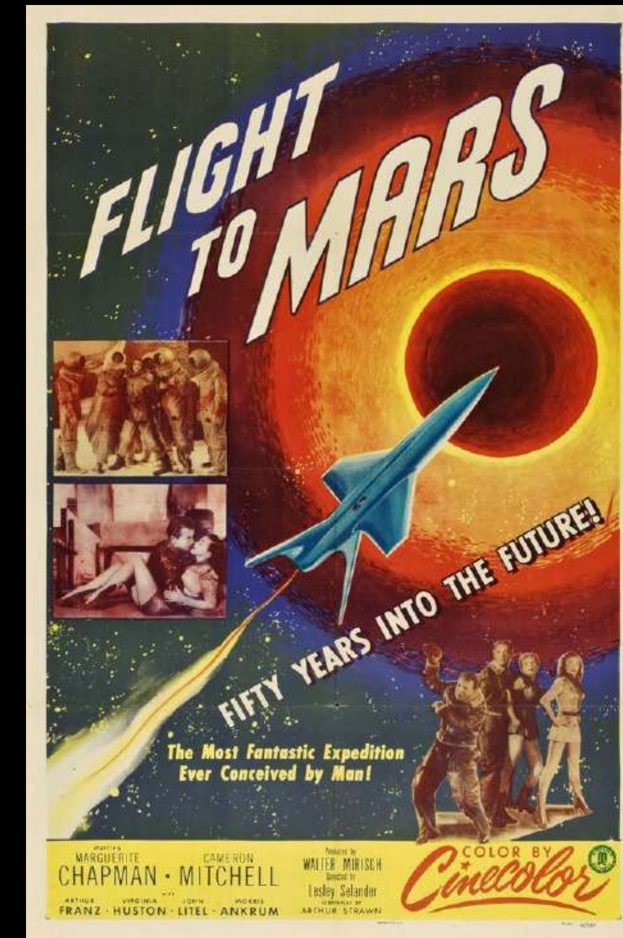
Mars

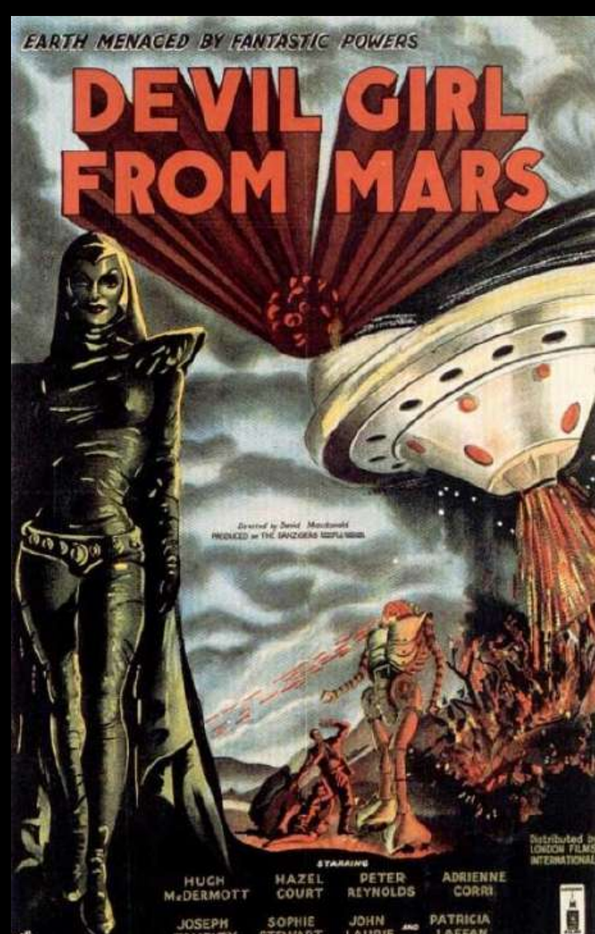

Venus
Average temperature: 500° C
Atmospheric pressure: 90 atm

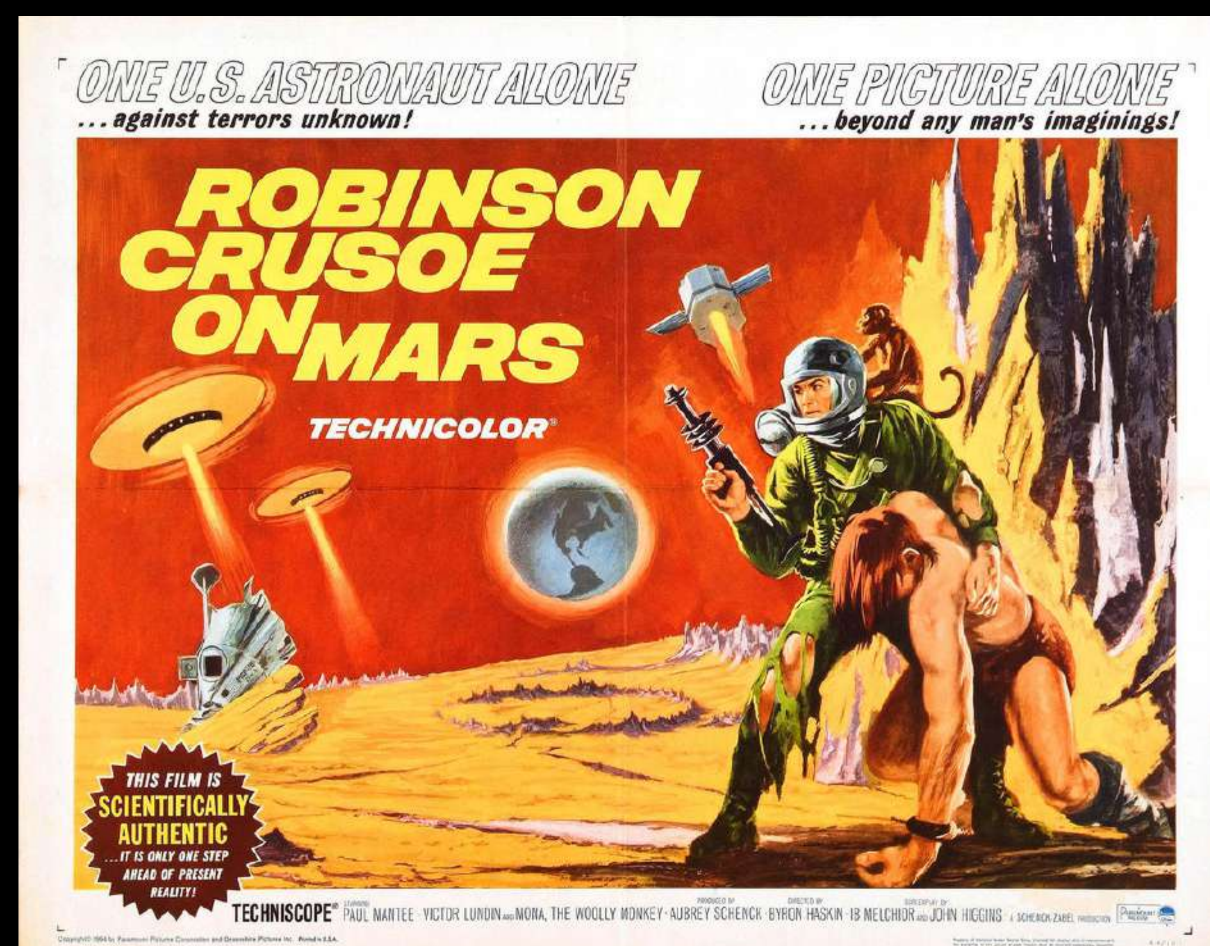

Mars
1 martian day = 1 terrestrial day
1 martian year = 2 terrestrial year
Average temperature: -60° C
Atmospheric pressure: 1% of Earth's
Radiations: 5 days = 1 year on Earth

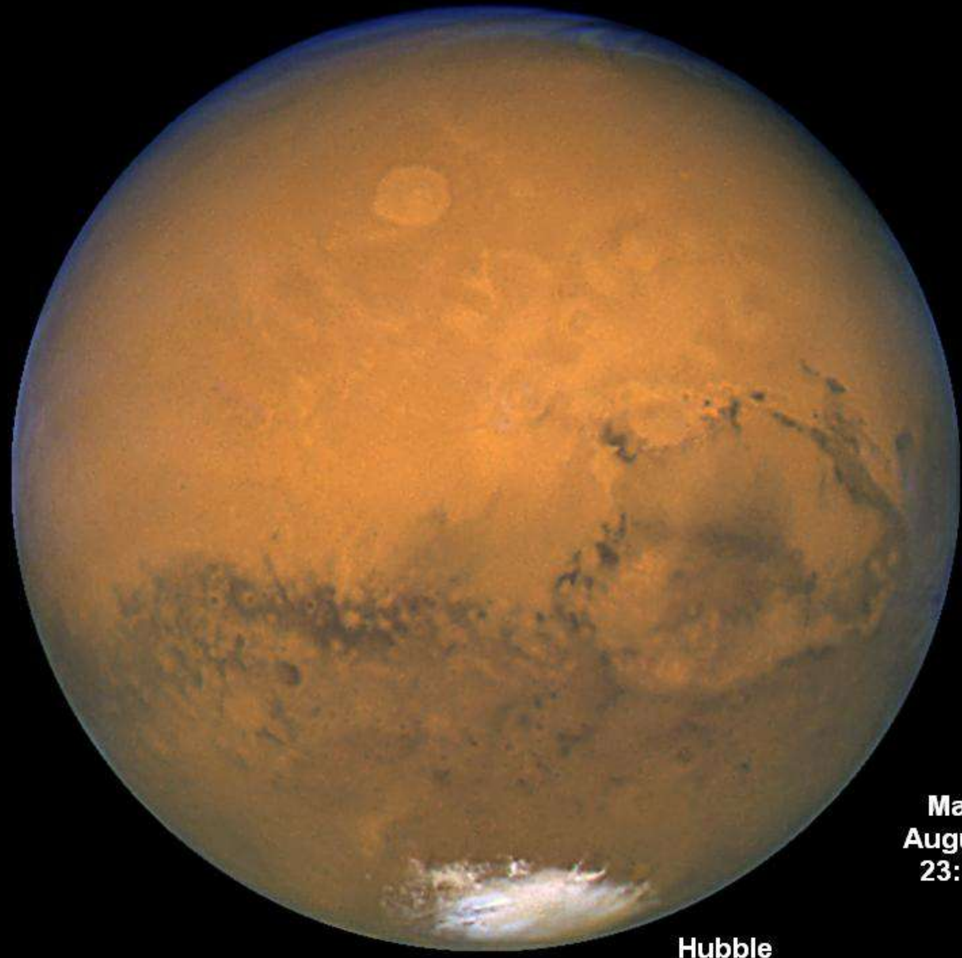

Nothing so Spectacular Ever Put on Film Before!
PARAMOUNT presents
H.G.WELLS'
THE WAR OF THE WORLDS
COLOR BY TECHNICOLOR
Produced by GEORGE PAL · Directed by BYRON HASKIN · Screenplay by BARRE LYNDON · Based on the Novel by H.G.WELLS


Ballantine/Novel/27058
MARS 1 $1.50
EDGAR RICE BURROUGHS
A PRINCESS OF MARS


FLIGHT TO MARS
FIFTY YEARS INTO THE FUTURE!
The Most Fantastic Expedition Ever Conceived by Man!
MARGUERITE CHAPMAN · CAMERON MITCHELL
ARTHUR FRANZ · VIRGINIA HUSTON · JOHN LITEL · MORRIS ANKRUM
COLOR BY Cinecolor

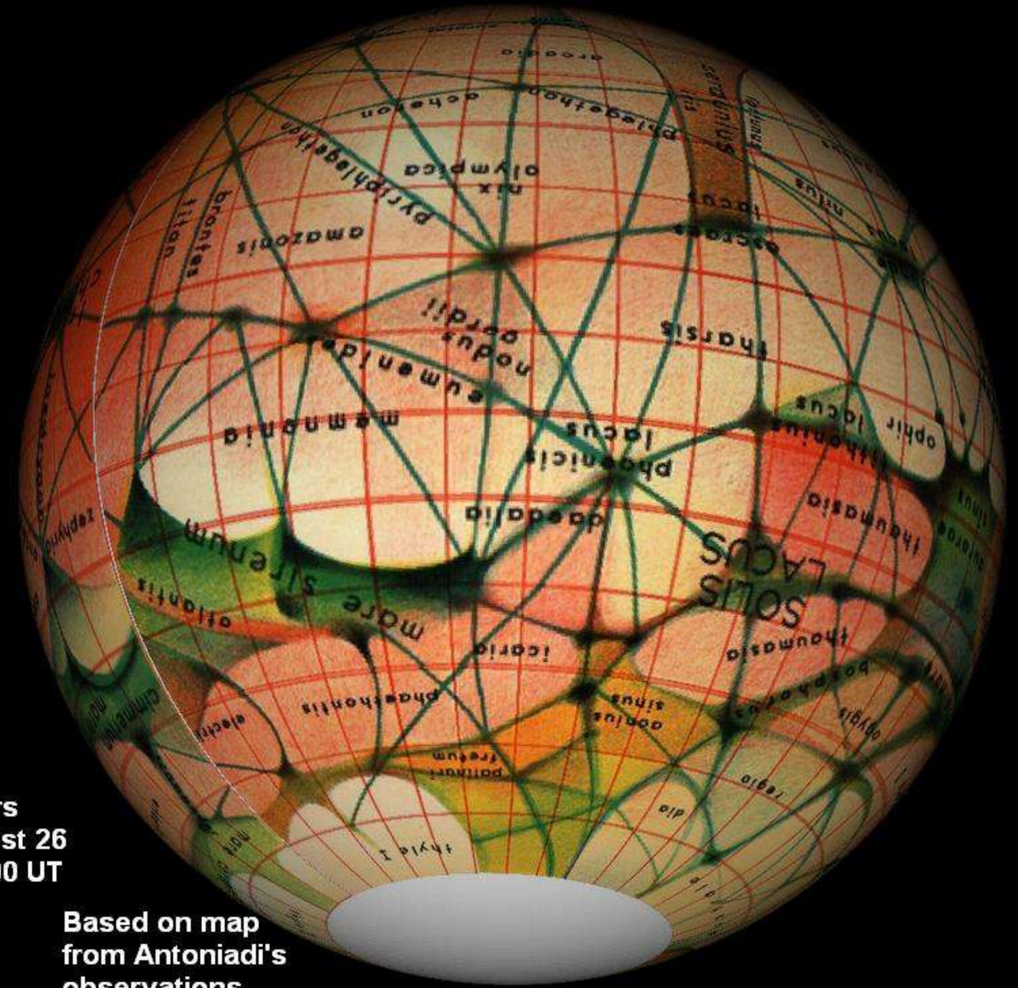

EARTH MENACED BY FANTASTIC POWERS
DEVIL GIRL FROM MARS
HUGH McDERMOTT · HAZEL COURT · PETER REYNOLDS · ADRIENNE CORRI
JOSEPH TOMELTY · SOPHIE STEWART · JOHN LAURIE · PATRICIA LAFFAN
Distributed by LONDON FILMS INTERNATIONAL


ONE U.S. ASTRONAUT ALONE
... against terrors unknown!
ONE PICTURE ALONE
... beyond any man's imaginings!
ROBINSON CRUSOE ON MARS
TECHNICOLOR
THIS FILM IS SCIENTIFICALLY AUTHENTIC
... IT IS ONLY ONE STEP AHEAD OF PRESENT REALITY!
TECHNISCOPE
PAUL MANTEE · VICTOR LUNDIN and MONA, THE WOOLLY MONKEY · AUBREY SCHENCK · BYRON HASKIN · IB MELCHIOR and JOHN HIGGINS

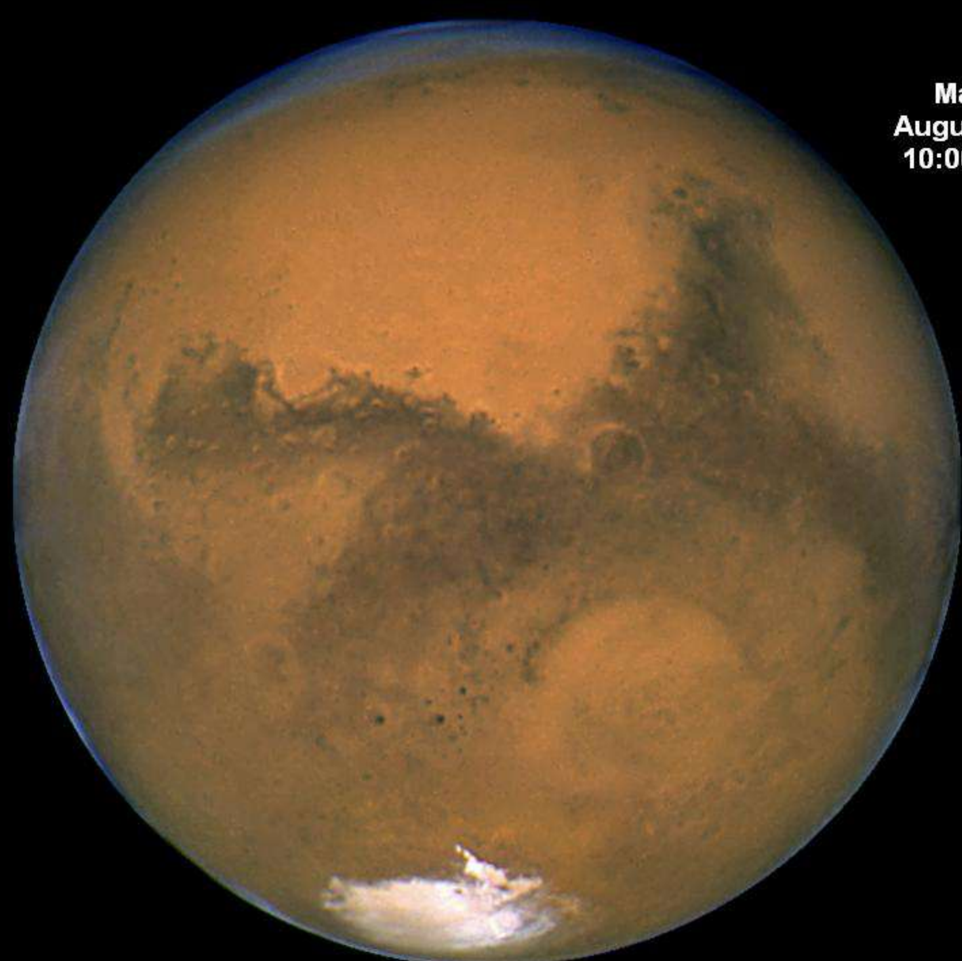


Hubble

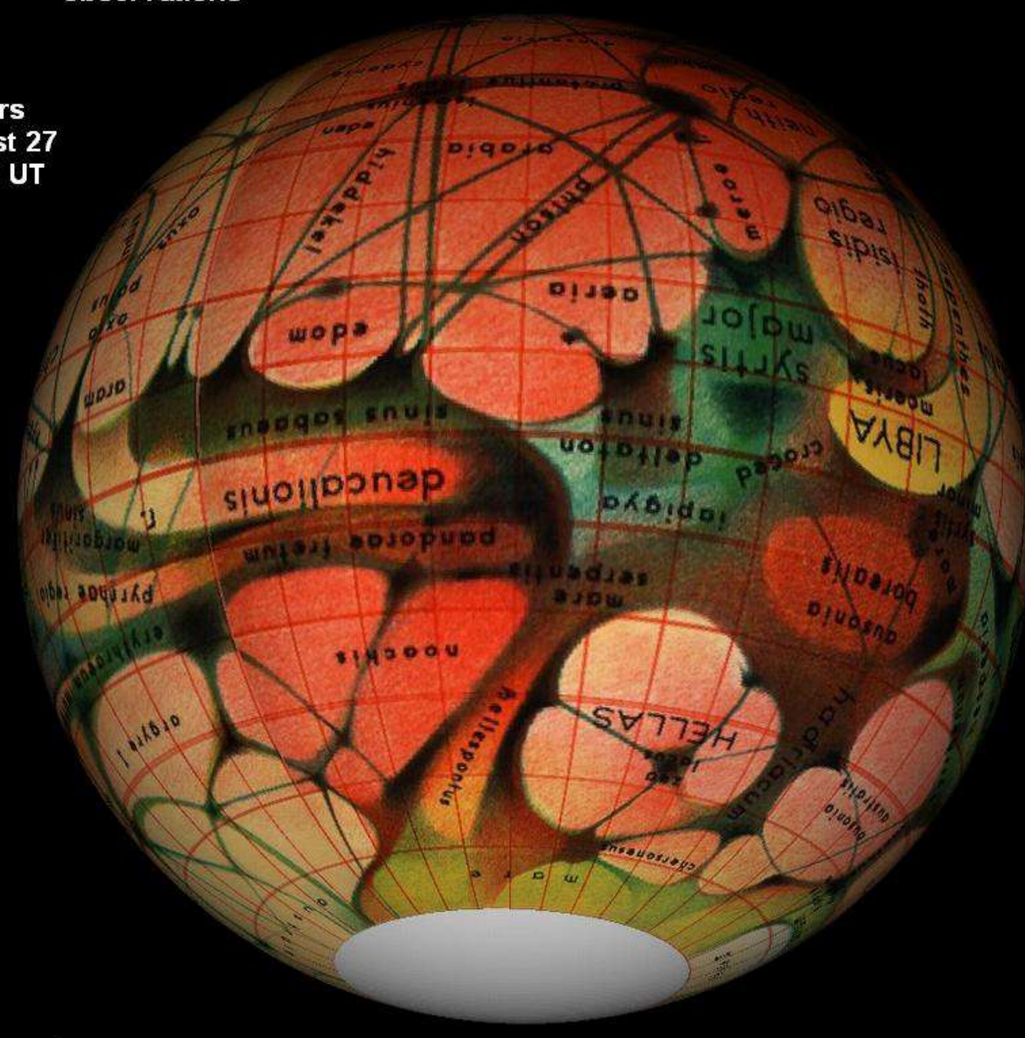
Mars
August 26
23:00 UT



Based on map
from Antoniadi's
observations



Mars
August 27
10:00 UT



THERE IS LIFE ON THE PLANET MARS

Prof. Percival Lowell, recognised as the greatest authority on the subject, declares there can be no doubt that living beings inhabit our neighbor world.

By Lilian Whiting.

THE legions of canals on Mars, forming a colossal and a wisely planned system designed to irrigate the oases of the vast deserts which make up the surface of this planet, are an unanswerable argument for the existence of conscious, intelligent life. A thing made predicates a maker. This truism, of course, was Paley's favorite assertion, but it is none the worse for that. Schiaparelli discovered 104 canals; Prof. Percival Lowell and his staff of the Lowell Observatory at Flagstaff, Arizona, have discovered over 350, and they regard this number as no limit. ...

... yet safe to assume that the ... can so distinguish." In ... emphasis on the fact that the ... with his mind as well as with ...

The New York Times.

...DAY, AUGUST 30, 1907.—SIXTEEN PAGES. ONE CENT

WATTERSON'S PAPER BURNED

Fire ... Cou...

LOUISV... Fire starte... building of ... of which ... 1 o'clock ... doomed. A...

SHUT...

Teachers ...

Spec...

PITTSBU... Senator Ro... sin, was p... tisan polit... here this ... Schools, S... Follette w... resentative...

Earlier ... quested to ... and in ope... "I have ... in my spe... want to sa... officials ... think.'

MARS INHABITED

REBUKE BY KING EDWARD.

...ing to the ...ance.

...g Edward ...he singing ... of public ...which was ...ntense ex...

... chantant ...one or two ...walked out ...ialous nat...nese com... ...y was fol... ...the other ...the Amer...

..." said the ...urage, and ...on of the ...ry side.

HAVANA.

...s the Bay

MARTIANS BUILD TWO IMMENSE CANALS IN TWO YEARS

Vast Engineering Works Accomplished in an Incredibly Short Time by Our Planetary Neighbors—Wonders of the September Sky.

By Mary Proctor.

ACCORDING to a telegram dated Aug. 17, from Flagstaff Observatory, Arizona, Dr. Percival Lowell announces the rediscovery of two new canals of Mars, which were seen for the first time at the last opposition in 1905. The canals are now very conspicuous, and attracting world-wide attention because of their startling significance.

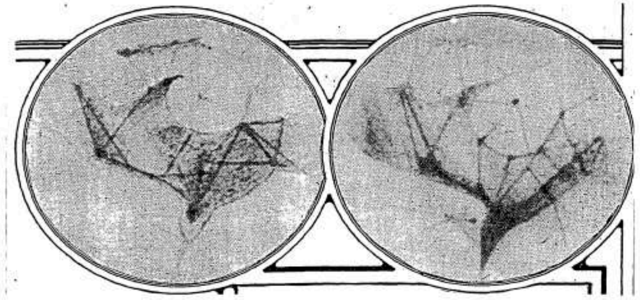
Measurement of their dimensions shows each of them to be a thousand miles long and some twenty miles wide. In comparison, the cañon of the Colorado River would be a secondary affair. What has been the cause of these vast chasms which have suddenly opened on Mars, where the internal forces are far less than could possibly be the case with our planet? Nothing like it has ever been seen or heard of before. To witness the coming into existence on another world of a surface feature in what we know to be no airy cloud-built fabric, but the solidest of ground, is in its character an event so far of unique occurrence.

That these vast chasms have been caused by some internal disturbance is out of the question, for shattering of the soil would certainly have left its mark in yawning, cavernous abysses—such as we see on our own planet in regions where volcanic disturbances have taken place. In the case of the new canals recently observed on Mars, such widespread, shattering effects are altogether absent, and as Dr. Lowell expresses it: "The outcome is purely local, and of most orderly self-restraint at that. An enormous change in the planet's features has taken place, with no concomitant disruption beyond the bounds it set. The whole thing is wonderfully clear-cut."

That the new canals were not a mere illusion or vagary of the imagination is proven by the fact that they are again visible, but they are as great a problem now as they were when first seen in 1905. Canals a thousand miles long and twenty miles wide are simply beyond our comprehension. Even though we are aware of the fact that, owing to the mass of the planet being a little less than one-ninth of the earth's mass, a rock which here weighs one hundred pounds would there only weigh thirty-eight pounds, engineering operations being in consequence less arduous than here, yet we can scarcely imagine the inhabitants of Mars capable of accomplishing this Herculean task within the short interval of two years.

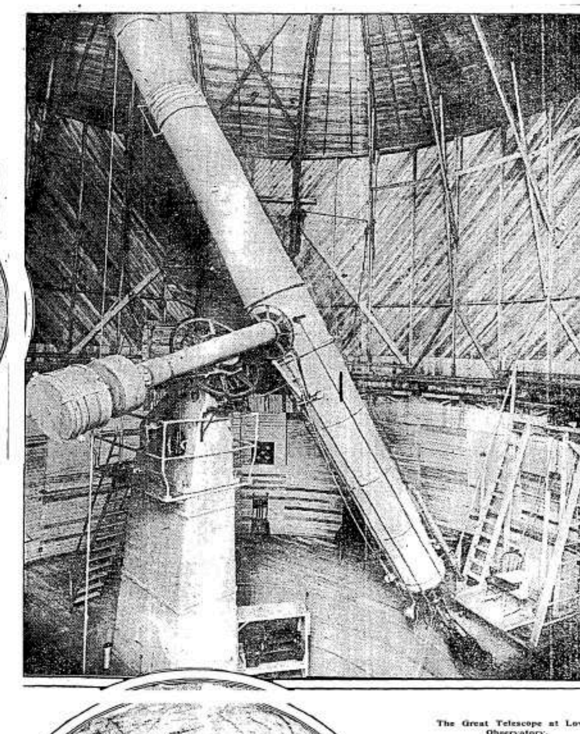
Examining the Flagstaff records for the past sixteen years, during which Mars has been kept under observation, no record has been found of these canals.

These Two Drawings by Prof. Lowell and Prof. E. C. Slipher Show the New Canals Just Observed.



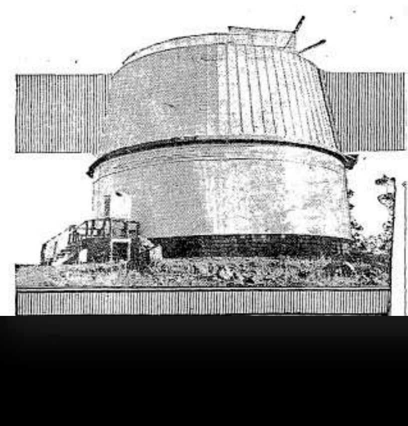
the planet. The record books were then examined, when it appeared that not a trace of them was to be found in the drawings of May, June, July, or August when this part of the planet was most carefully observed and drawn. That they had not been observed in previous years was then conclusively ascertained by examination of the records of those years.

The record of canals seen at Flagstaff is registered at the Lowell Observatory after each opposition or near approach of the planet, when it is well placed for observation. From these records a fresh map, including all new details observed, is made of the planet's surface. These maps are, therefore, of the greatest value in enabling us to trace any peculiarities or changes on Mars, and they keep us in touch with any alterations which may be taking place on that planet. What new revelations are in store for us, at the present opposition, we know not, but of one fact we are certain, and that is the untiring energy and boundless enthusiasm of Dr. Lowell and his able assistants at the Lowell Observatory will make it simply impossible for any detail of the slightest significance on Mars to escape their vigilance.



The Great Telescope at Lowell Observatory.

Prof. Percival Lowell, Discoverer of the Canals on Mars.



cross-piece consists of three stars, a central star and two on each side.

Take an opera glass and turn it in the direction of Alpha at the top of the cross. Slightly to the northwest can be seen Brooks's comet, so called because it was just discovered by Prof. Brooks of Geneva, N. Y. The comet has returned to our neighborhood for a brief visit, and, though insignificant compared with Halley's comet of recent fame, yet it is interesting because it can be seen with the unaided eye, and almost exactly overhead

Worlds Than Ours" he wrote: "I know nothing better calculated to lead men to choose astronomy as their favorite subject of study than the contemplation of the Saturnian system. I can well remember the sensation with which I saw the ringed planet for the first time. I look on that view as my introduction to the most fascinating of all the sciences." In his book, "Half Hours with the Telescope," he encourages the amateur to make a study of the planet, for even a good two-inch telescope will do much in

field of view adorned by their leader. Imperceptibly the moments flew by, while the writer enjoyed the wondrous scene. Then the clouds, baneful enemies of astronomers, drifted across the field of view, completely hiding Saturn from sight. Yet this was a memorable experience to be numbered among the red letter days of one's work at visual observations.

The climax, as far as seeing Saturn is concerned, is yet to be attained by enjoying a view of the planet through the great five-foot reflector at Mount Wilson, Cal. Last August forty of the world's most renowned astronomers climbed above the clouds hovering around Mount Wilson to visit the Solar Observatory, which is erected at an elevation of nearly 6,000 feet above sea level. Not only is the sun studied in all its phases at this observatory, but incidentally the stars and Saturn can be seen to the very greatest advantage with the five-foot reflector. Those who saw Saturn by its means returned with the most glowing accounts of their experience.

"It is hopeless to attempt a description of Saturn," writes one observer, in his account given for the Scientific American. "The rings are complex, while the dark or crape ring seemed to be much wider and nearer the planet than when seen in small telescopes. A tinge of blue was observed on the Saturnian south pole, and yellow bands toward the Equa-

---

MARTIANS FINISH CANAL ON PLANET

MARS' IRRIGATION SCHEME SEEN TO WORK WONDERS.

Professor Percival Lowell, of Flagstaff, A. T., Says He's Photographed Redeemed Desert.

CHICAGO, Feb. 14.—(Special.)—An announcement of final proof that the planet Mars is inhabited was made by Professor Percival Lowell, the famous

THE ASTROPHYSICAL JOURNAL

AN INTERNATIONAL REVIEW OF SPECTROSCOPY AND
ASTRONOMICAL PHYSICS

VOLUME 126 SEPTEMBER 1957 NUMBER 2

SPECTROSCOPIC EVIDENCE FOR VEGETATION ON MARS

WILLIAM M. SINTON
Smithsonian Astrophysical Observatory
Received May 6, 1957

ABSTRACT

A new test for the presence of vegetation on Mars depends on the fact that all organic molecules have absorption bands in the vicinity of 3.4 μ. These bands have been studied in the reflection spectrum of terrestrial plants, and it is found that for most plants a doublet band appears which has a separation of about 0.1 μ and is centered about 3.46 μ. Spectra of Mars taken during the 1956 opposition indicate the probable presence of this band. This evidence and the well-known seasonal changes of the dark areas make it extremely probable that vegetation in some form is present.

Science
Vol 130, Issue 3384
06 November 1959

Further Evidence of Vegetation on Mars

The presence of large organic molecules is indicated by recent infrared-spectroscopic tests.

William M. Sinton

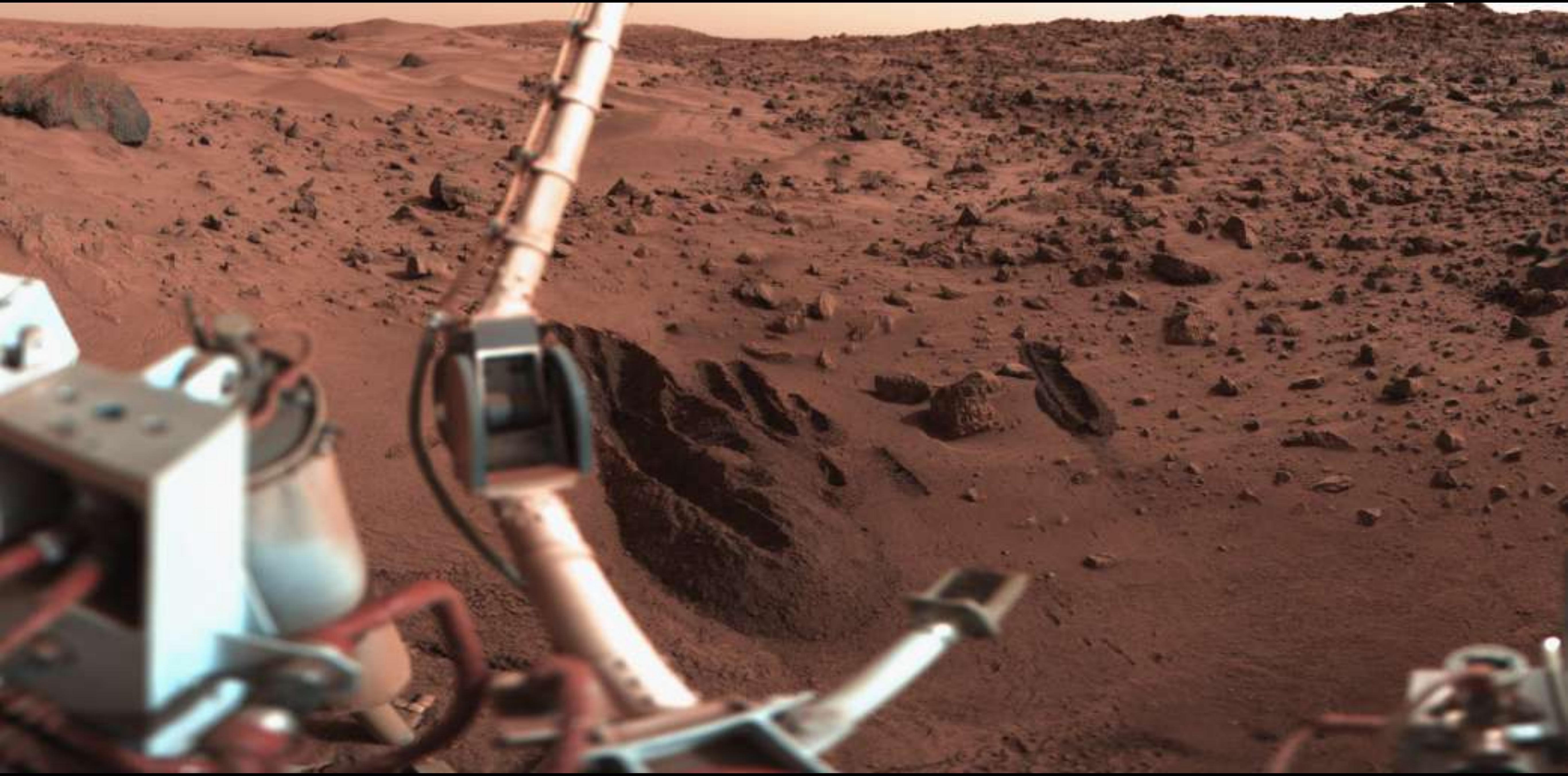
There has long been evidence pointing to the presence of vegetation on Mars. Photographs taken by E. C.

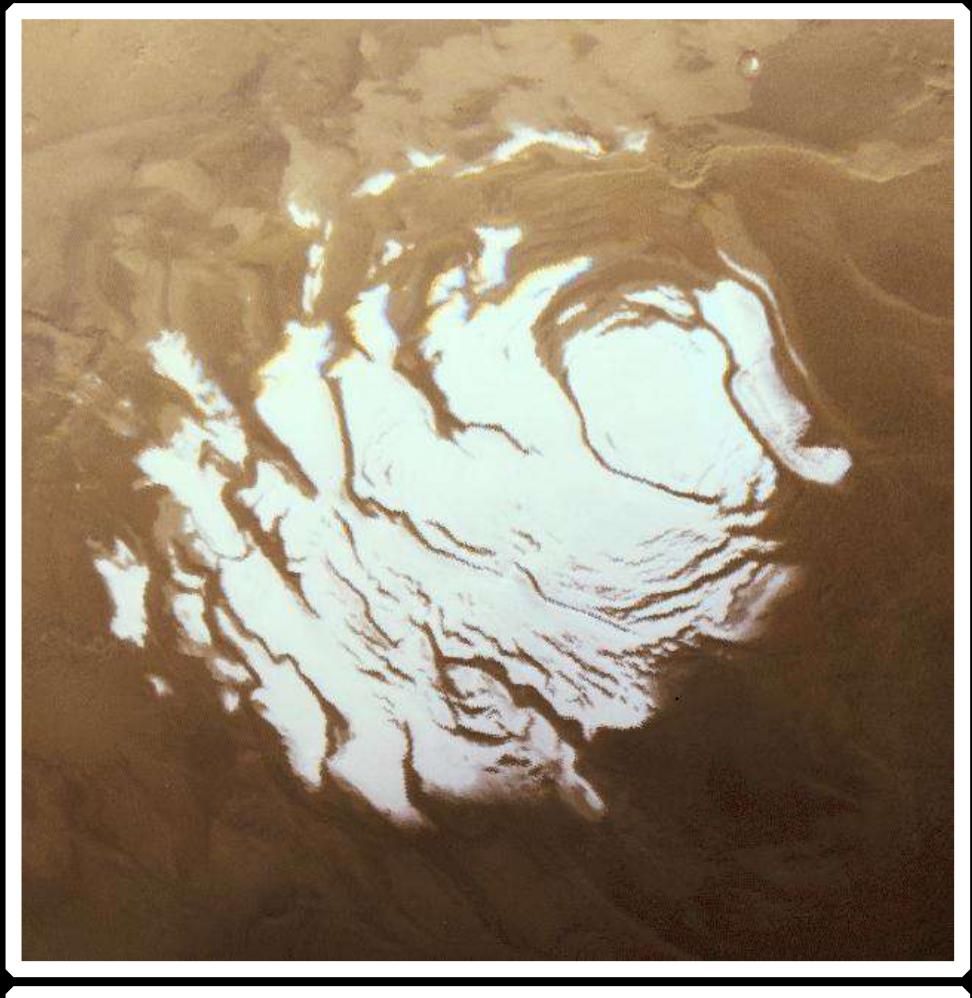
(2). The region in which it is situated has, however, been undergoing development for many years.

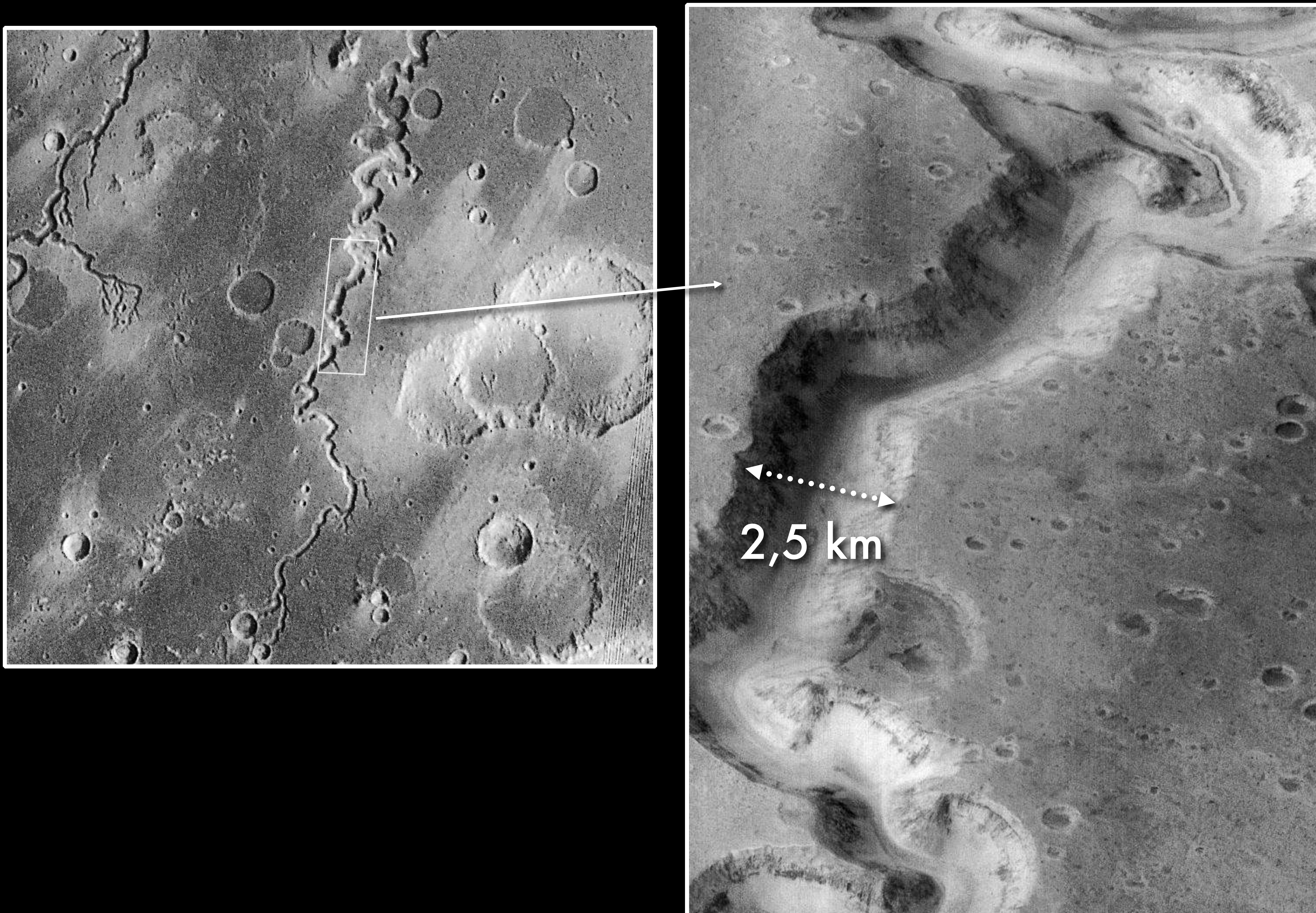
Martian plants possess a pigment that absorbs the near infrared.

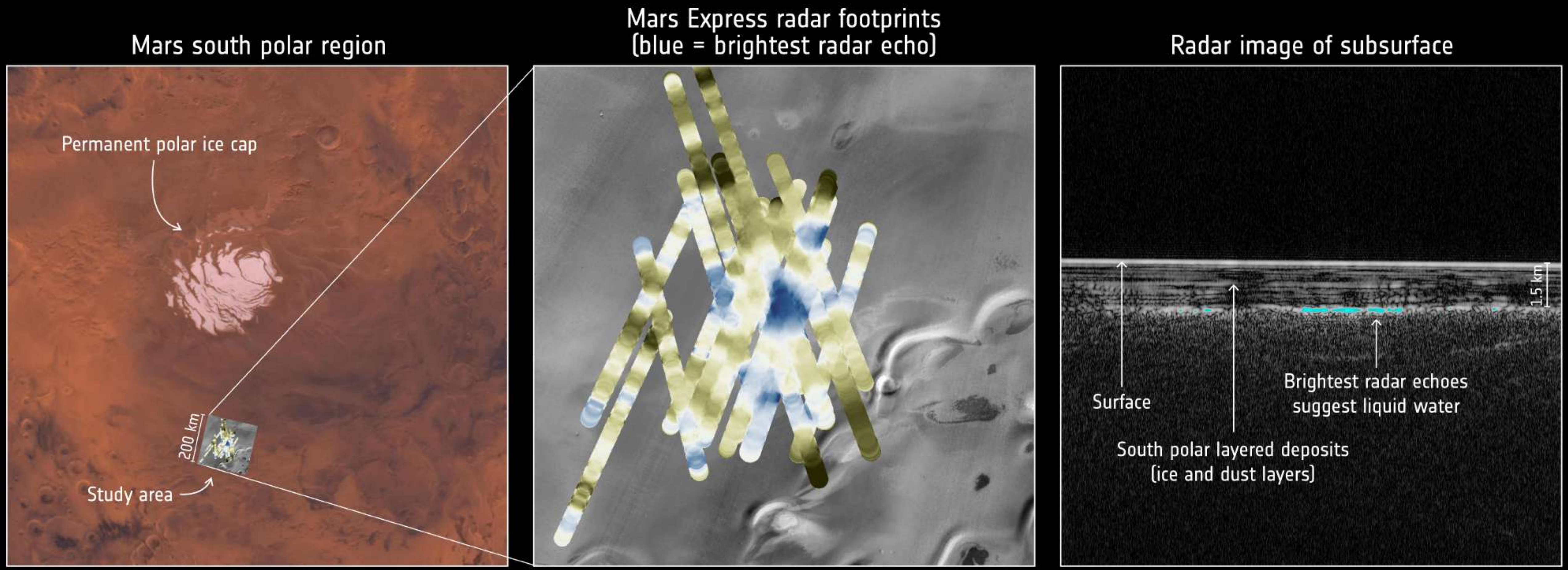
Using the 61-inch telescope of the Harvard College Observatory during the 1956 opposition, I made a new test for the presence of organic molecules on Mars (5). Organic molecules possess strong absorption bands at 3.5 μ as a result of the resonance of their carbon-hydrogen bonds. It was found that in the plants tested this band was double, most likely as a result of interaction between a pair of hydrogen atoms attached to the same carbon atom, as occurs in paraffin molecules.

The results of the 1956 observations indicated the presence of the band in the light reflected from Mars, but they left some doubt about the reality of the absorption. Furthermore, the regions of Mars which produced the absorption were not ascertained in this work. At

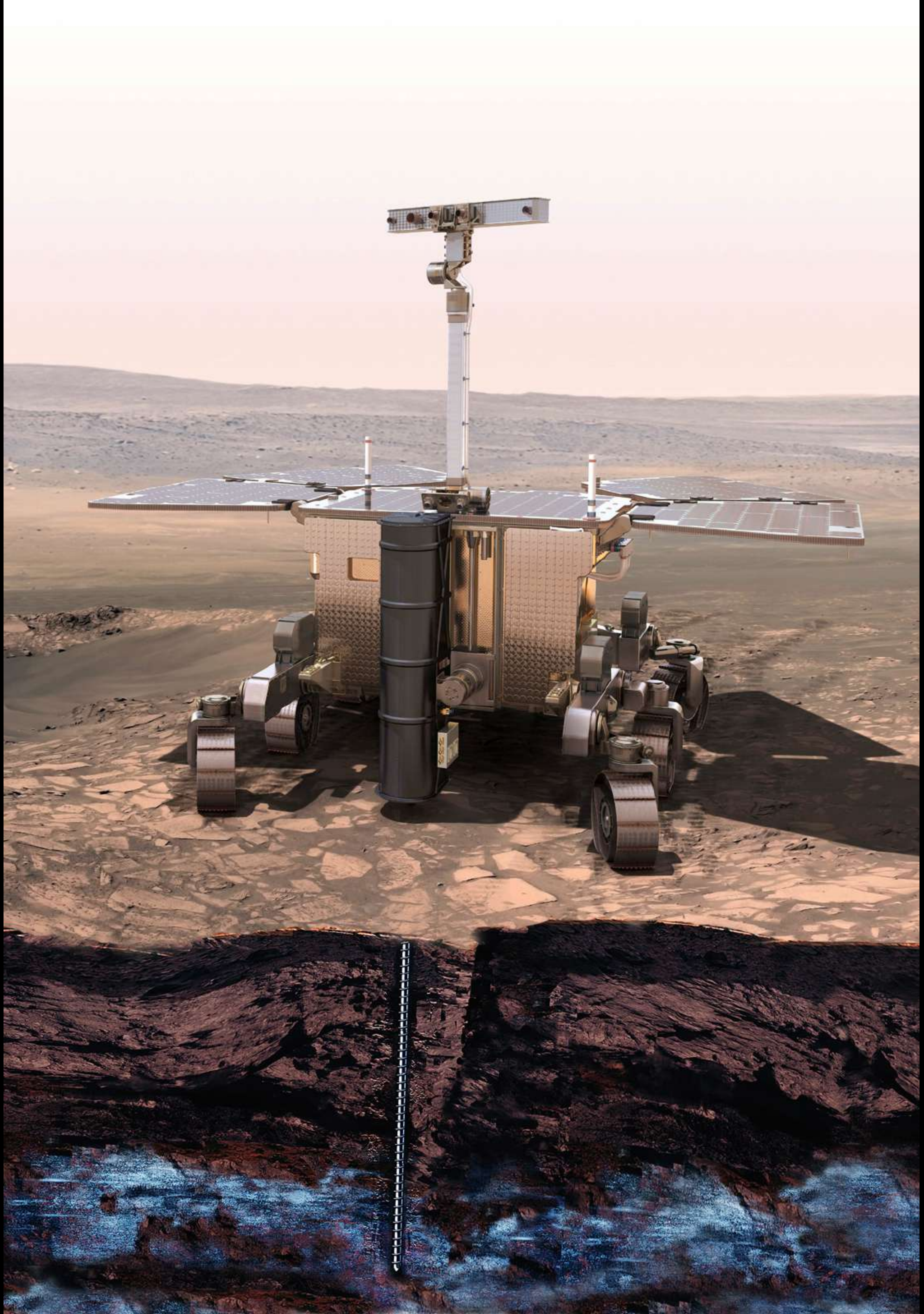




2,5 km

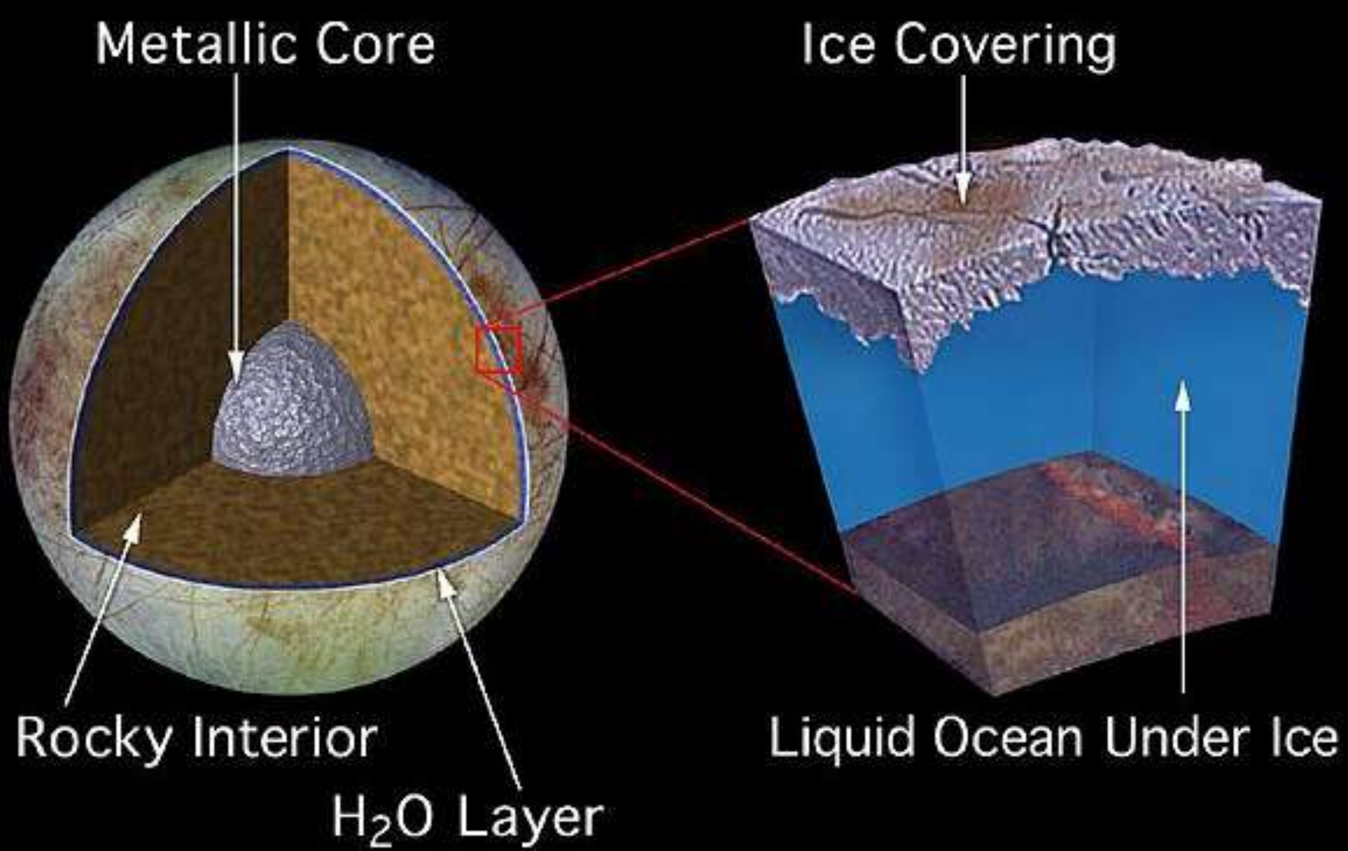


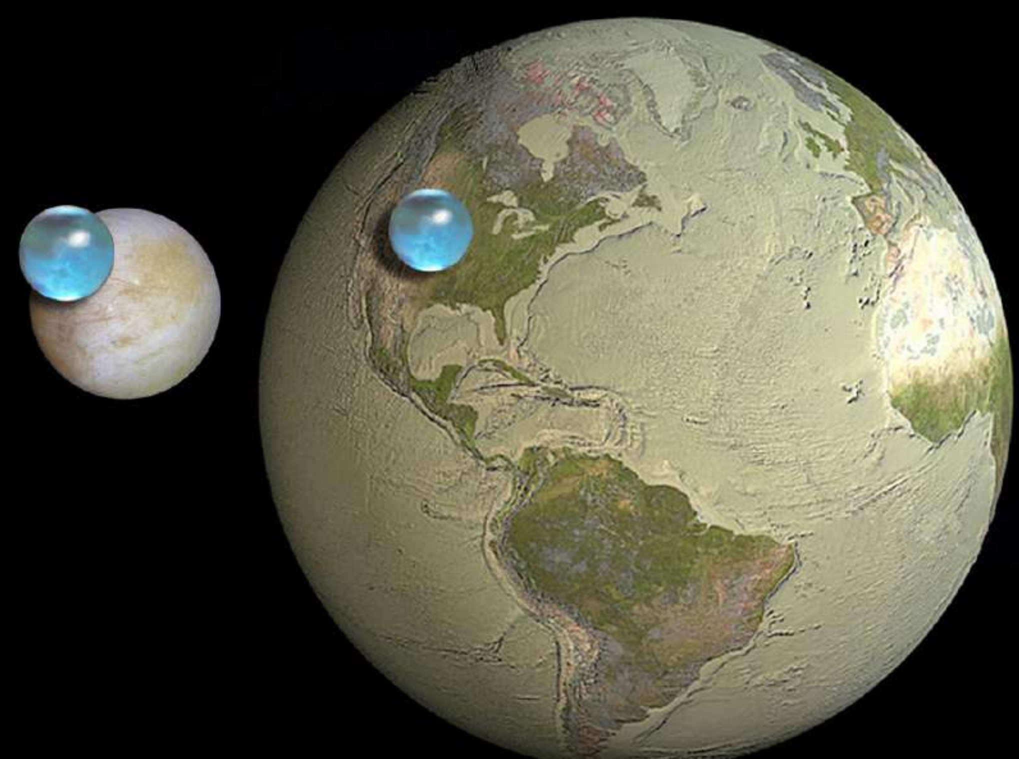
Orosei et al., *Science* (2018)

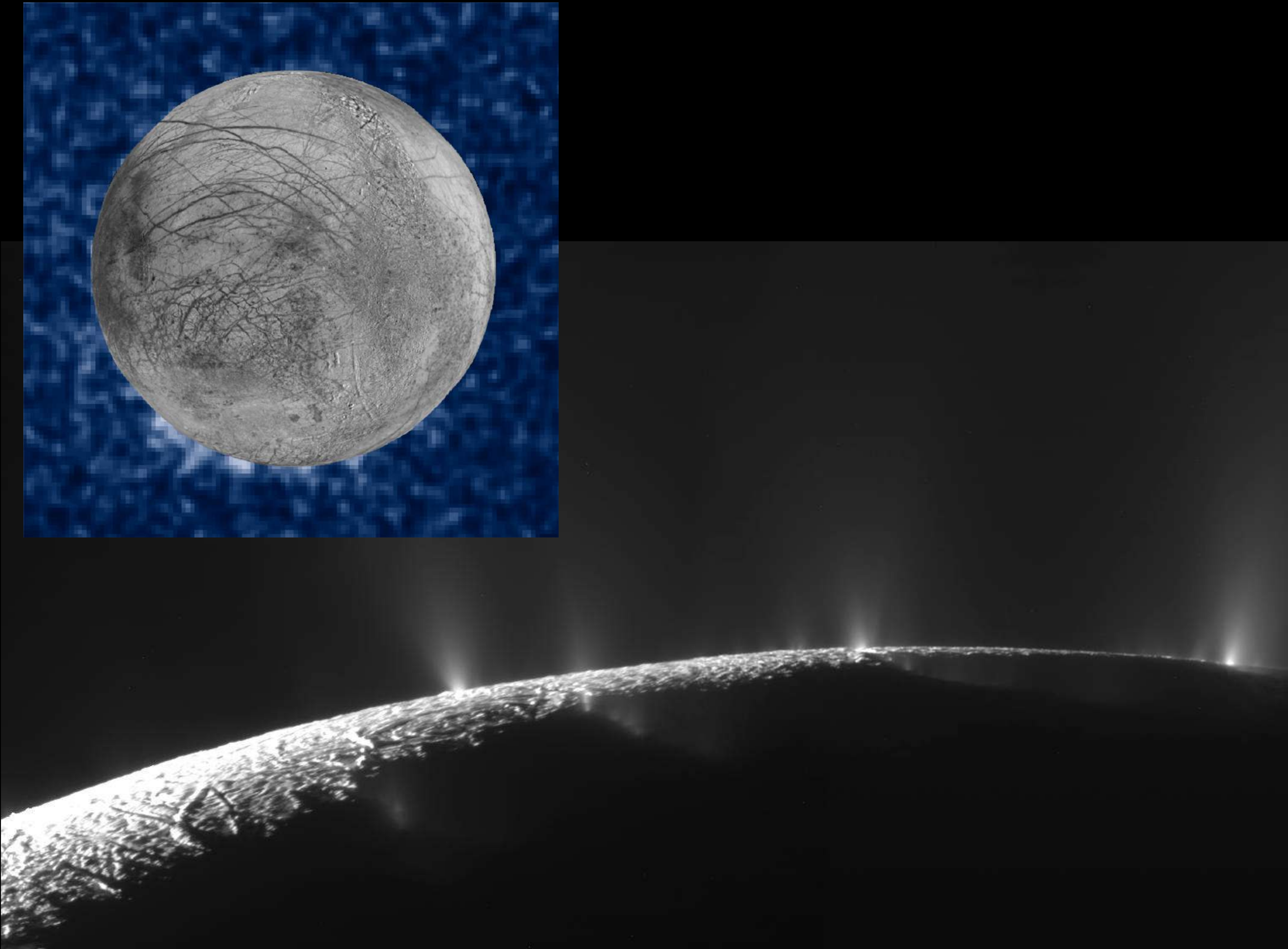


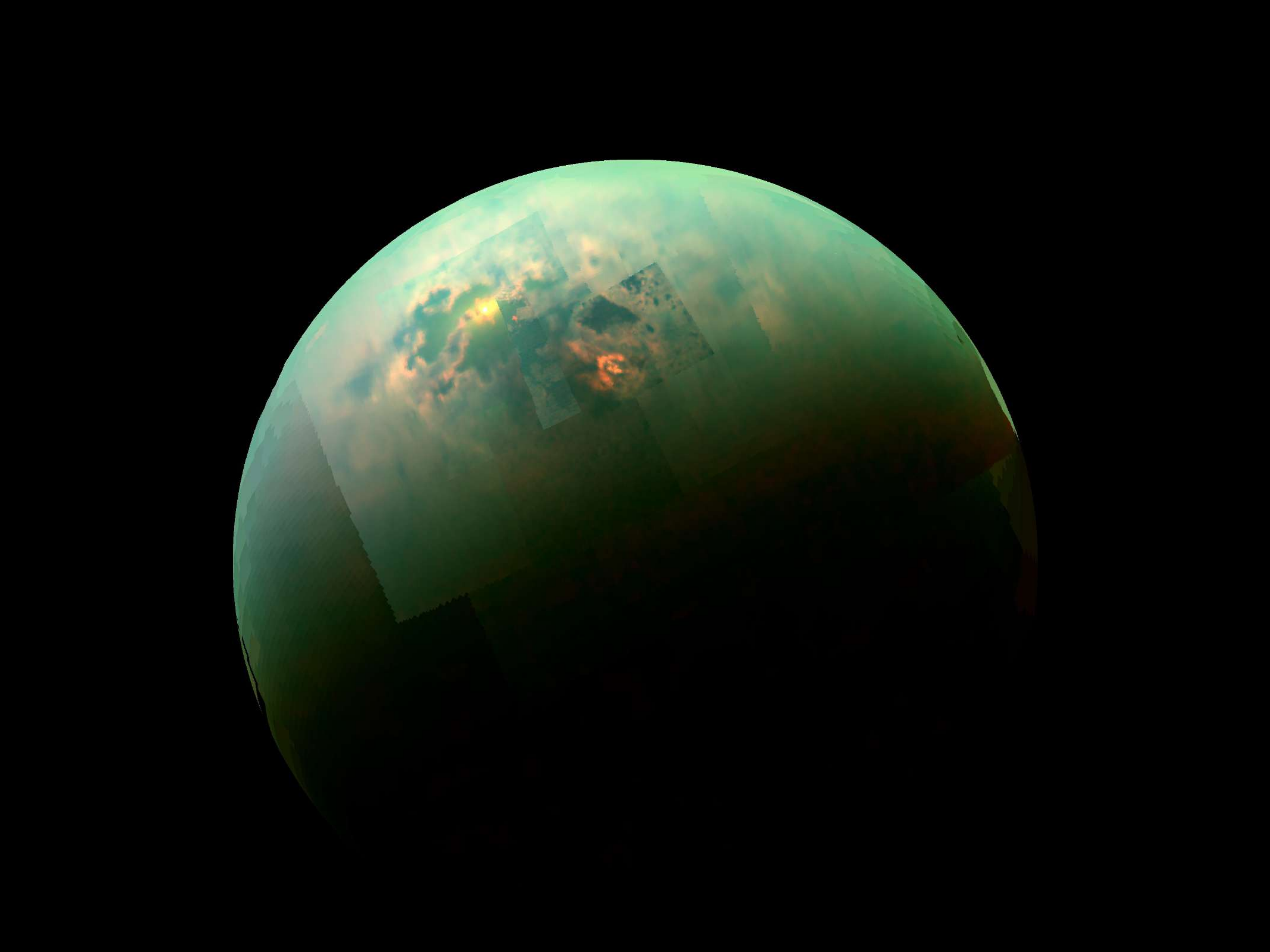
Black Smokers & **Hot Vent Creatures** at **Endeavour Ridge** (2190m)

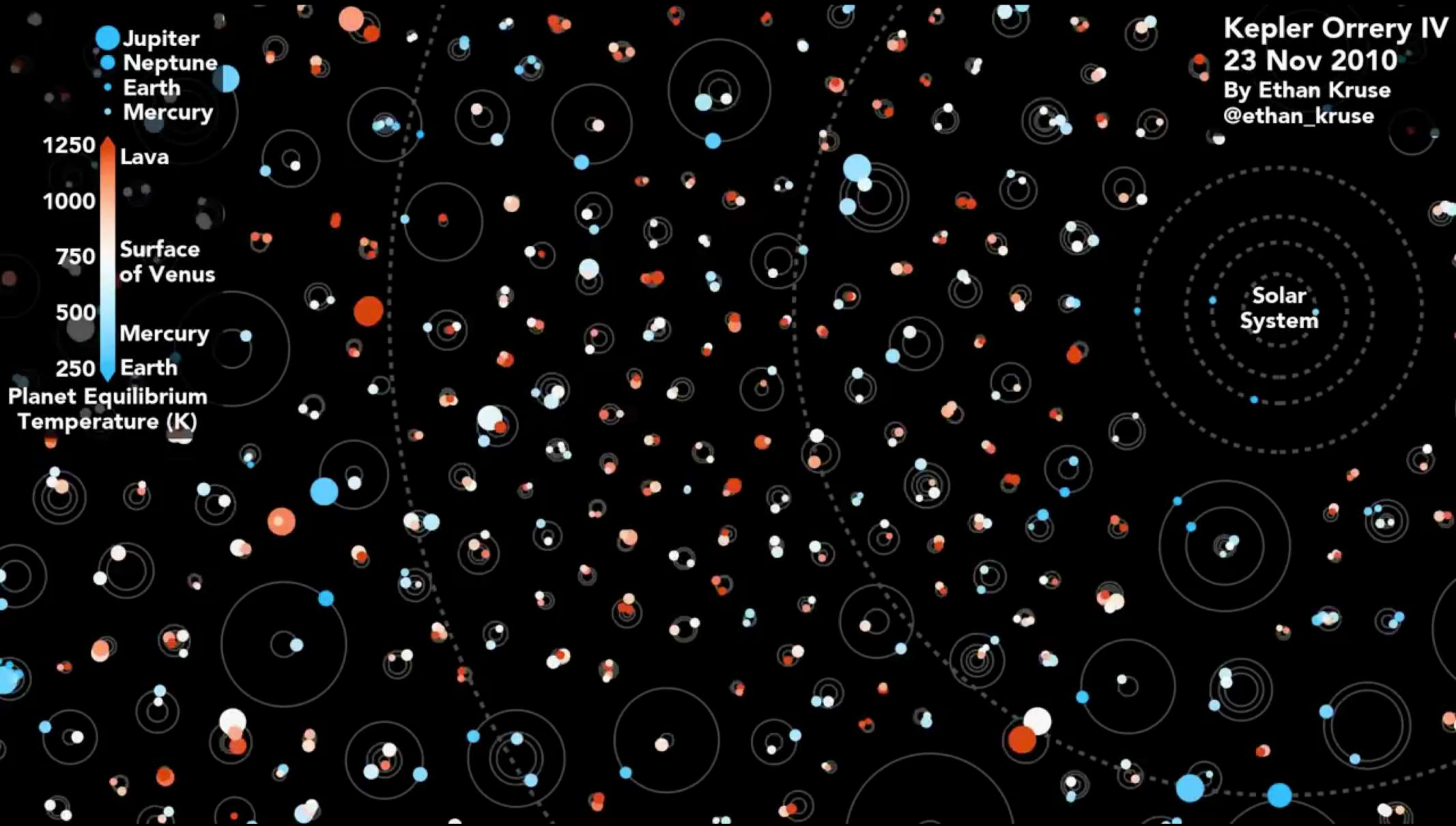
8 October 2010:
Specially adapted tubeworms, scale worms and limpets thrive in the hot sulfide-laced waters of Grotto Hydrothermal Vent.


Metallic Core
Ice Covering
Rocky Interior
H_2O Layer
Liquid Ocean Under Ice

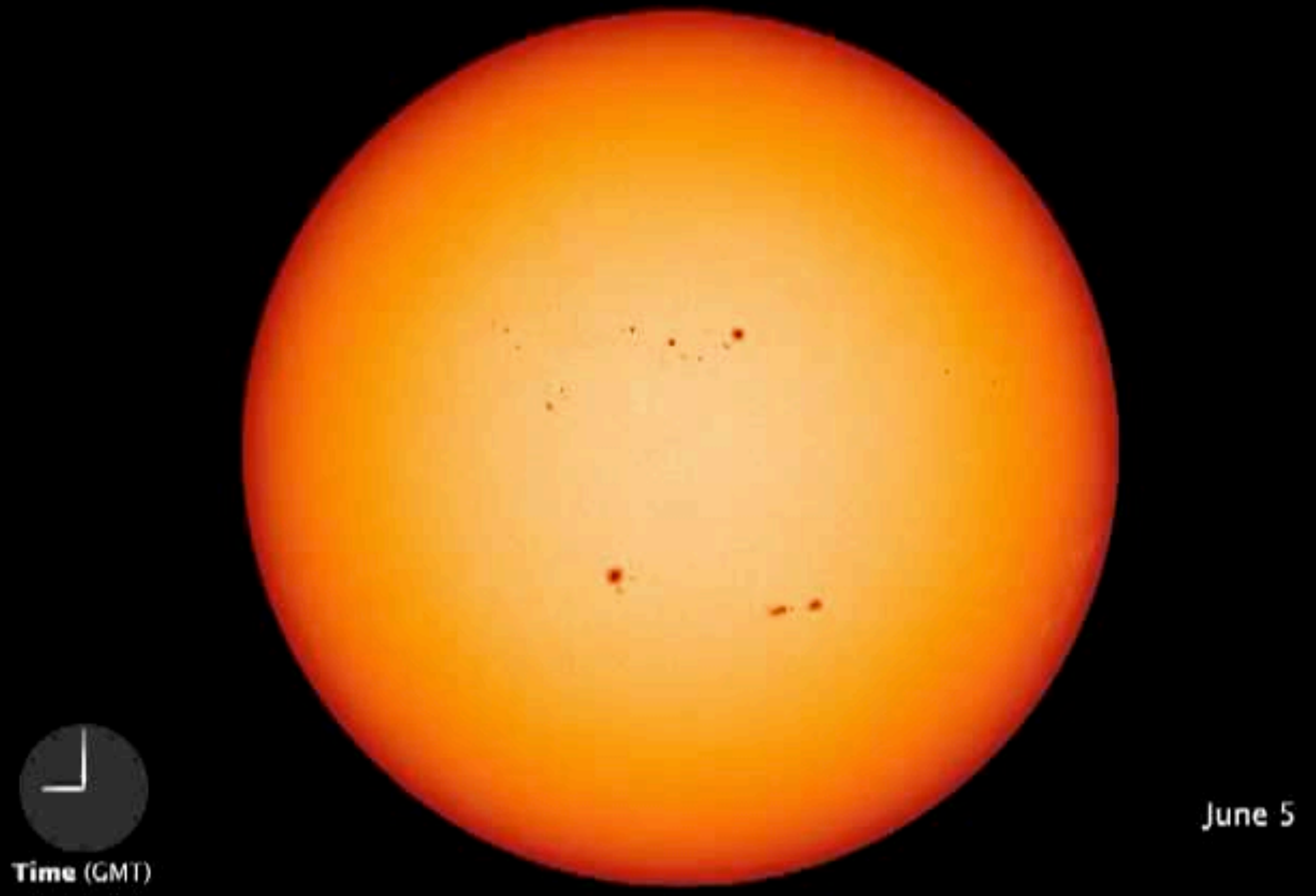




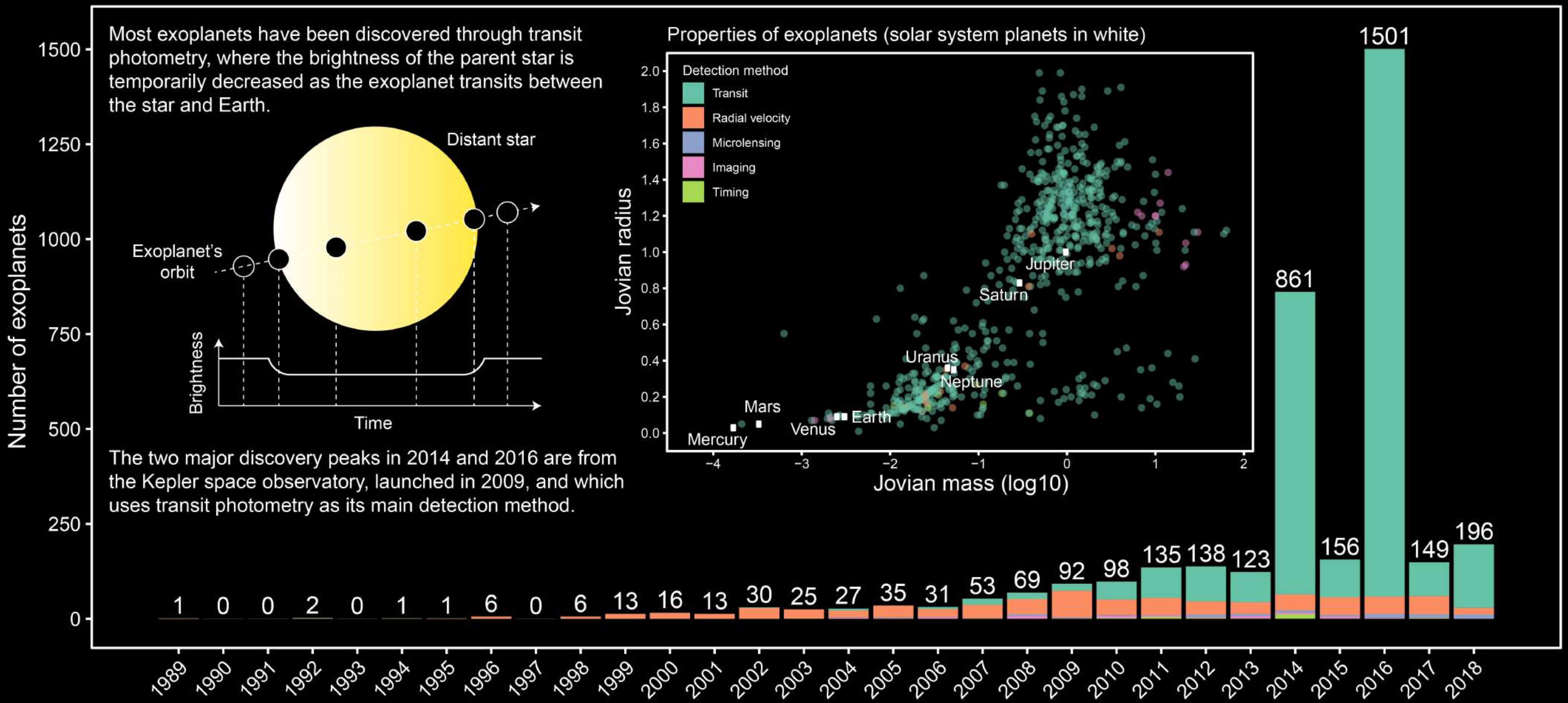


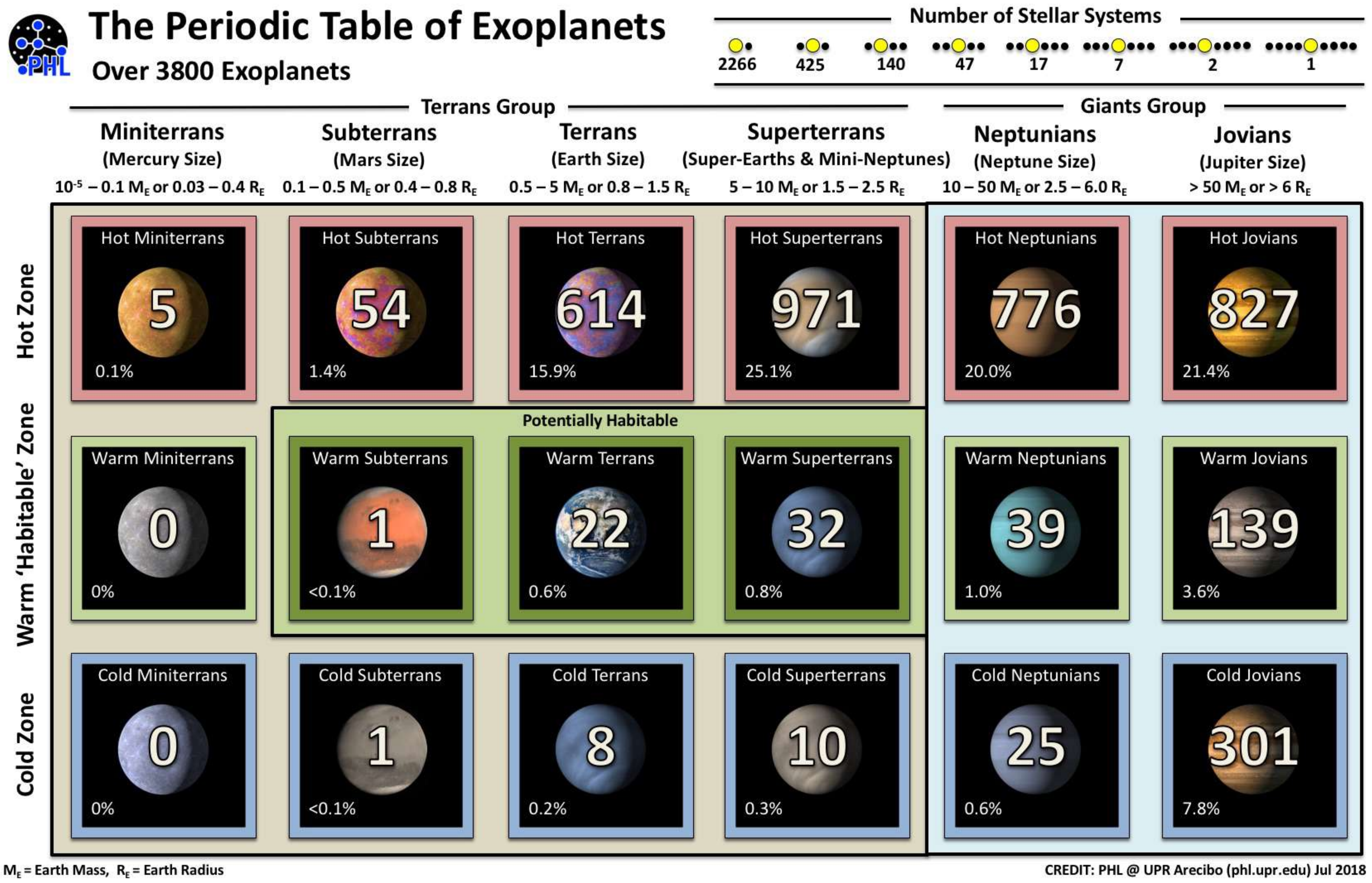

Jupiter
Neptune
Earth
Mercury
1250
Lava
1000
750
Surface of Venus
500
Mercury
250
Earth
Planet Equilibrium Temperature (K)
Kepler Orrery IV
23 Nov 2010
By Ethan Kruse
@ethan_kruse
Solar System

PLANETQUEST
THE SEARCH FOR ANOTHER EARTH


Time (GMT)
June 5

Discovery of exoplanets since 1989 per year and by detection method (per August 21st 2018)

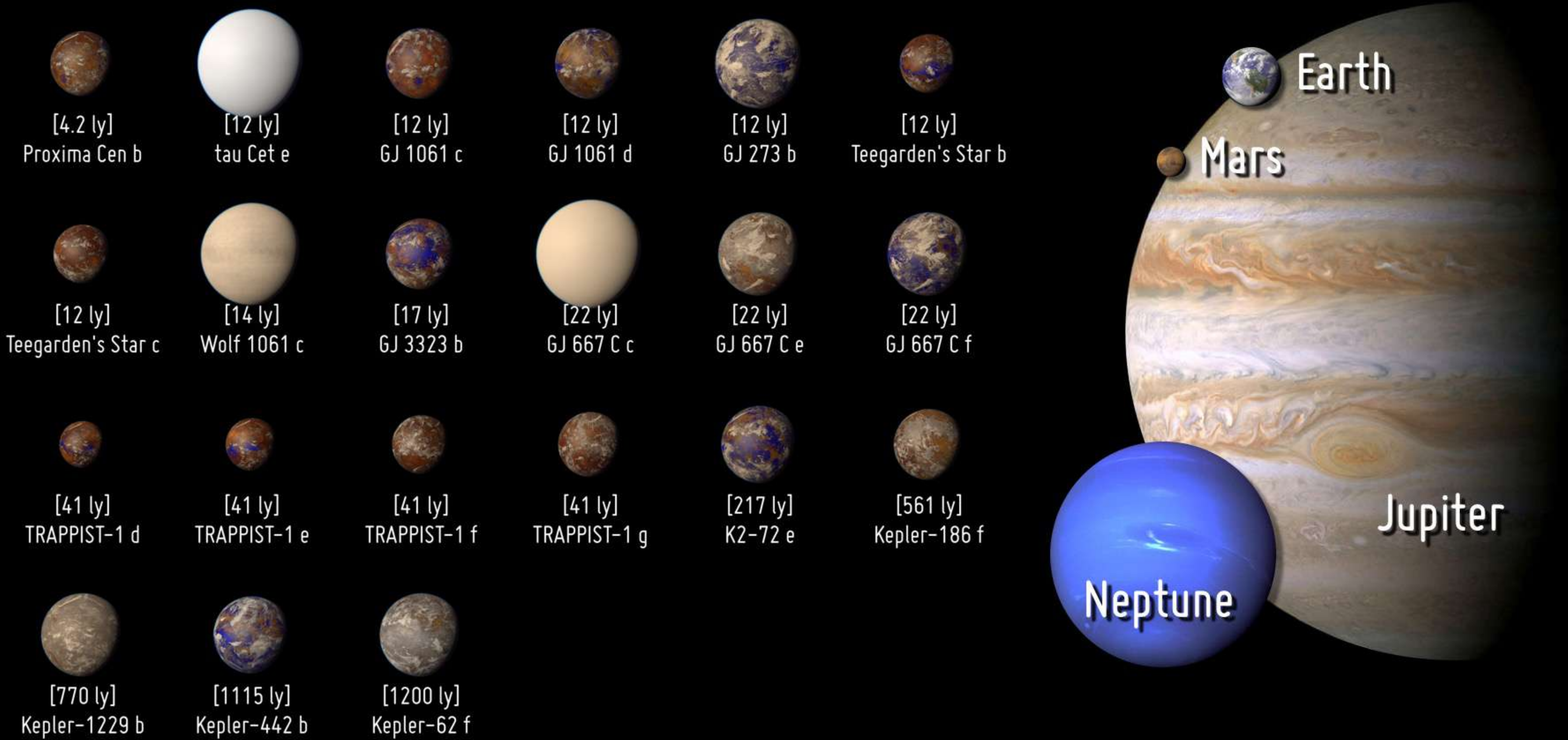




The Periodic Table of Exoplanets
Over 3800 Exoplanets
Number of Stellar Systems
2266
425
140
47
17
7
2
1
Terrans Group
Giants Group
Miniterrans (Mercury Size) 10^{-5} – 0.1 M_E or 0.03 – 0.4 R_E
Subterrans (Mars Size) 0.1 – 0.5 M_E or 0.4 – 0.8 R_E
Terrans (Earth Size) 0.5 – 5 M_E or 0.8 – 1.5 R_E
Superterrans (Super-Earths & Mini-Neptunes) 5 – 10 M_E or 1.5 – 2.5 R_E
Neptunians (Neptune Size) 10 – 50 M_E or 2.5 – 6.0 R_E
Jovians (Jupiter Size) > 50 M_E or > 6 R_E
Hot Zone
Warm 'Habitable' Zone
Cold Zone
Potentially Habitable
Hot Miniterrans 5 0.1%
Hot Subterrans 54 1.4%
Hot Terrans 614 15.9%
Hot Superterrans 971 25.1%
Hot Neptunians 776 20.0%
Hot Jovians 827 21.4%
Warm Miniterrans 0 0%
Warm Subterrans 1 <0.1%
Warm Terrans 22 0.6%
Warm Superterrans 32 0.8%
Warm Neptunians 39 1.0%
Warm Jovians 139 3.6%
Cold Miniterrans 0 0%
Cold Subterrans 1 <0.1%
Cold Terrans 8 0.2%
Cold Superterrans 10 0.3%
Cold Neptunians 25 0.6%
Cold Jovians 301 7.8%
M_E = Earth Mass, R_E = Earth Radius
CREDIT: PHL @ UPR Arecibo (phl.upr.edu) Jul 2018

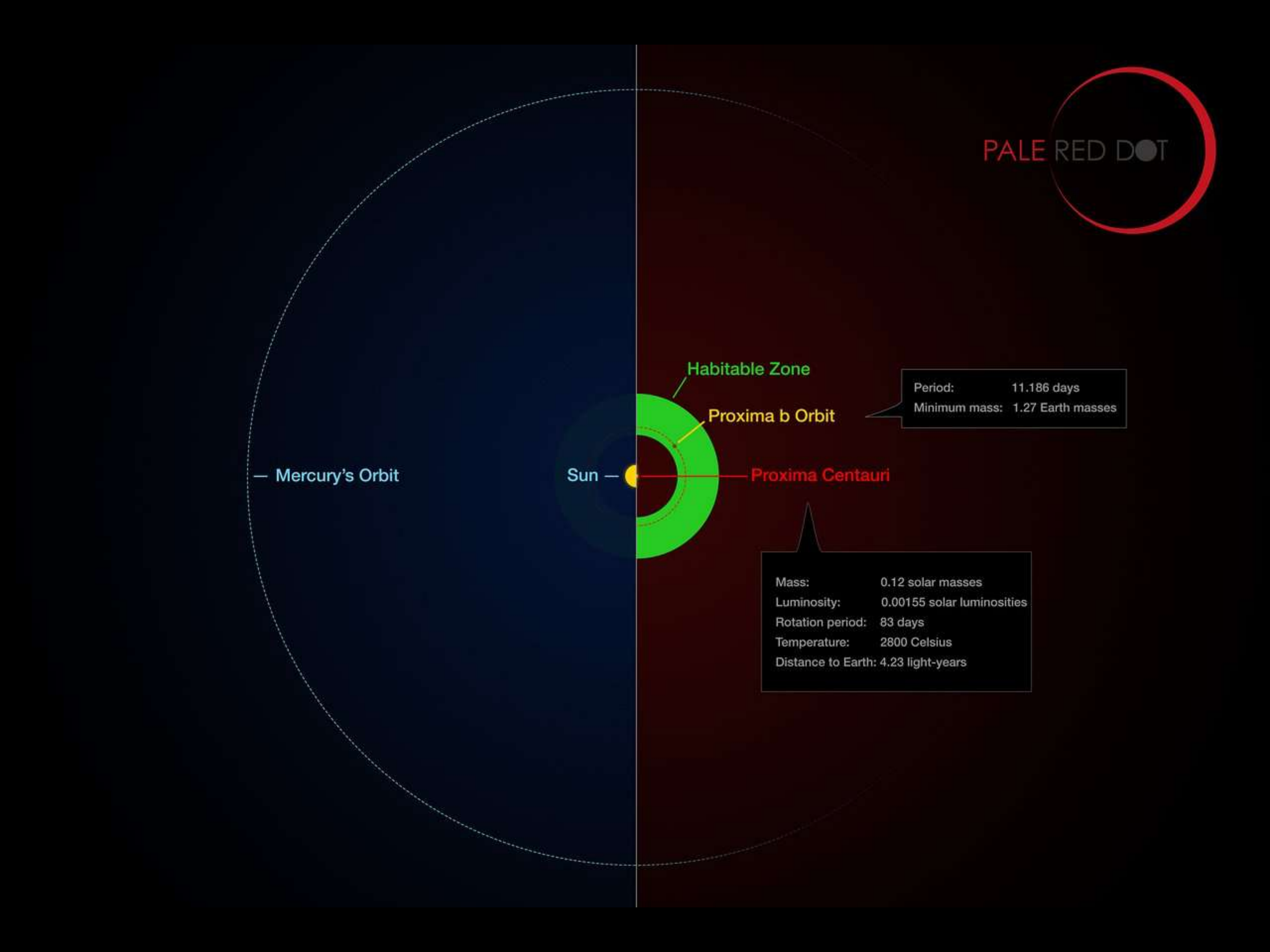
Potentially Habitable Exoplanets

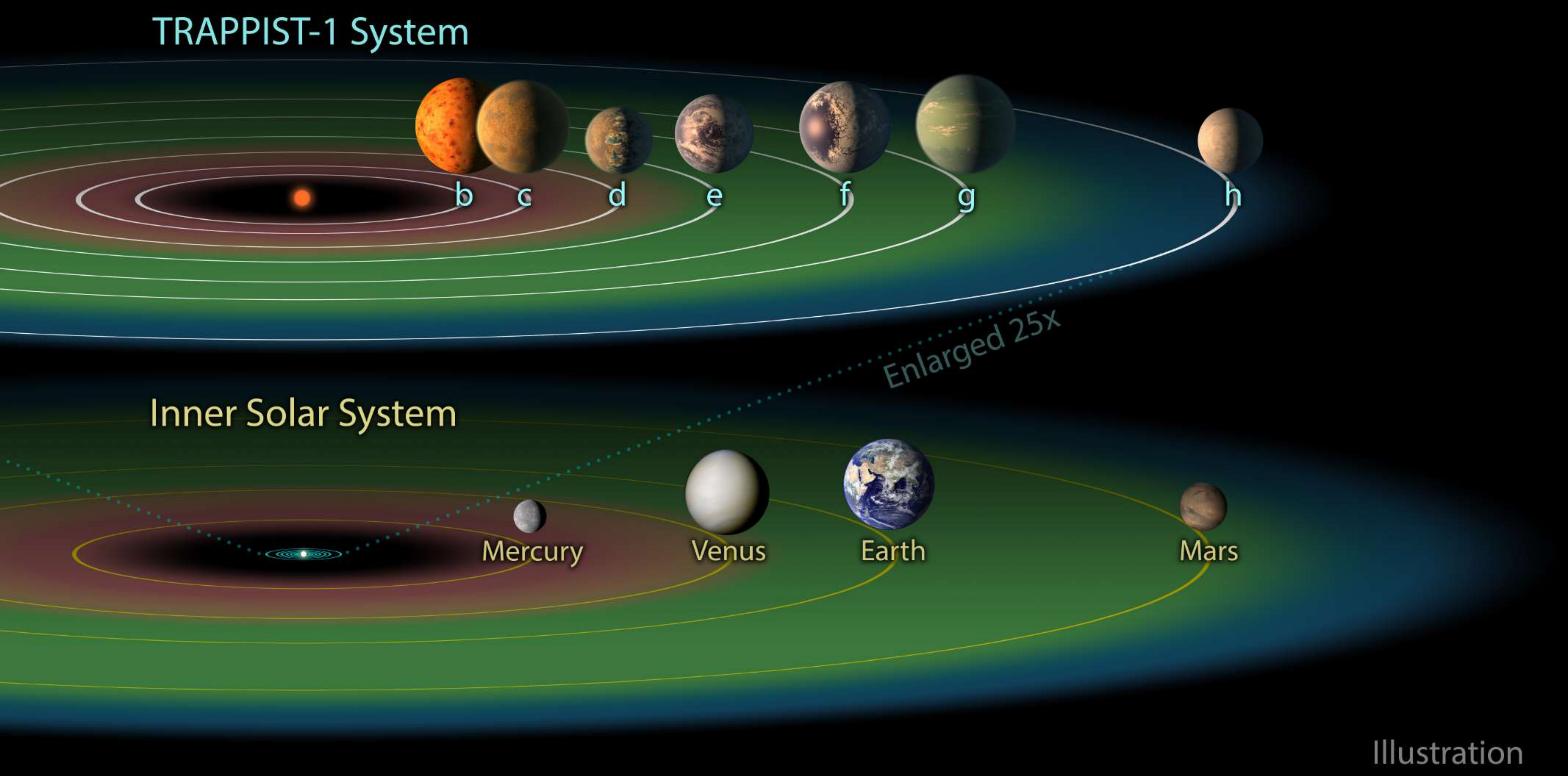
Ranked by Distance from Earth (light years)



Artistic representations. Earth, Mars, Jupiter, and Neptune for scale. Distance from Earth is between brackets.

CREDIT: PHL @ UPR Arecibo (phl.upr.edu) Sep 4, 2019


PALE RED DOT
Habitable Zone
Proxima b Orbit
Period: 11.186 days
Minimum mass: 1.27 Earth masses
Mercury's Orbit
Sun
Proxima Centauri
Mass: 0.12 solar masses
Luminosity: 0.00155 solar luminosities
Rotation period: 83 days
Temperature: 2800 Celsius
Distance to Earth: 4.23 light-years


TRAPPIST-1 System
b
c
d
e
f
g
h
Enlarged 25x
Inner Solar System
Mercury
Venus
Earth
Mars
Illustration

A search for life on Earth from the Galileo spacecraft

Carl Sagan*, W. Reid Thompson*, Robert Carlson†, Donald Gurnett‡ & Charles Hord§

* Laboratory for Planetary Studies, Cornell University, Ithaca, New York 14853, USA
† Atmospheric and Cometary Sciences Section, Jet Propulsion Laboratory, Pasadena, California 91109, USA
‡ Department of Physics and Astronomy, University of Iowa, Iowa City, Iowa 52242-1479, USA
§ Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, Colorado 80309, USA

In its December 1990 fly-by of Earth, the Galileo spacecraft found evidence of abundant gaseous oxygen, a widely distributed surface pigment with a sharp absorption edge in the red part of the visible spectrum, and atmospheric methane in extreme thermodynamic disequilibrium; together, these are strongly suggestive of life on Earth. Moreover, the presence of narrow-band, pulsed, amplitude-modulated radio transmission seems uniquely attributable to intelligence. These observations constitute a control experiment for the search for extraterrestrial life by modern interplanetary spacecraft.

AT ranges varying from ~100 km to ~100,000 km, spacecraft have now flown by more than 60 planets, satellites, comets and asteroids. They have been equipped variously with imaging systems, photometric and spectrometric instruments extending from ultraviolet to kilometre wavelengths, magnetometers and charged-particle detectors. In none of these encounters has compelling, or even strongly suggestive, evidence for extraterrestrial life been found. For the Moon, Venus and Mars, orbiter and lander observations confirm the conclusion from fly-by spacecraft. Still, extraterrestrial life, if it exists, might be quite unlike the forms of life with which we are familiar, or present only marginally. The most elementary test of these techniques—the detection of life on Earth by such an instrumented fly-by spacecraft—had, until recently, never been attempted.

Galileo is a single-launch Jupiter orbiter and entry probe currently in interplanetary space and scheduled to arrive in the Jupiter system in December 1995. It could not be sent directly to Jupiter; instead, the mission incorporated two close gravitational assists at the Earth and one at Venus. This greatly lengthened the transit time, but it also permitted close observations of the Earth. The

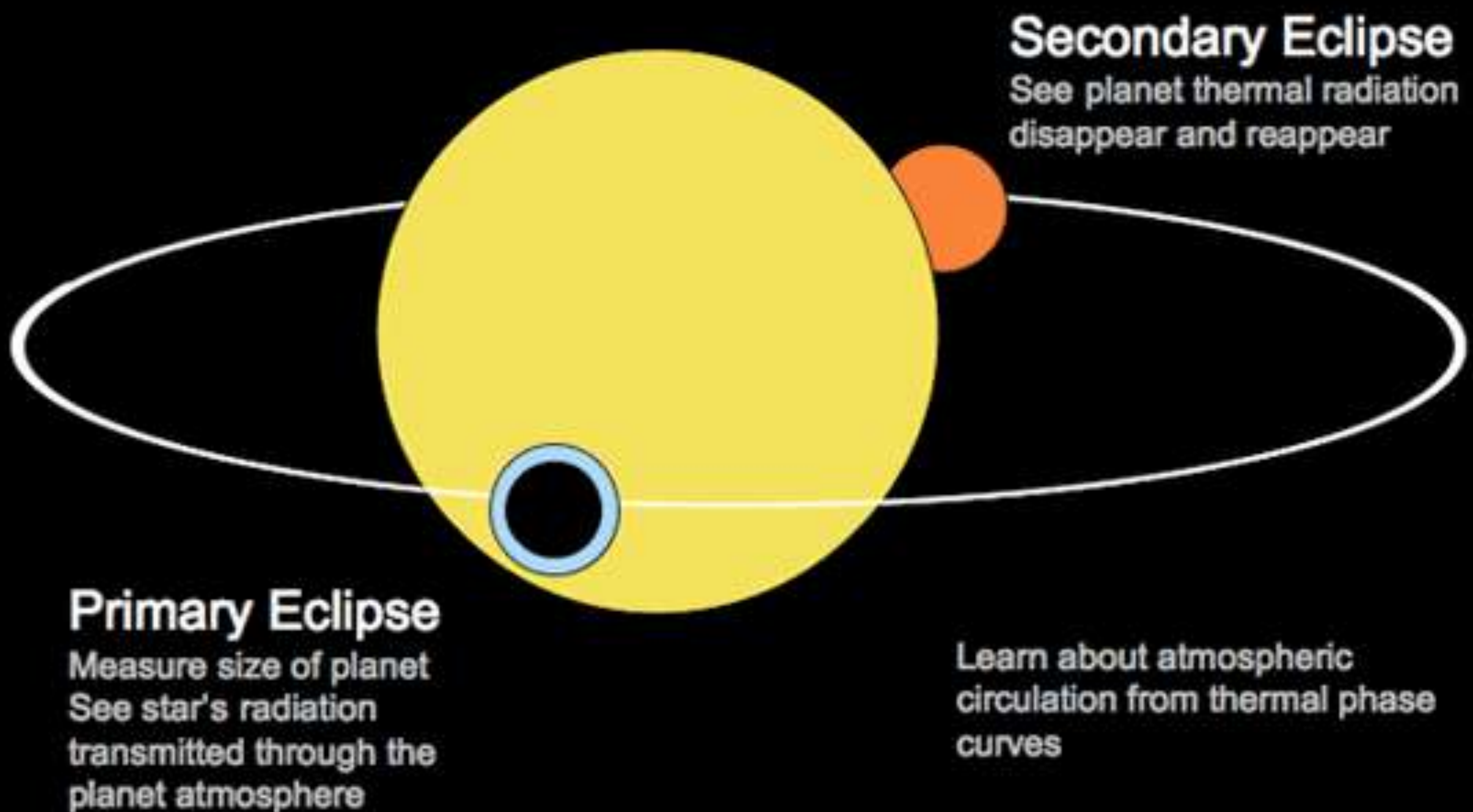
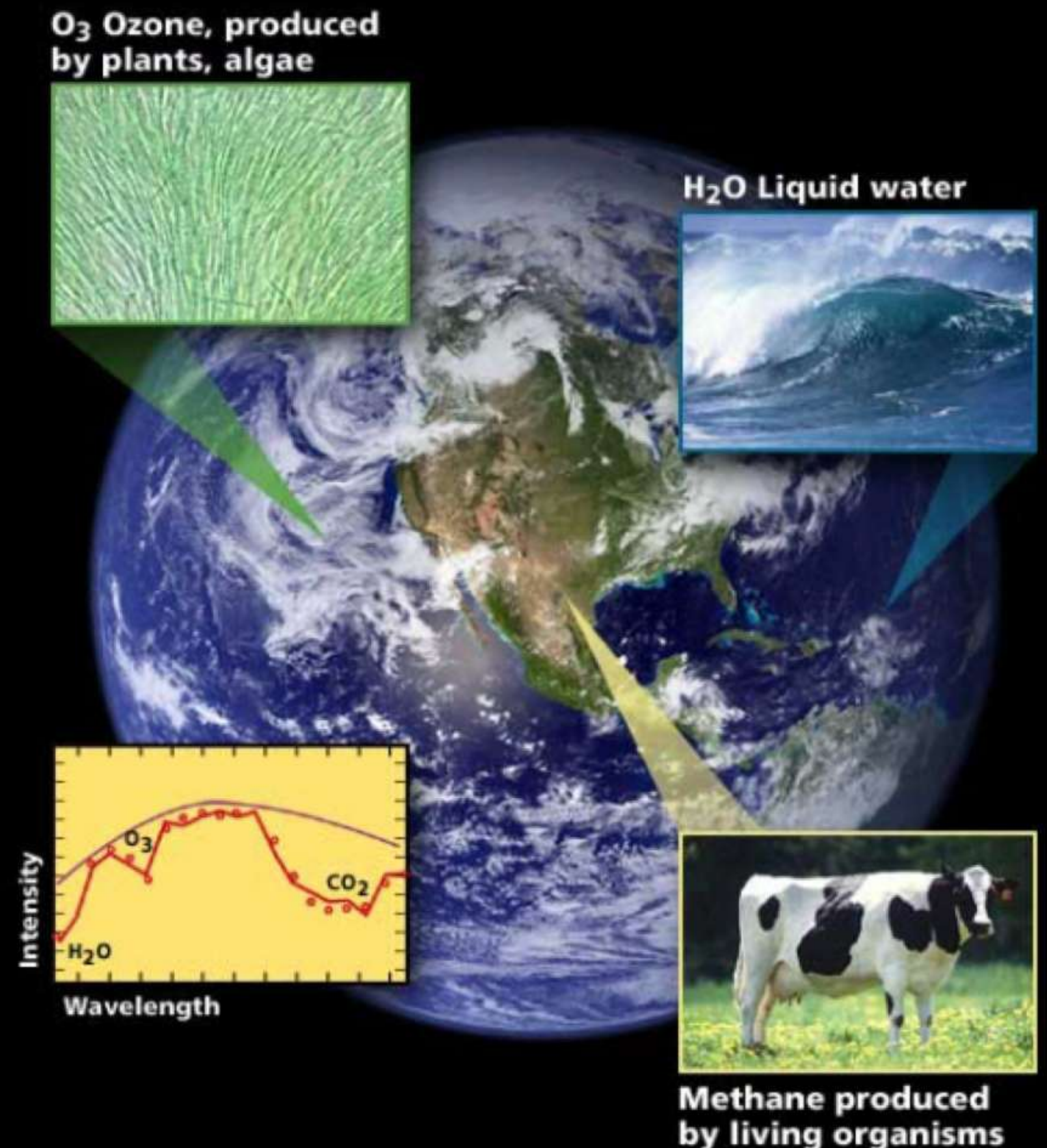
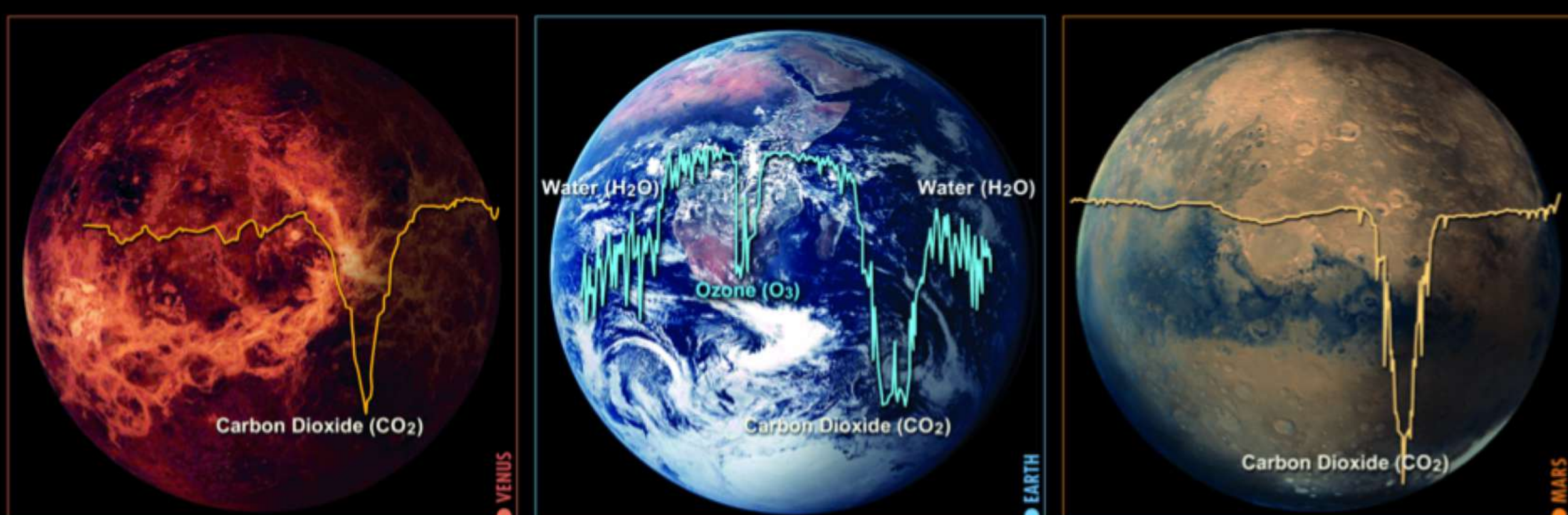


Figure by S. Seager


O3 Ozone, produced by plants, algae
H2O Liquid water
O3
CO2
H2O
Intensity
Wavelength
Methane produced by living organisms


Carbon Dioxide (CO2)
VENUS
Water (H2O)
Water (H2O)
Ozone (O3)
Carbon Dioxide (CO2)
EARTH
Carbon Dioxide (CO2)
MARS