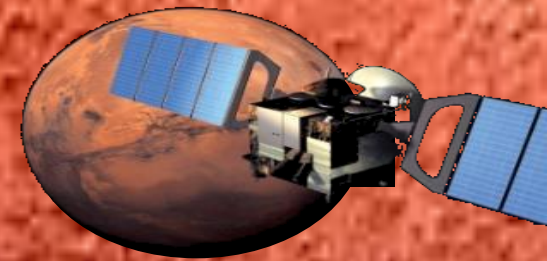


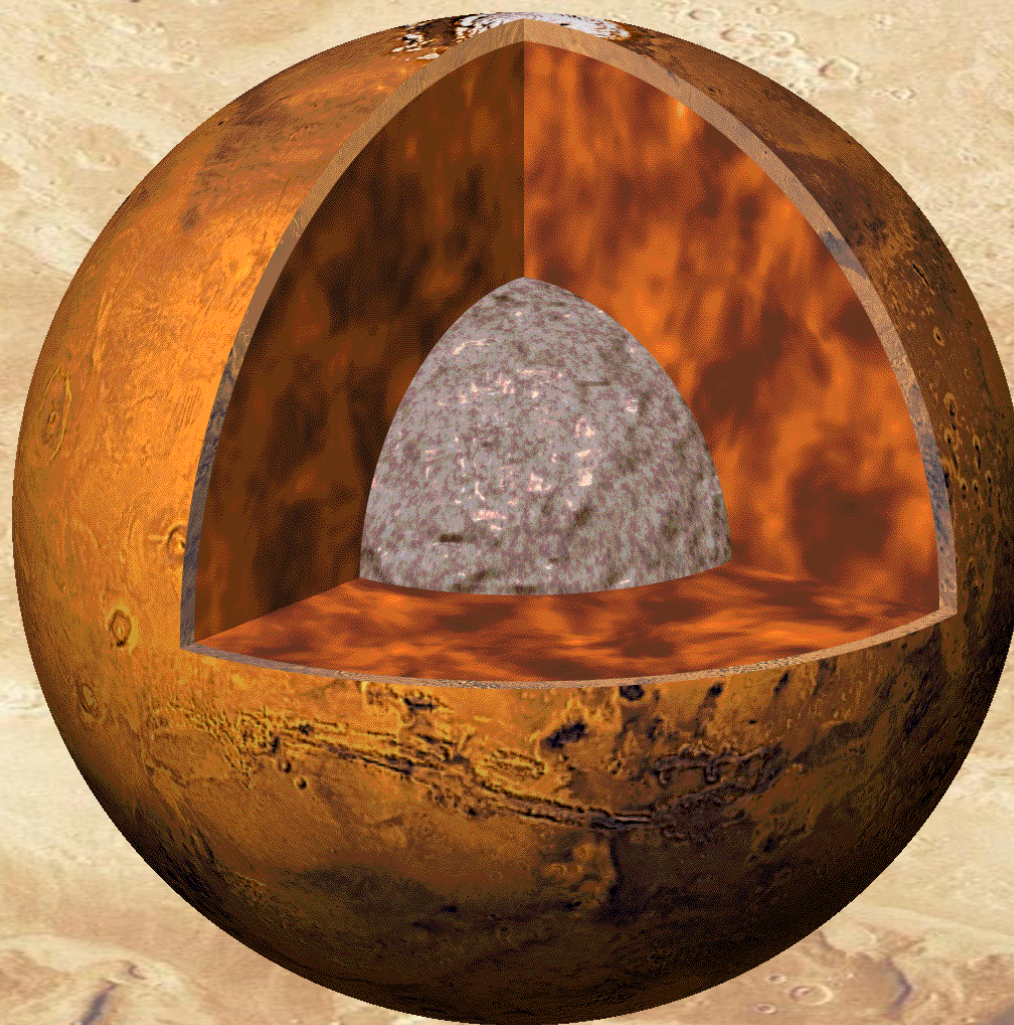


Mars Science & Exploration

Dr. Alejandro Cardesín Moinelo
Mars Express & ExoMars Science Operations
European Space Astronomy Centre



Planet Mars introduction



Roman God of War

4th planet in the Solar System

Furthest terrestrial “rocky” planet

Reddish surface caused by Ferric Oxide



1/2 Earth's Diameter

1/4 Earth's surface

1/10 Earth's mass

1/3 Earth's gravity

Thin CO2 atmosphere

Martian day (Sol) similar to Earth's day

Martian year almost double duration

Two little moons: Phobos & Deimos

DATOS	MARTE	TIERRA
Distancia desde el sol	227 millones de Km.	149 millones de Km.
Diámetro	67,000Kms	12,700 Kms.
Duración del año	687 días terrestre	365.25 días
Duración del día	24 horas y 37 minutos	23 horas y 56 minutos
Temperatura promedio	-67.2 grados centígrados	13.8 grados centígrados
Atmósfera	Dióxido de carbono y vapor de agua	Nitrógeno, oxígeno, argon
Número de lunas	2	1



The Seven "Travellers"

Jupiter

- 7 moving anomalies in the sky: "travelling" stars → planets
- Lack of technology, limited knowledge → especulations → Mythology ...

Moon, Mars, Mercury, Jupiter, Venus, Saturn, Sun

monday, tuesday, wednesday, thursday, friday, saturday, sunday

Luna, Marte, Mercurio, Jupiter, Venus, Saturno, Sol

lunes, martes, miercoles, jueves, viernes, sabado, domingo

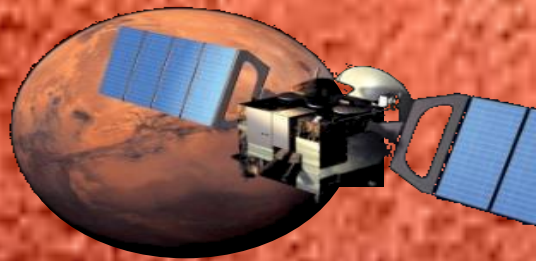
lundi, mardi, mercredi, jeudi, vendredi, samedi, dimanche

lunedì, martedì, mercoledì, giovedì, venerdì, sabato, domenica

...

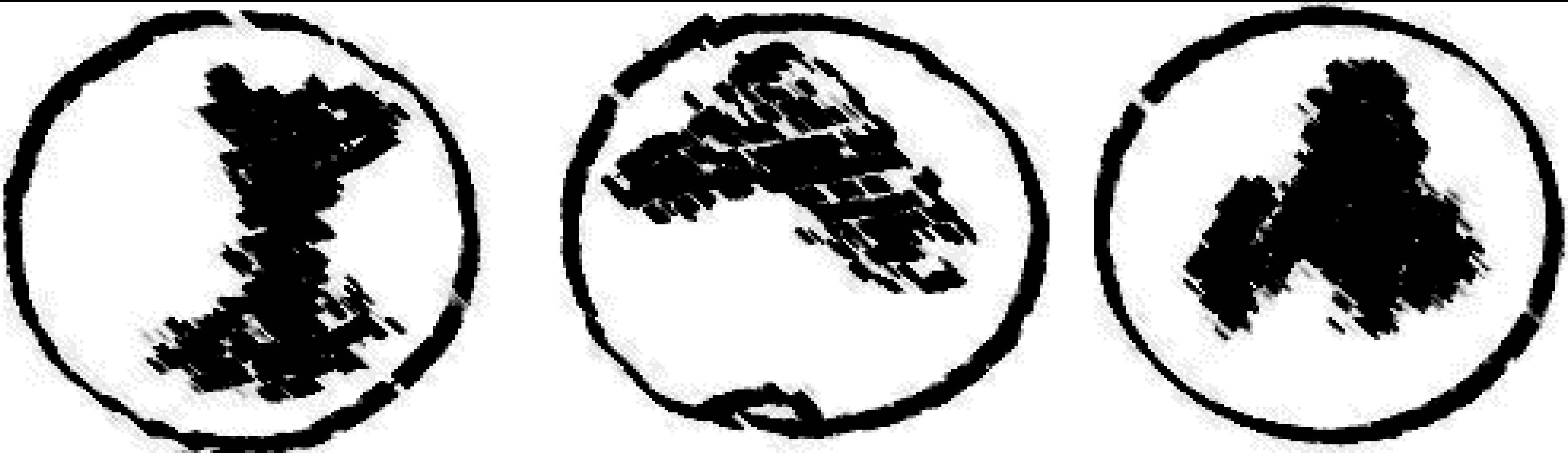
Mercury

Mars throughout history: Technology enables knowledge



1610 Galileo starts using the telescope looking at the Moon, Venus, Mars...

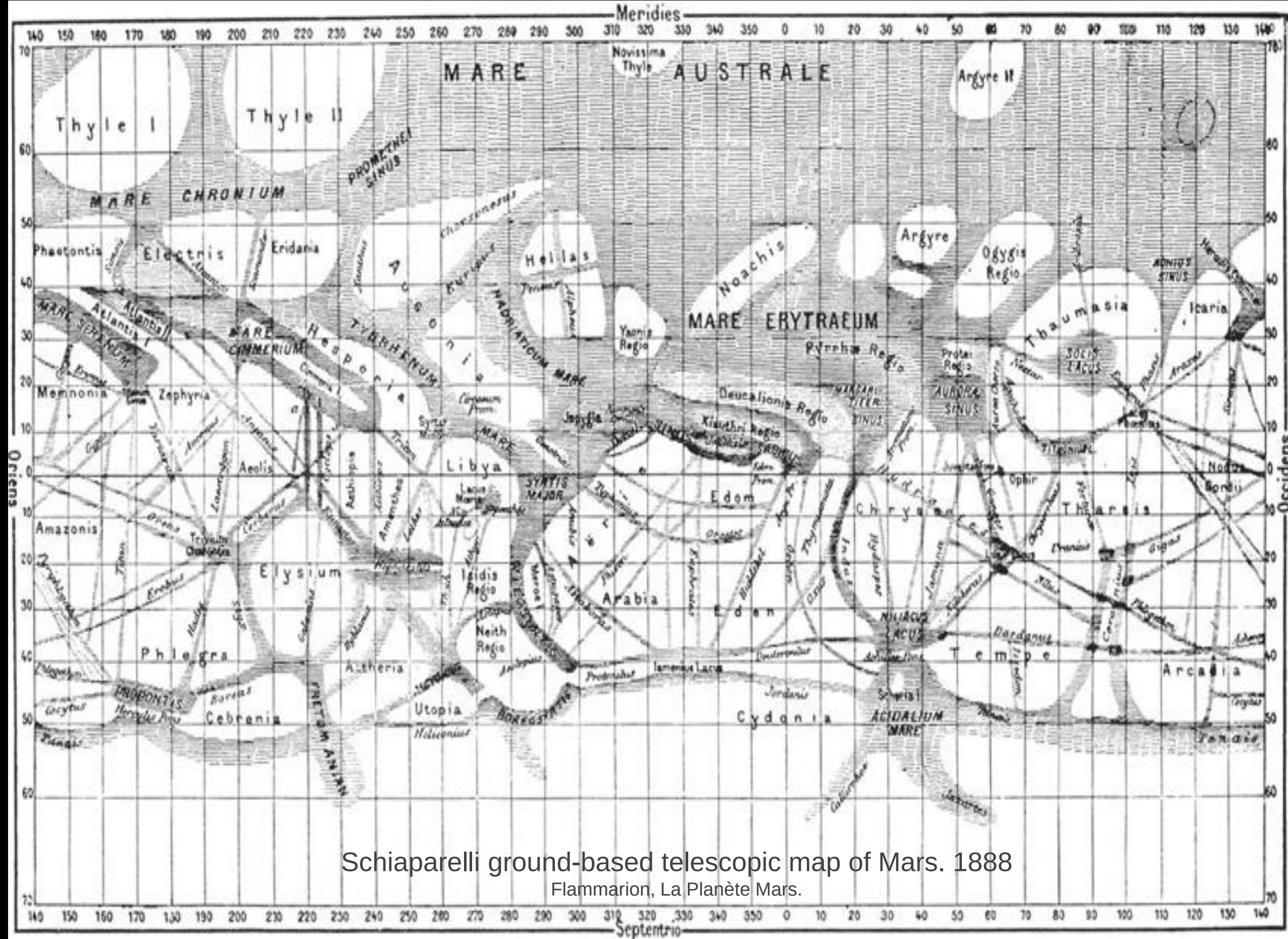
**1659 Huygens observes a dark spot and calculates rotation ~24h,
diameter ~60% of Earth and polar caps!**



A NEW WORLD!!!

1880s Schiaparelli

Knowledge again limited by technology → speculations...



Schiaparelli ground-based telescopic map of Mars. 1888

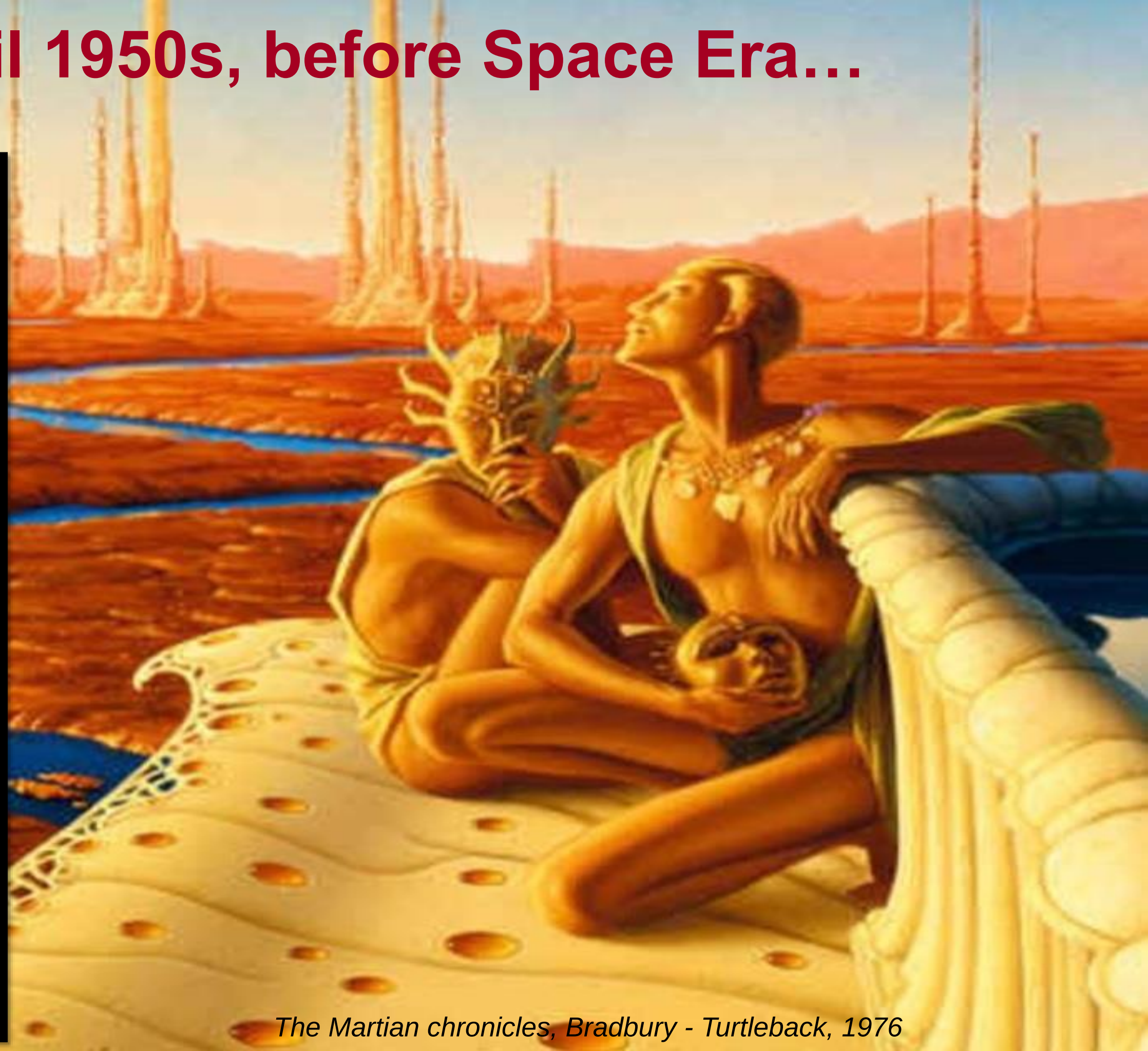
Flammarion, La Planète Mars.

Mars view until 1950s, before Space Era...

Orson Welles 1938



DAILY NEWS
**FAKE RADIO 'WAR'
STIRS TERROR
THROUGH U.S.**



The Martian chronicles, Bradbury - Turtleback, 1976

A satellite with large blue solar panels is shown in orbit around the reddish-brown planet of Mars. The satellite is positioned in the center, with its solar panels extending outwards. The planet's surface, showing various craters and features, is visible in the background.

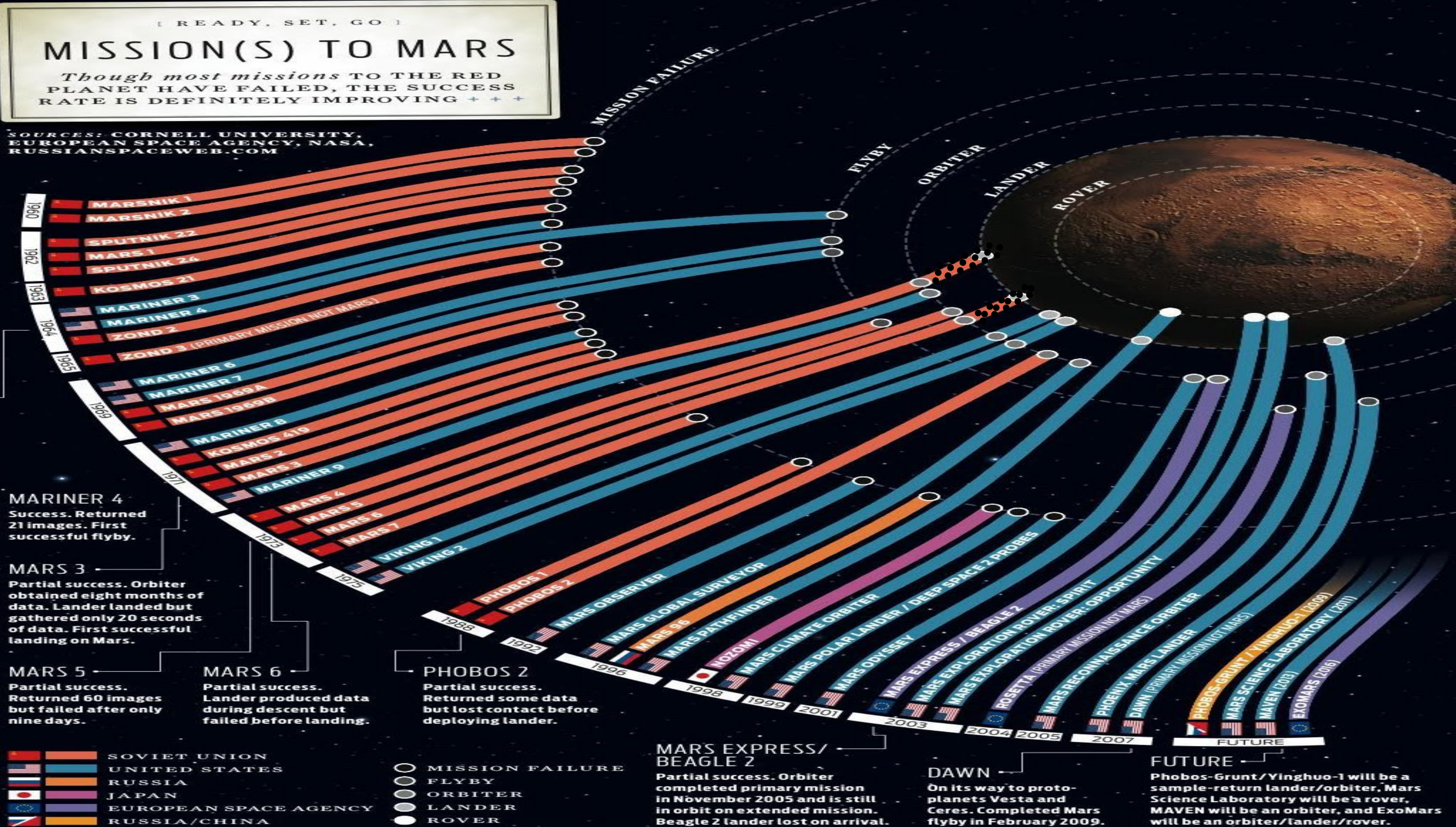


[READY, SET, GO]

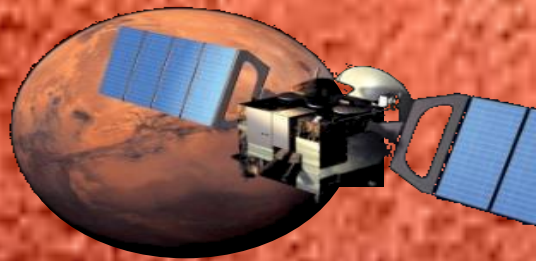
MISSION(S) TO MARS

Though most missions to the red planet have failed, the success rate is definitely improving + + +

SOURCES: CORNELL UNIVERSITY, EUROPEAN SPACE AGENCY, NASA, RUSSIANSPEACEWEB.COM



Mars Exploration nowadays...



2001 ... 2009

Mars Express
(ESA)

Odyssey

MRO

2011



Phobos-
Grunt
(RUSSIA)

2013/14

MAVEN



MOM
(India)



2016

TGO
(ESA-RUSSIA)

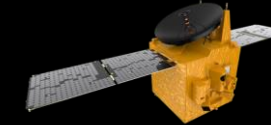


Schiaparelli



2018

2020



Arab
Emirates



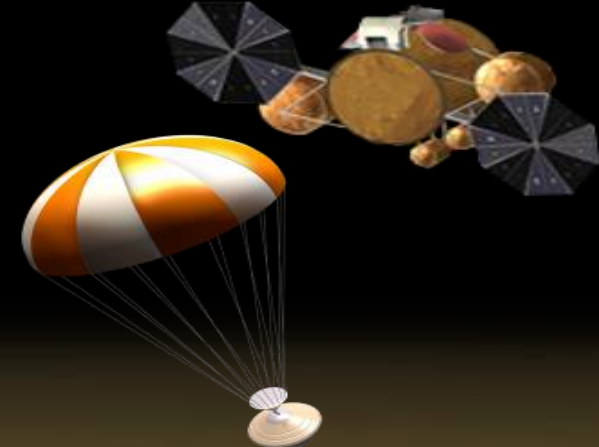
China

2022

ExoMars 2022
(ESA-RUSSIA)

future ...

Mars
Sample
Return



SpaceX?



?

Opportunity

Phoenix



Spirit



MSL Curiosity



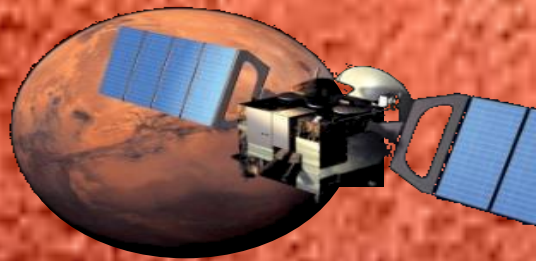
Insight



Mars 2020

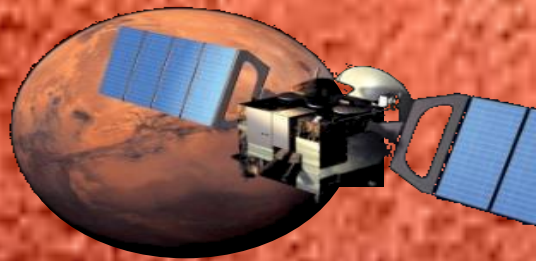


Mars Express 2003-2022 ...



First European Mission to orbit another Planet!
First and last mission of the "Rosetta family"
Up and running since 2003

Mars Express science investigations



Martian Moons: Phobos & Deimos:
surface, mass, volume, density, ...

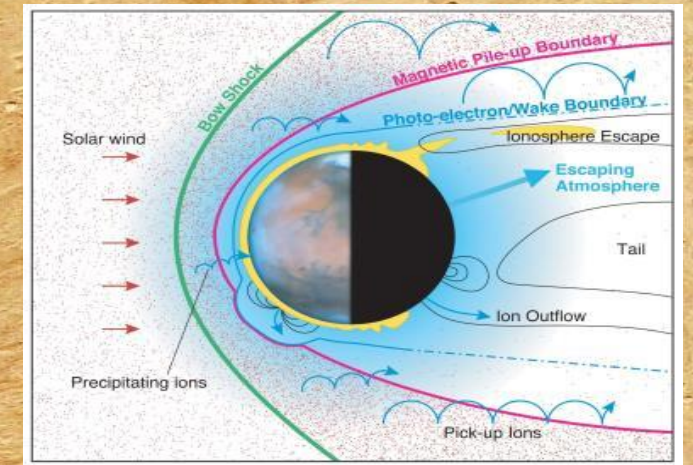
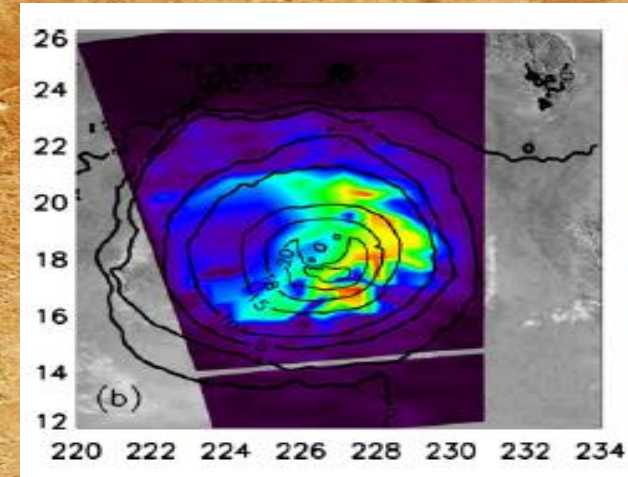
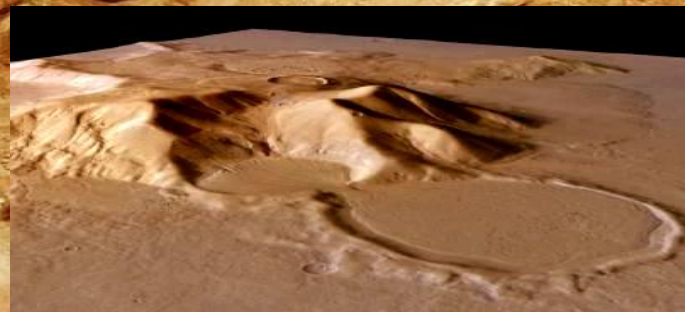
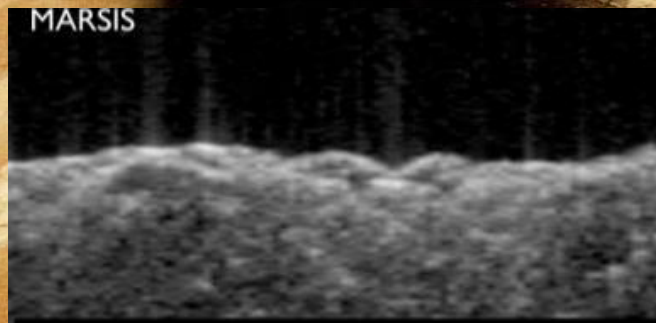
Atmosphere:
composition,
dynamics,
temperature,
climate, clouds, ...

**Ionosphere,
Magnetosphere,
Exosphere,**
Interaction with solar
wind, auroraes

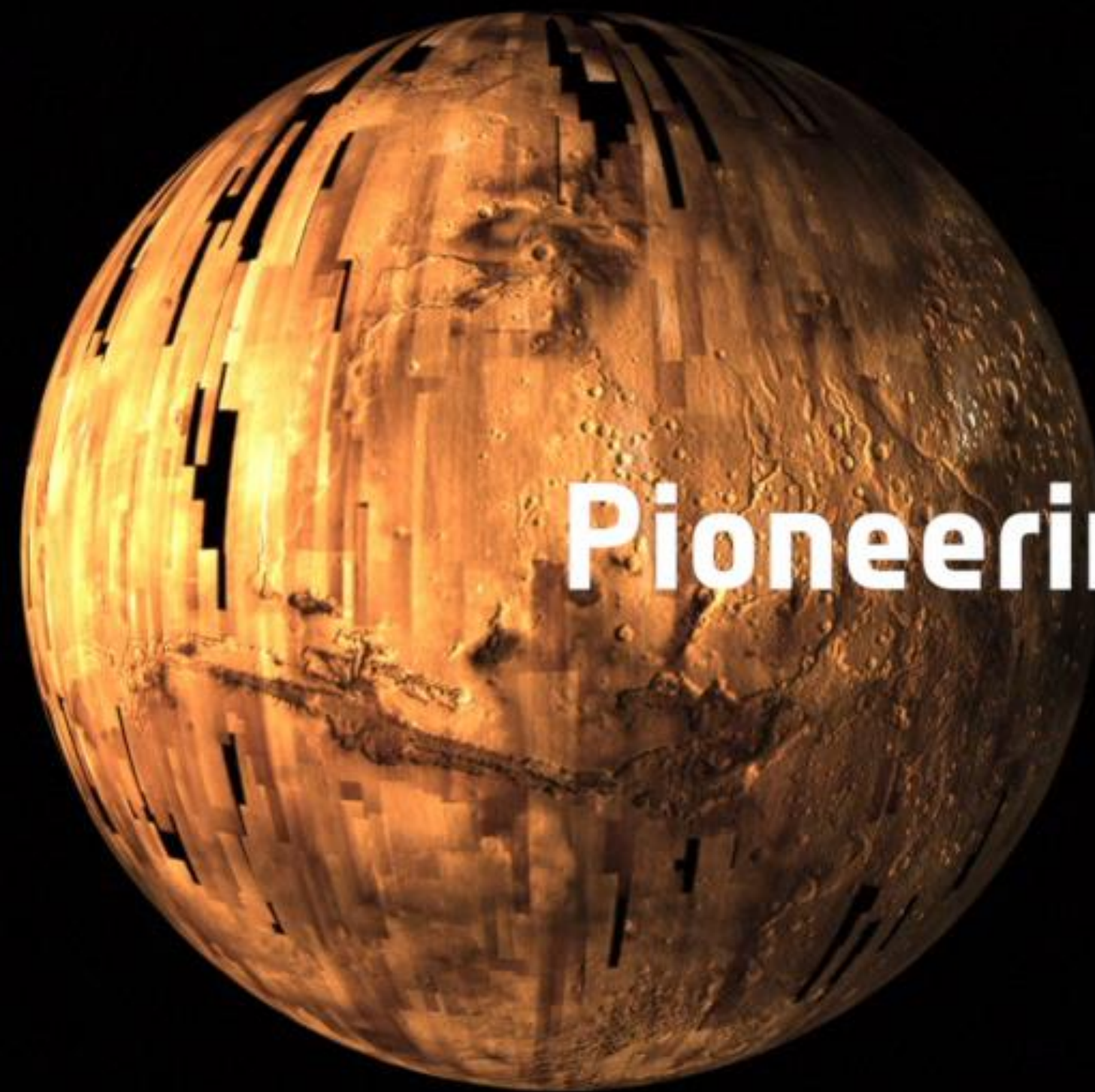
Surface: geology,
composition,
mineralogy, ...

Sub-surface:
physical properties
and structures

Interior:
Gravity field

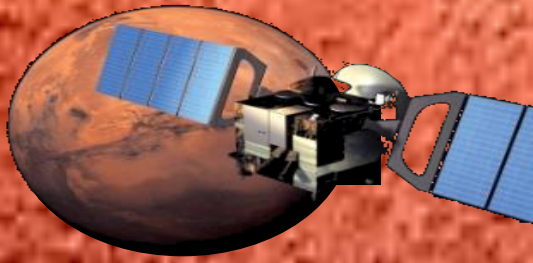


Comprehensive study of the planet and its history



Pioneering science

Mars History of liquid water... (and life???)

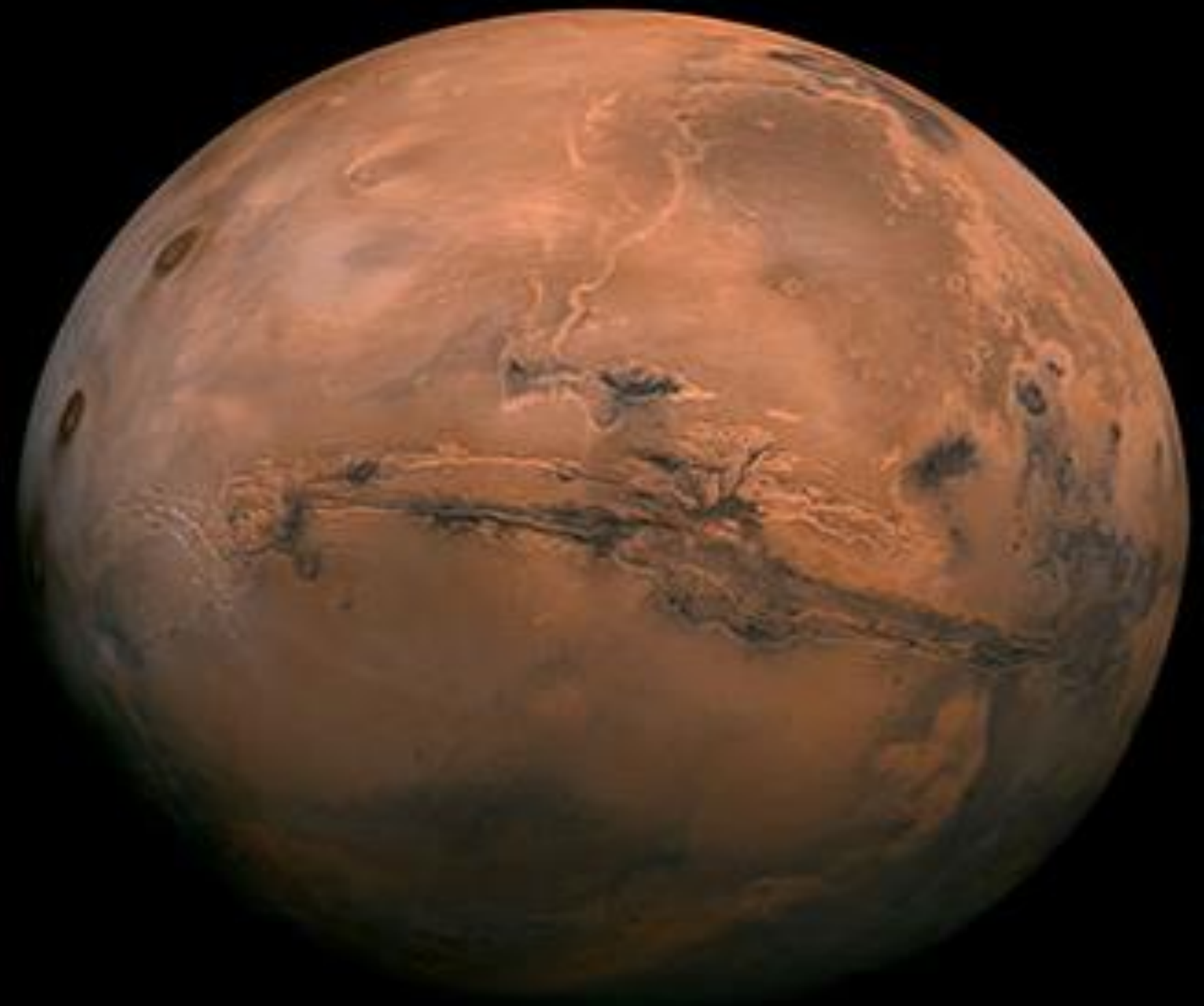


Río Tinto, Spain

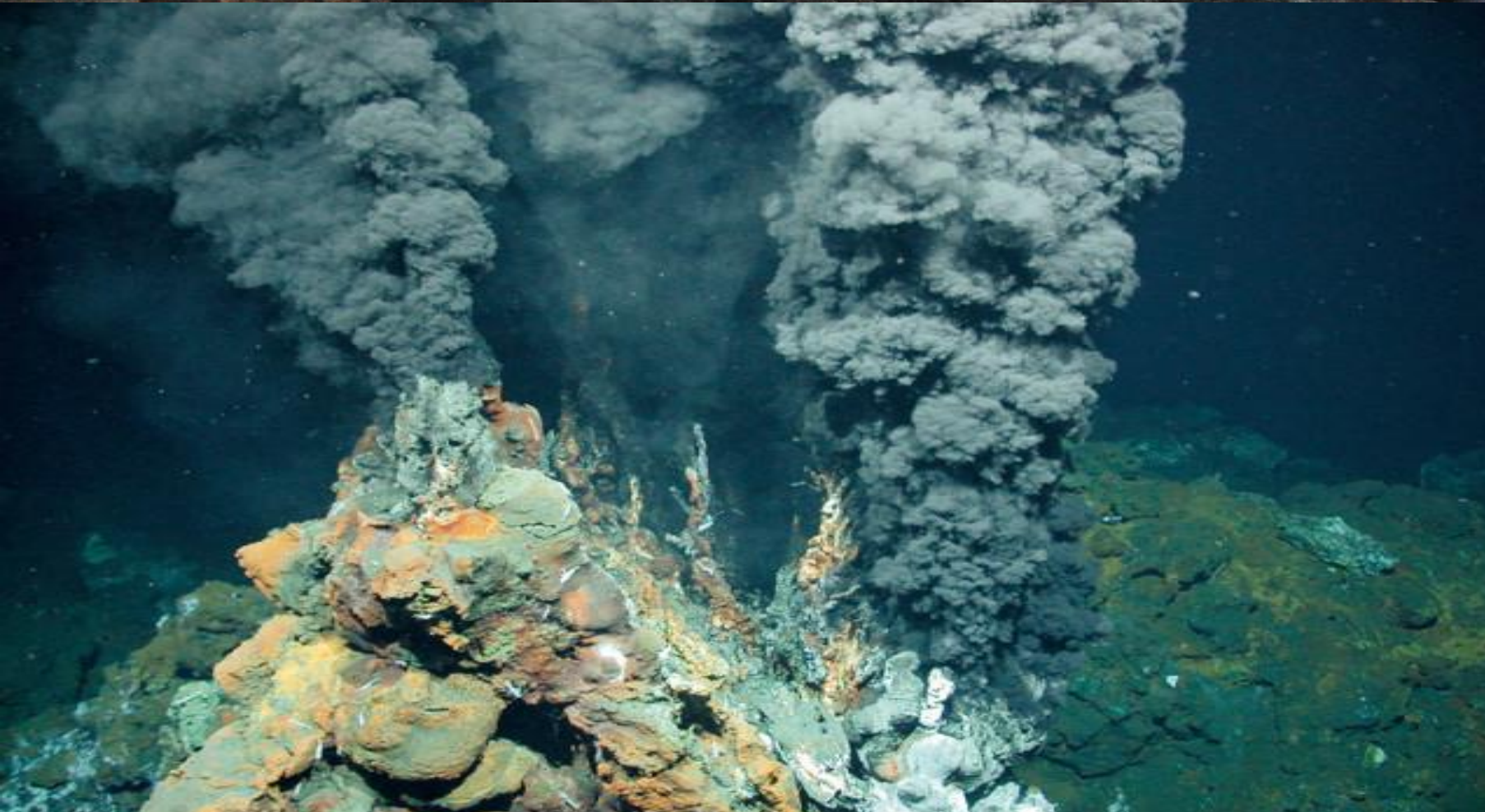
**Life on Earth
is everywhere!!!**



**But on Mars there is not
a single life organism! (?)**



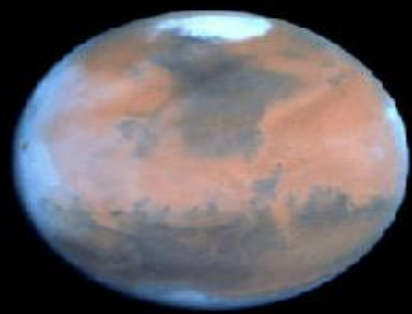
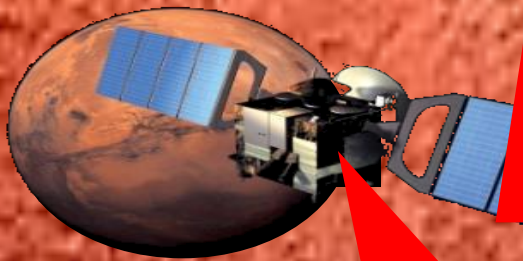
**more life in one hand than anywhere else in the solar system ?
or anywhere else in the universe ???**



Liquid water is the key !!



"Habitability zone" in the Solar System



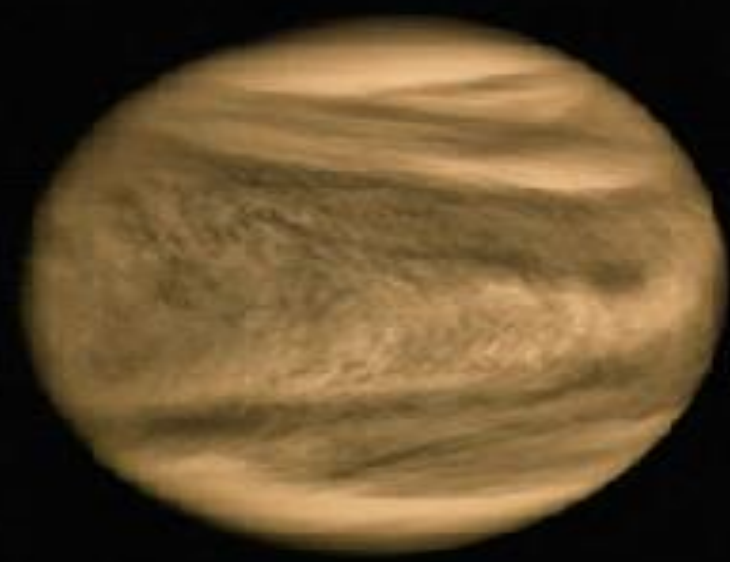
MARS

1.52



EARTH

1 AU



VENUS

0.72



MERCURY

0.39

distance



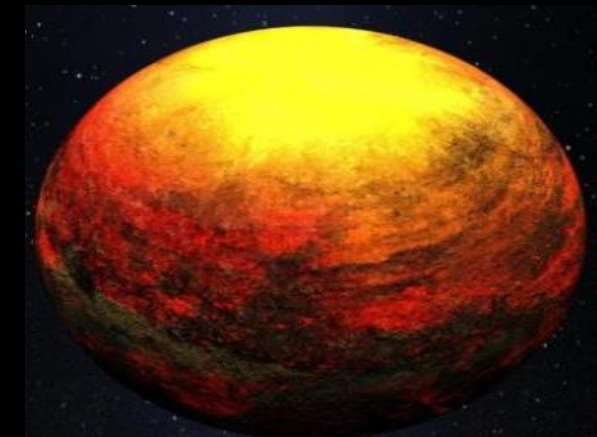
*Global
fridge*



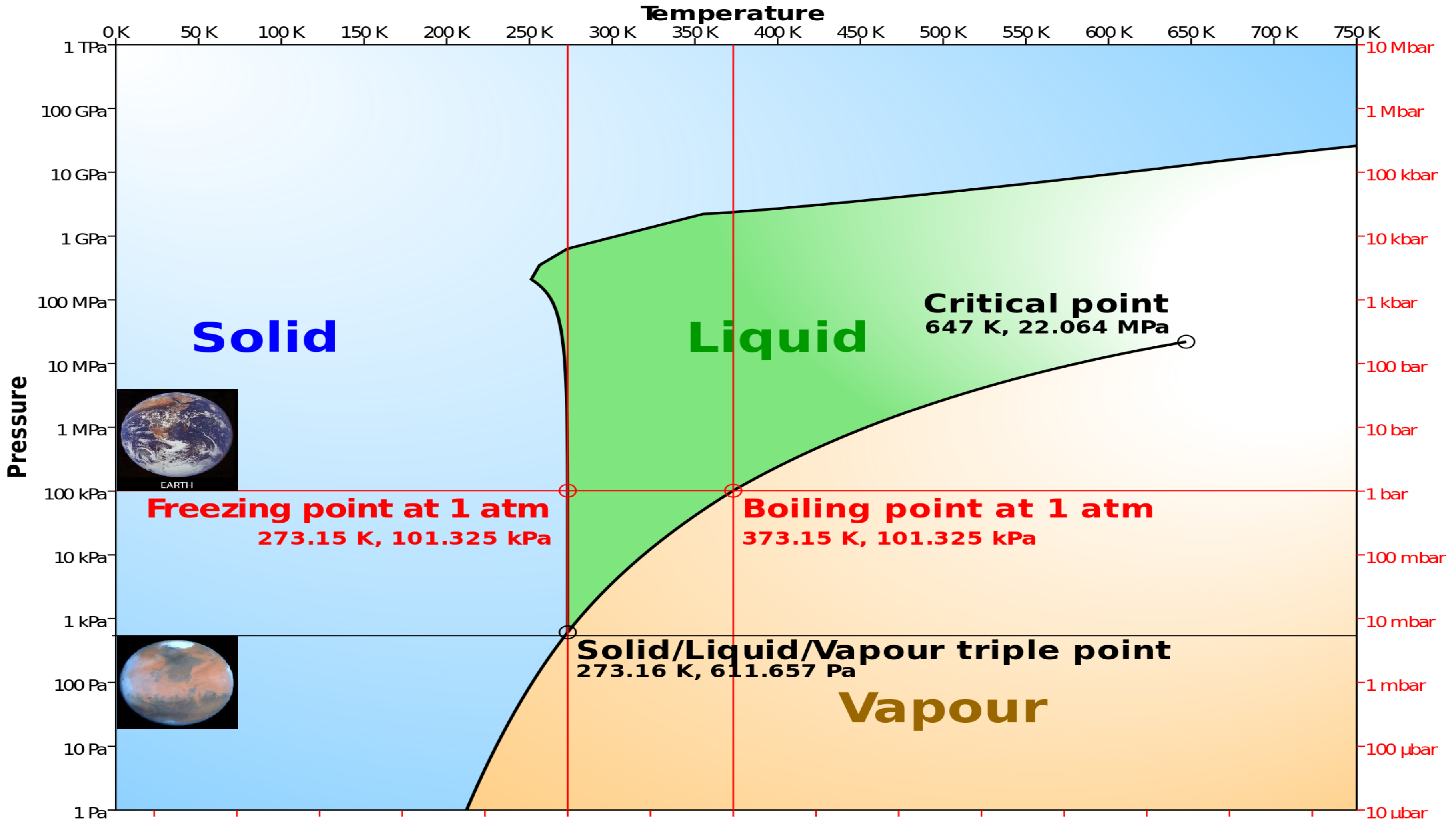
"Paradise"



*Greenhouse
oven*



Frying pan



[illegible]

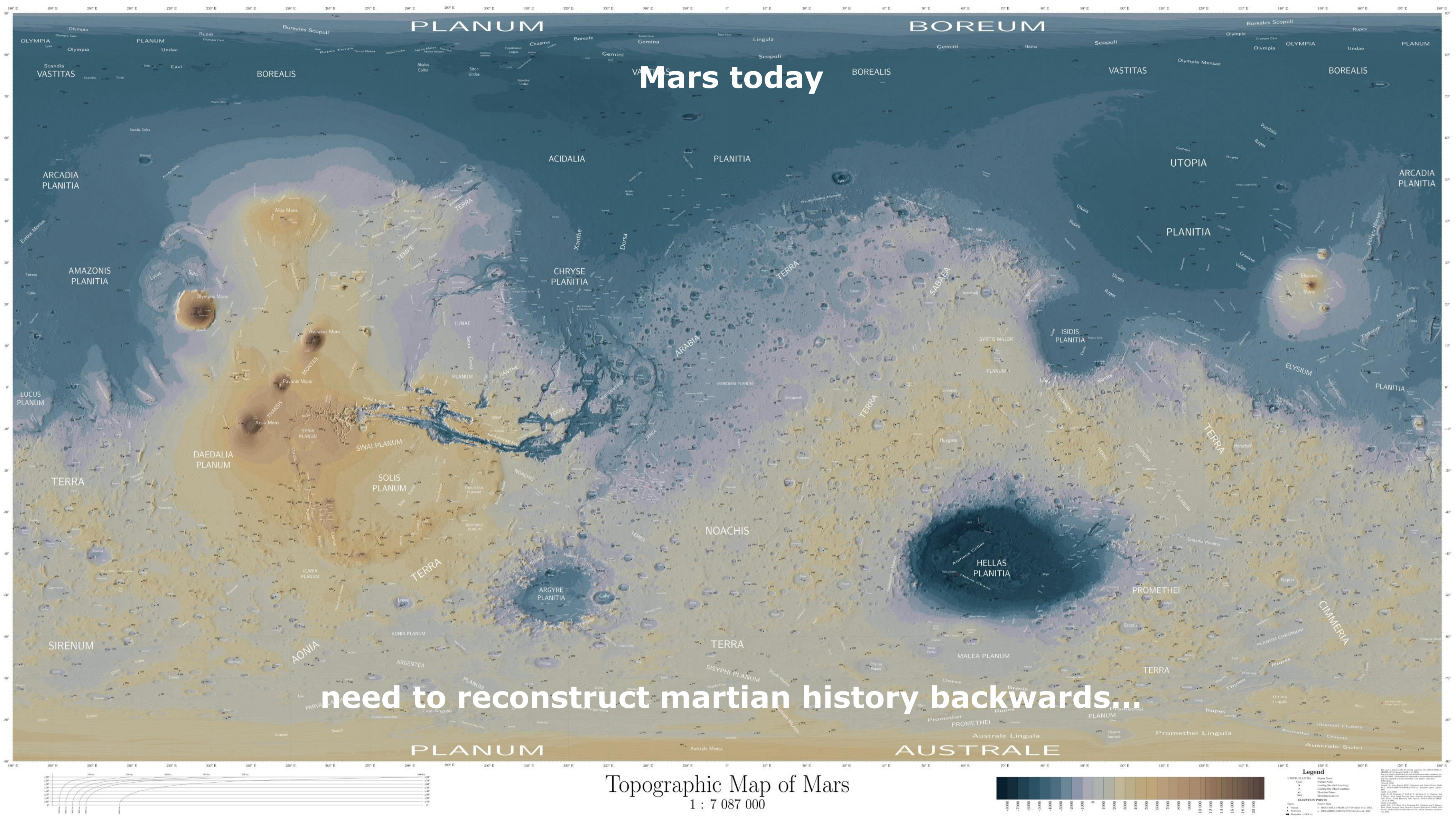
Mars today

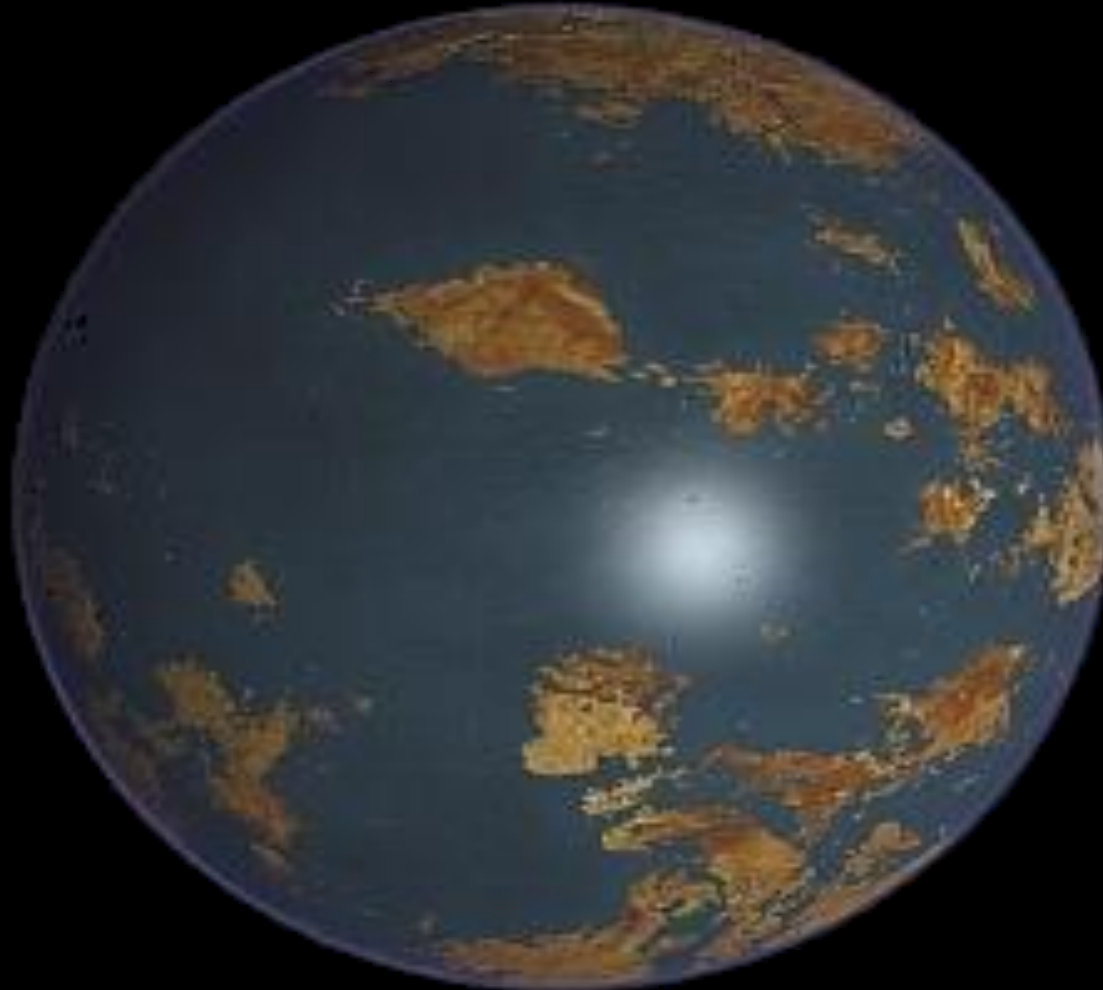
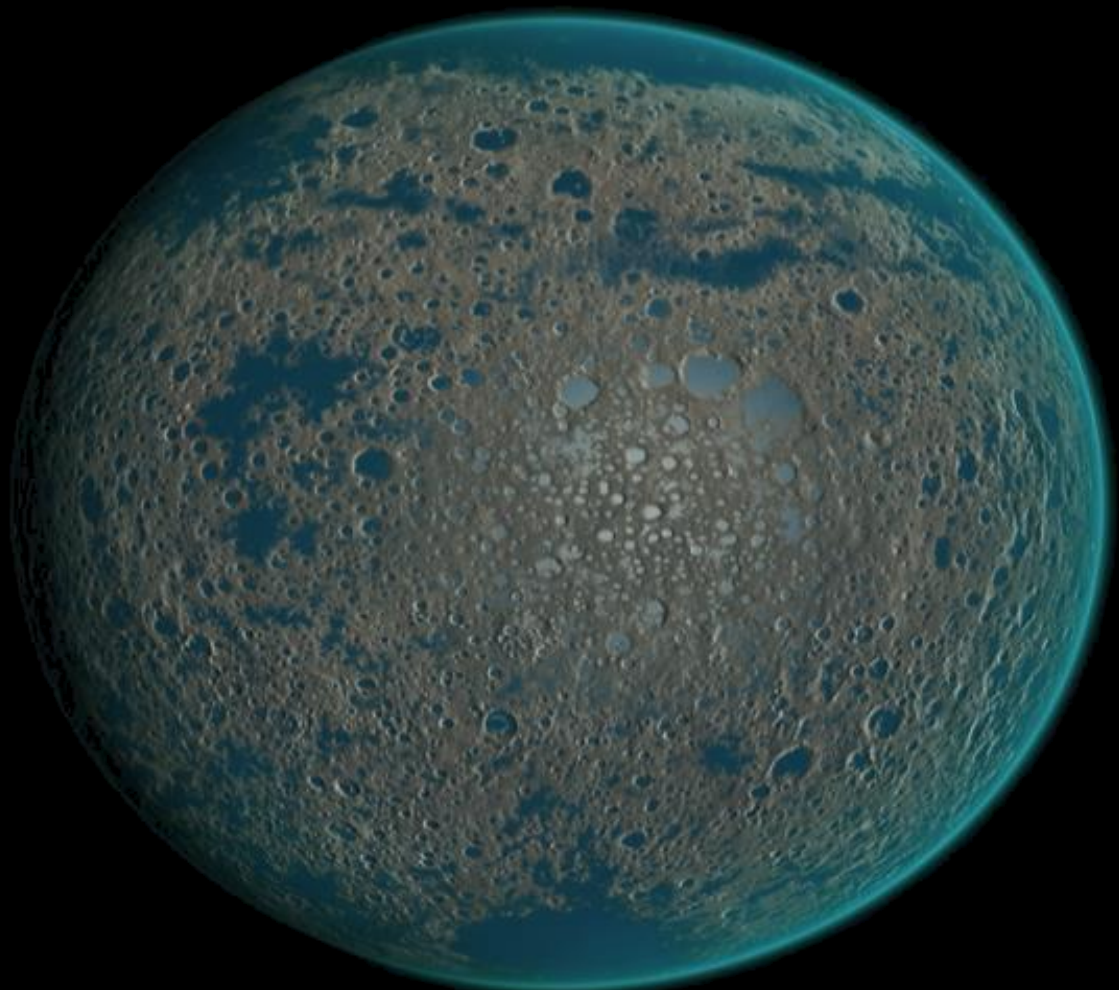
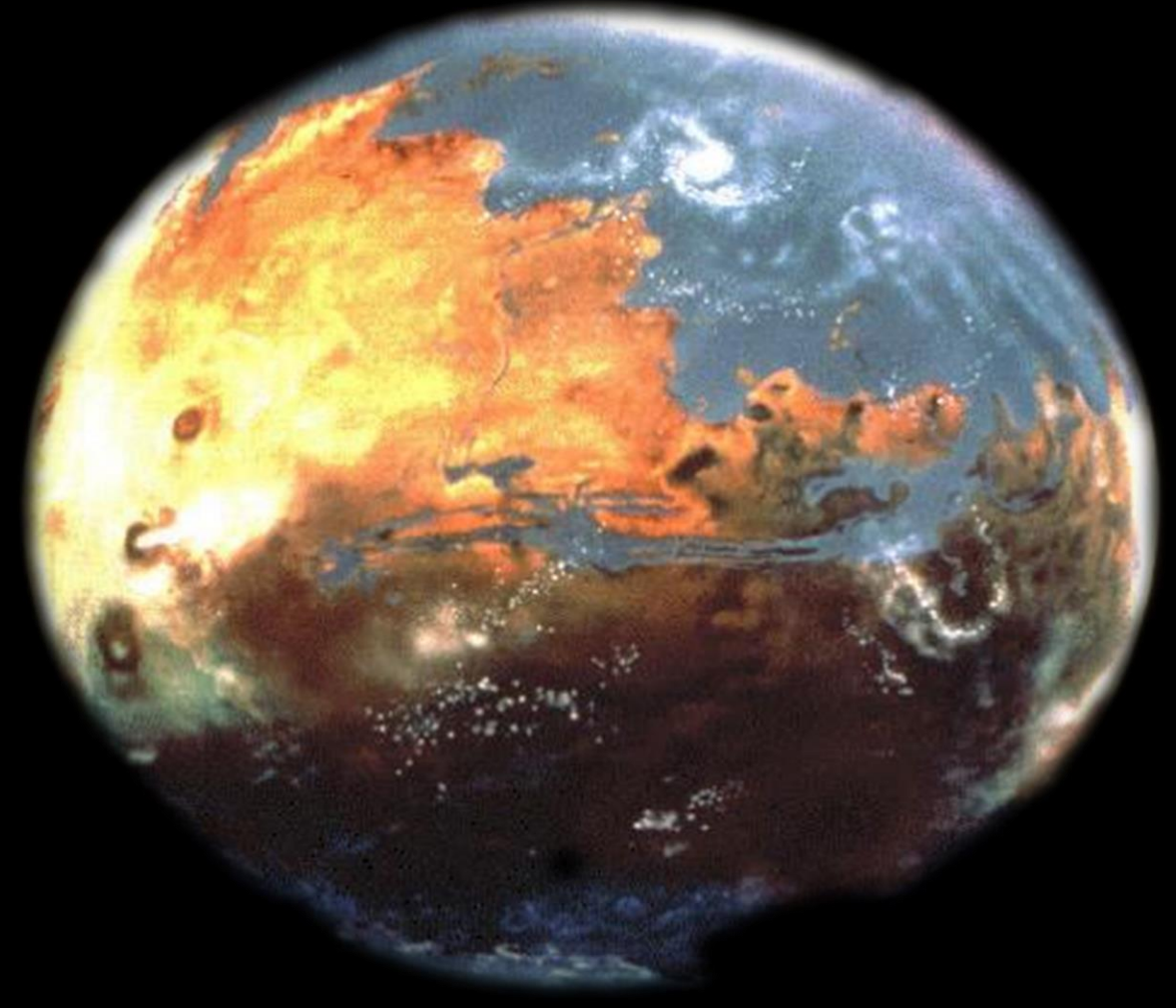
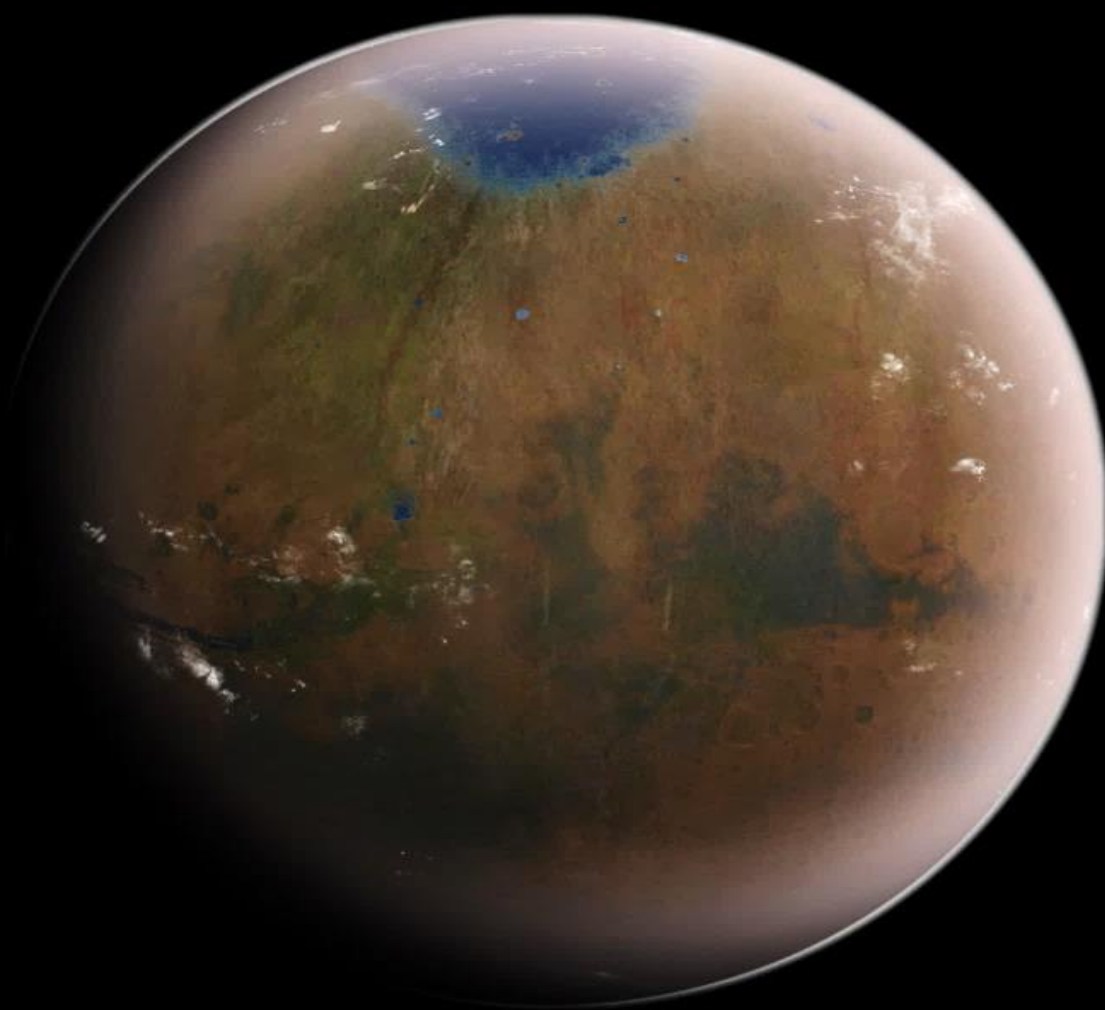
need to reconstruct martian history backwards...

Topographic Map of Mars
1 : 7 087 000

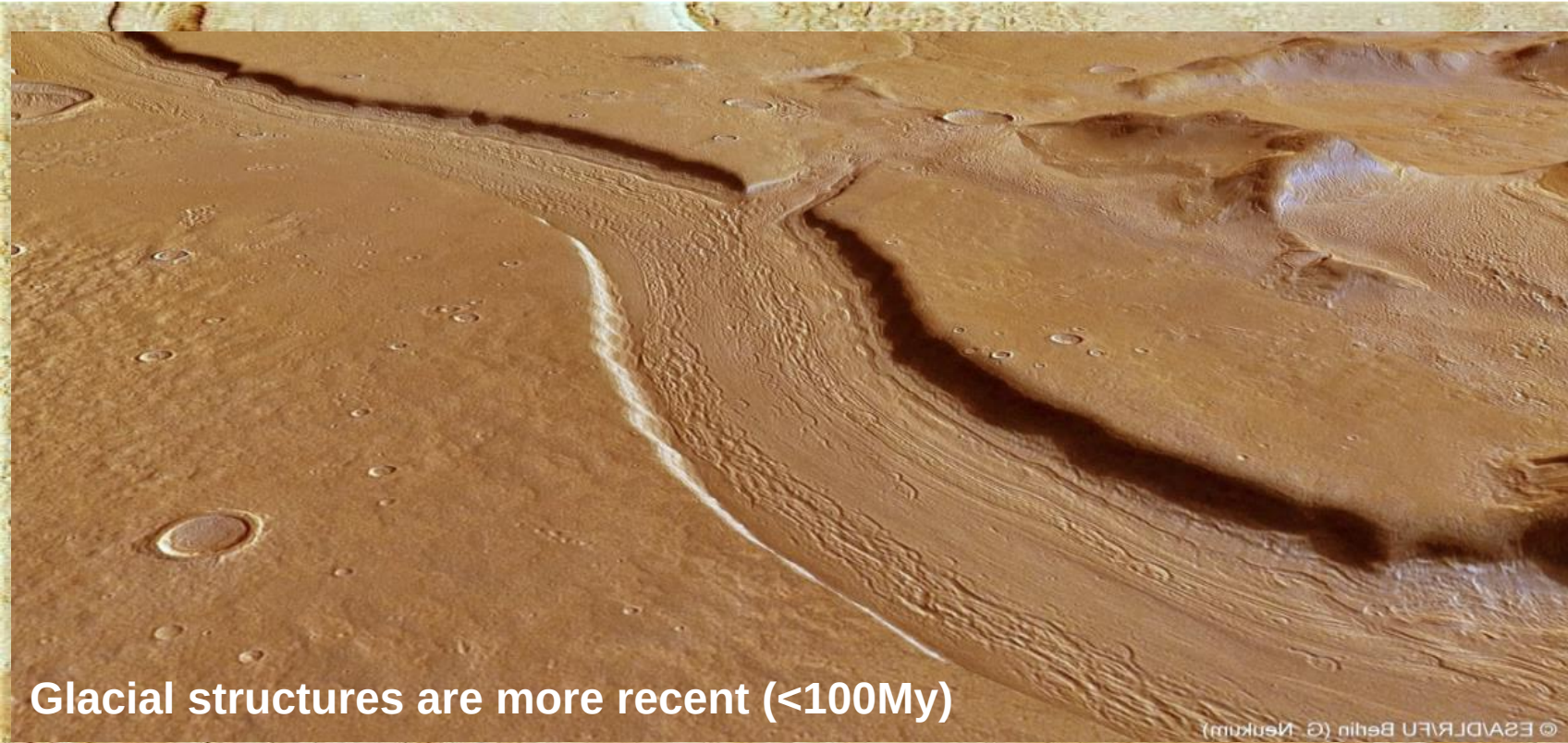
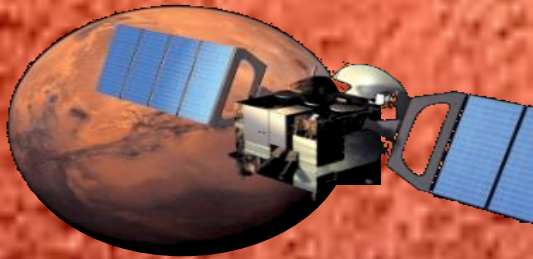
The map displays the topography of Mars, with a color scale ranging from -8000 to 20,000 meters. The map is divided into several regions, including the northern plains (Planum), the southern highlands (Terra), and the Tharsis volcanic plateau. The map also shows the locations of various craters, including the large Hellas impact crater and the Tharsis volcanic plateau. The map is labeled with various geographical names in Latin and Greek, such as Planum, Terra, and Mons. A scale bar and a legend are included at the bottom.

A detailed topographic map of Mars, color-coded by elevation from -8000m (dark blue) to 20,000m (brown). The map shows major geological features like Olympus Mons, Tharsis Plateau, and Valles Marineris. It includes latitude and longitude markings and a scale bar at the bottom.

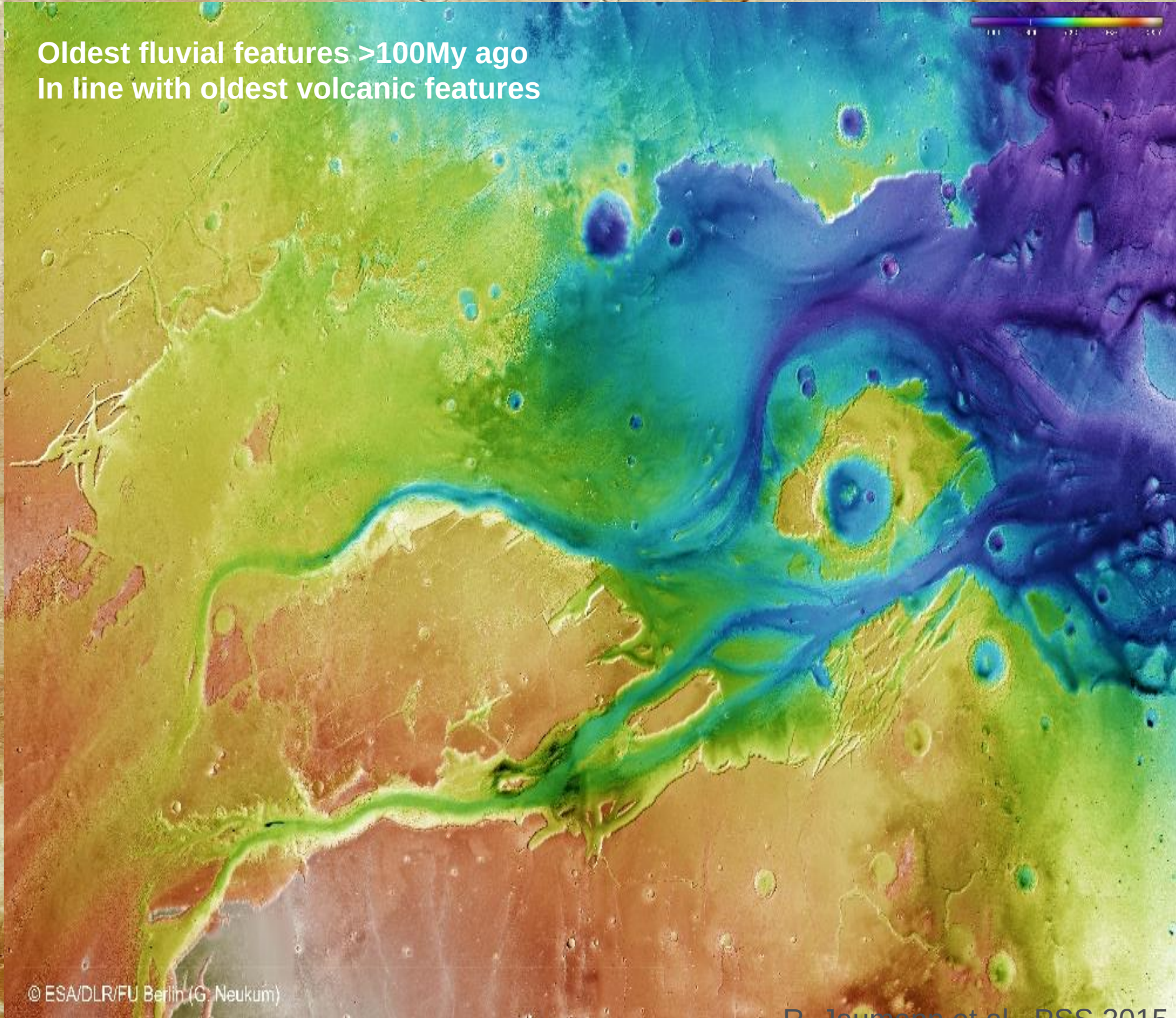




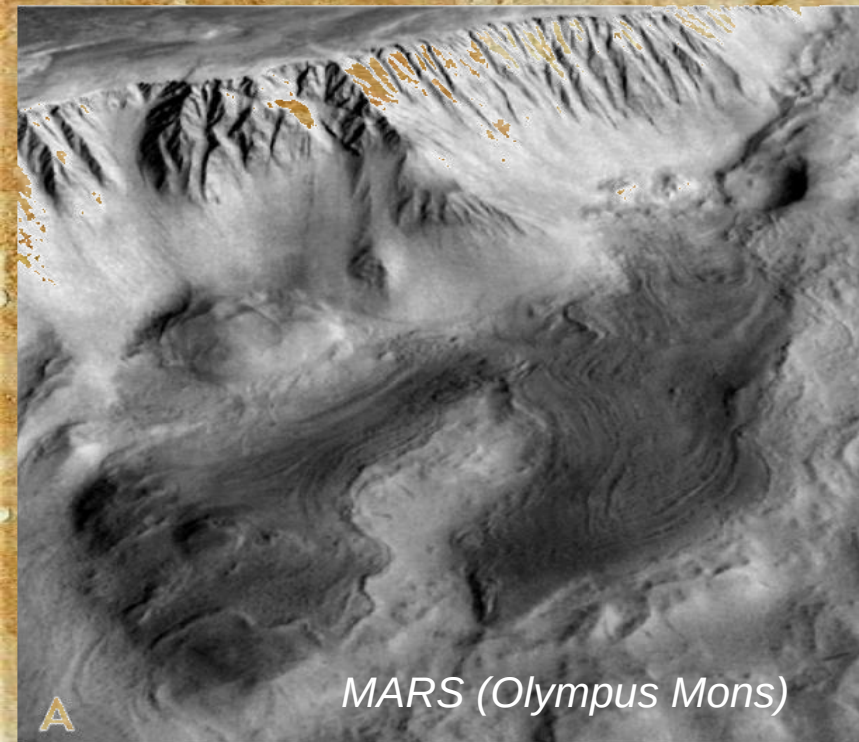
History based on Geologic Analysis: Glacial and Fluvial features by MEX/HRSC camera



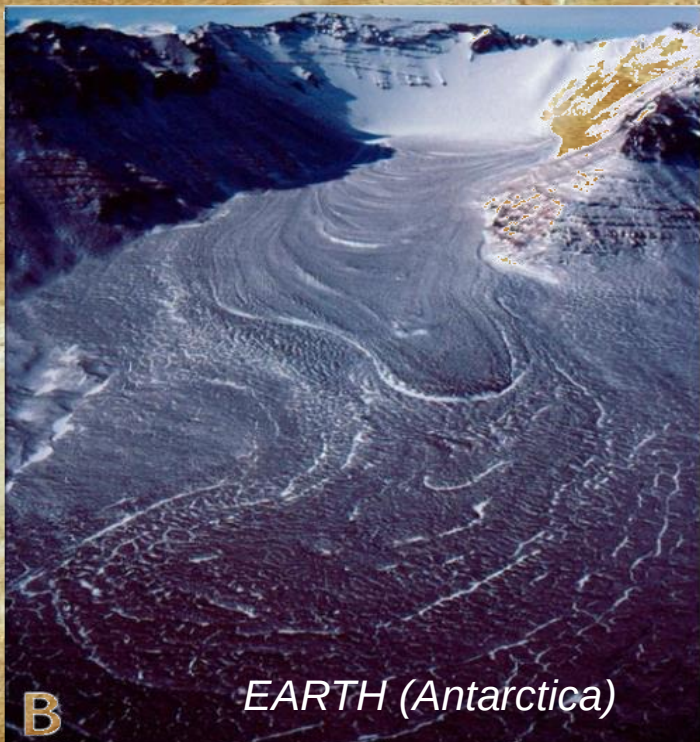
Glacial structures are more recent (<100My)



Oldest fluvial features >100My ago
In line with oldest volcanic features

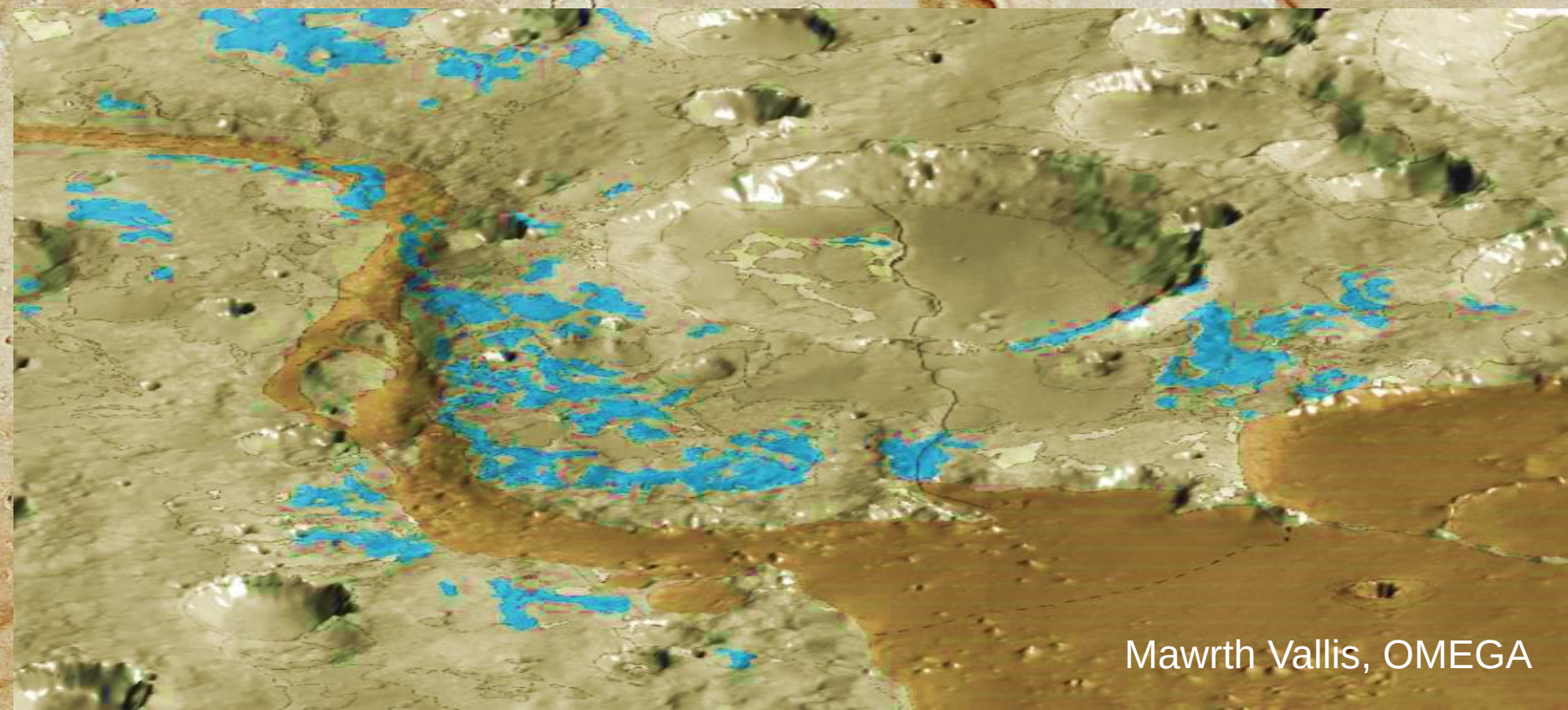
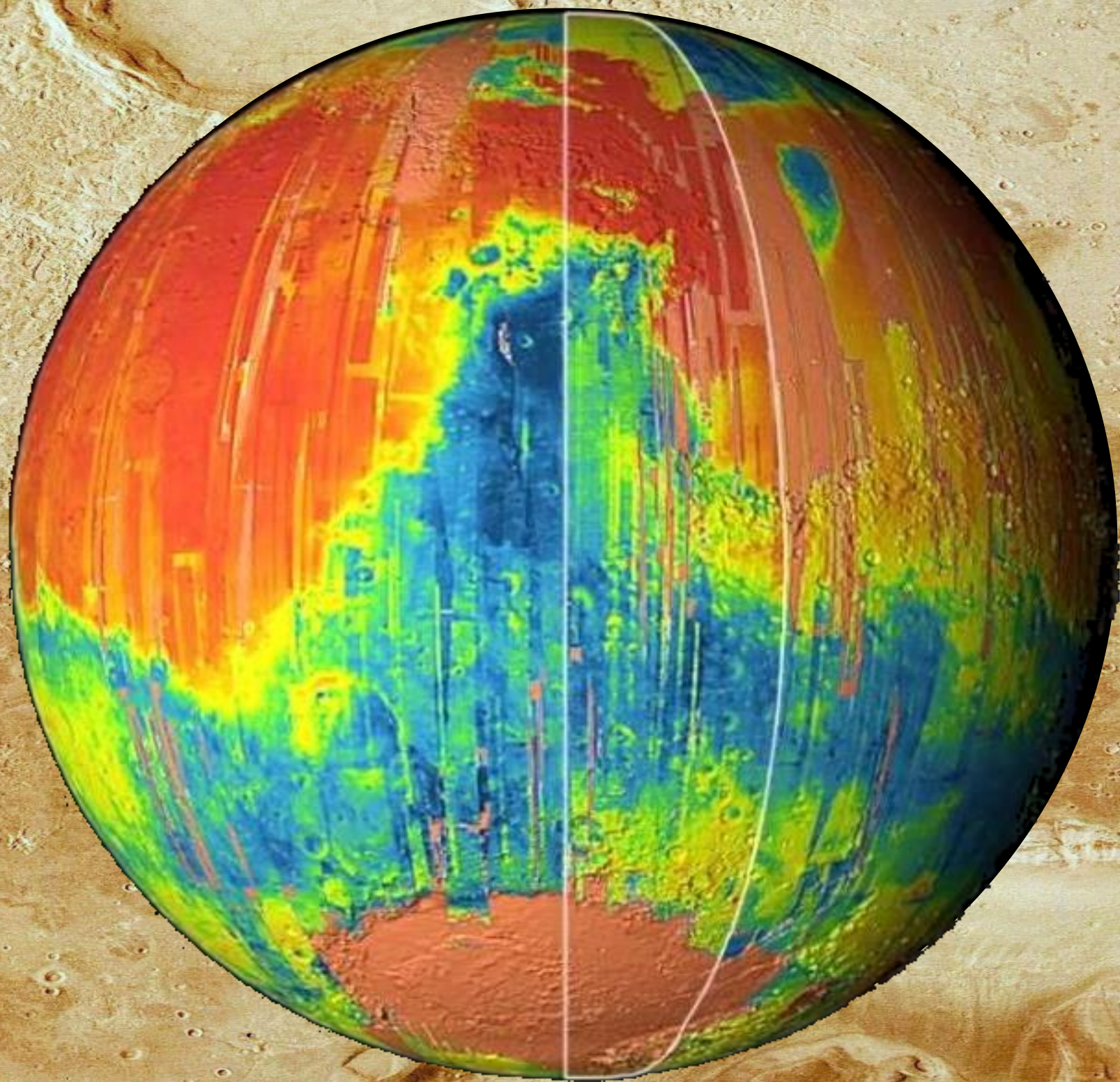
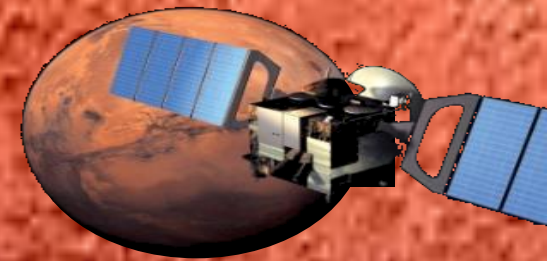


MARS (Olympus Mons)

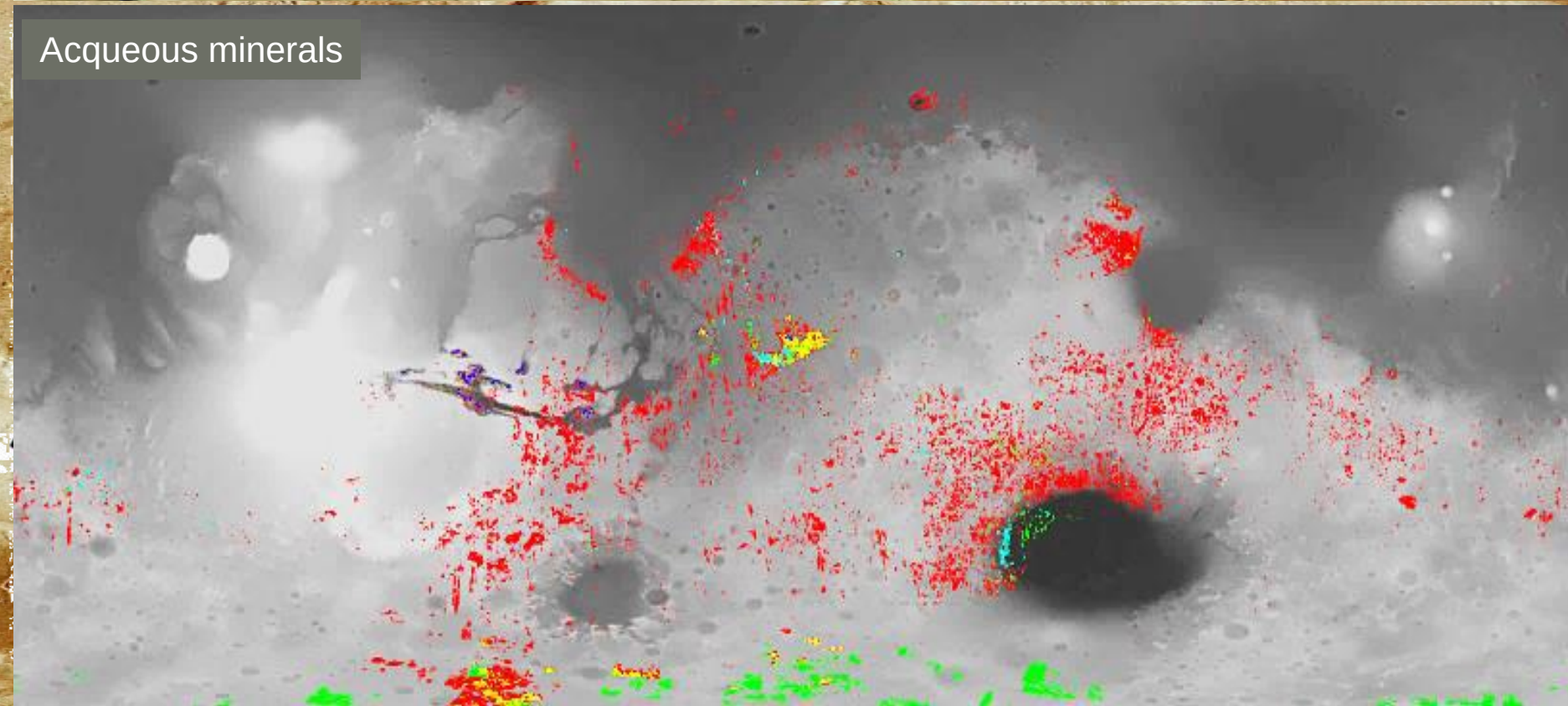


EARTH (Antarctica)

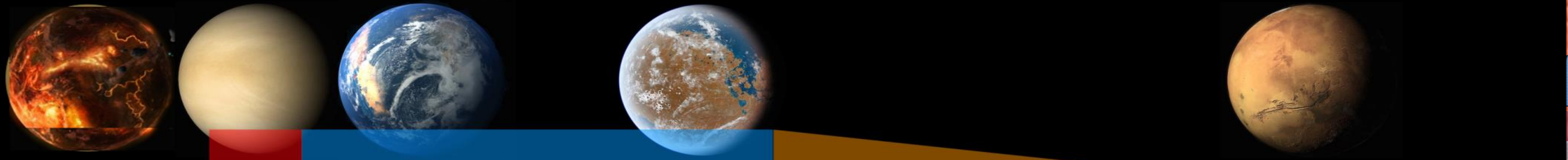
History based on chemical analysis: hydrated minerals detected by MEX/OMEGA spectrometer



Mawrth Vallis, OMEGA



Acqueous minerals



Start of conditions compatible with life

Surface conditions becoming less habitable

4.1

3.85

Pre-Noachian

Noachian

Hesperian

Mars

Early heavy bombardment

Late heavy bombardment

Earth

Hadean

Archaean

Ga

4.568

4.4

3.9

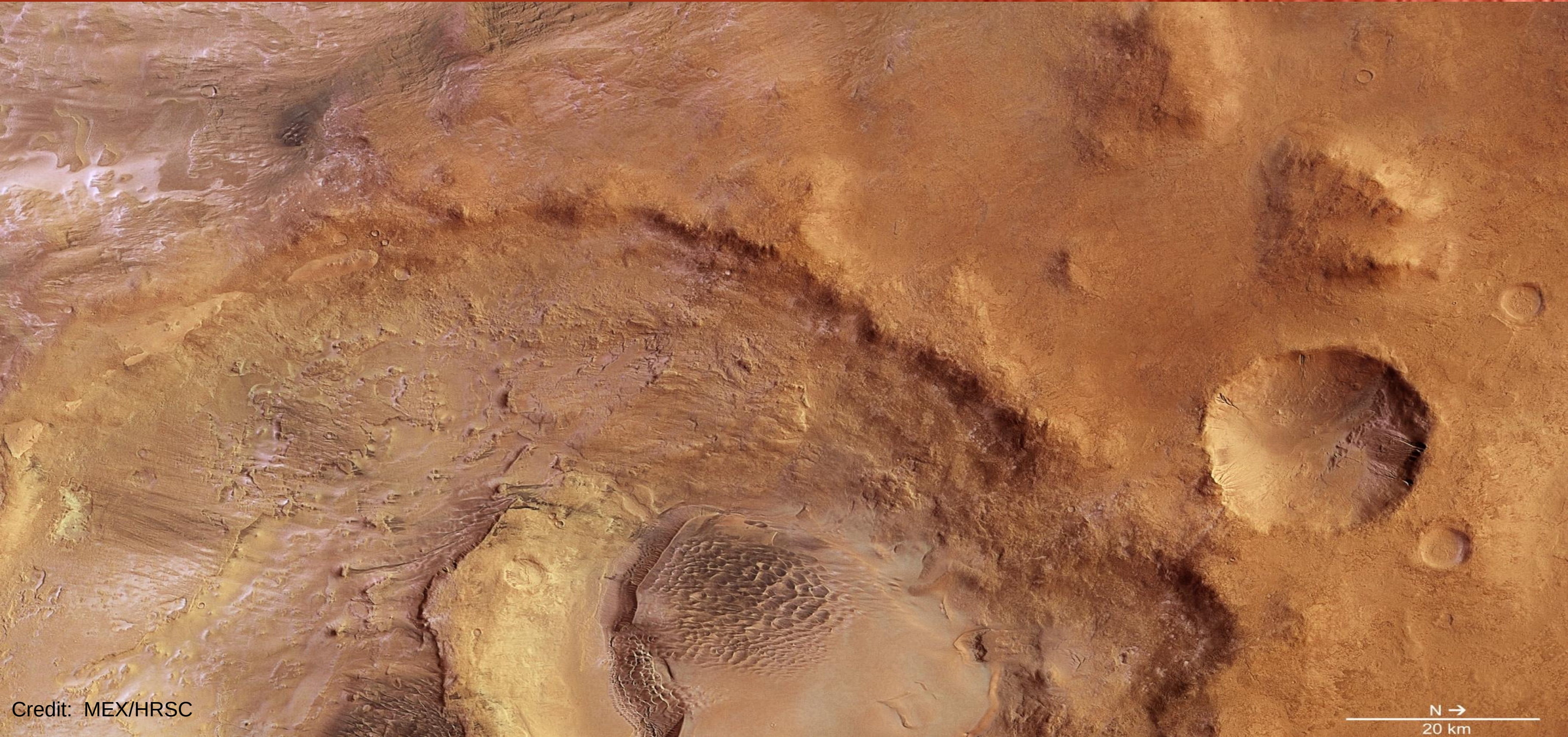
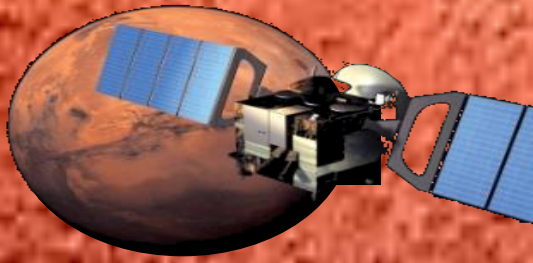
3.5

Beginning of terrestrial planet accretion

Oldest preserved traces of life

Credit: MEX/HRSC

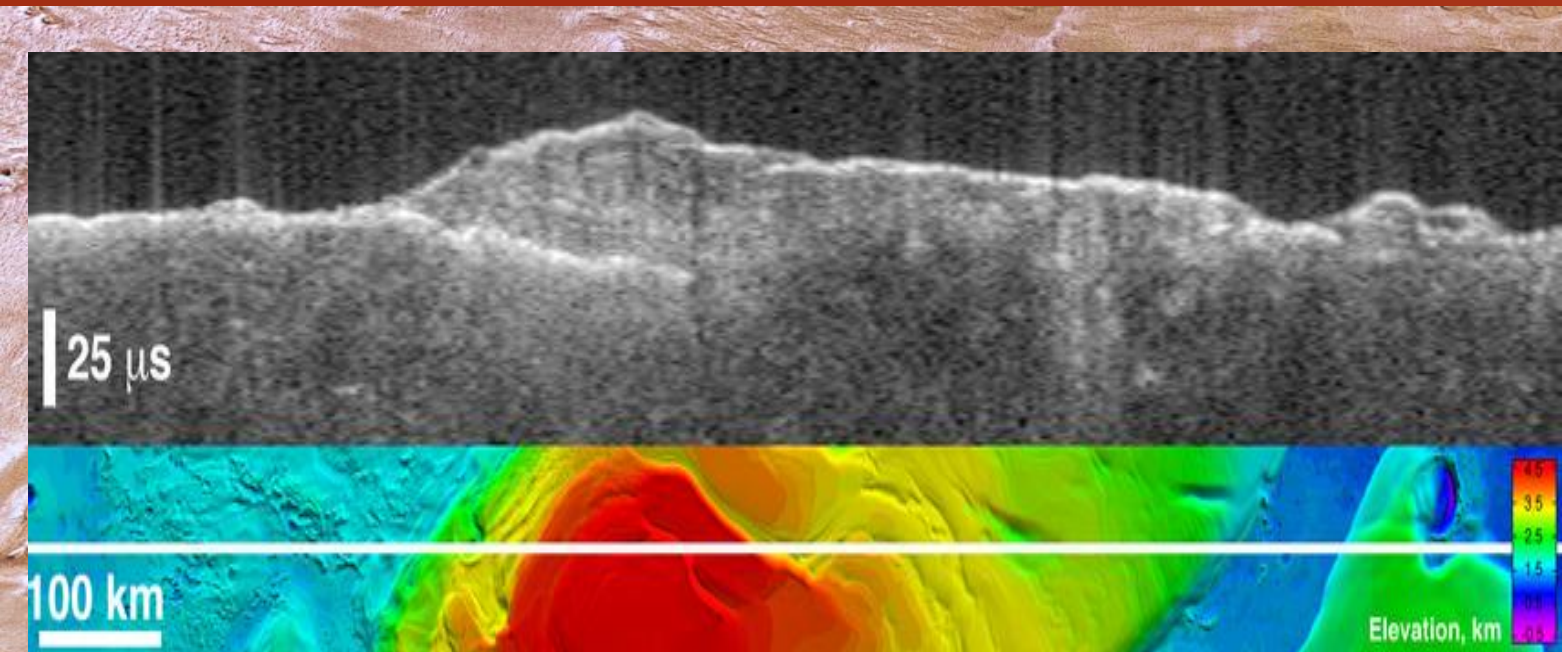
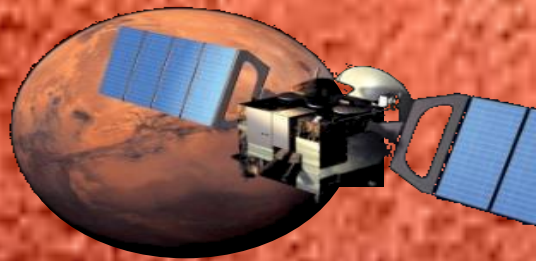
but where is the water now???



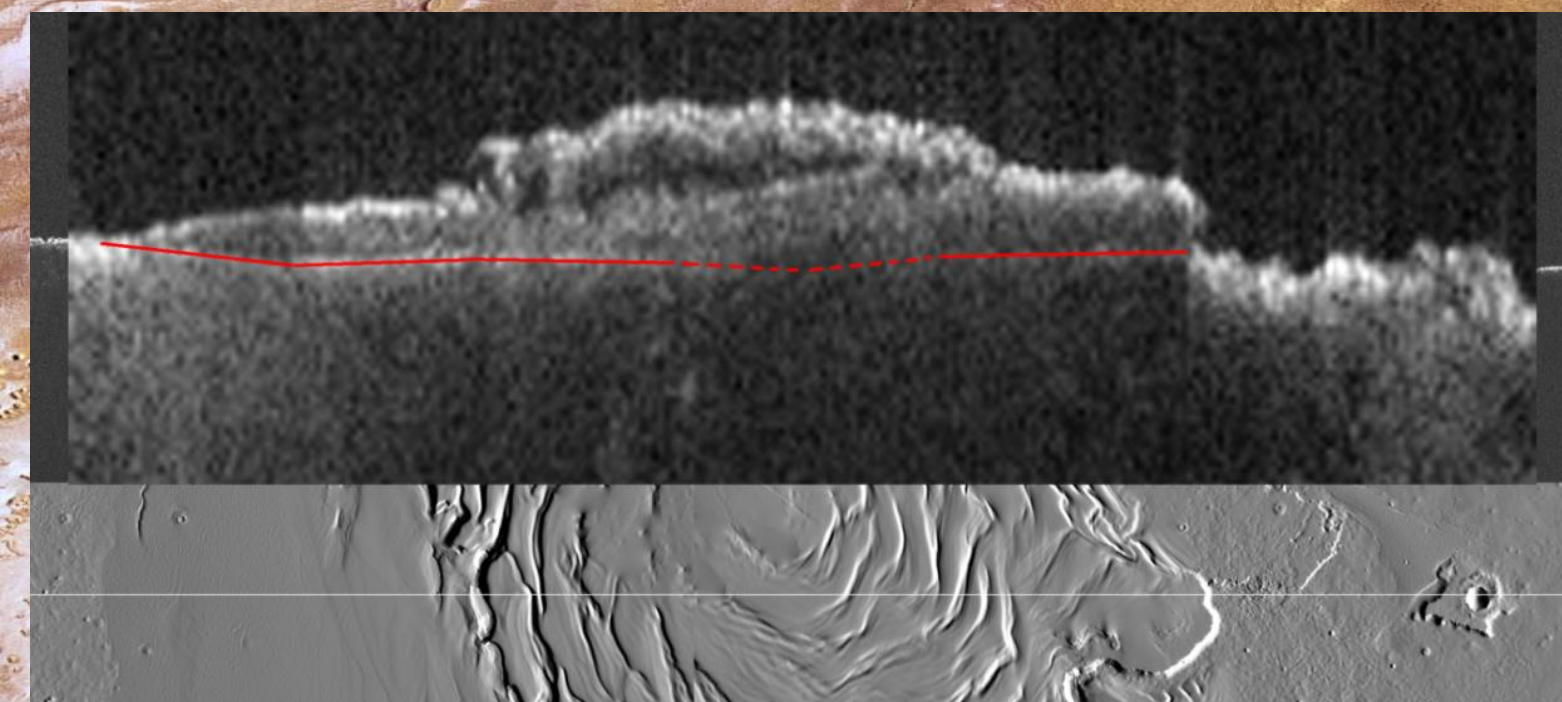
Credit: MEX/HRSC

N →
20 km

Water ice in the polar caps and subsurface seen by radar MEX/MARSIS

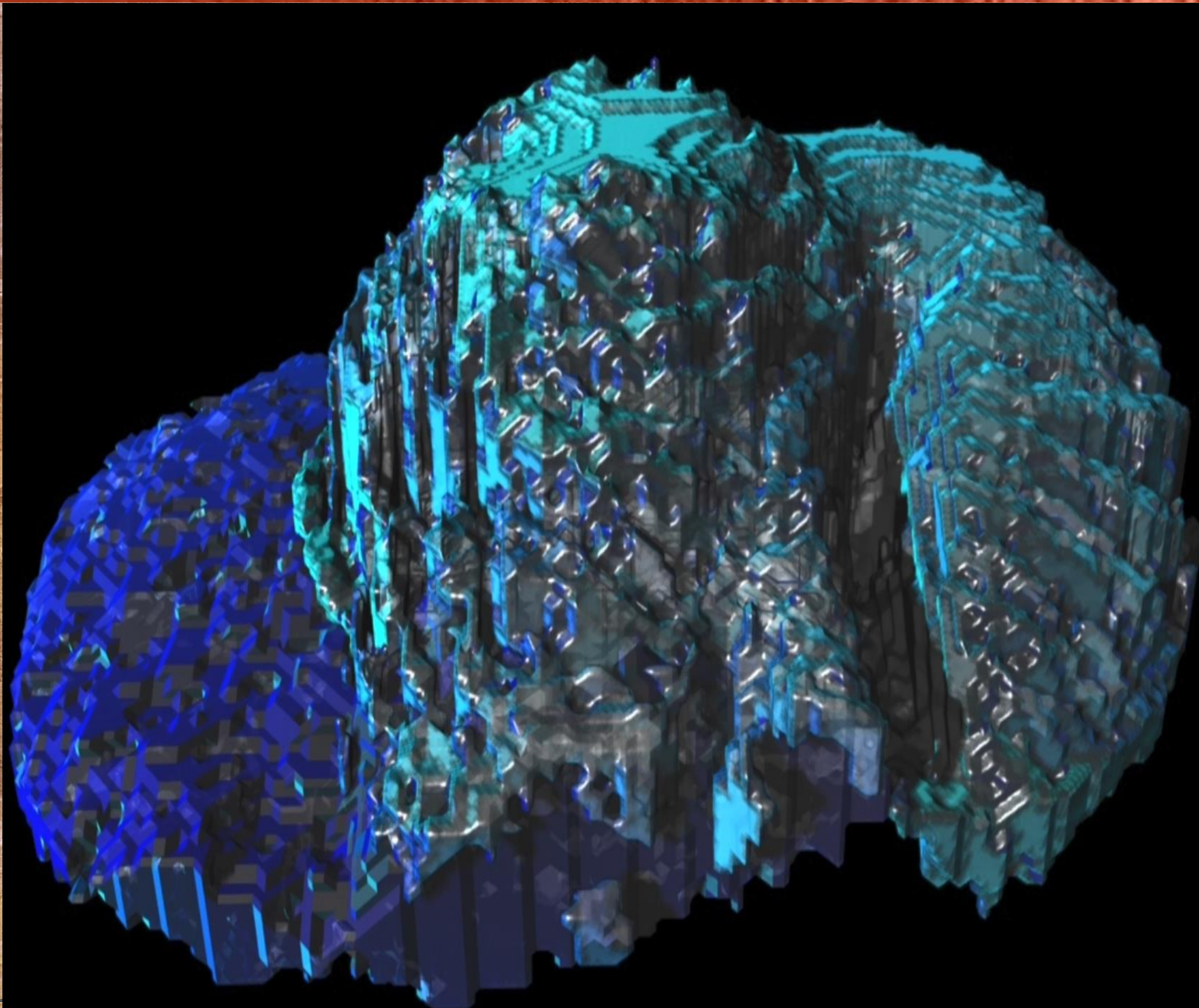


3D reconstruction of ice polar caps

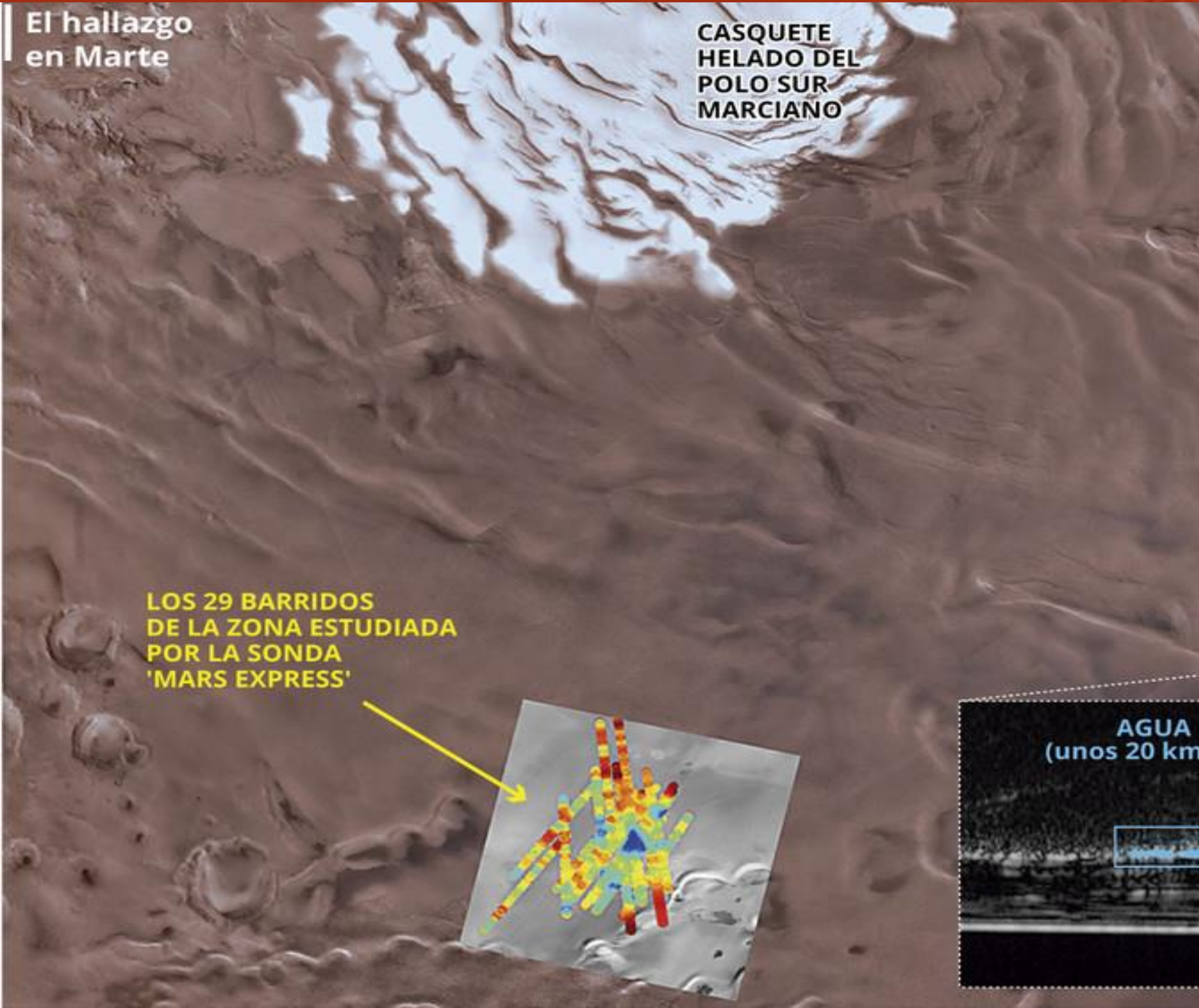
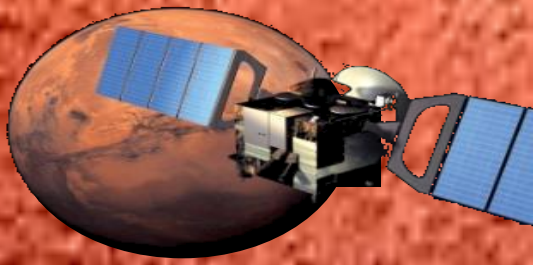


Credit: MEX/HRSC

Frigeri et al.



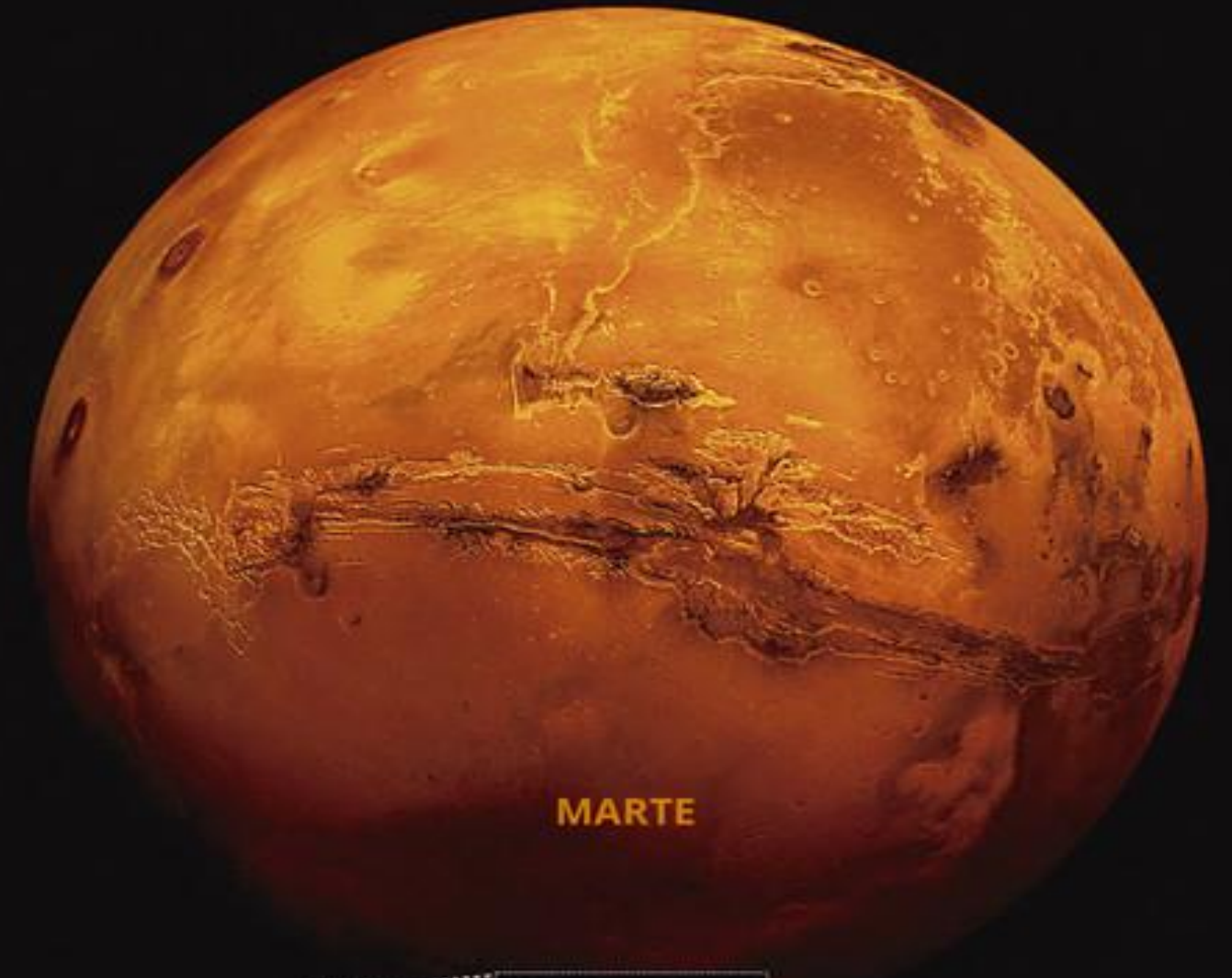
2018: Liquid water lake below south polar cap!!!



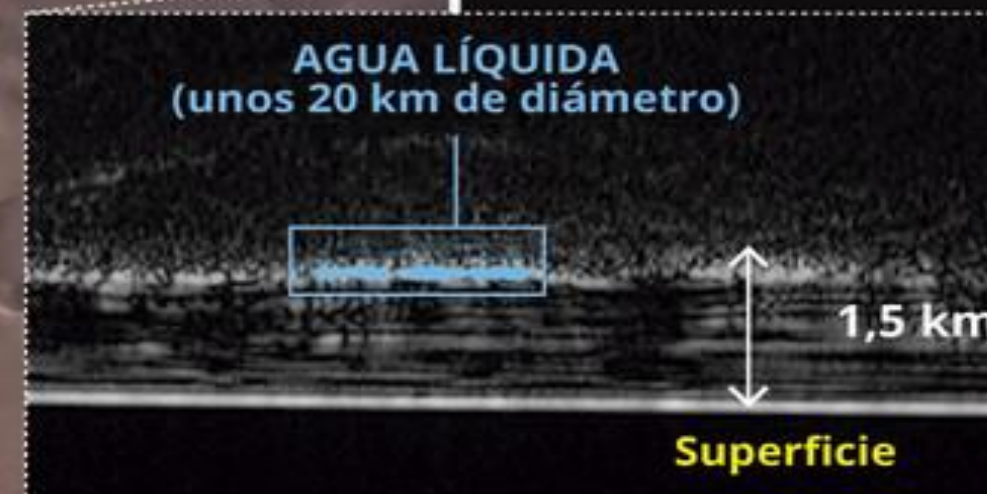
El hallazgo
en Marte

CASQUETE
HELADO DEL
POLO SUR
MARCIANO

LOS 29 BARRIDOS
DE LA ZONA ESTUDIADA
POR LA SONDA
'MARS EXPRESS'



MARTE



AGUA LÍQUIDA
(unos 20 km de diámetro)

1,5 km

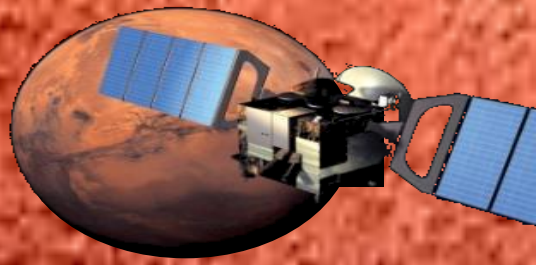
Superficie



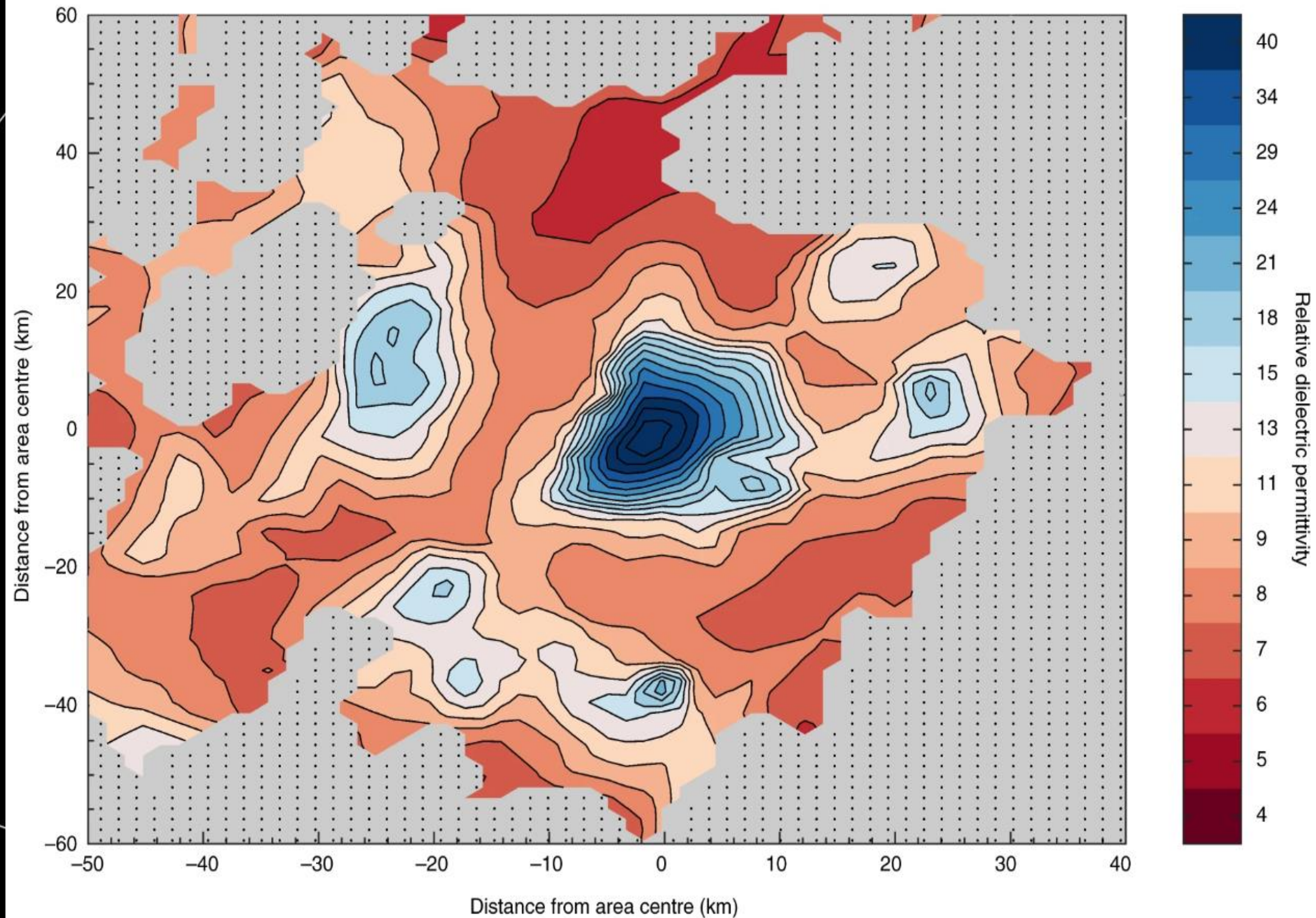
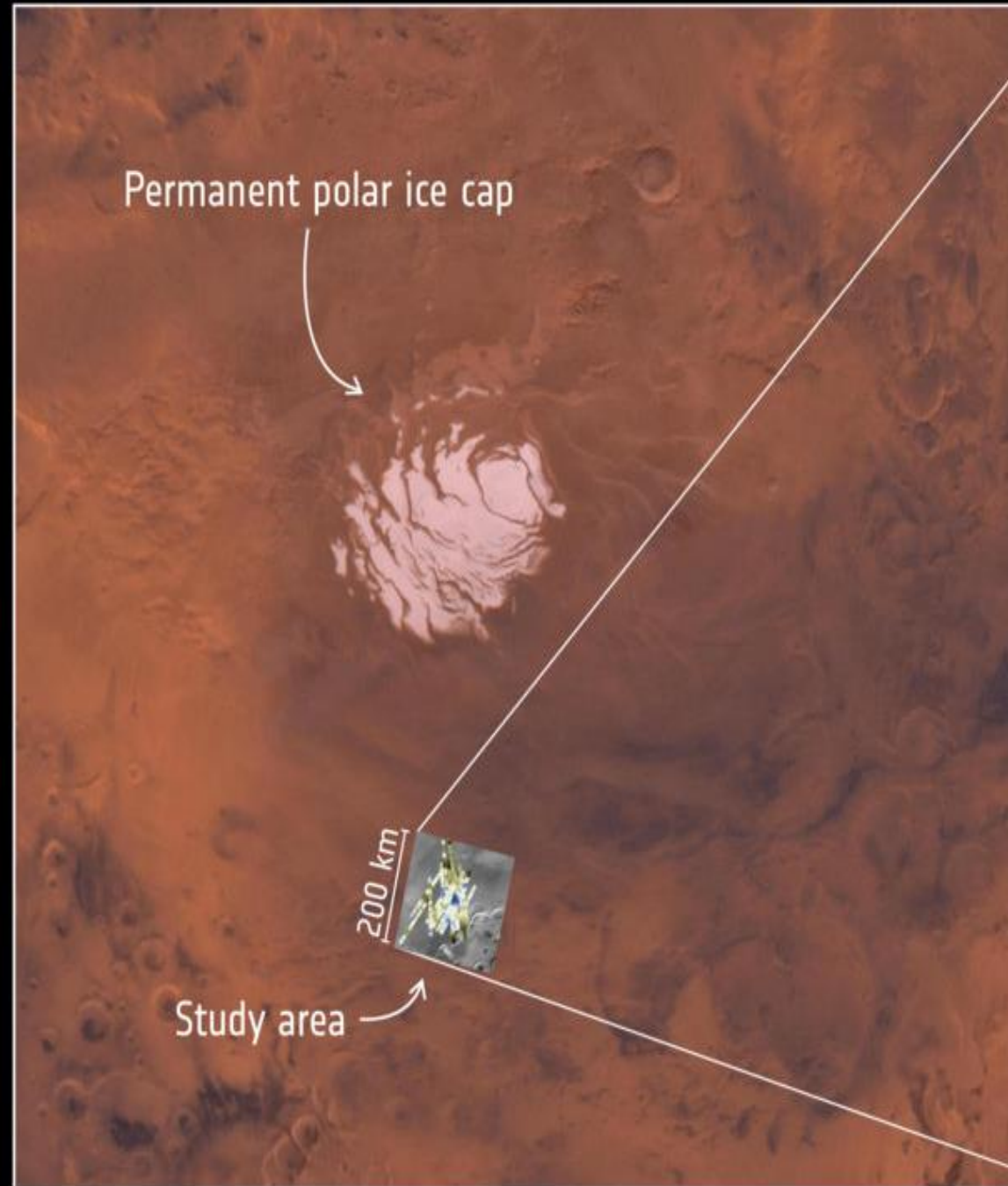
Pulsos del radar
'MARSIS' penetran en
la superficie y reflejan
la presencia de agua

SONDA
'MARS EXPRESS'

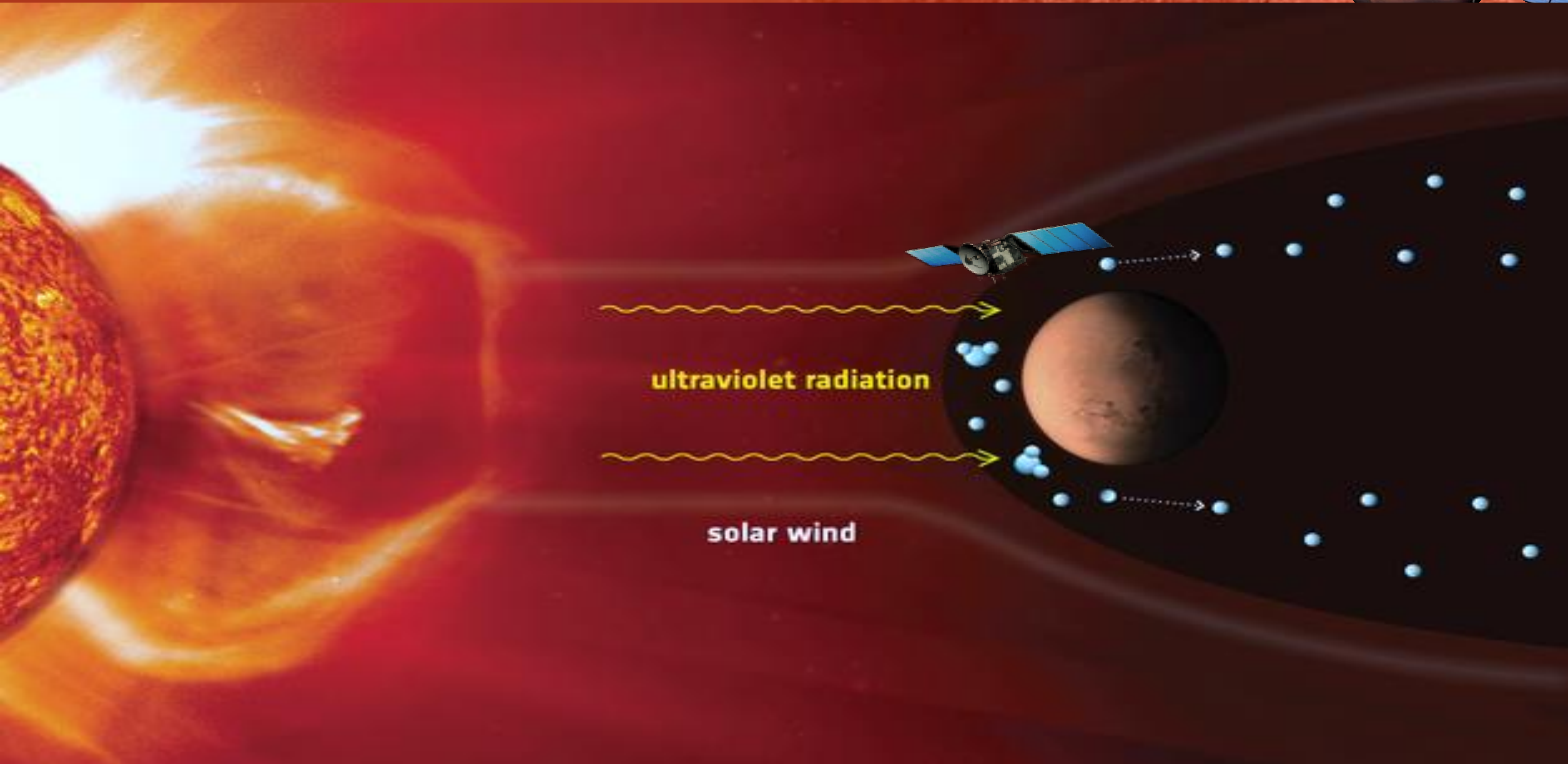
2020: More liquid water lakes confirmed!!!



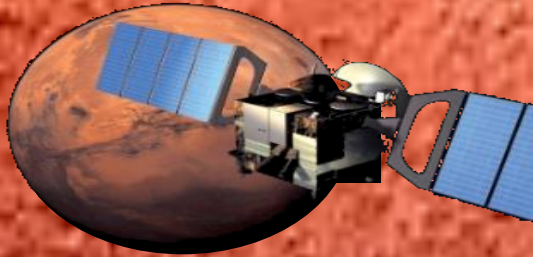
Mars south polar region



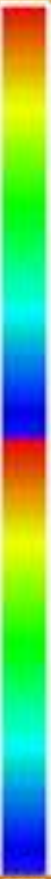
Water escape through the ionosphere solar wind interaction



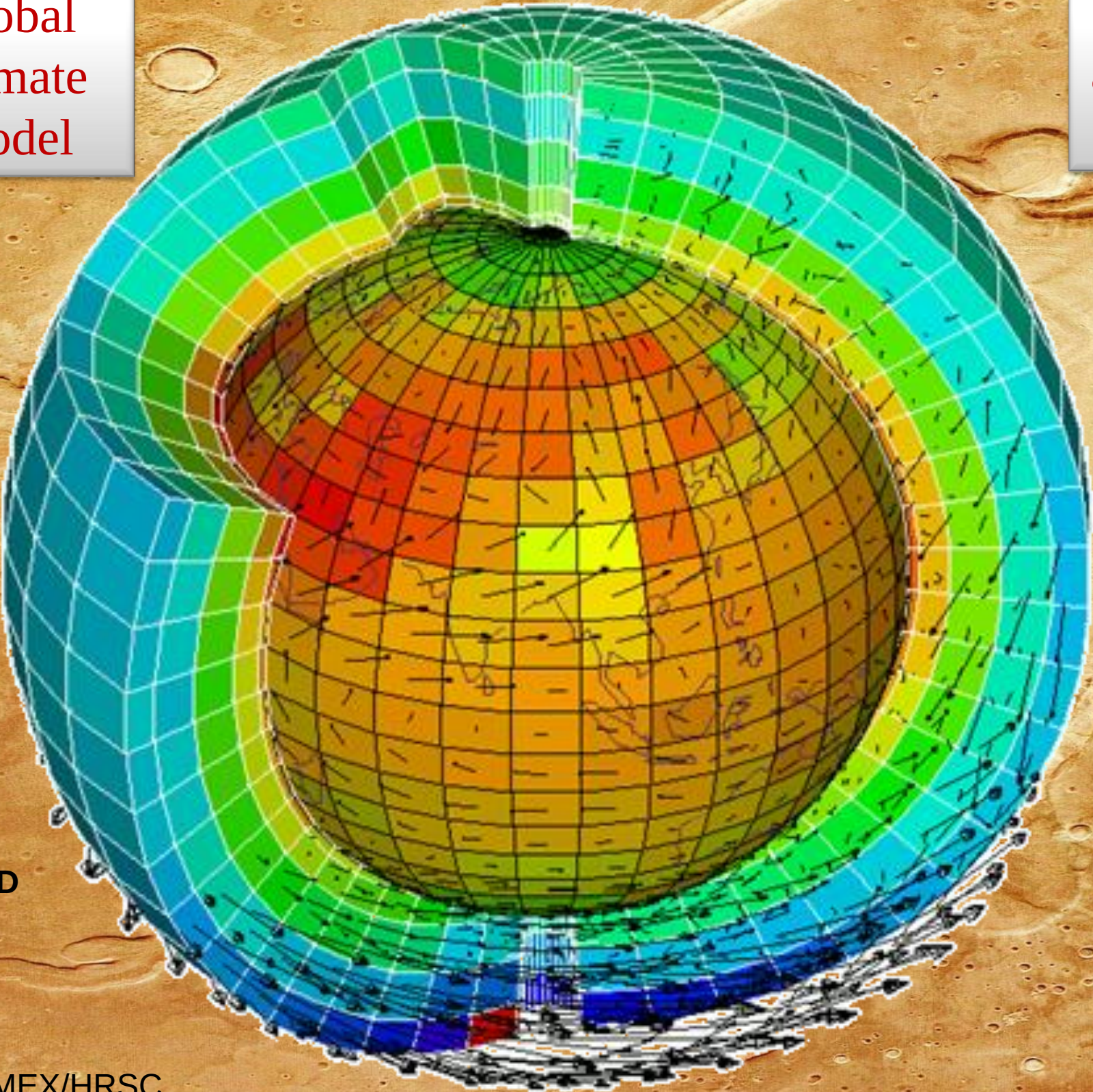
Global Monitoring of Climate variability



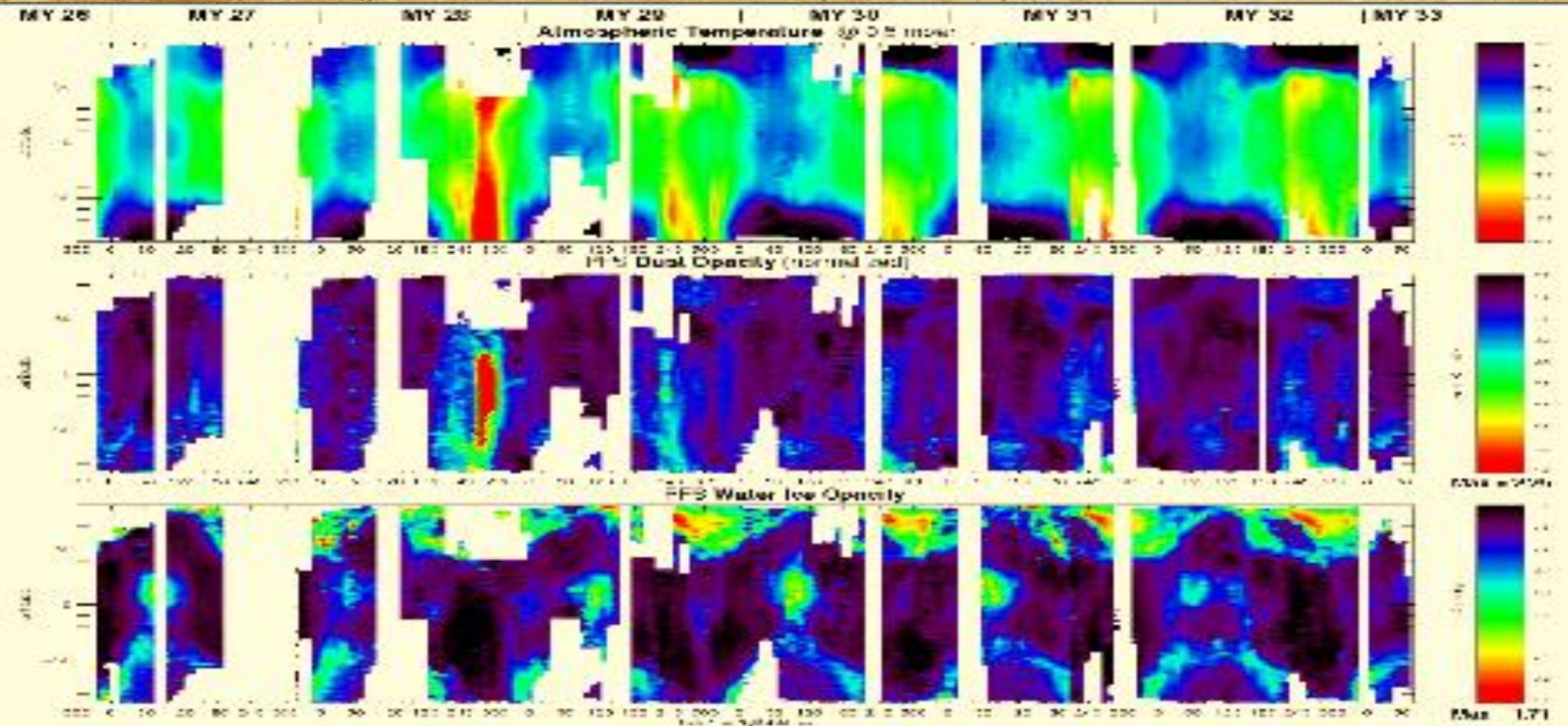
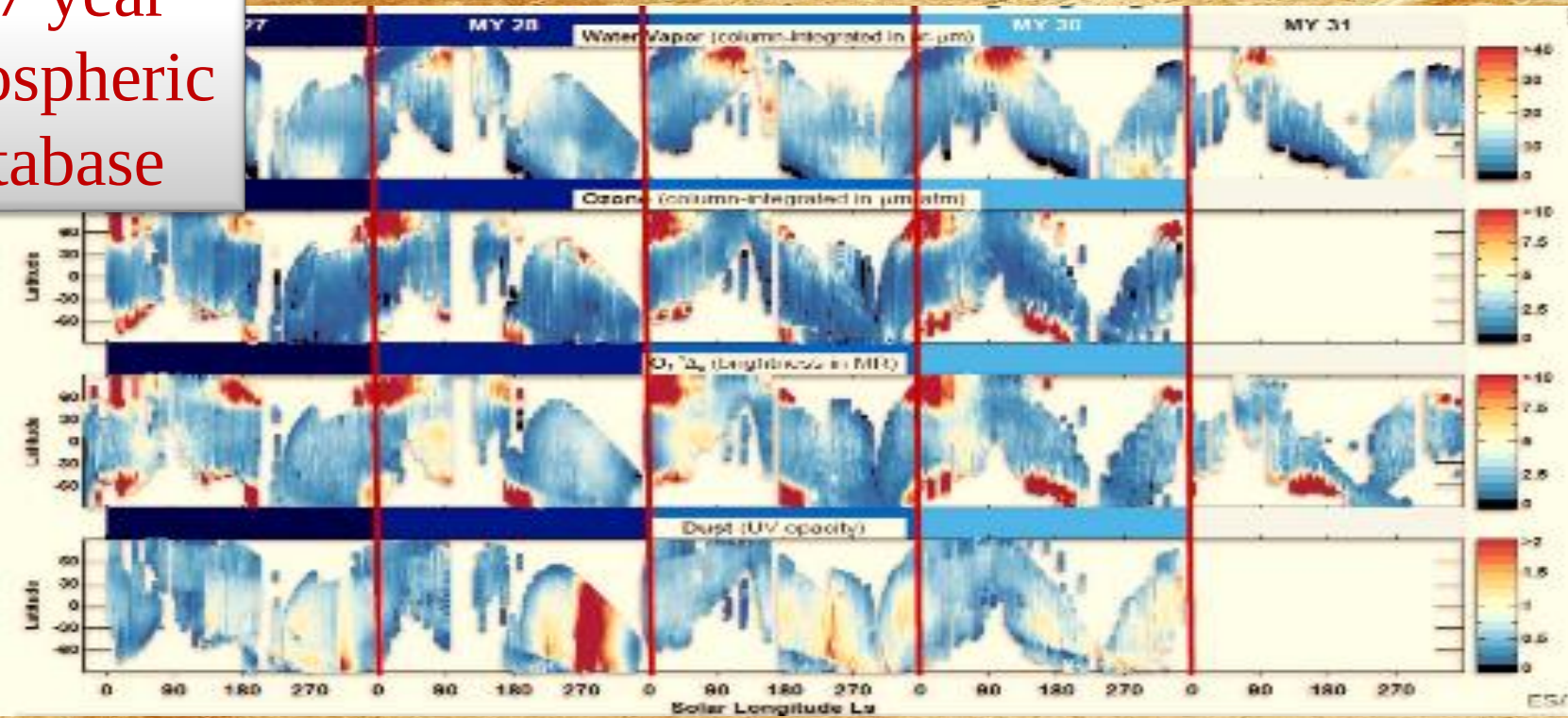
Global
Climate
Model



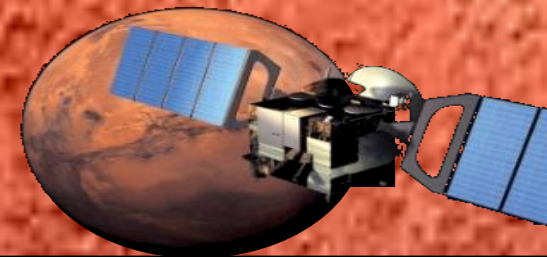
LMD



>17 year
atmospheric
database



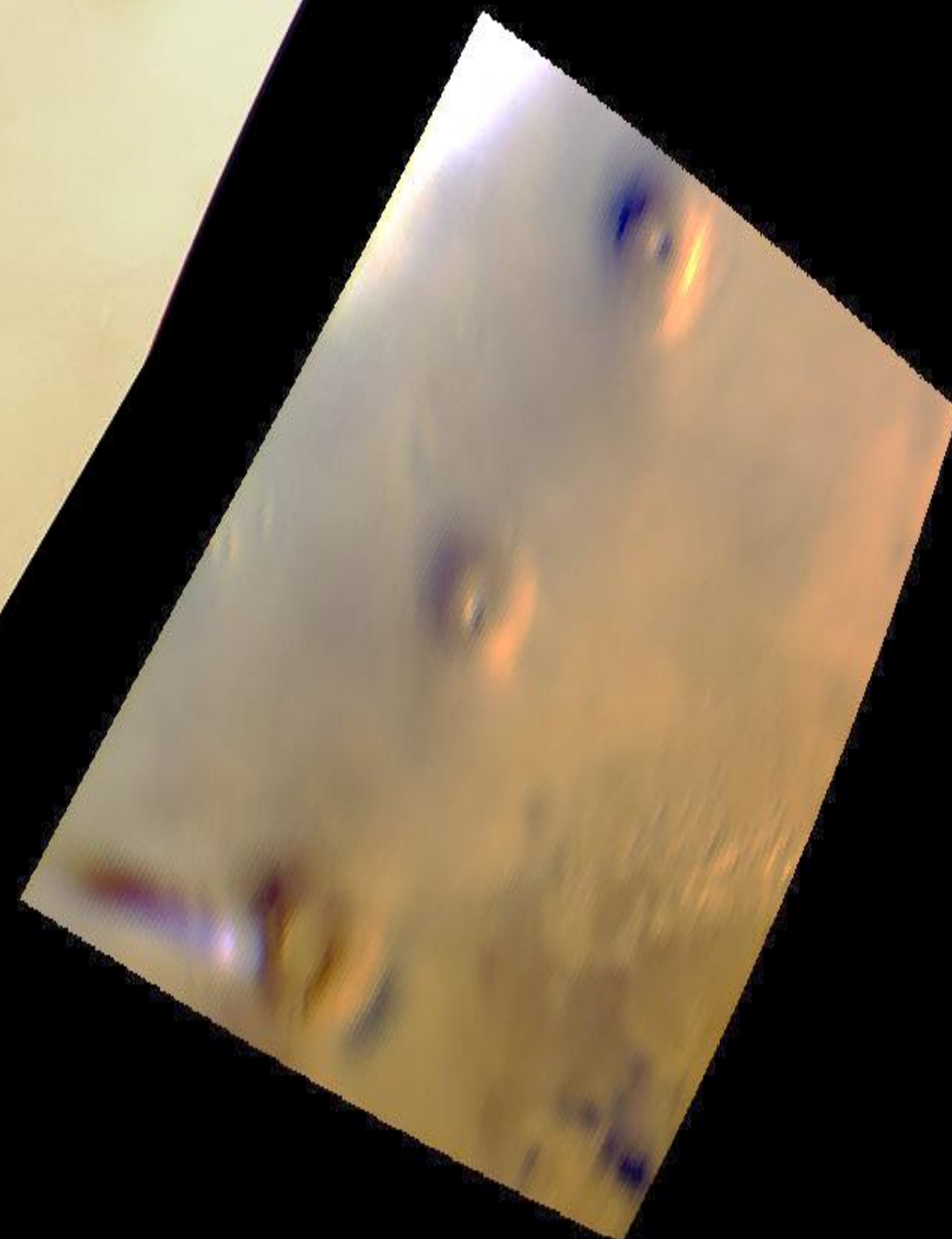
Routine atmospheric monitoring with all instruments



VMC Monitoring



HRSC High-Res



OMEGA Spectrum

2018: Global Dust Storm growing

2019: Local Dust storms (HRSC/VMC/OMEGA)

May 22nd

North Pole



Elysium
Mons

May 26th

North Pole



Elysium
Mons

June 6th

North Pole



Olympus
Mons

July 10th

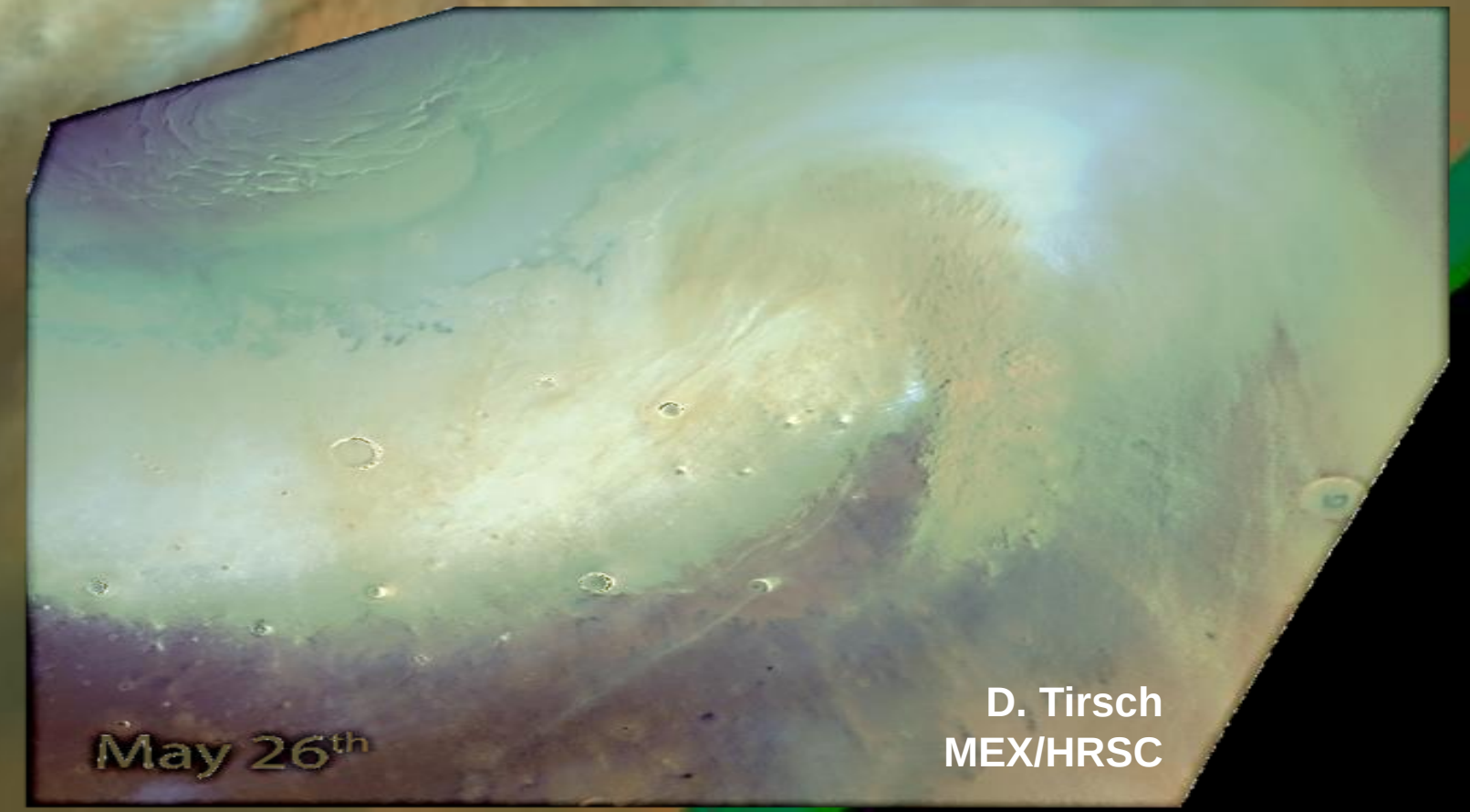
North Pole



Olympus
Mons



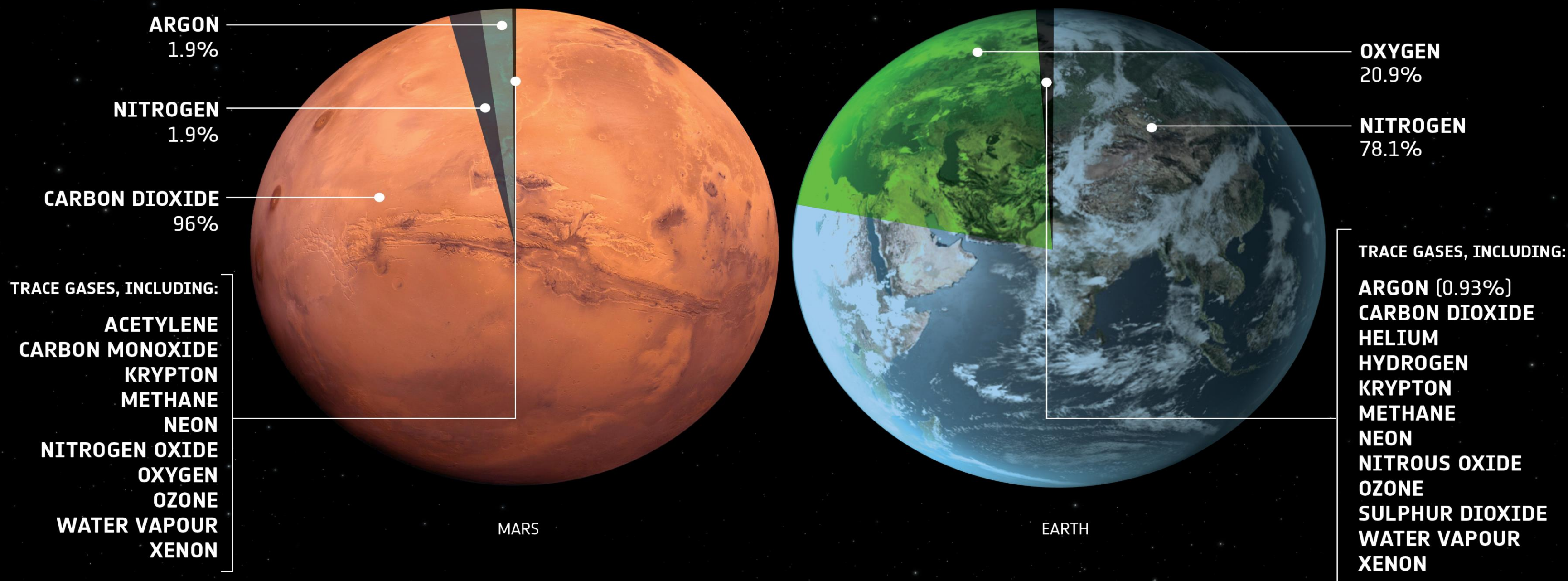
J. Hernandez
MEX/VMC



May 26th

D. Tirsch
MEX/HRSC

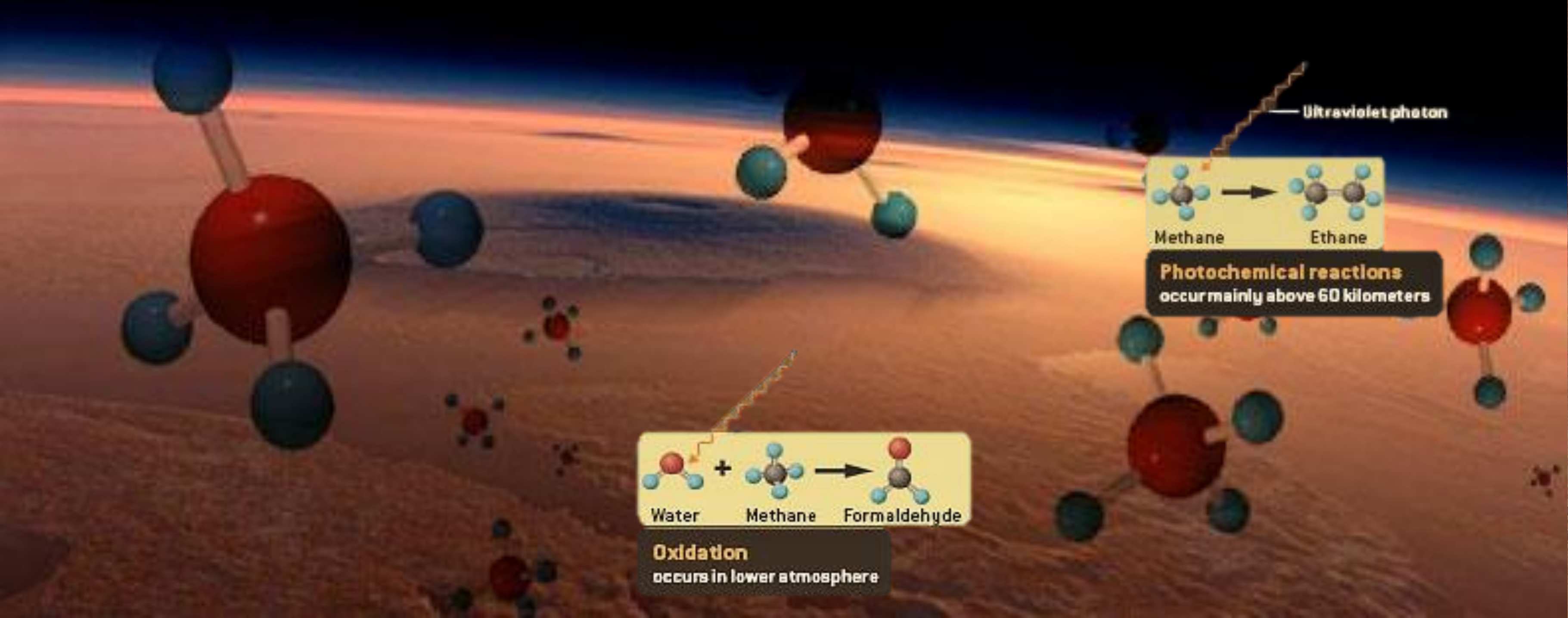
→ COMPARING THE ATMOSPHERES OF MARS AND EARTH



Atmospheric composition by volume | Planets not to scale | Atmosphere of Mars is less than 1% of Earth's | Trace gases listed alphabetically

Methane (CH_4) on Mars should NOT be there

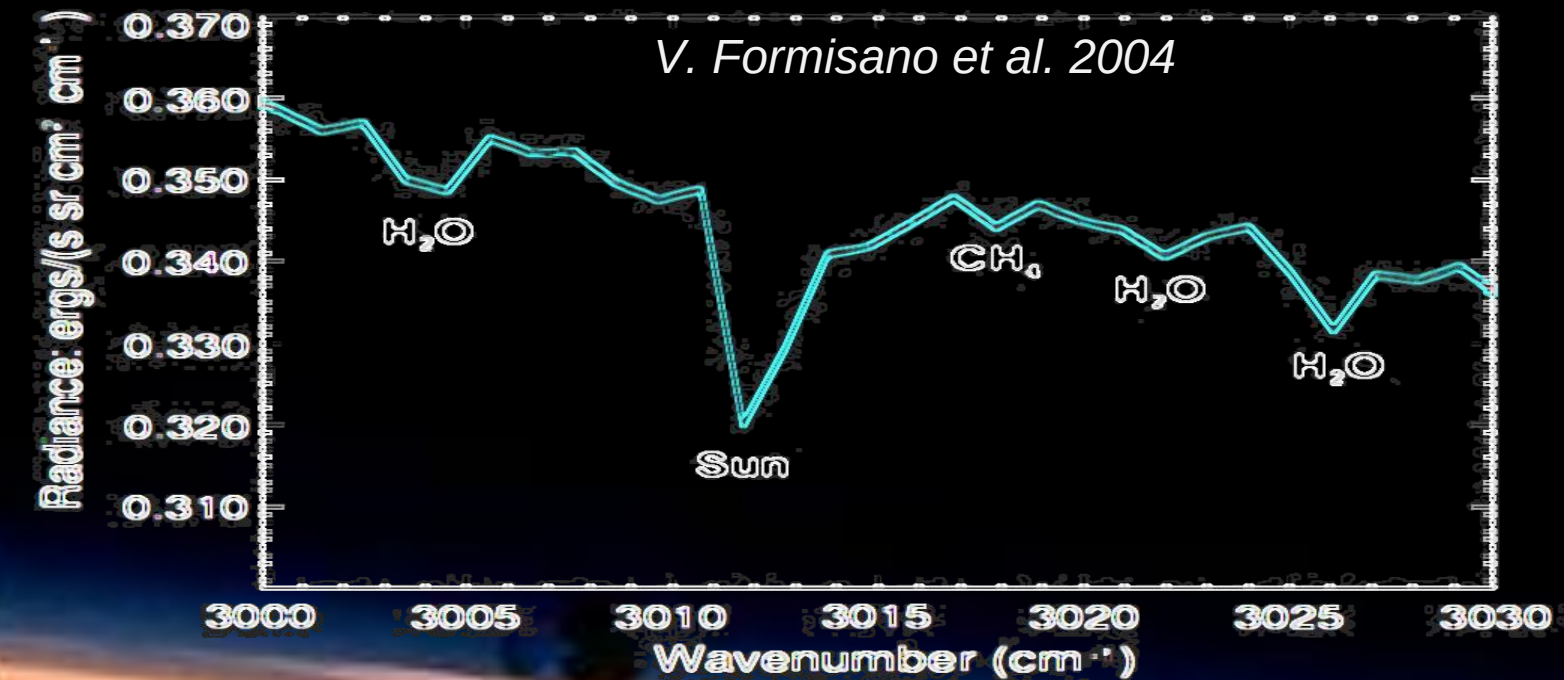
Methane molecules are destroyed by UV radiation within 100~300 years



Methane (CH₄) on Mars was detected in 2004

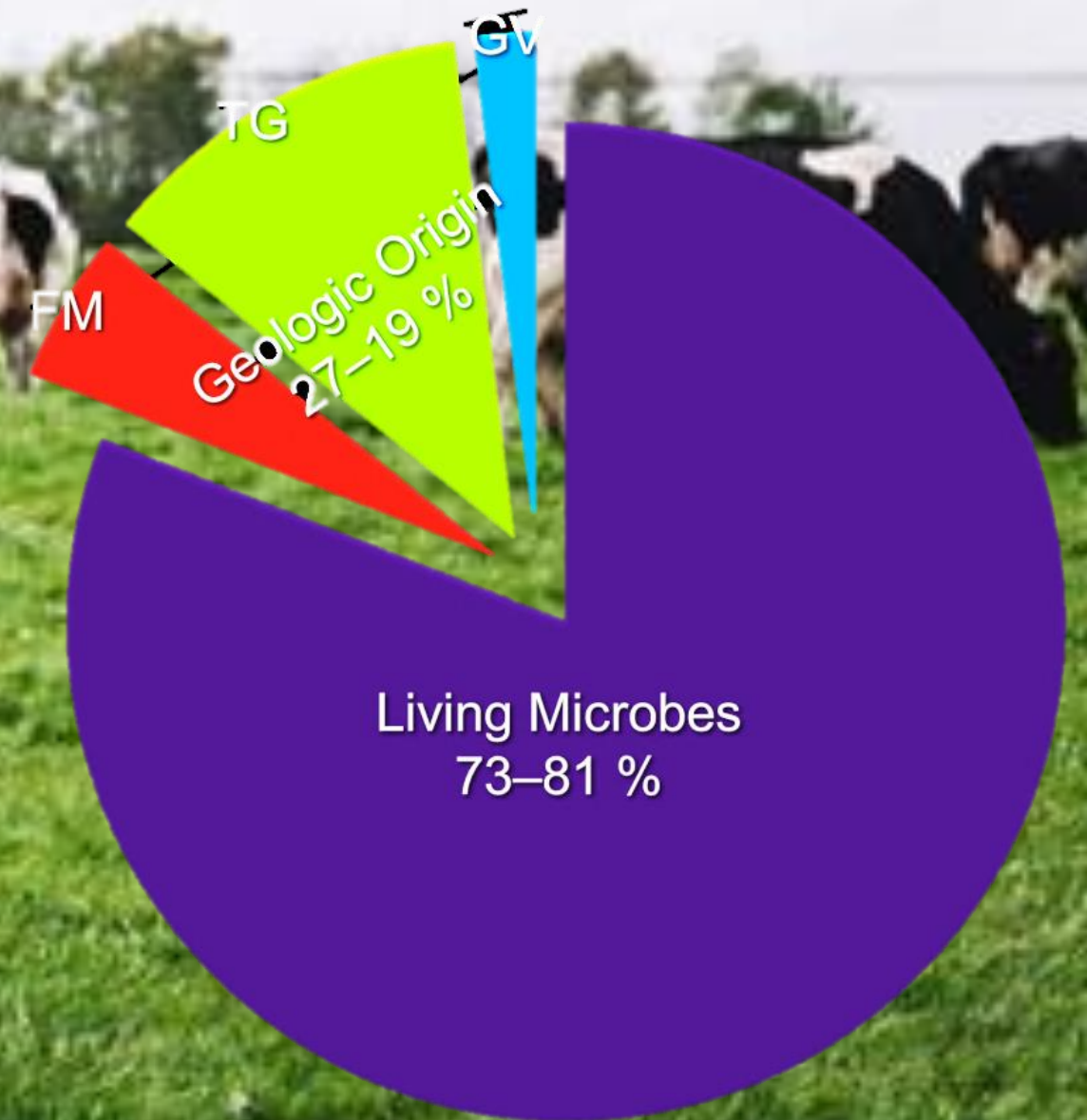
by 3 different groups:

- *Formisano et al.* (Science 2004) 0~35ppbv
- *Krasnopolsky et al.* (Icarus 2004) ~10ppbv
- *Mumma et al.* (DPS meeting 2004) ~250ppbv



Methane existence has great geological/biological implications

Where is Methane on Earth coming from?



Methane may mean either **life** or **geology** : both with **liquid water** !

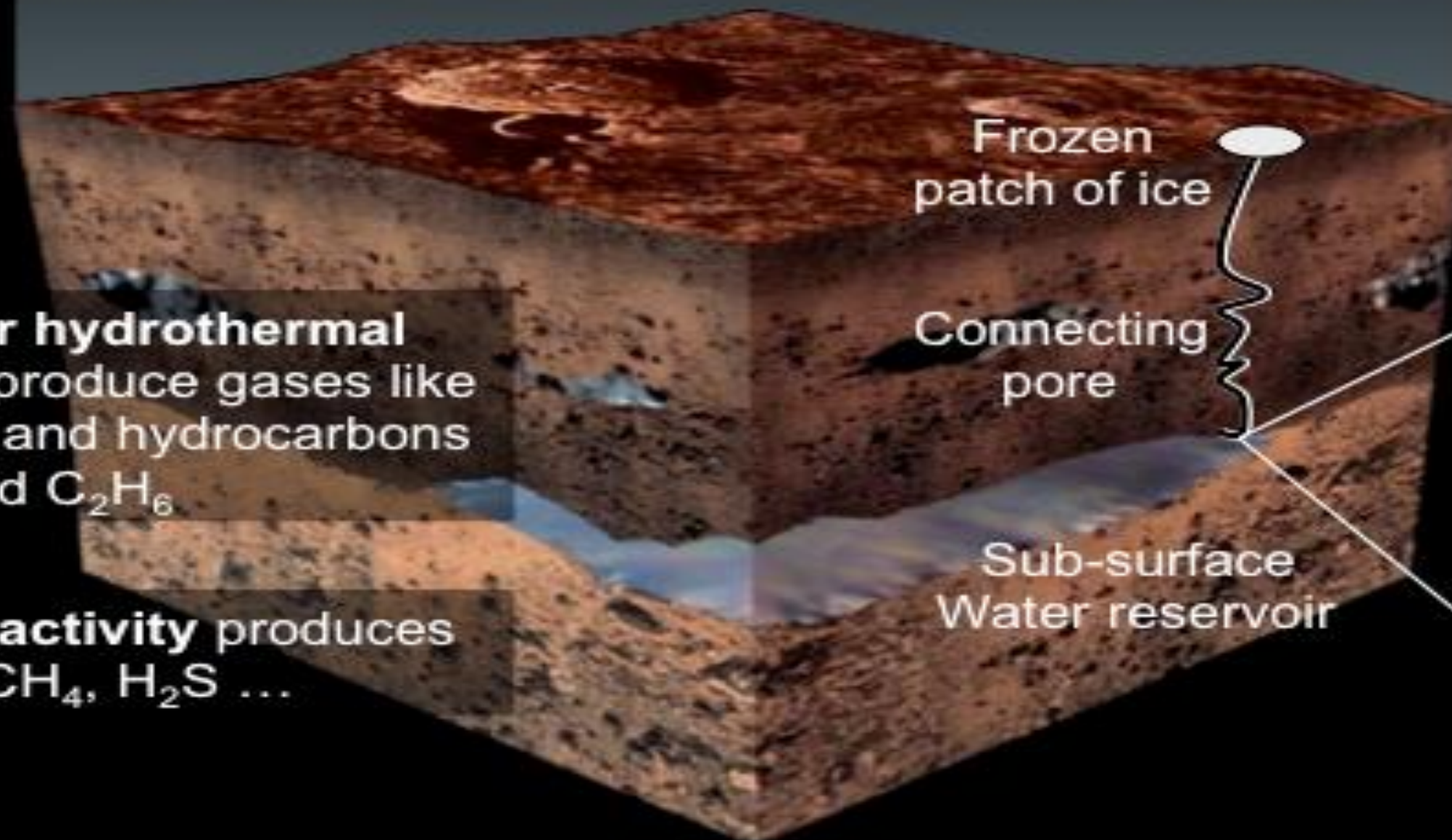
Subsurface Methane Sources



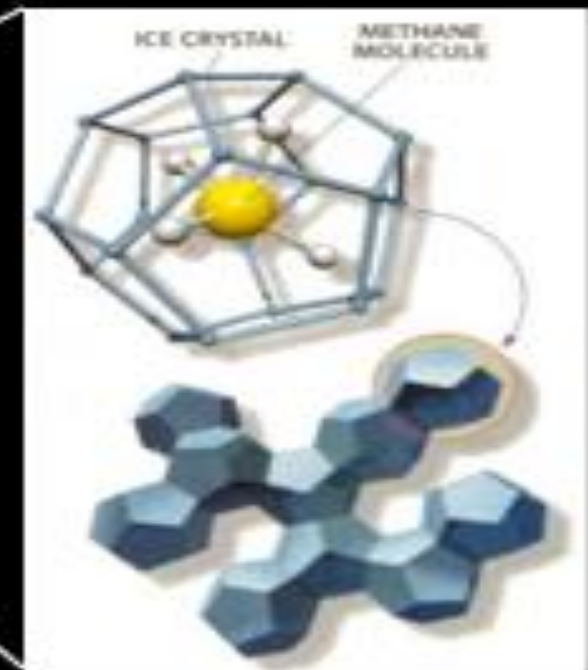
Volcanic or hydrothermal processes produce gases like SO_2 , CO_2 , ... and hydrocarbons like CH_4 and C_2H_6



Biological activity produces gases like CH_4 , H_2S ...

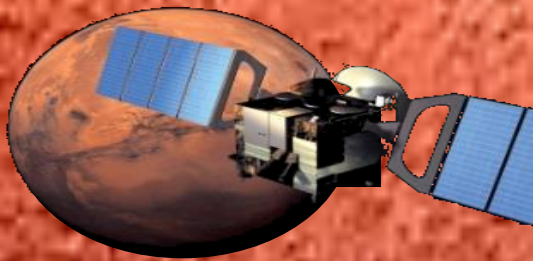


Methane could be stored in the form of clathrates

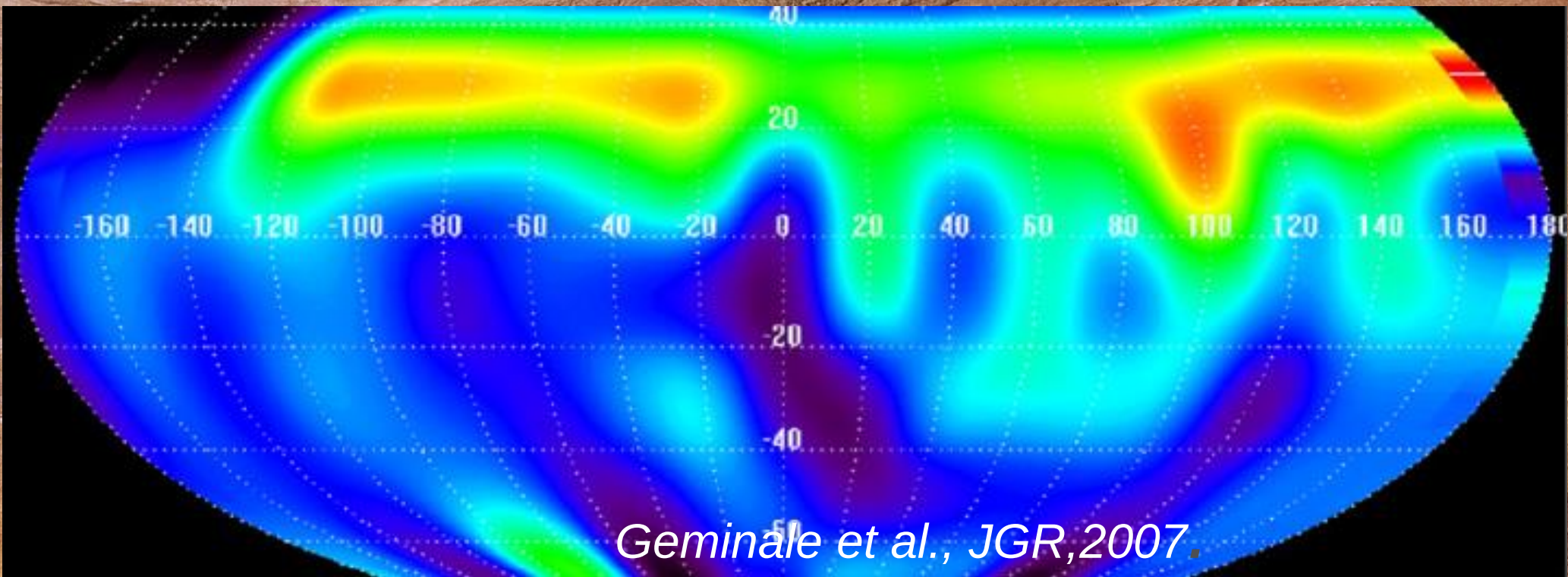
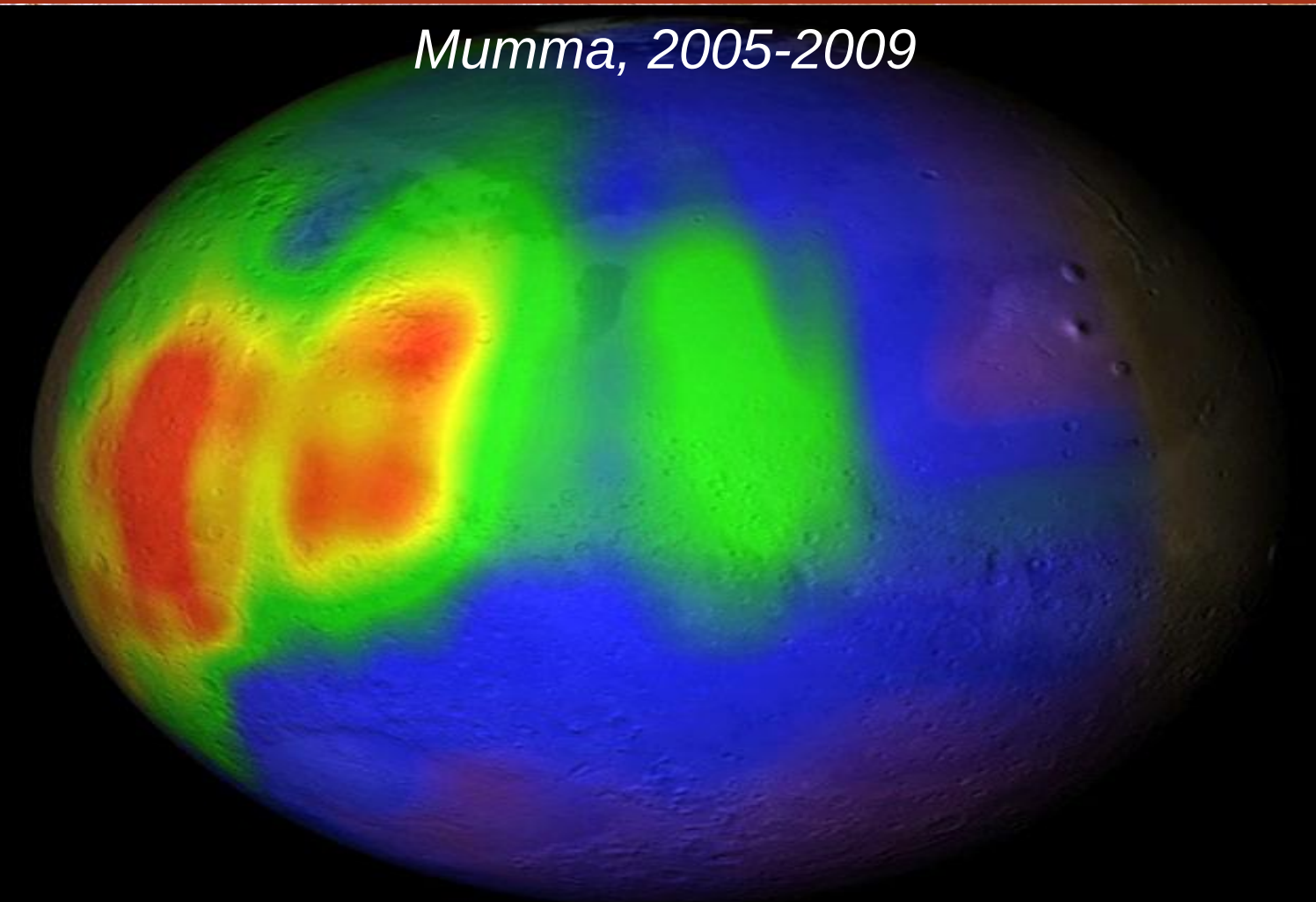


Methane detection over time

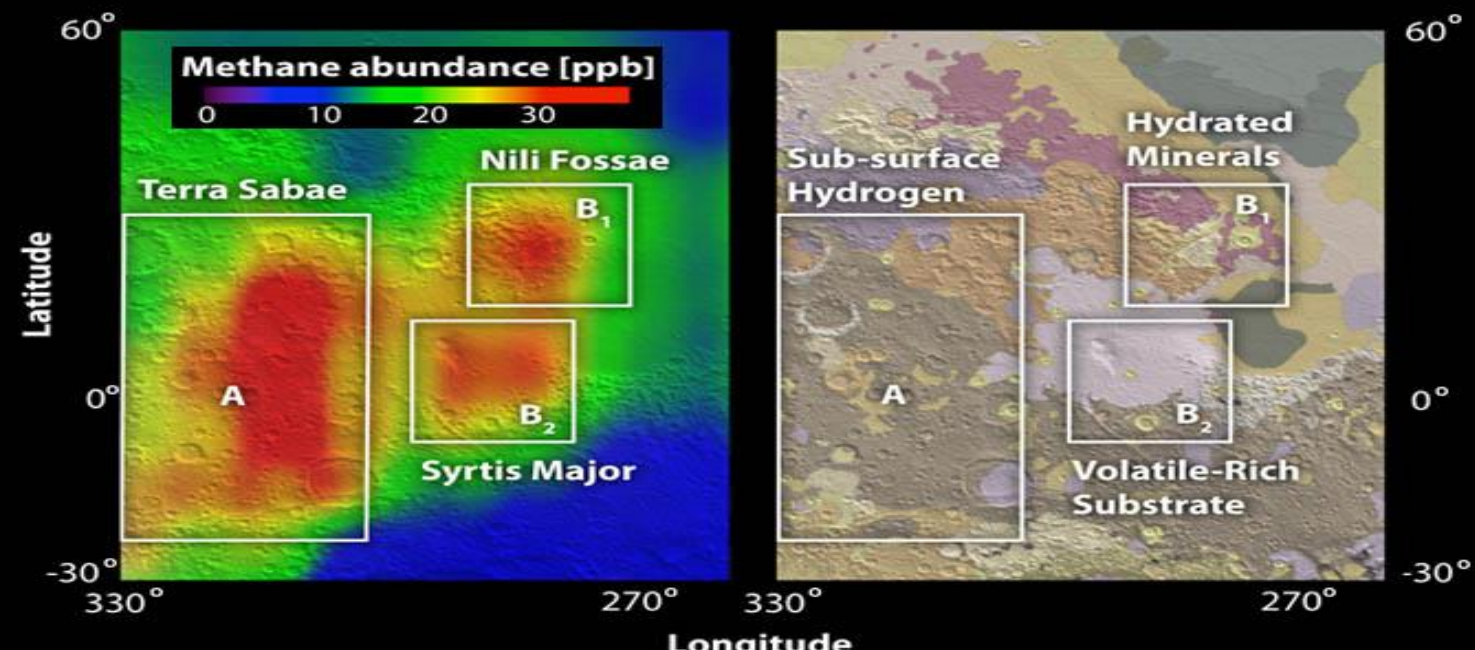
further measurements, but still controversial



Mumma, 2005-2009



Geminale et al., JGR, 2007.



Workshop on Methane on Mars

Current observations, interpretation and future plans 25-27 November 2009, ESRIN, Frascati, Italy

Methane has been detected in the Martian atmosphere by ground-based telescopes and from orbit. This discovery indicates that the planet is either biologically or geologically active. The goal of the workshop is to review the available measurements, the potential reservoirs and release mechanisms of Methane and its circulation in the atmosphere, and to discuss all possible origins of this constituent.

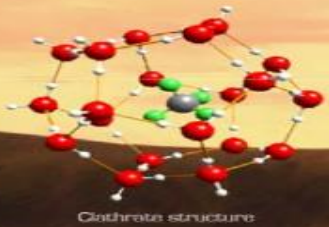


Diagram illustrating the structure of a methane molecule (CH₄).

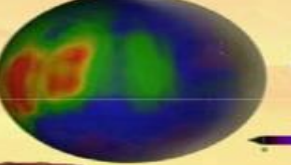
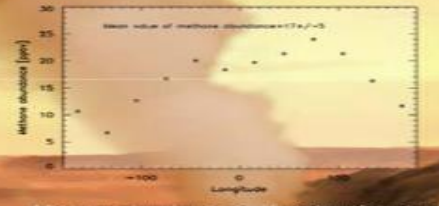


Diagram illustrating the methane plume during the northern summer season. Credit: Trent Schindler/NASA.



Graph showing methane abundance as a function of longitude. (Mars Express/PFS)

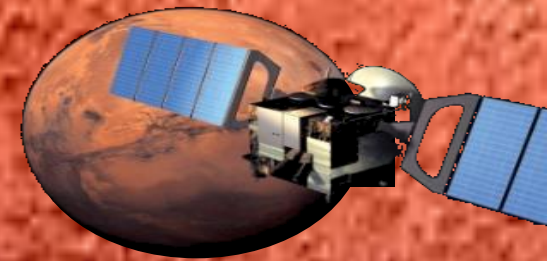
Deadline for abstracts: 1st September 2009

<http://www.congrex.nl/09c26/>

Scientific Organising Committee: Nicolas Altobelli (ESA/ESAC, Madrid), Sushil Atreya (The University of Michigan), Vincent Chevrier (University of Arkansas), Agustin Chicarro (ESA/ESTEC, Noordwijk), Therese Encrenaz (Observatoire de Paris-Meudon), Enrico Flamini (ASI, Roma), Vittorio Formisano (IFI- INAF, Frascati), Franck Lefevre (LATMOS, Paris), Paul Mahaffy (NASA Goddard Space Flight Center), Michael Mumma (NASA Goddard Space Flight Center), Buford Price (University of California, Berkeley), Olivier Witasse (ESA/ESTEC, Noordwijk). Local Organizing Committee: Clare Bingham (ESA/ESTEC, Noordwijk), Carmen Compertto (ESA/ESRIN, Italy), Sylvie Espinasse (ASI, Roma), Olivier Witasse (ESA/ESTEC, Noordwijk).



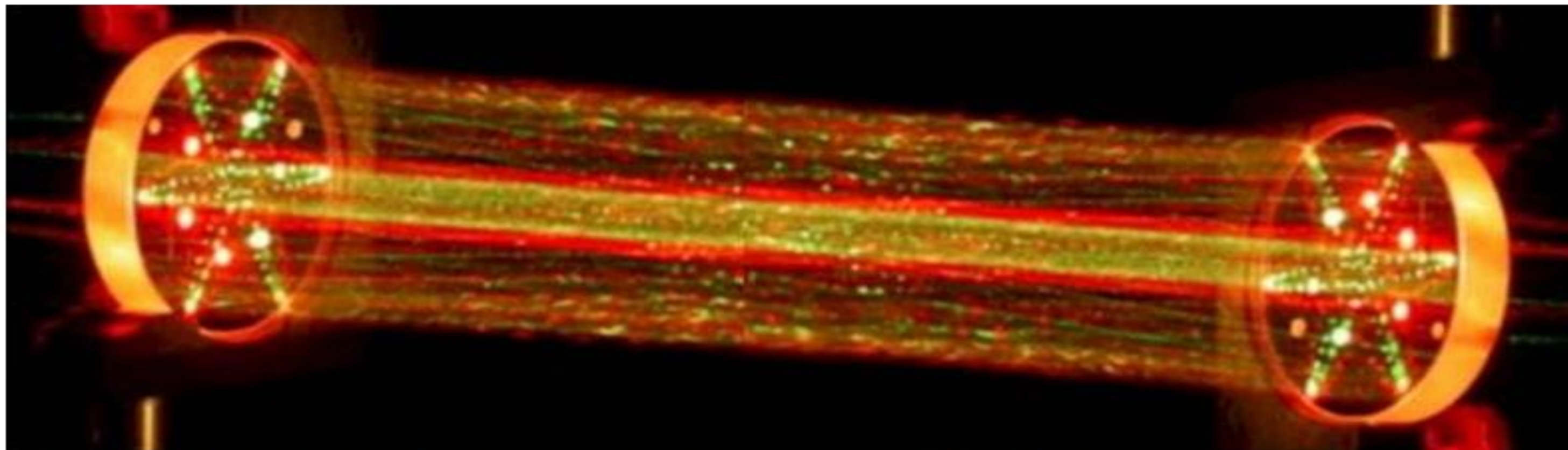
MSL Curiosity 2013: no Methane???



Mars Curiosity

Sept. 19, 2013

NASA Curiosity Rover Detects No Methane on Mars



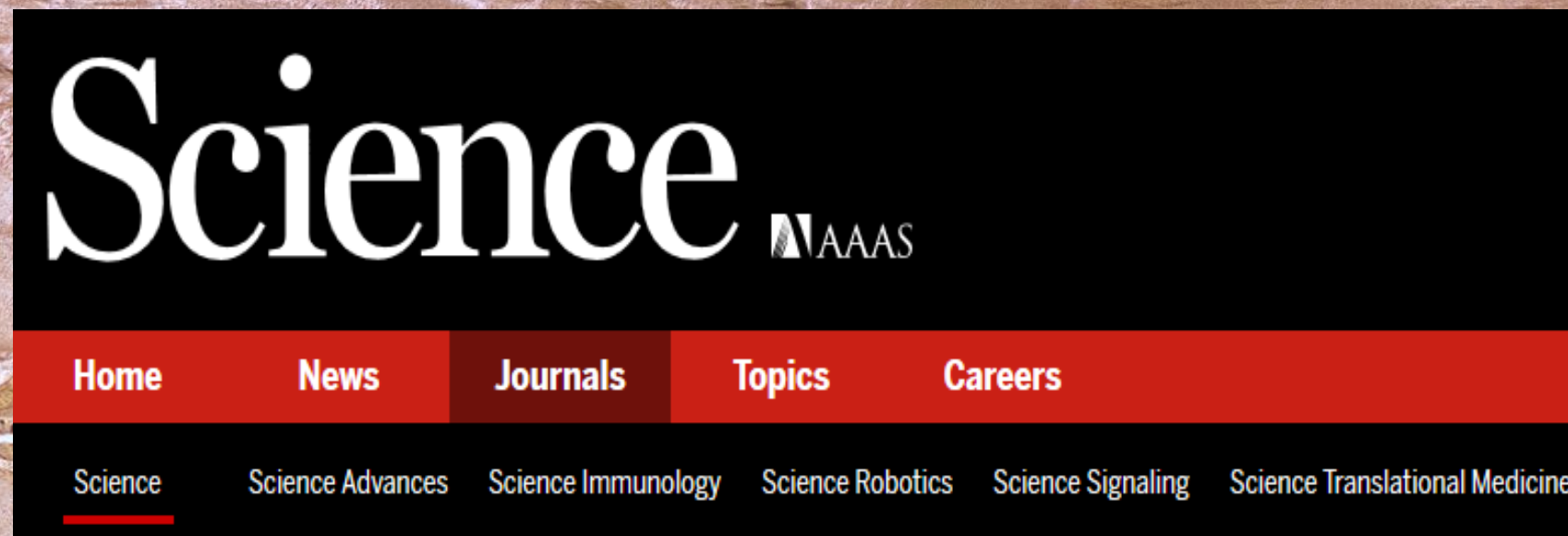
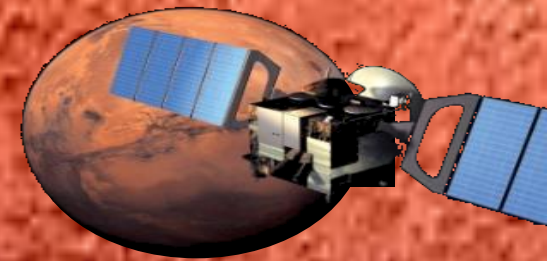
This picture shows a lab demonstration of the measurement chamber inside the Tunable Laser Spectrometer, an instrument that is part of the Sample Analysis at Mars investigation on NASA's Curiosity rover.

Credits: NASA/JPL-Caltech

PASADENA, Calif. — Data from NASA's Curiosity rover has revealed the Martian environment lacks methane. This is a surprise to researchers because previous data reported by U.S. and international scientists indicated positive detections.



MSL Curiosity 2014: Methane is there! but comes and goes???



SHARE

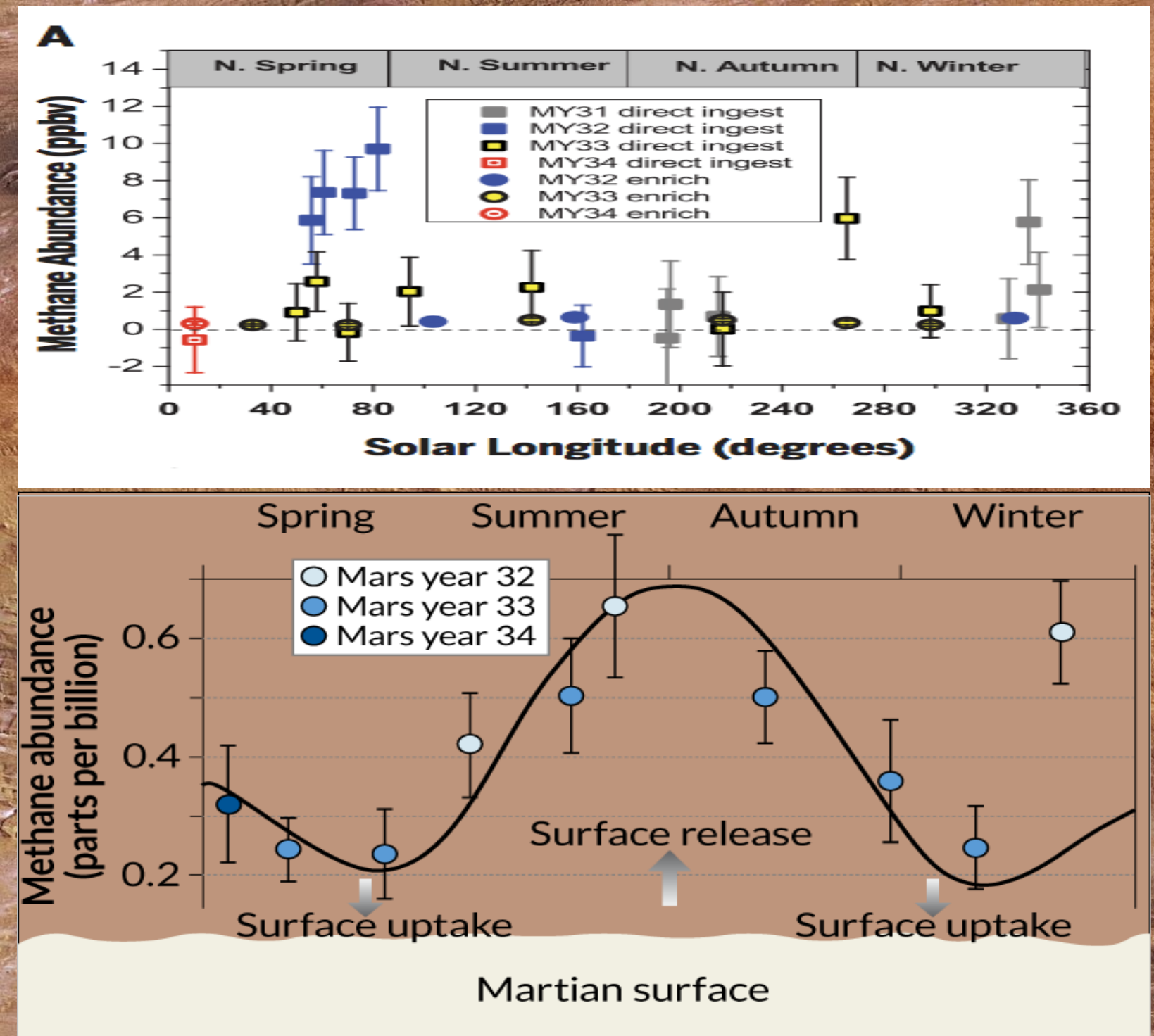
REPORT

Mars methane detection and variability at Gale crater

Christopher R. Webster^{1,*}, Paul R. Mahaffy², Sushil K. Atreya³, Gregory J. Flesch¹, Michael A. Mischna¹, Pierre-Yves Meslin⁴, Kenneth A. Farley⁵, Pamela G. Conrad², Lance E. Christensen¹, Alexander A. Pavlov², Javier Martín-Torres⁶, María-Paz Zorzano⁷, Timothy H. McConnochie⁸, Tobias Owen⁹, Jennifer L. Eigenbrode², Daniel P. Glavin², Andrew Steele¹⁰, Charles A. Malespin², P. Douglas Archer Jr.¹¹, Brad Sutter¹¹, Patrice Coll¹², Caroline Freissinet², Christopher P. McKay¹³, John E. Moores¹⁴, Susanne P. Schwenzer¹⁵, John C. Bridges¹⁶, Rafael Navarro-Gonzalez¹⁷, Ralf Gellert¹⁸, Mark T. Lemmon¹⁹, the MSL Science Team[†]

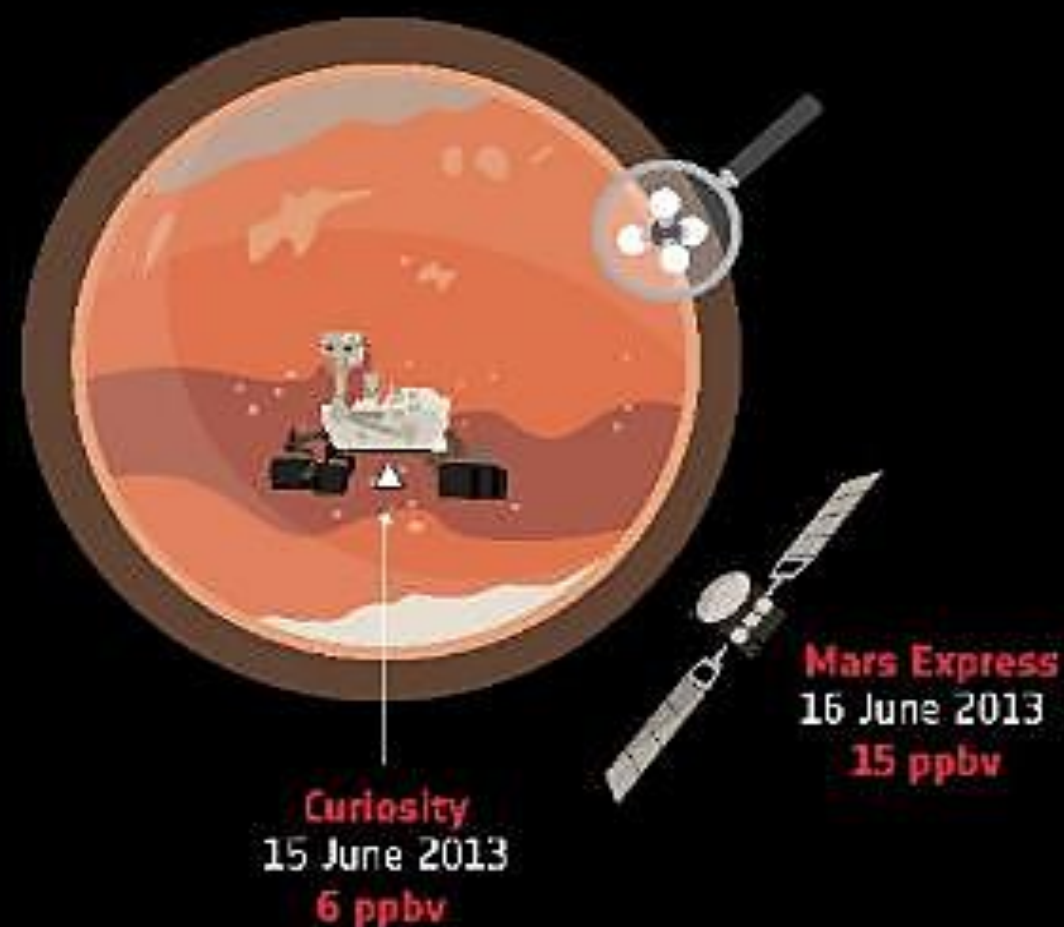
+ Author Affiliations

*Corresponding author. E-mail: chris.r.webster@jpl.nasa.gov

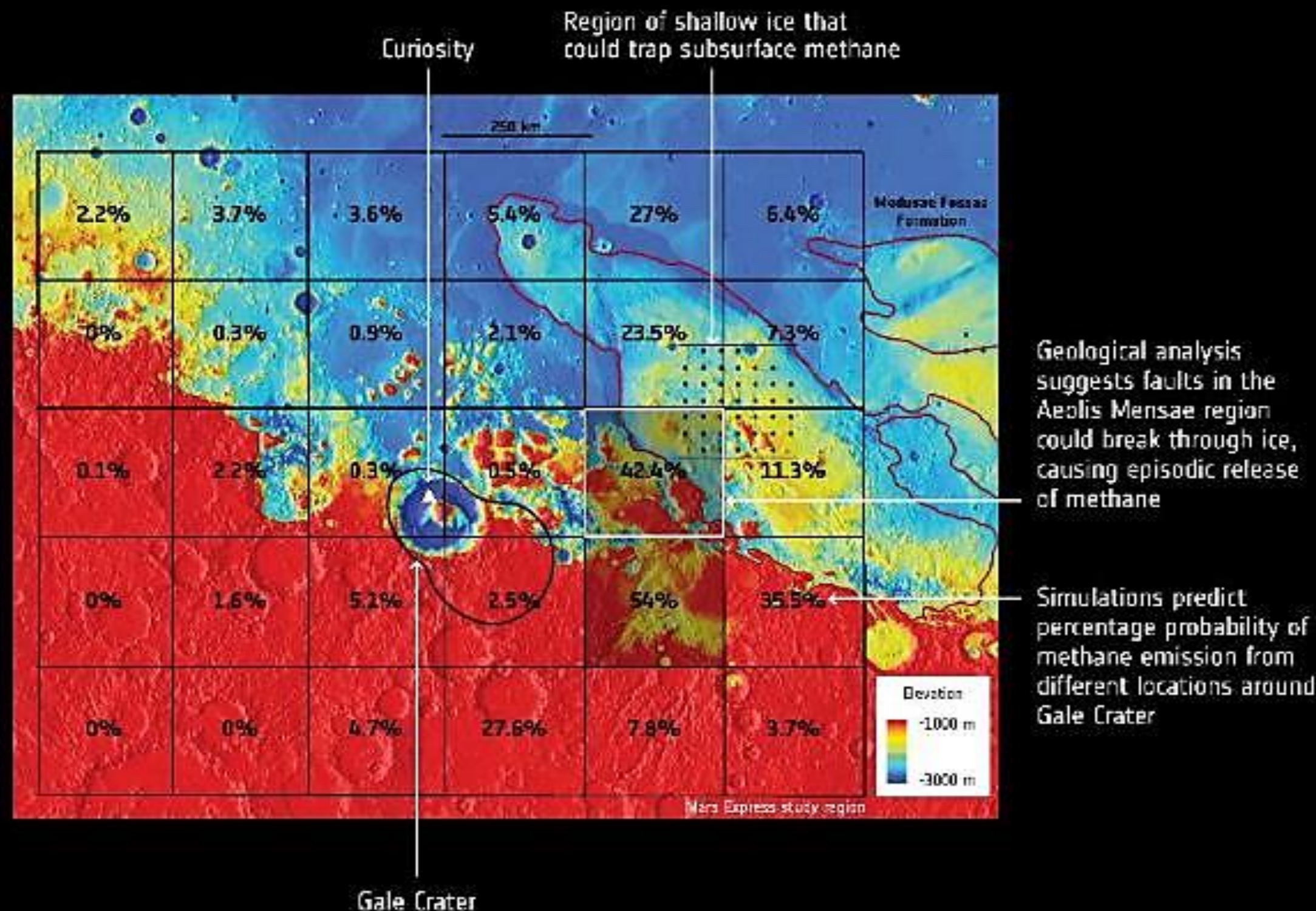


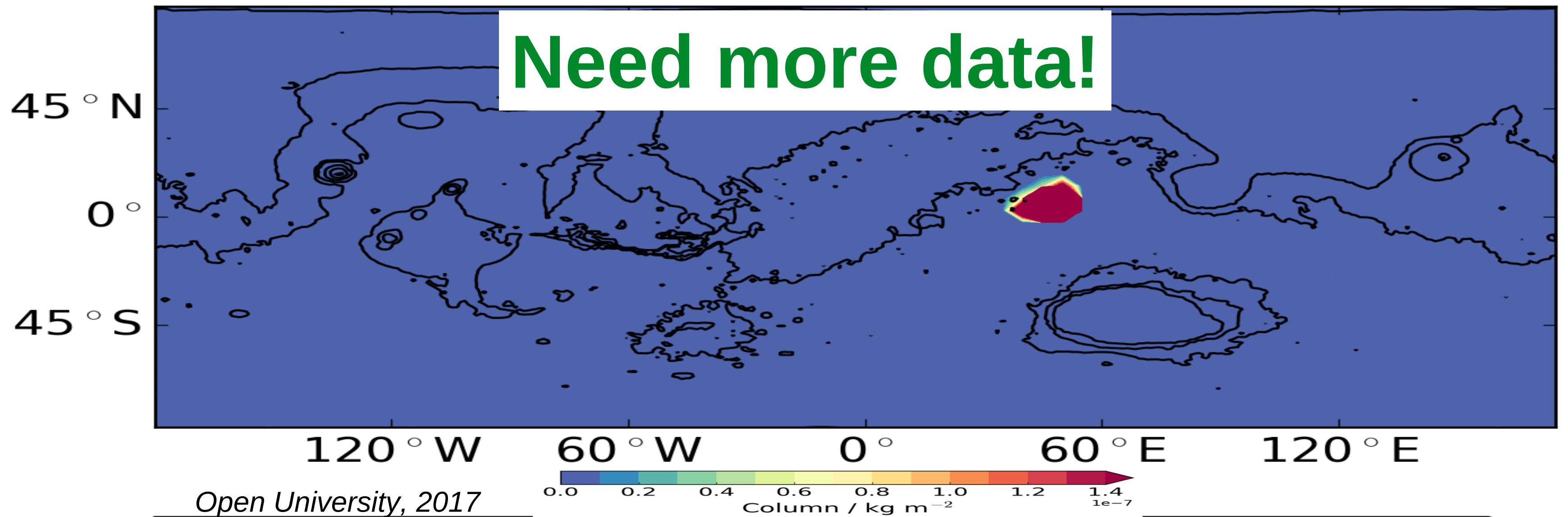
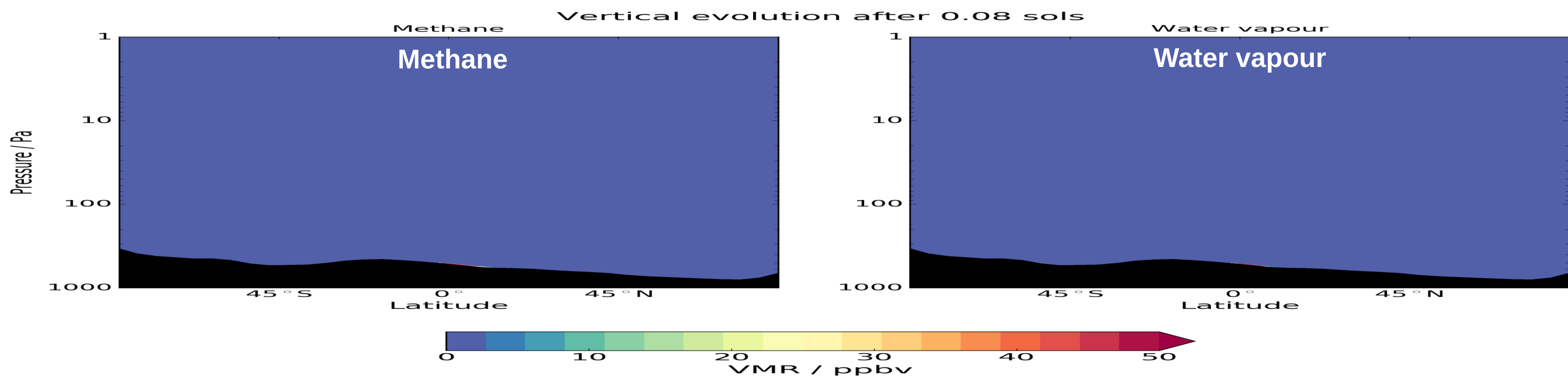
Methane creation and destruction??

→ FIRST INDEPENDENT CONFIRMATION OF A METHANE SPIKE ON MARS



ppbv = parts per billion by volume





ExoMars Programme

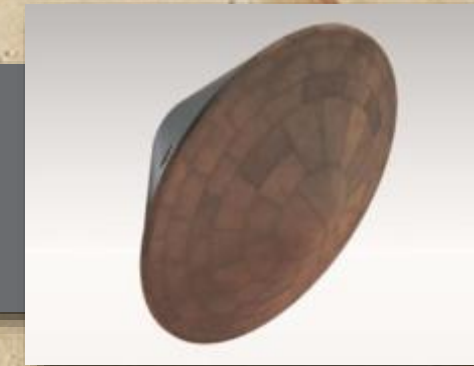


2 missions: Trace Gas Orbiter in 2016, Rover and Surface Platform in 2022

- Cooperation between ESA and Roscosmos

TECHNOLOGY OBJECTIVES (experimental)

- ▶ Test Entry, Descent and Landing concepts

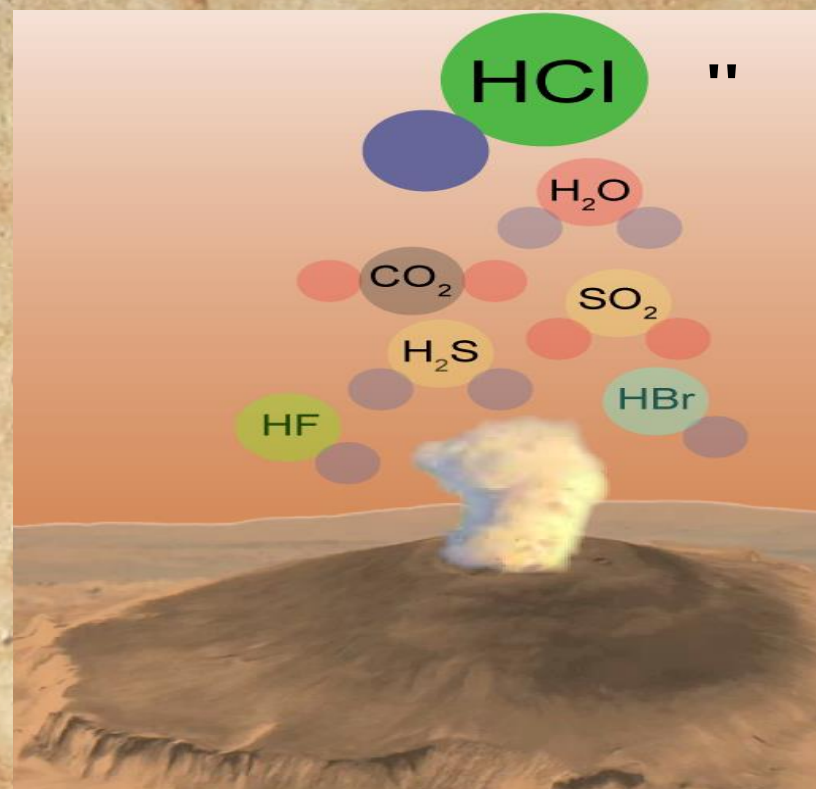


2016

SCIENCE OBJECTIVES 2018-2022

TRACE GAS ORBITER (TGO)

- ▶ Study of Martian atmosphere: **trace gases** and sources
- ▶ Mapping of surface **water ice** and geology



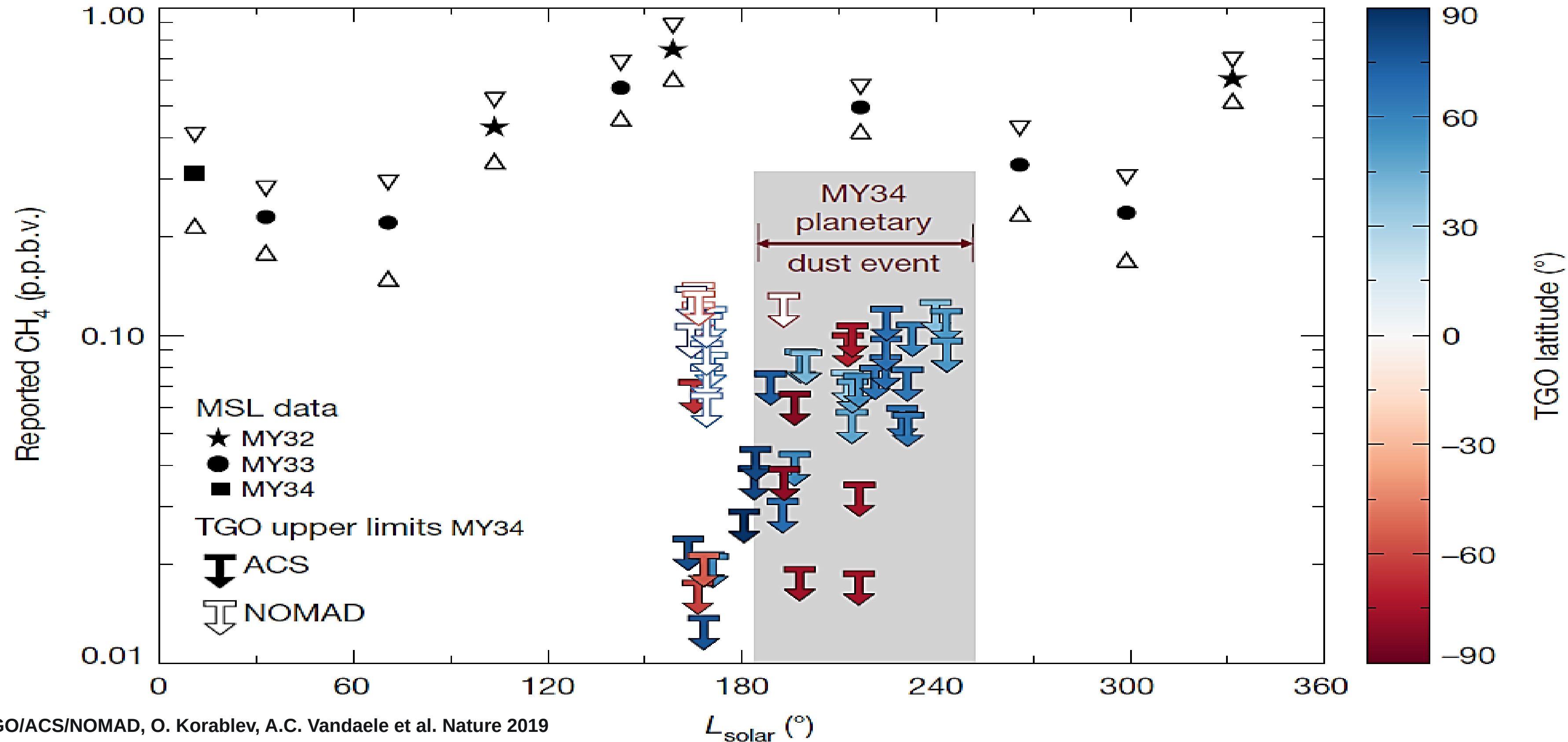
- ▶ Relay communications for ESA/NASA rovers



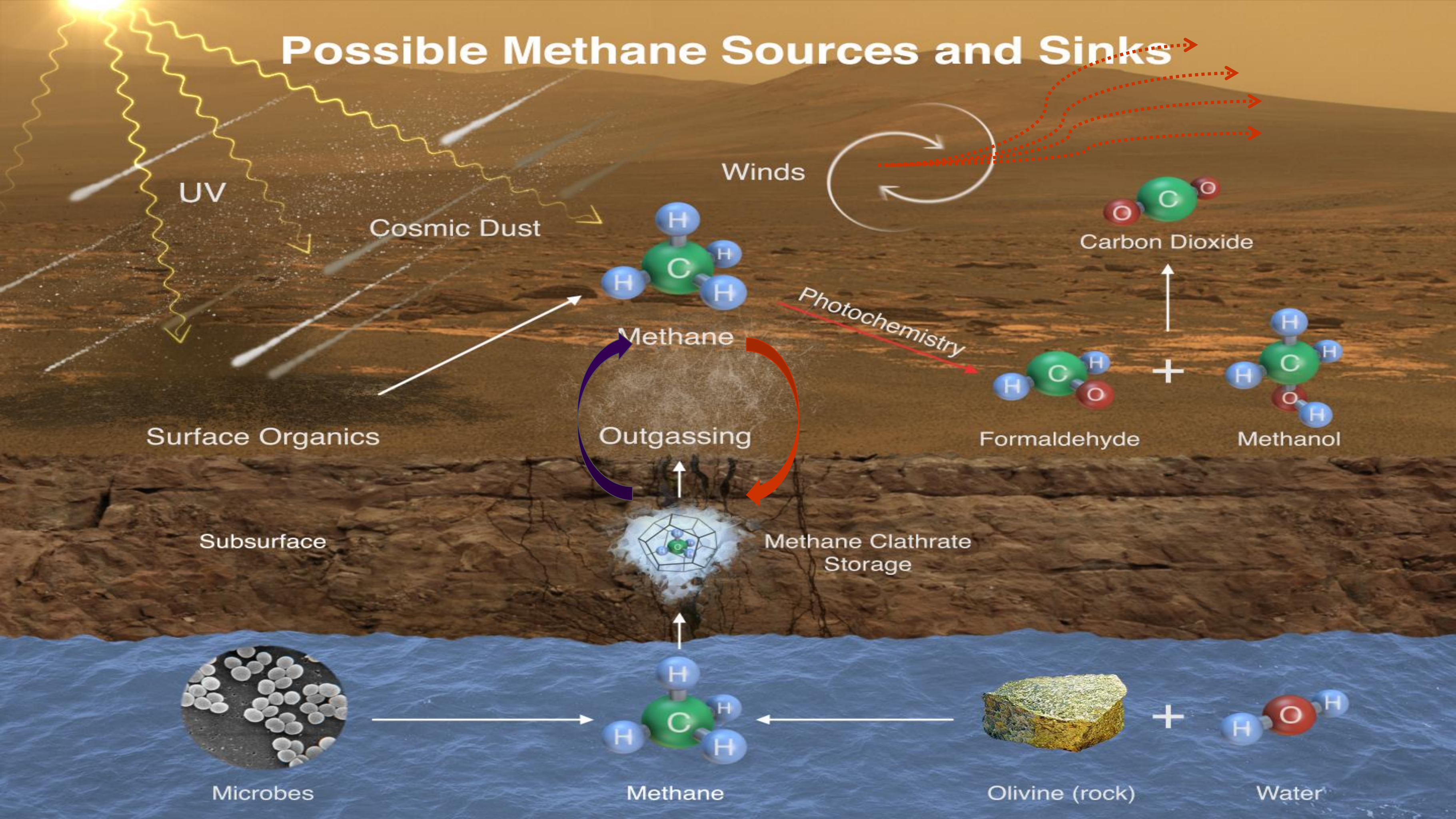
Sunset hunter

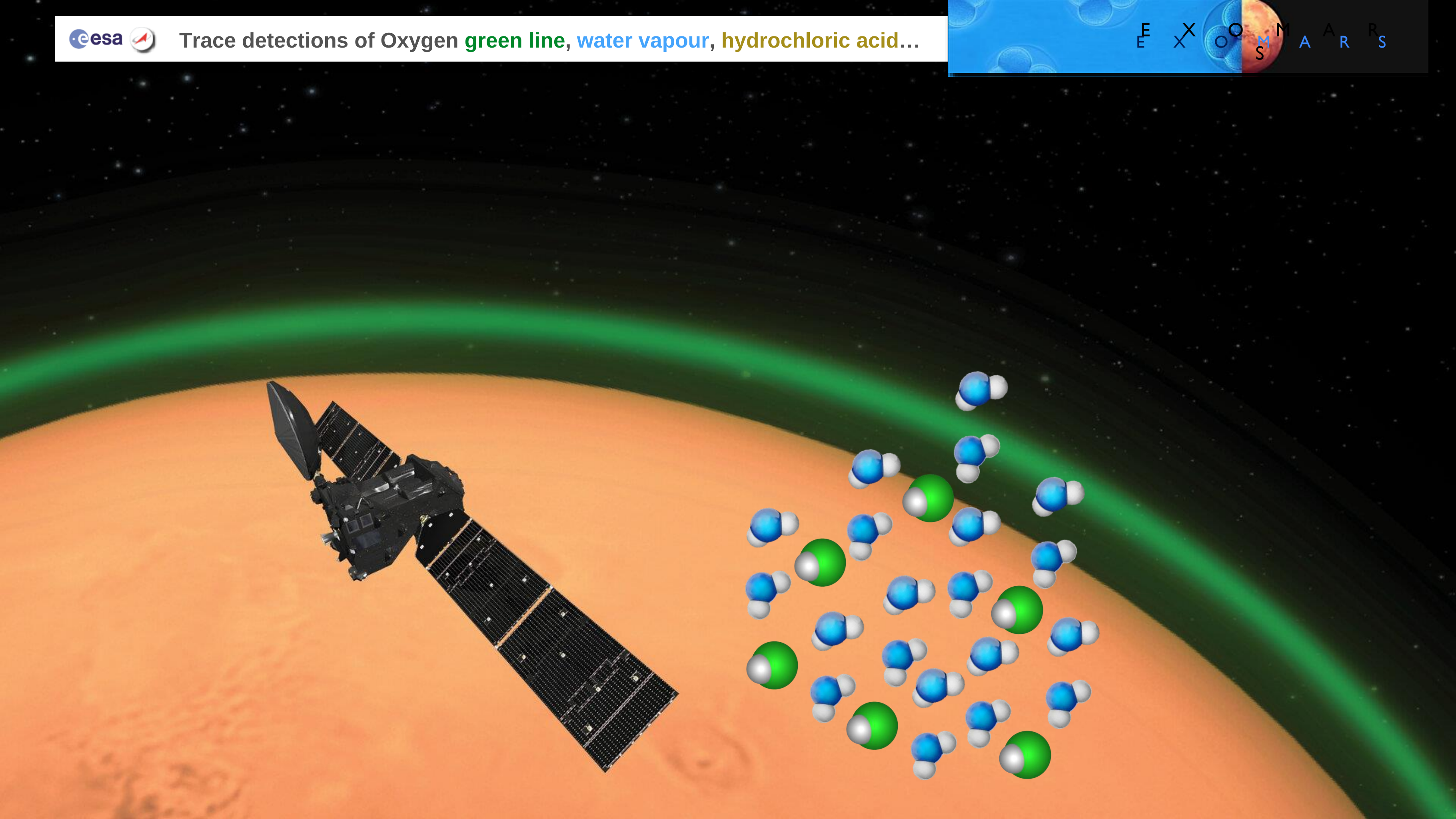
Observe sun light at sunset and sunrise
to detect trace gases, **methane**, **water vapour**, dust, ...

TGO detection attempts₄ combined with the MSL enriched mode dataset



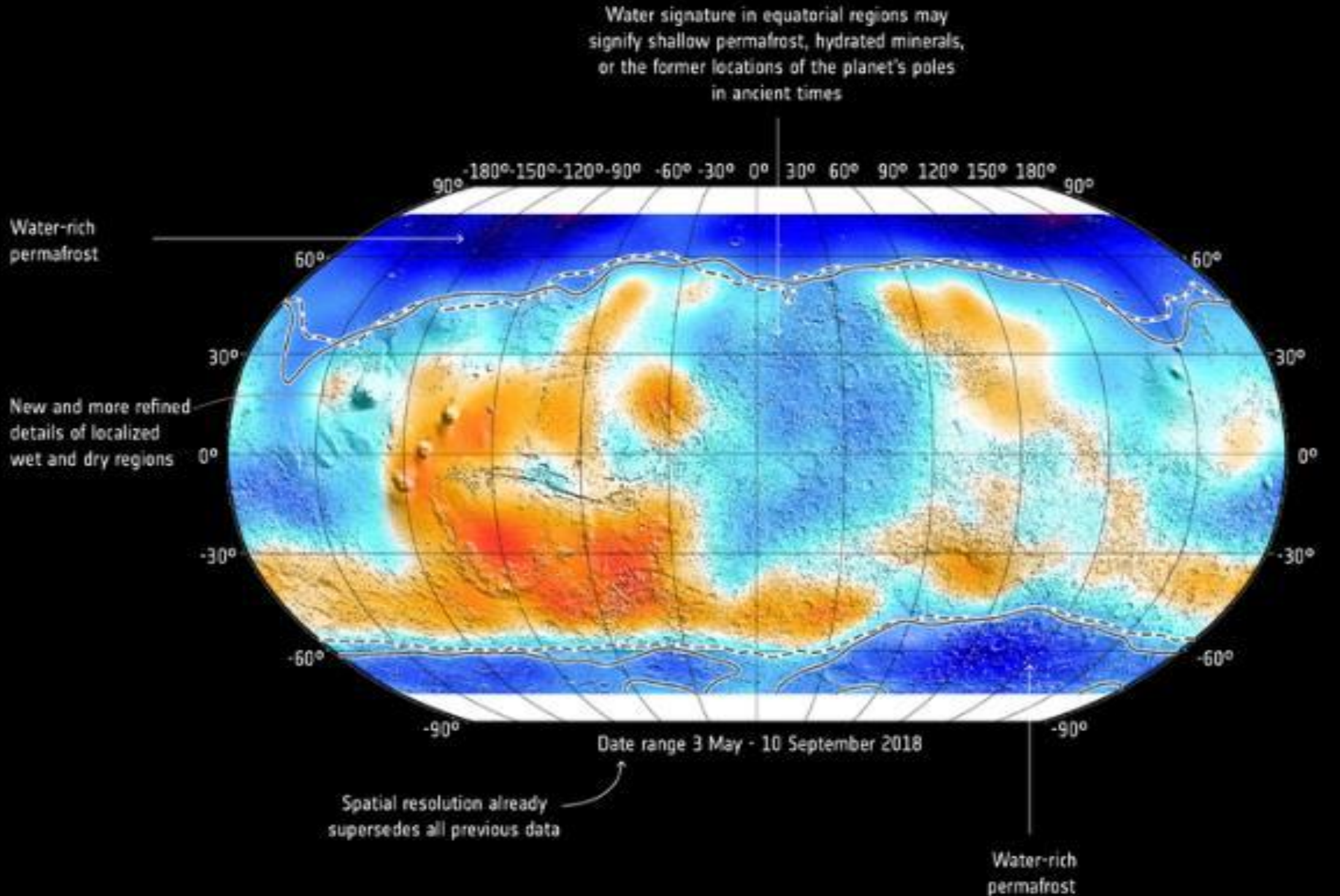
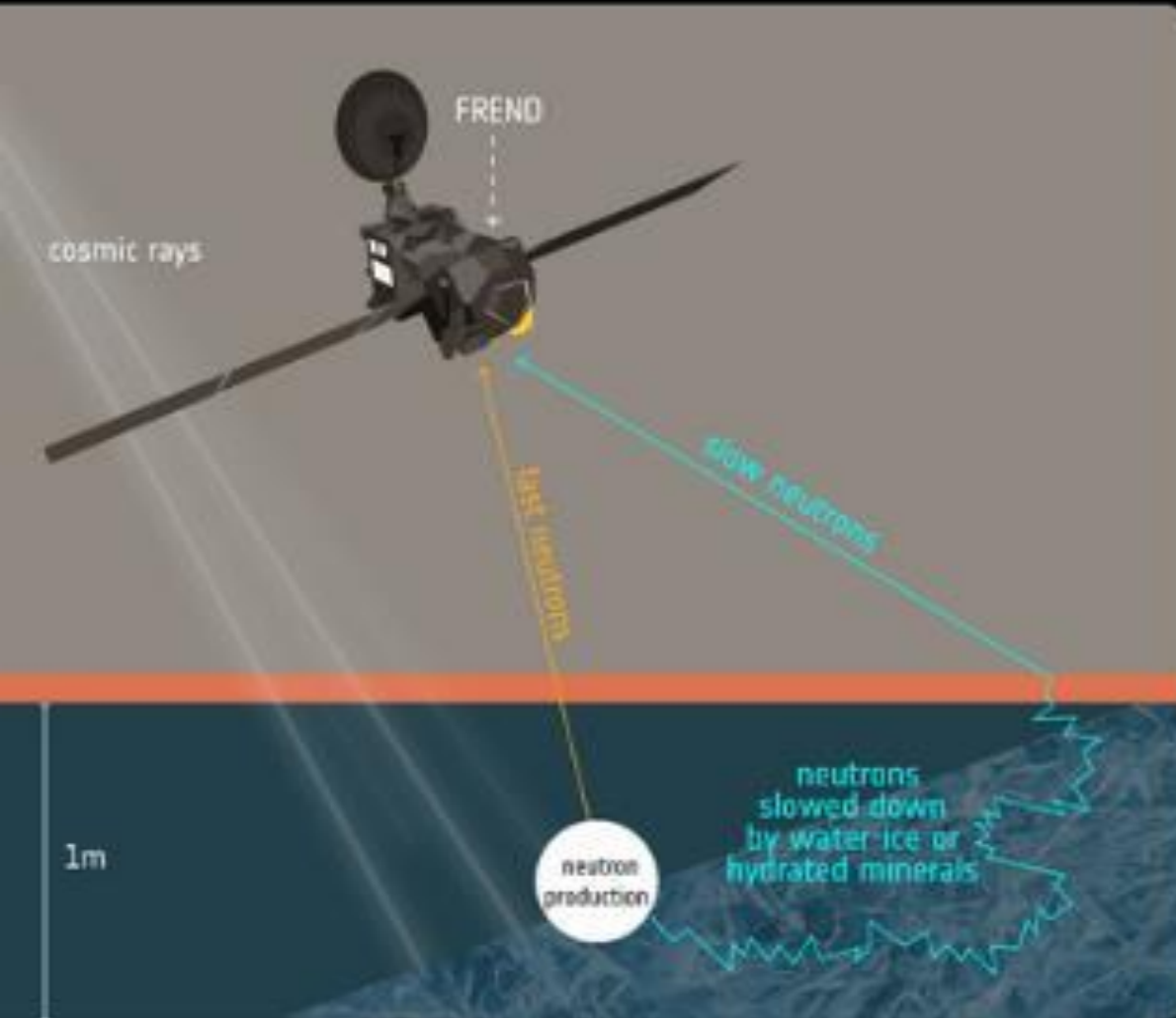
Possible Methane Sources and Sinks



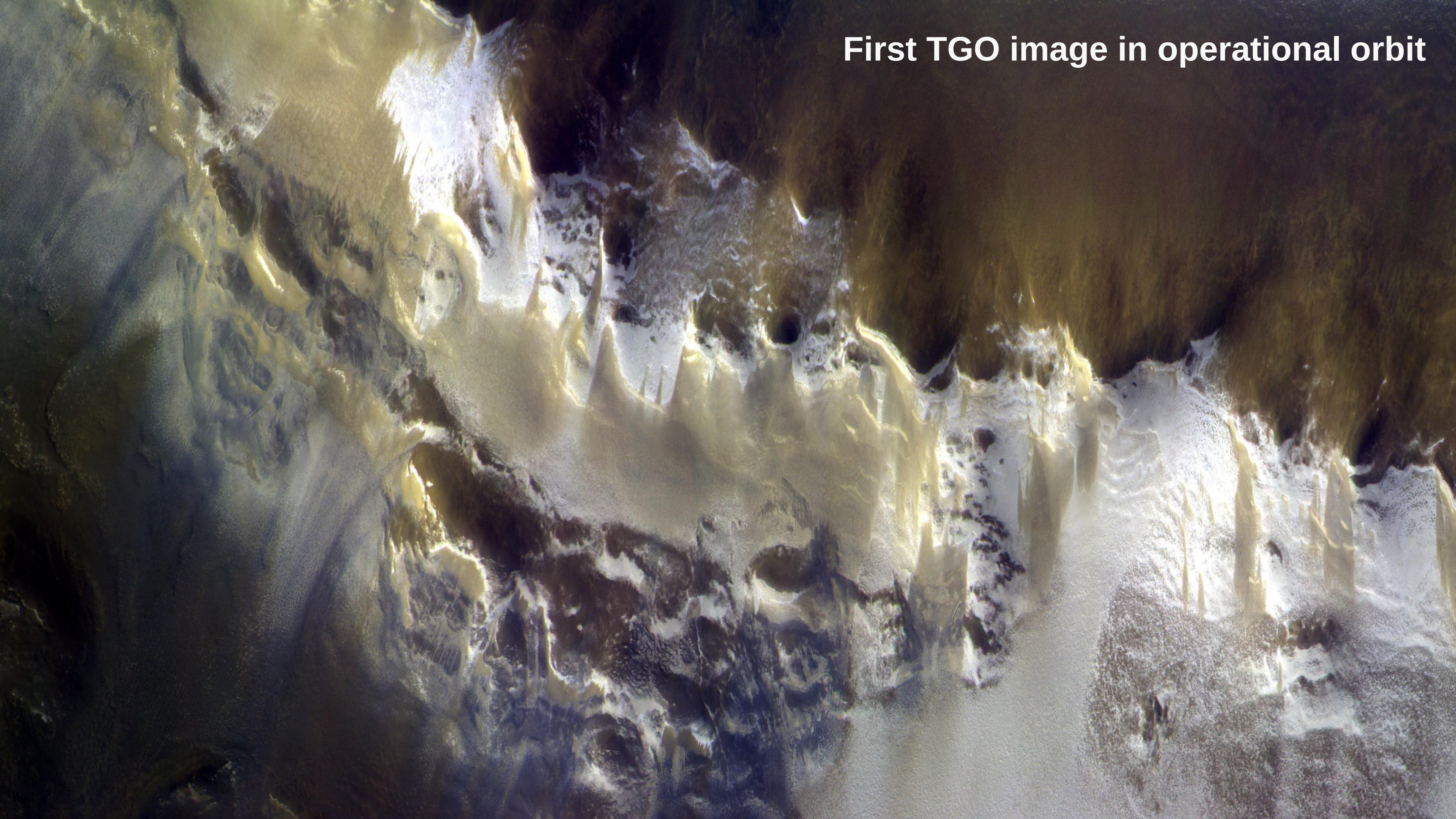


→ FIRST RESULTS FROM THE EXOMARS TRACE GAS ORBITER

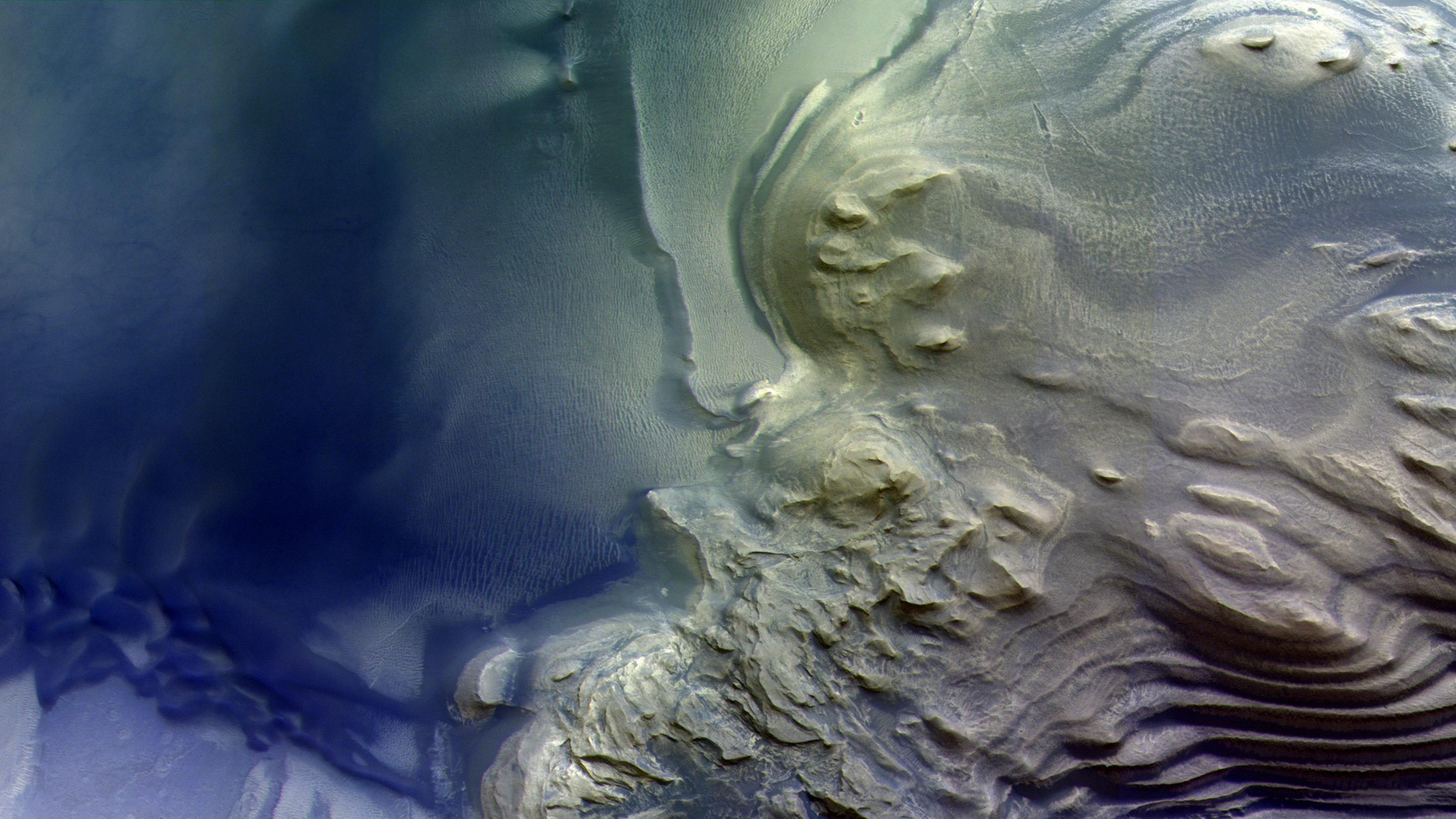
First map of subsurface water distribution

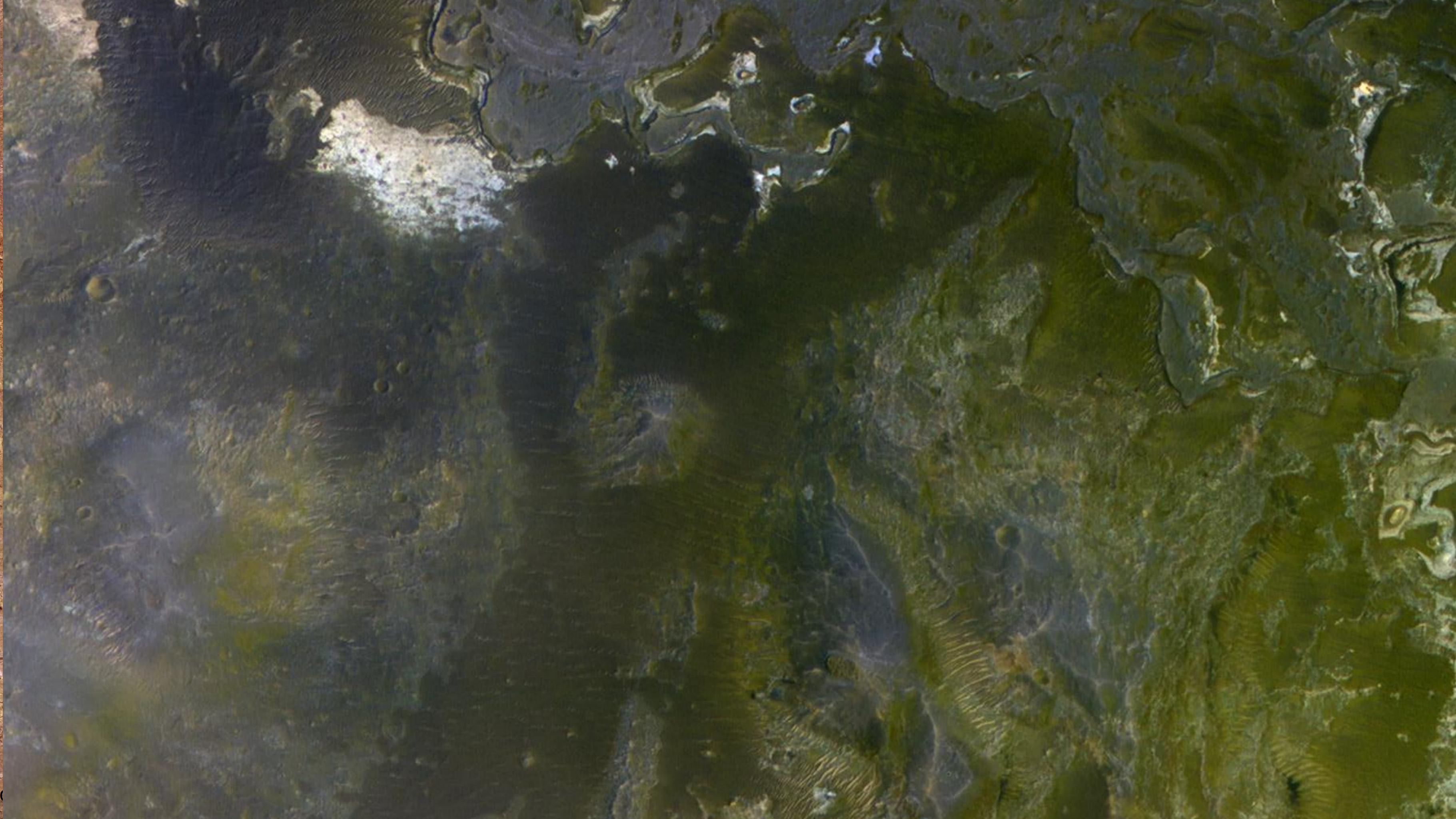


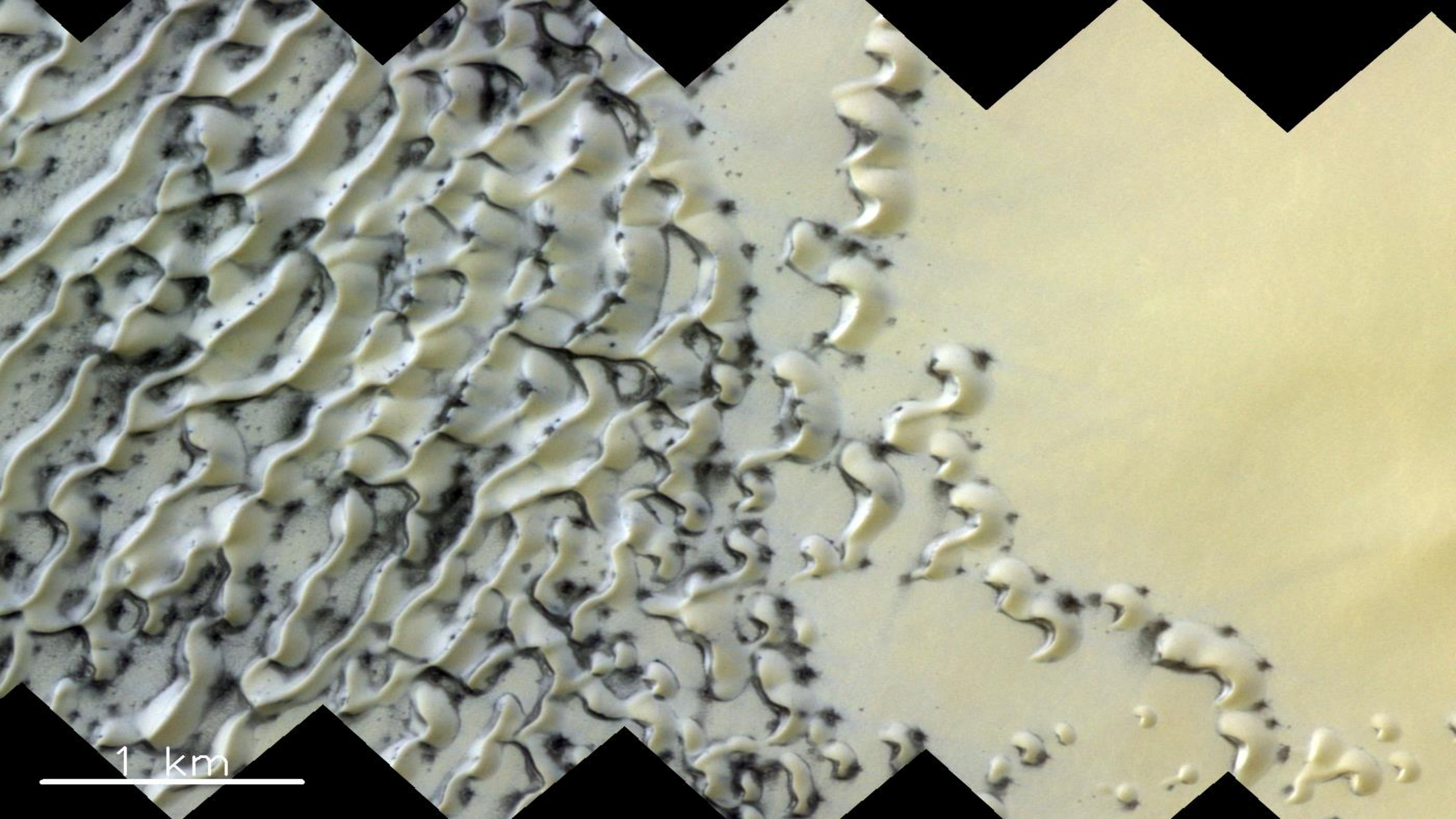
First TGO image in operational orbit



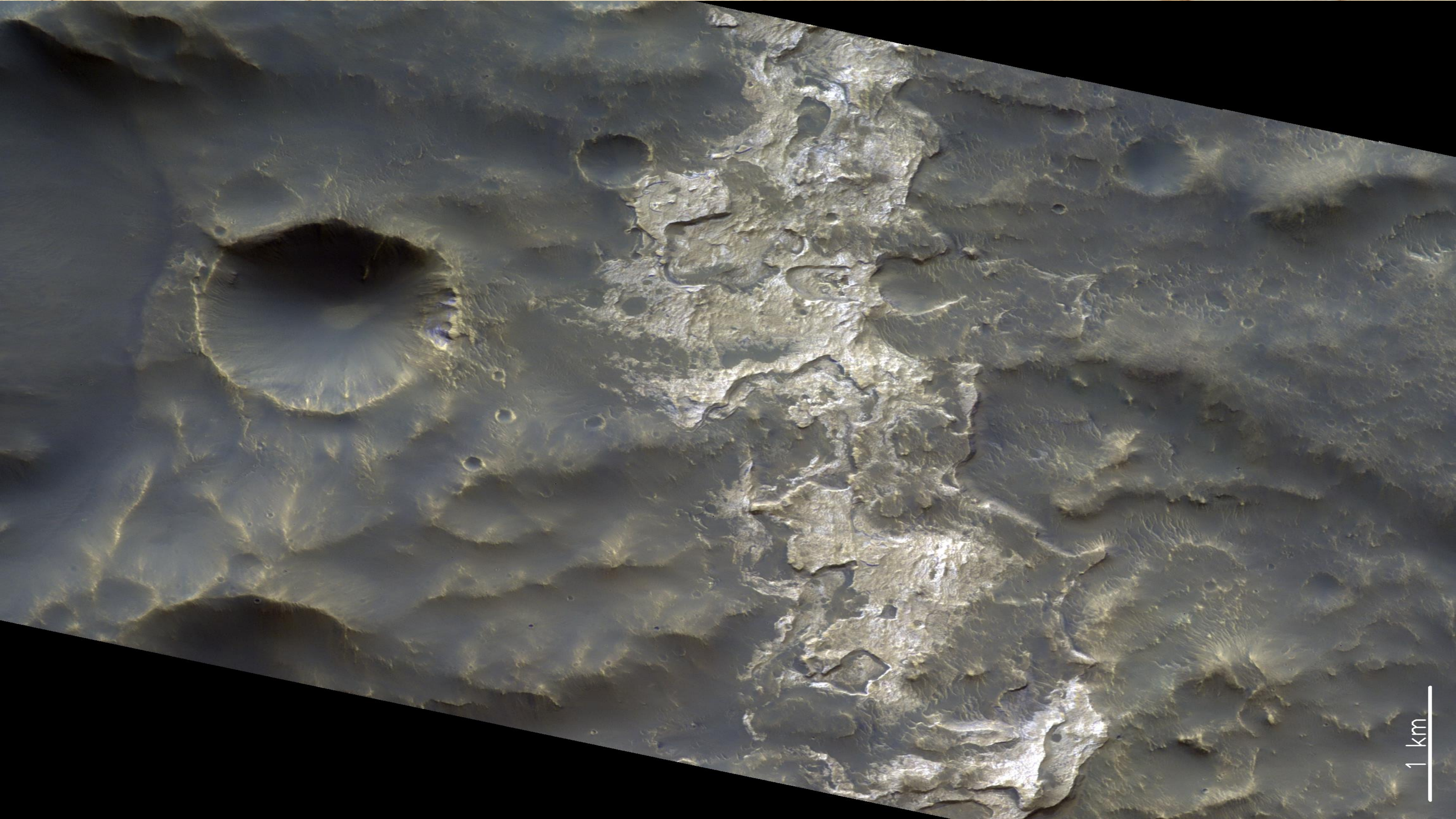




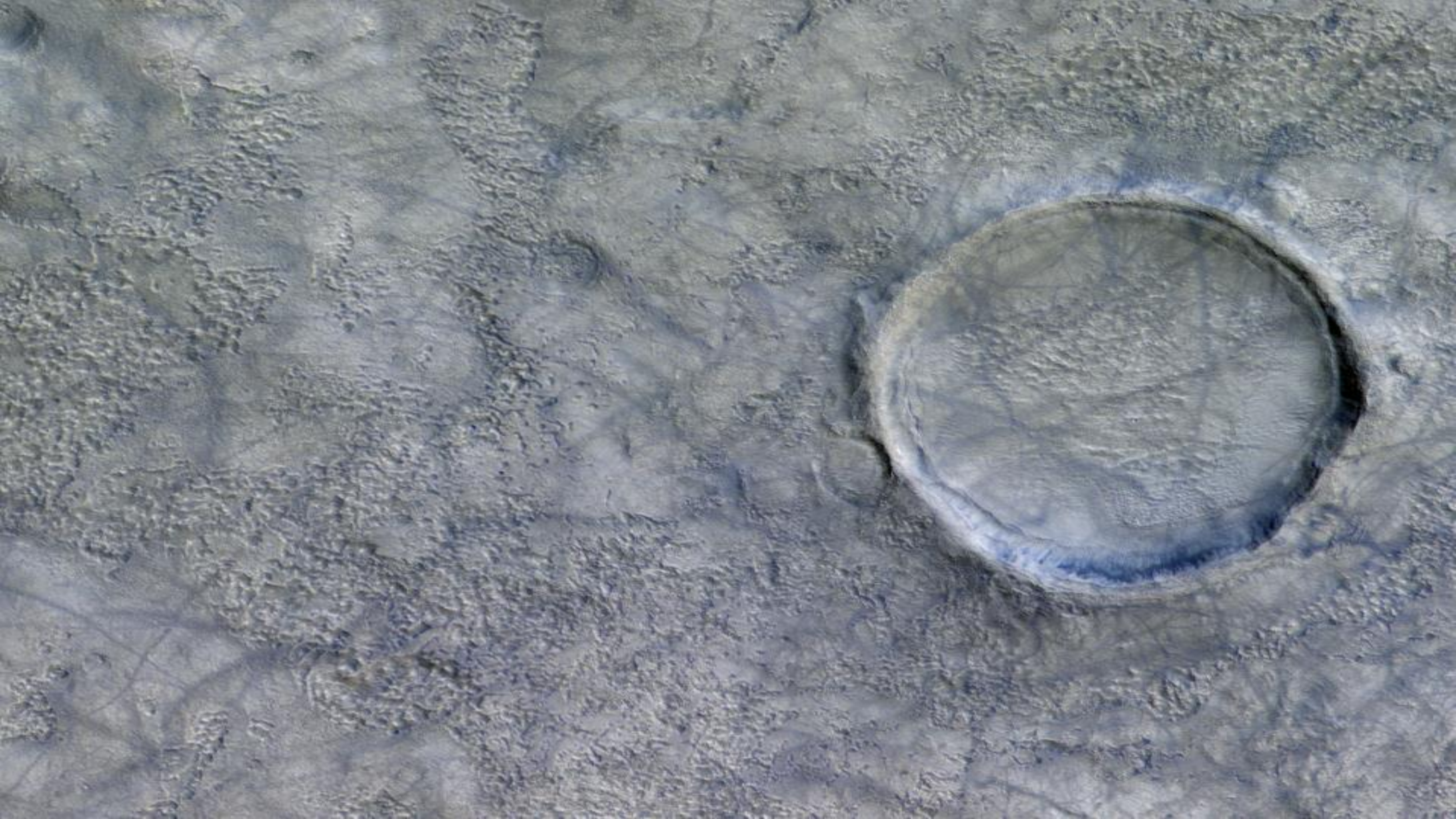


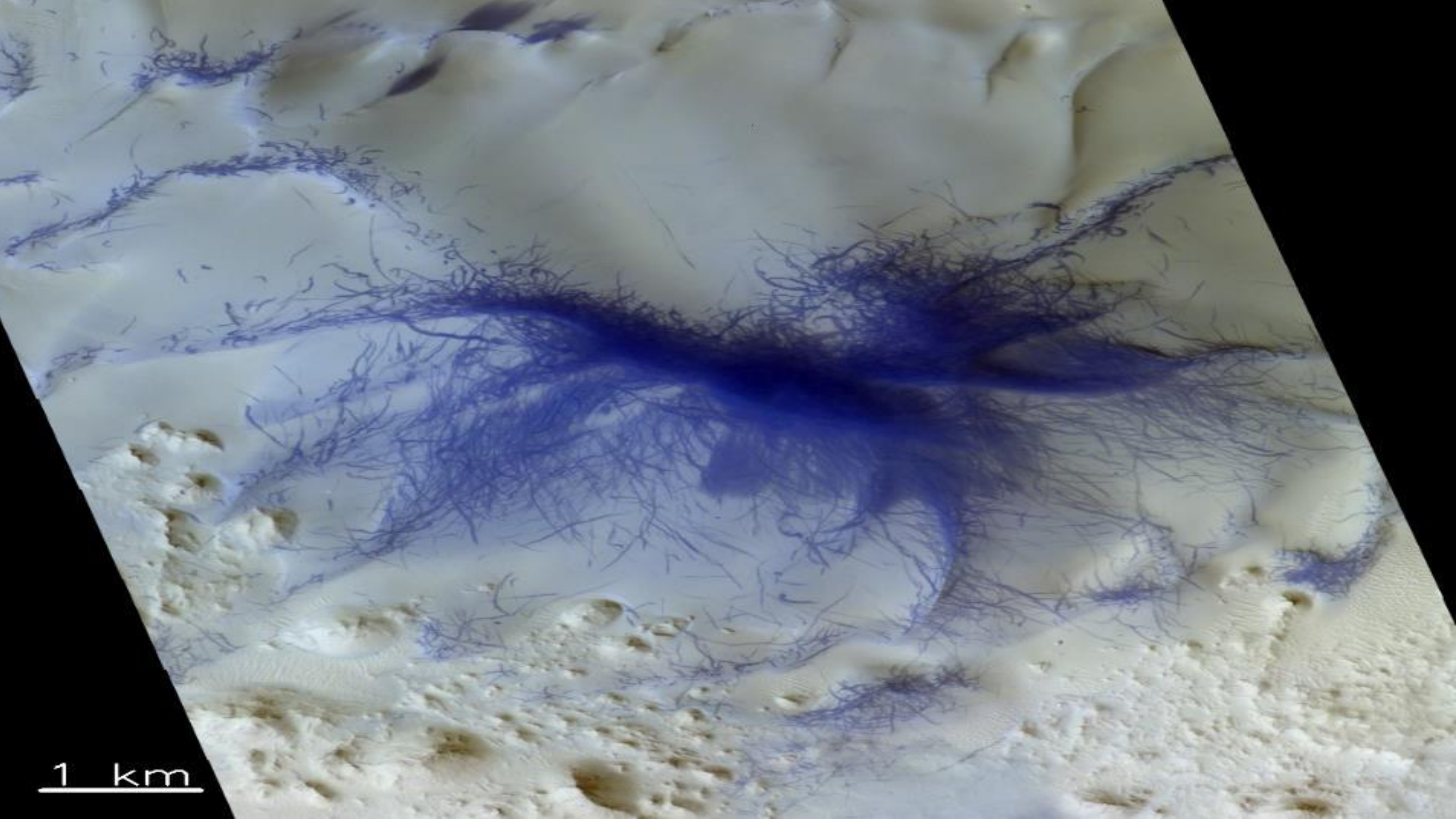


1 km

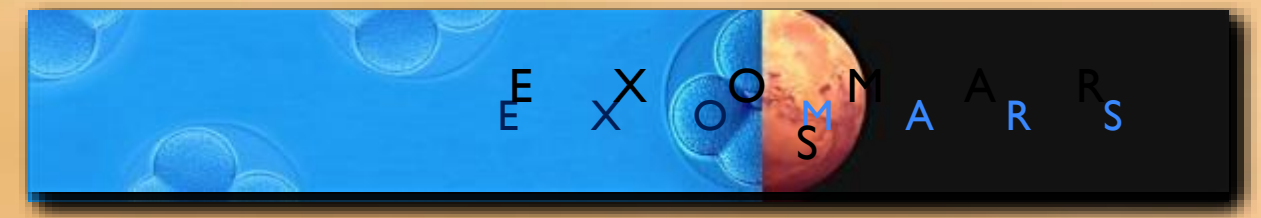


1 km





2022

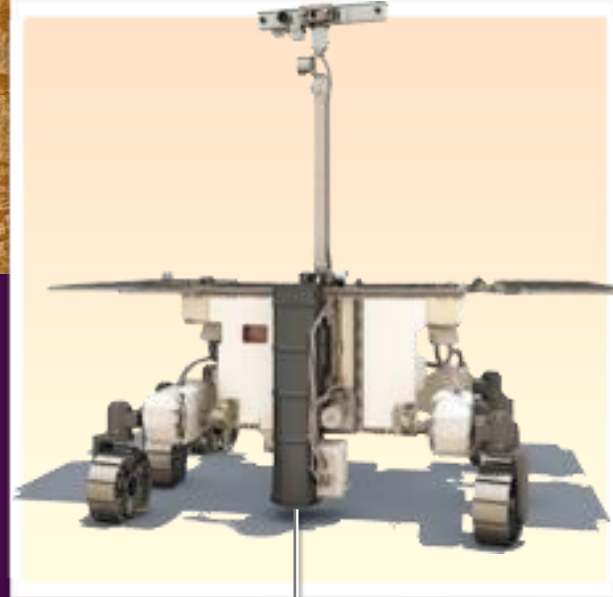


E X O M A R S

ROVER
&
SURFACE PLATFORM



2022



SCIENCE OBJECTIVES

- Search for signs of present and past life on Mars
- Research for water in subsurface and environment

TECHNOLOGY OBJECTIVES

- Mobility on Msurface (up to a few kilometers);
- Direct access to martian subsurface (2m depth drill);
- Sample acquisition and analysis from surface and subsurface



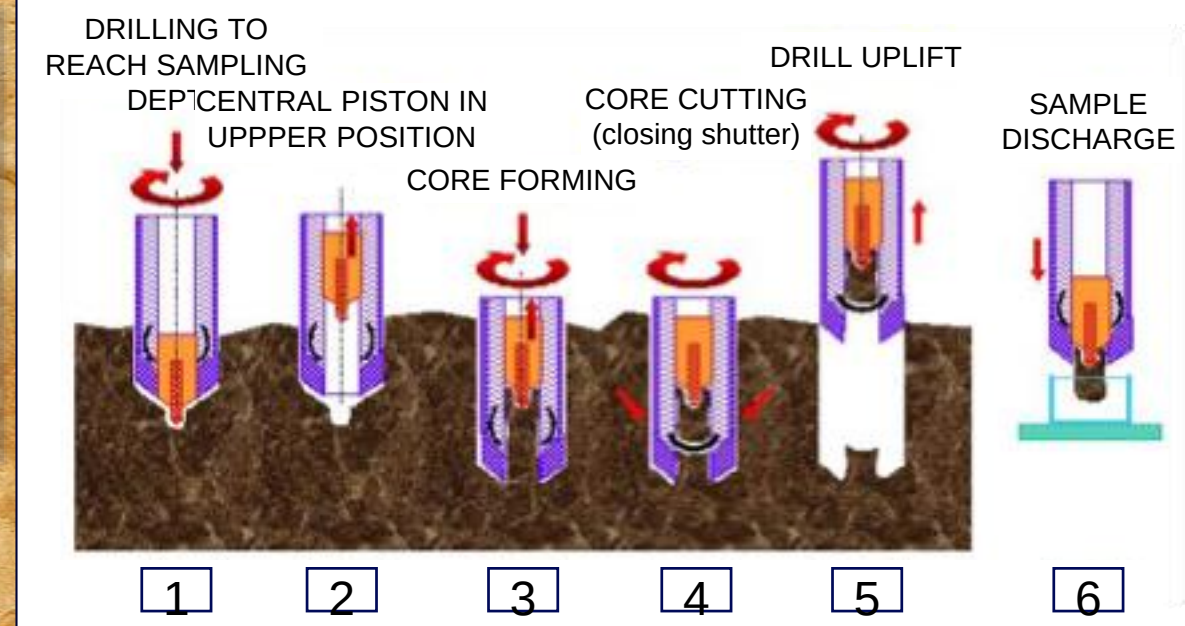
SCIENCE OBJECTIVES

- Characterisation of Surface environment.

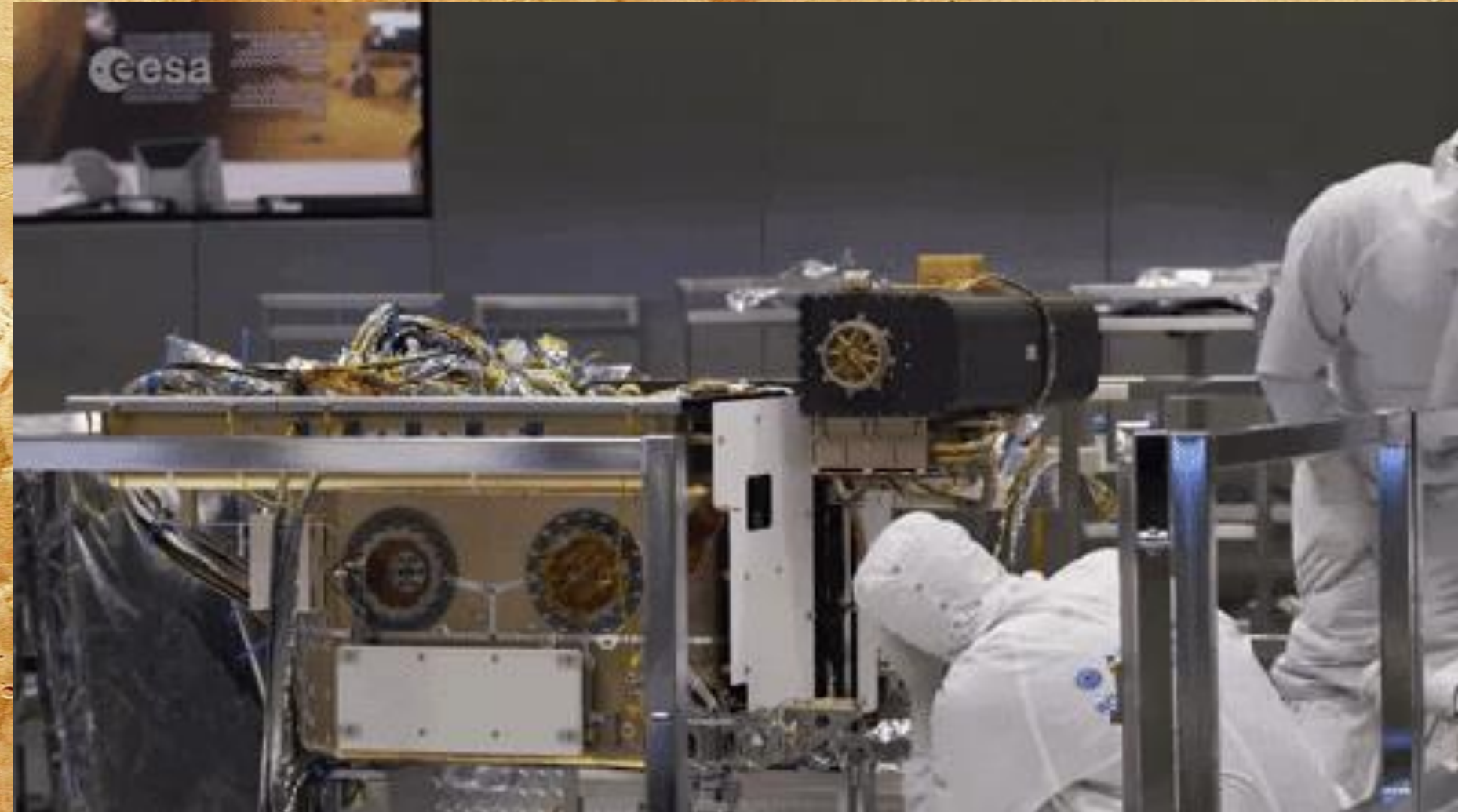
TECHNOLOGY OBJECTIVES

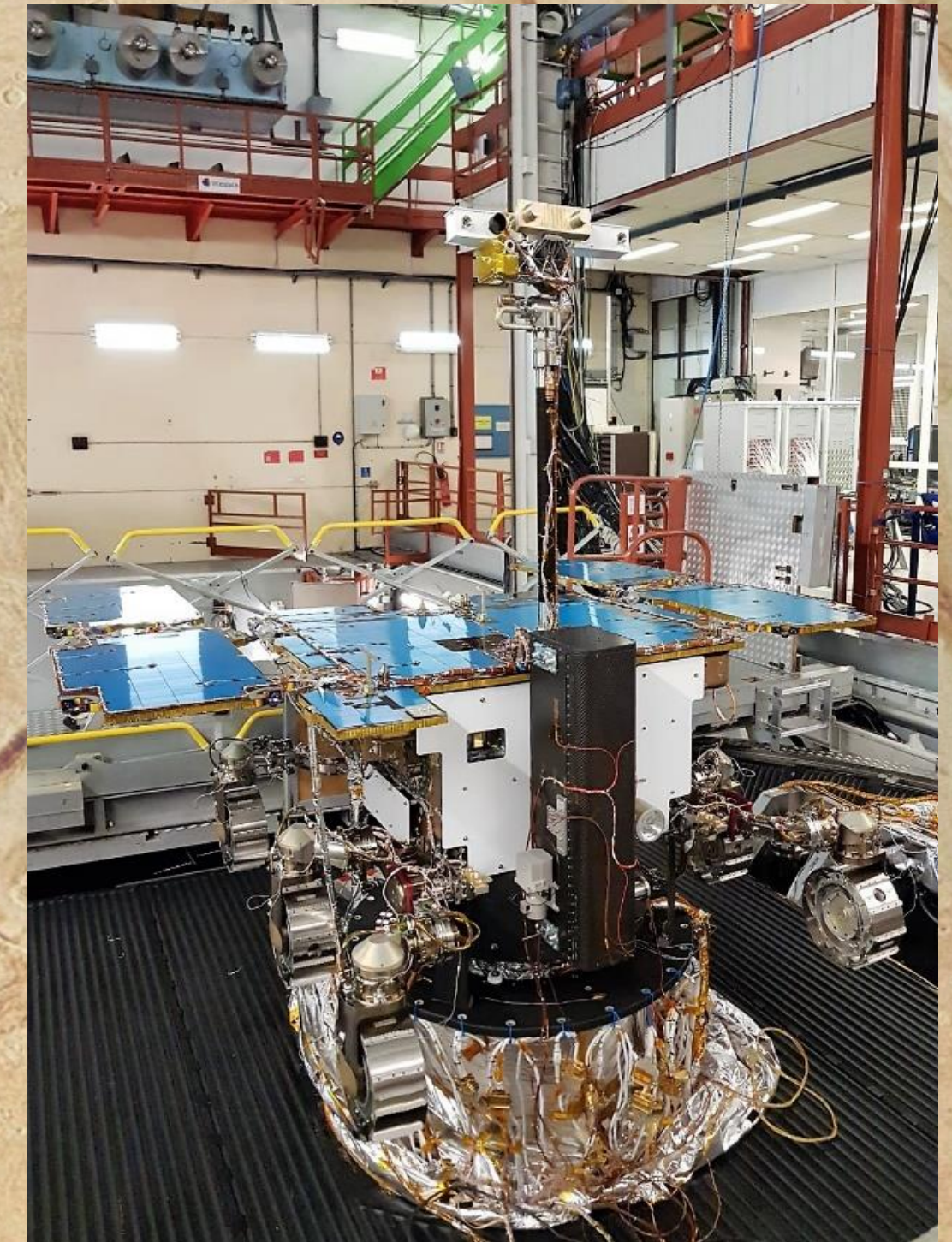
- Descent and landing platform
- Communications with European and Russian stations

Nominal mission : 218 sols
 Nominal science : 6 Experiment Cycles + 2 Vertical Surveys
 EC length : 16–20 sols
 Rover mass : 300-kg class
 Mobility range : Several km



2-m depth





2016: ExoMars Trace Gas Orbiter

- Improve our understanding of Mars and atmospheric processes of exo-biological relevance
- Example of international cooperation.
- Technology demonstration for future exploration.

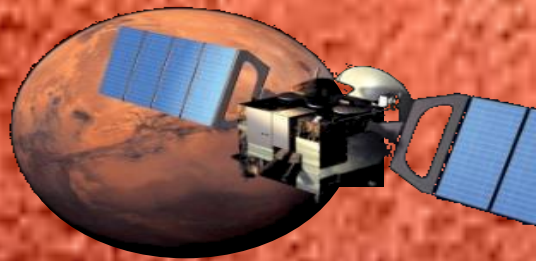
2022: ExoMars Rover and Surface Platform

- Mission with great exo-biological importance.
- First attempt to combine mobility and sub-surface sounding.
- Rover with state-of-the-art scientific instrumentation.
- Pasteur Module will study for the first time:
 - Organic molecules and bio-markers for present and past life;
 - Vertical characterisation of geochemistry and water.
- Surface platform will measure environmental properties.

One more step in the roadmap for exploration towards the Mars Sample Return challenge



Mars Exploration nowadays...



2001 ... 2009

Mars Express
(ESA)

Odyssey

MRO

2011



Phobos-
Grunt
(RUSSIA)

2013/14

MAVEN

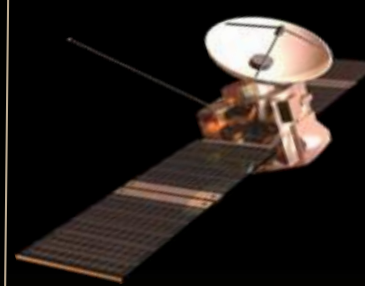


MOM
(India)



2016

TGO
(ESA-RUSSIA)

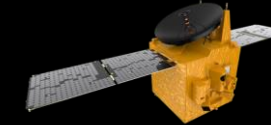


Schiaparelli



2018

2020



Arab
Emirates



China

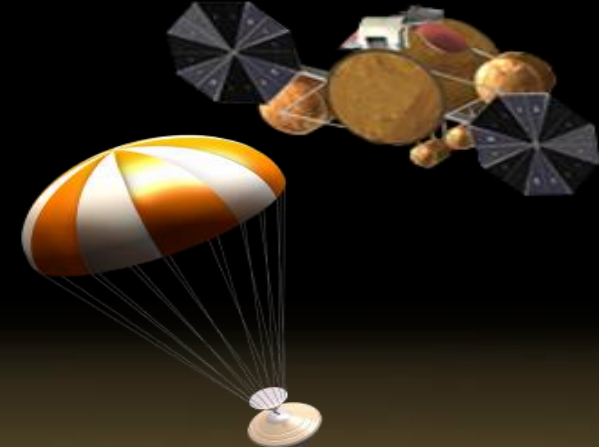


2022

ExoMars 2022
(ESA-RUSSIA)

future ...

Mars
Sample
Return



SpaceX?



?

Opportunity

Phoenix



Spirit



MSL Curiosity

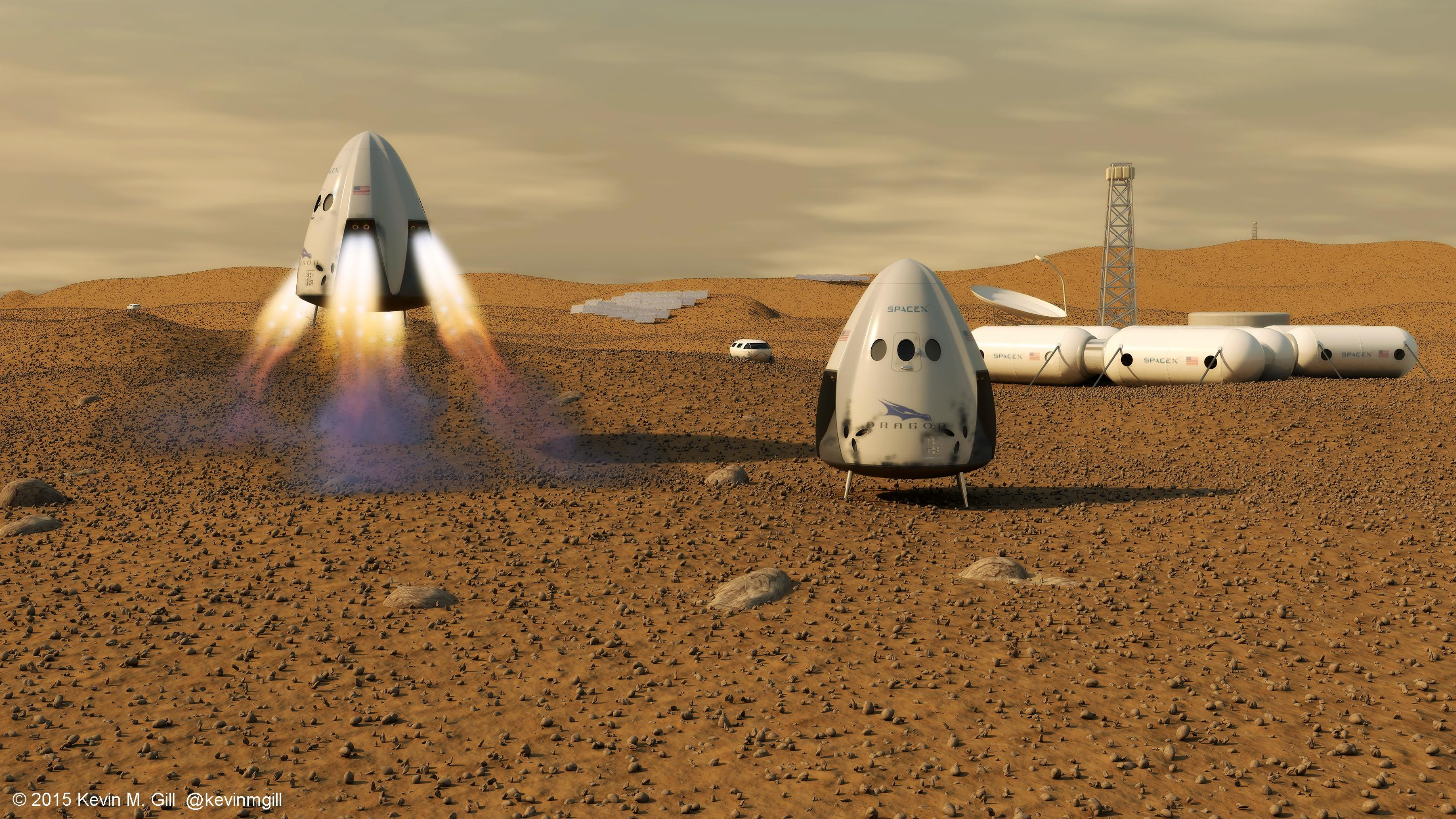


Insight



Mars 2020







GRACIAS



THANKS