PH20104 Planets and Exoplanets

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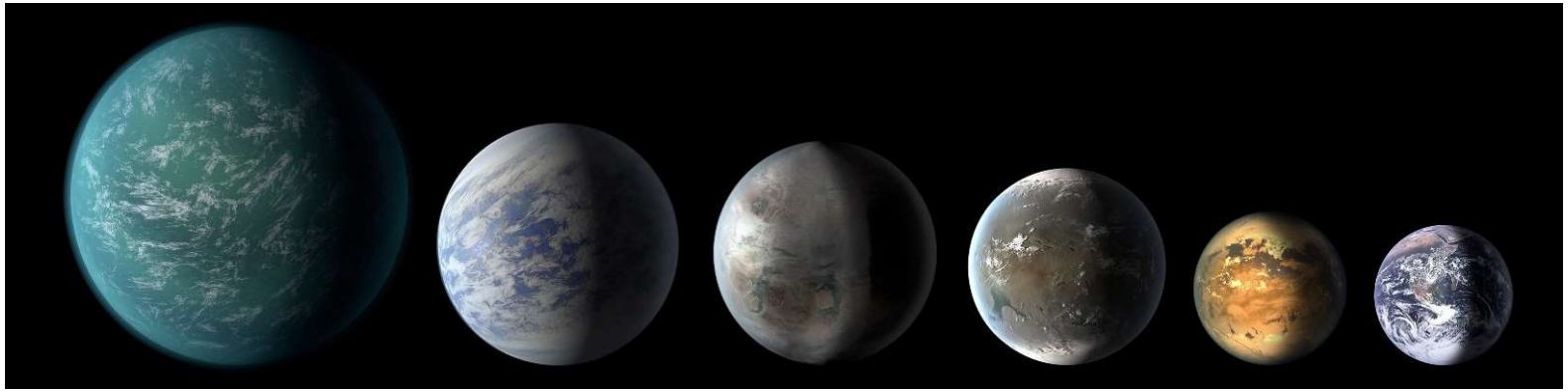


CSAOS
Centre for Space, Atmospheric & Oceanic Science

UNIVERSITY OF BATH

Week #	Tuesday 10:15-11:05	Thursday 11:15-12:05	Friday 10:15-11:05
	4E3.10	8W3.22	5W2.3
19	8th February Lecture	15th February Lecture	11th February Lecture
20	15th February Lecture	17th February Lecture	18th February Lecture
21	22nd February Lecture	24th February Lecture	25th February PC#1, group A
22	1st March Lecture	3rd March Lecture	4th March PC#1, group B
23	8th March Lecture	10th March Lecture	11th March PC #2, group A
24	15th March Lecture	17th March Lecture	18th March PC#2, group B
25	22nd March Revision Lecture	24th March **"Planets" exam workshop**	25th March Office hour
26	29th March Lecture	31st March Lecture	1st April Lecture
27	5th April Lecture	7th April Lecture	8th April Lecture
Easter Vacation	12th April	14th April	15th April
Easter Vacation	19th April	21st April	22nd April
30	26th April PC#3, group A	28th April PC#3, group B	29th April Office hour
31	3rd May Revision Lecture	5th May **"Exoplanets" exam workshop**	6th May Office hour

PB

GM

Sample exam on Moodle – Past exams on Library webpage

Revision "checklist" + workshop at the end of each part of the unit.

What this unit is about

Present the latest discoveries in Planetary Physics and explain the science

Show how all fields of Physics combine to make these discoveries

Introduce the key tools used in the study of planets and exoplanets

Summarise current scientific challenges

> *"If you're teaching today what you were teaching 5 years ago, either the field is dead or you are"*

(Noam Chomsky, interview to New Scientist, 17 March 2012)

What this unit is not about

Encyclopaedic description of each and every technique

Last-minute developments, especially if not relevant or not validated

Long demonstrations of key equations: they can be found in textbooks

Long presentations of historical developments: we will focus on current science

Unit outline

1. Taking Stock – A grand tour of the Solar System

2. Measuring the Solar System – Traditional and new techniques

3. Planetary Missions – Design, from orbital mechanics to science

4. Radar Mapping– Basics of radar scattering, applications to planetary imaging

5. Atmospheric processes

6. Planetary magnetospheres

Revisions + exam workshop

Exoplanets – Introduction

…

1. Taking Stock

Topic 1a: Rocky planets

Mercury

Venus

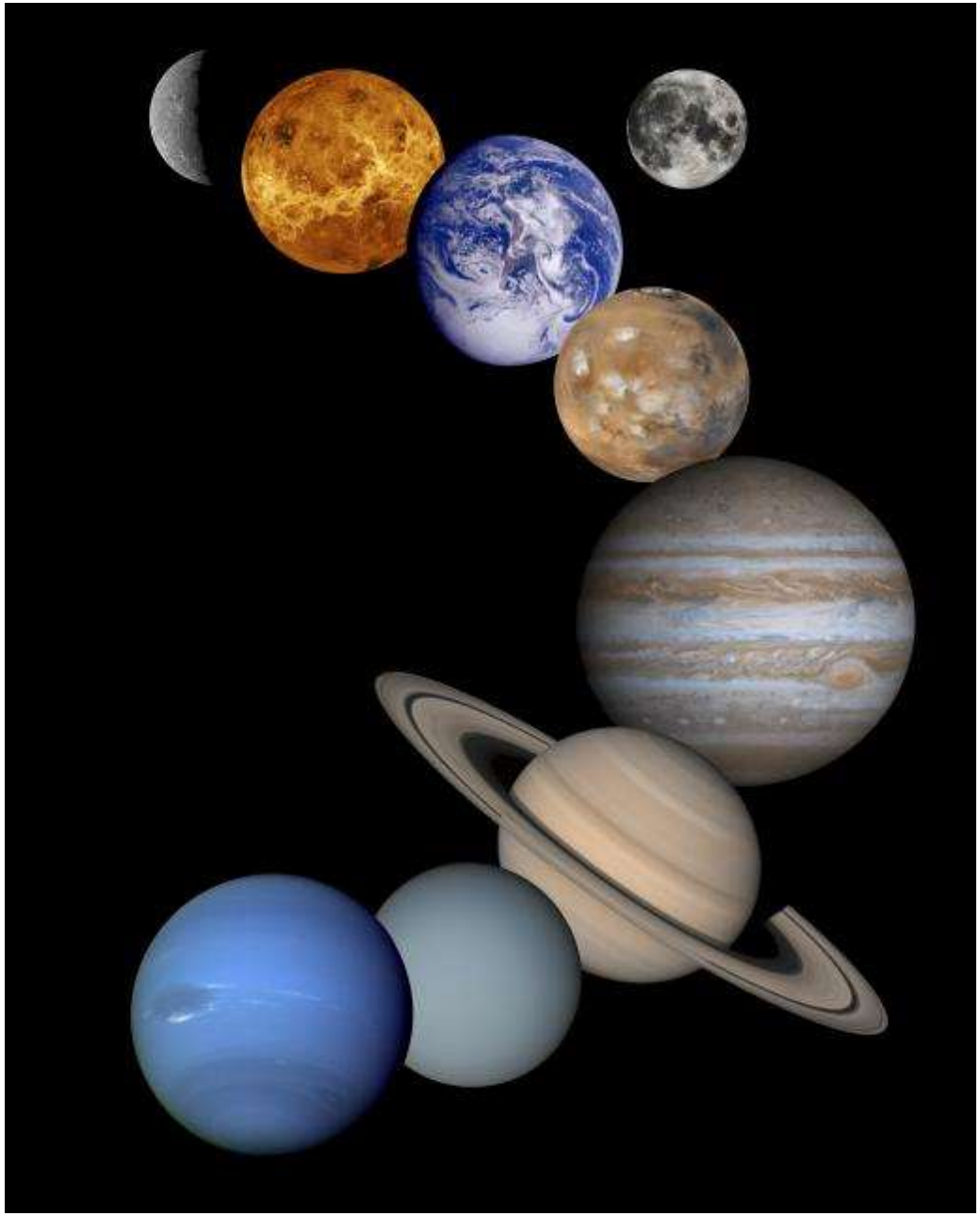
Earth

Moon

Mars

Not examinable

The Solar System



Large – Mostly rocks and gas

Sun	1,390,000 km diameter
Mercury	4,879 km
Venus	12,104 km
Earth	12,756 km
+ Moon	3,475 km

146 million km from Sun (1 AU)

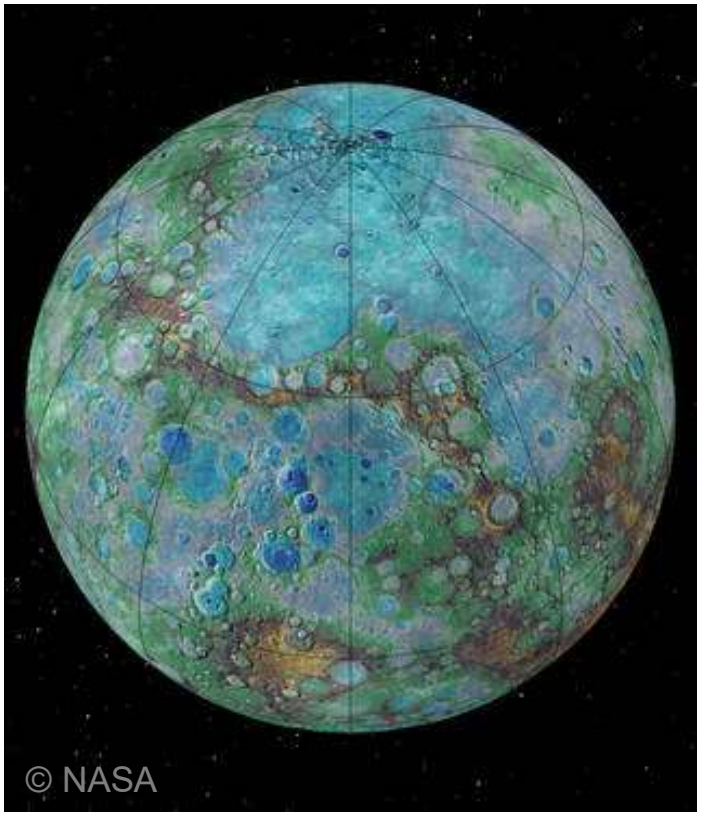
Mars	6,794 km
Jupiter	142,984 km
Saturn	120,536 km
Uranus	51,118 km
Neptune	49,528 km

4.5 billion km from Sun (30.07 AU)

… and Pluto …

Mercury

blue deeper
green higher



Smallest planet (a bit larger than the Moon)

58 million km (0.39 AU) from Sun

Orbits the Sun in 88 (Earth) days
1 Mercury day = 59 Earth days

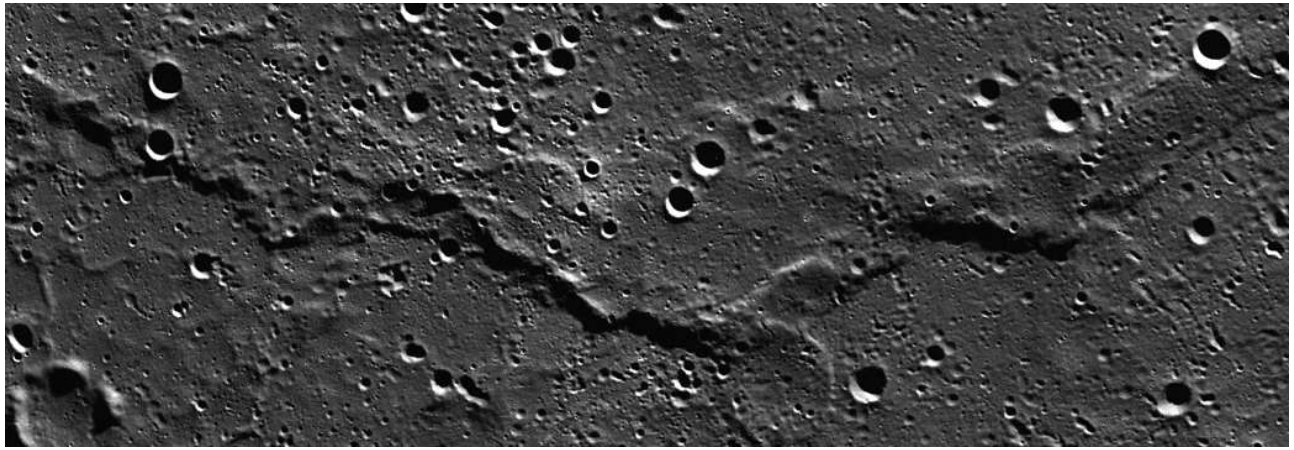
Thin atmosphere: O_2, Na, H_2, He, K
ejected from surface by solar wind

Surface: 430°C (day) to -180°C (night)

Only 2 missions: Mariner 10, 1974-75
MESSENGER, 2011

Rocky surface – Traces of volcanism and tectonics – Impact craters

old surface



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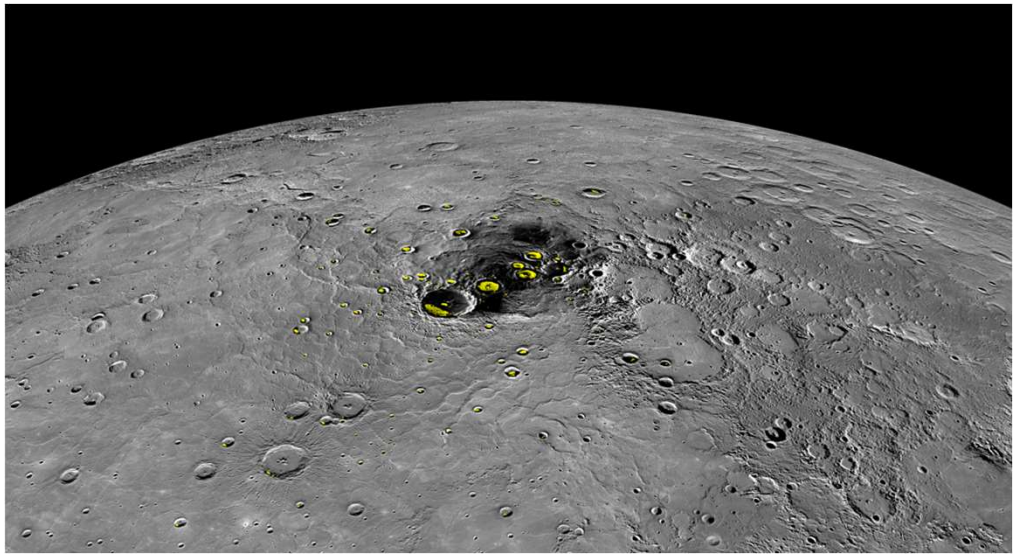
Mercury



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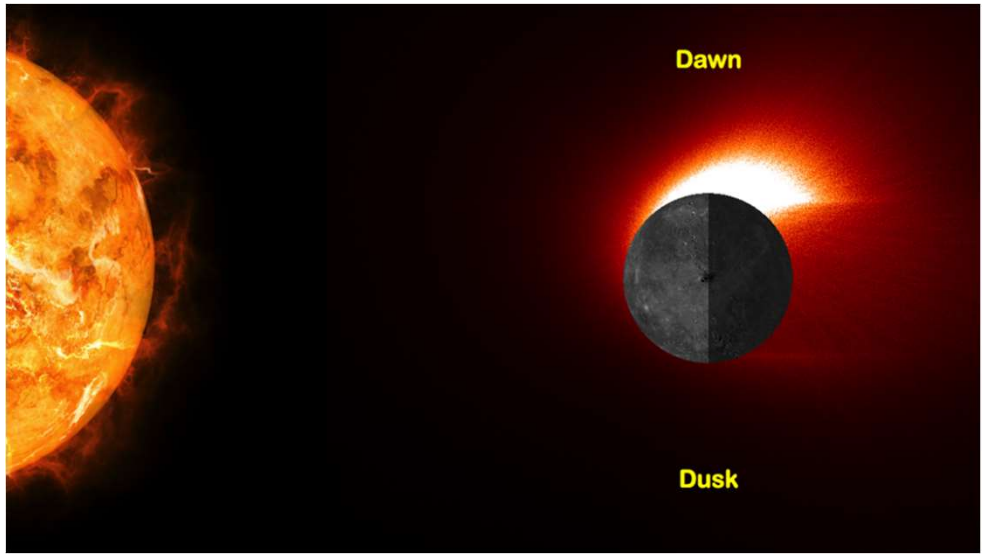


https://messenger.jhuapl.edu/

Presence of water ice at the poles
(detected with Earth radiotelescope and orbiting spectrometers)

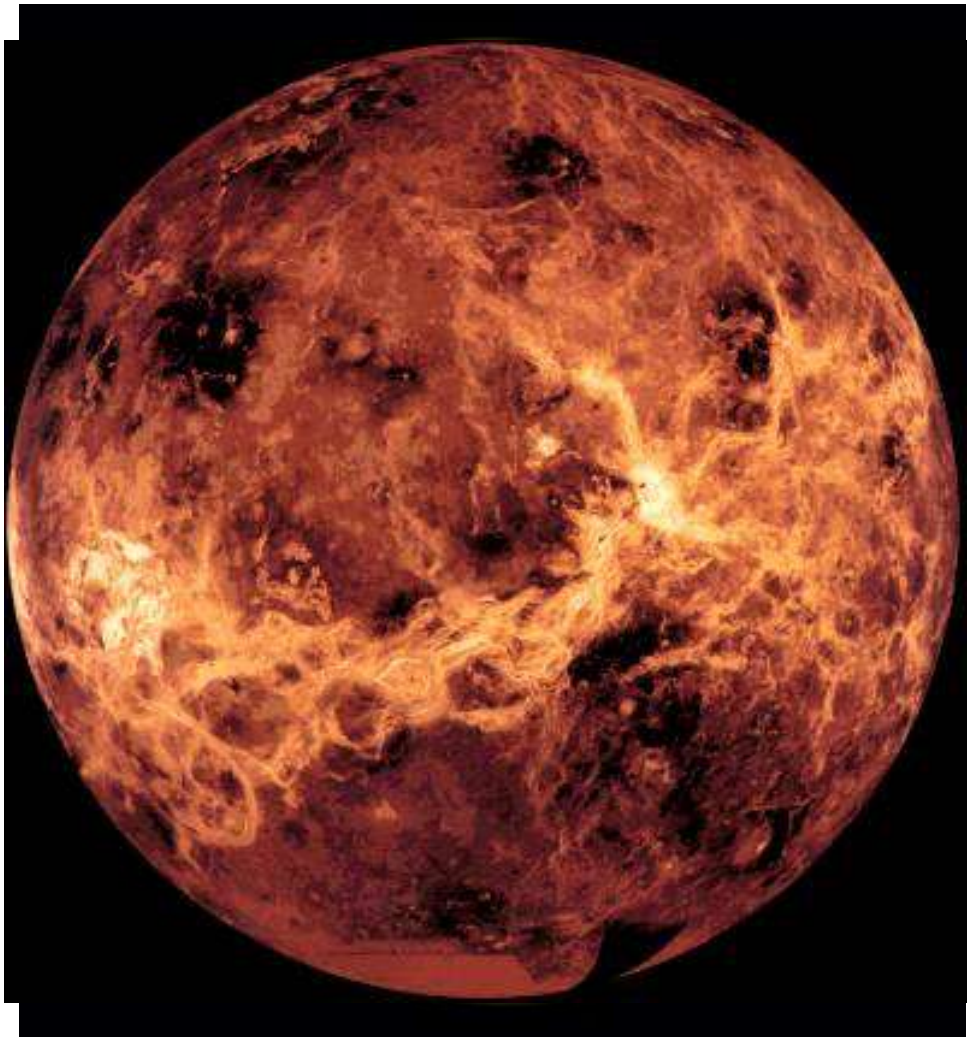
Calcium exosphere?
Single source region – Why? How?

Magnetic field (1% Earth's) - Interacts with solar wind's magnetism

Bepi-Colombo (ESA) 2-spacecraft mission: launched 2018 (arrival 2025)
Some of its aims:

Is core liquid or solid?
Still active tectonically?
No iron at surface?
Testing general relativity (proximity to Sun)

Venus – Earth's evil twin?



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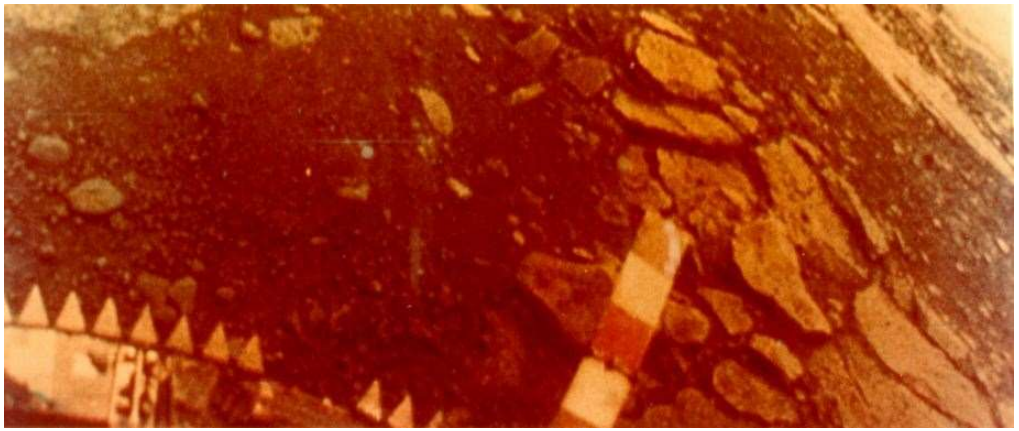


USSR Academy of Sciences

Earth size – 0.7 AU from Sun

40+ missions (recently: Magellan, Venus Express and Akatsuki)

Orbits the Sun in 225 Earth days

1 Venus day = 243 Earth days

Retrograde spin

Thick atmosphere: CO_2, clouds of sulfuric acid

Greenhouse effect

Surface: 490 ºC – Pressure: 92 bars (very high)

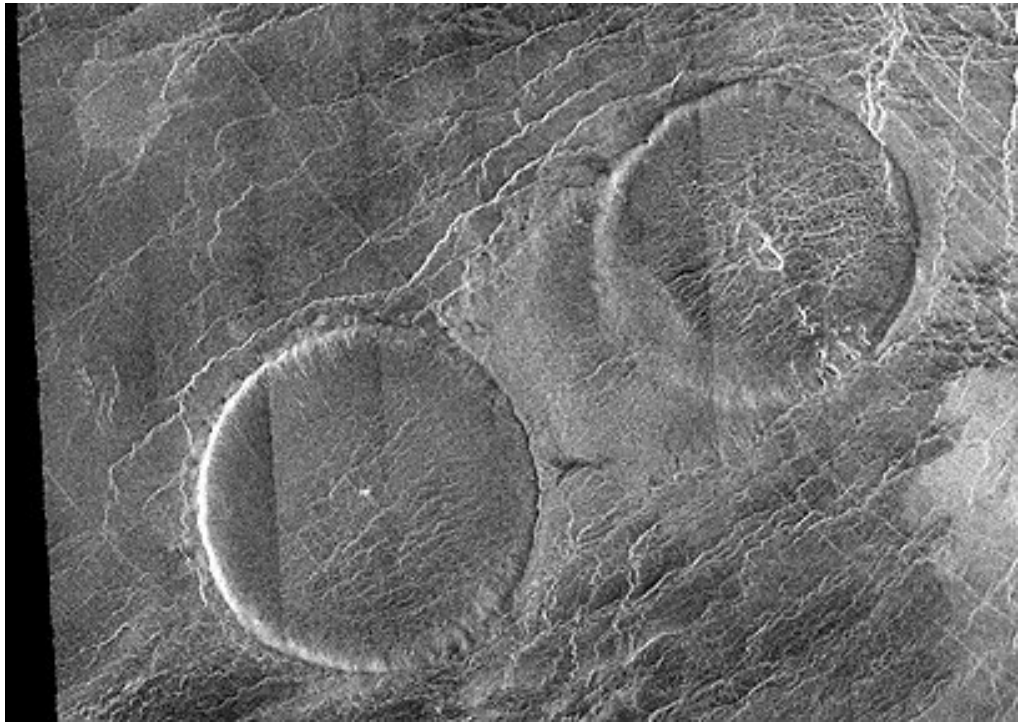
Rocky surface – Volcanism and tectonics – Impact craters

volcanic rocks

↑ volcanos everywhere

active?

Venus



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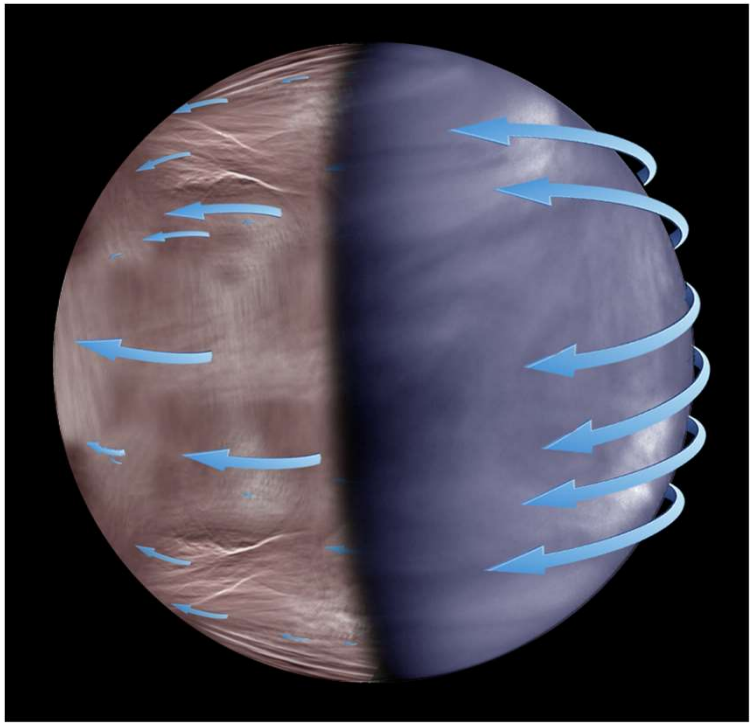
Magellan radar image



JAXA / ESA / J. Peralta, JAXA / R. Hueso, UPV/EHU

Venus Express / Akatsuki
3.8 μm (IR) / 360 nm (UVI)

Open scientific questions:

Very thick and dynamic atmosphere: wind speeds > 400 km/h at surface

Equatorial jets and high-altitude winds?

Origin and significance of persistent atmospheric structures near mountains?

Is it still volcanically active? What about phosphine (PH_3) in the atmosphere?

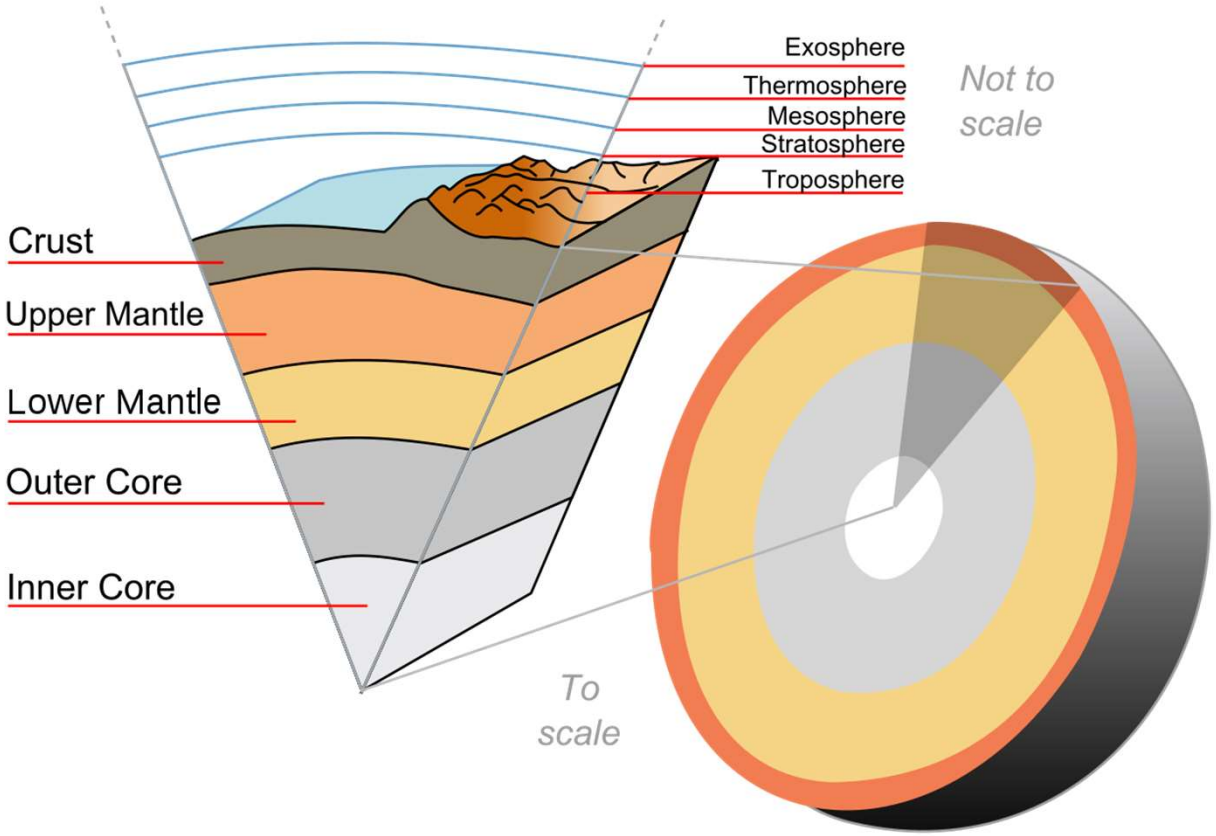
Age of last resurfacing: 300 – 500 My? Dates from impact craters and samples?

Earth and the Moon

Close companionship (384,402 km average distance) – Same age? (4.53 billion years)

The **only** planetary bodies directly sampled with *human **and** robotic* presence.

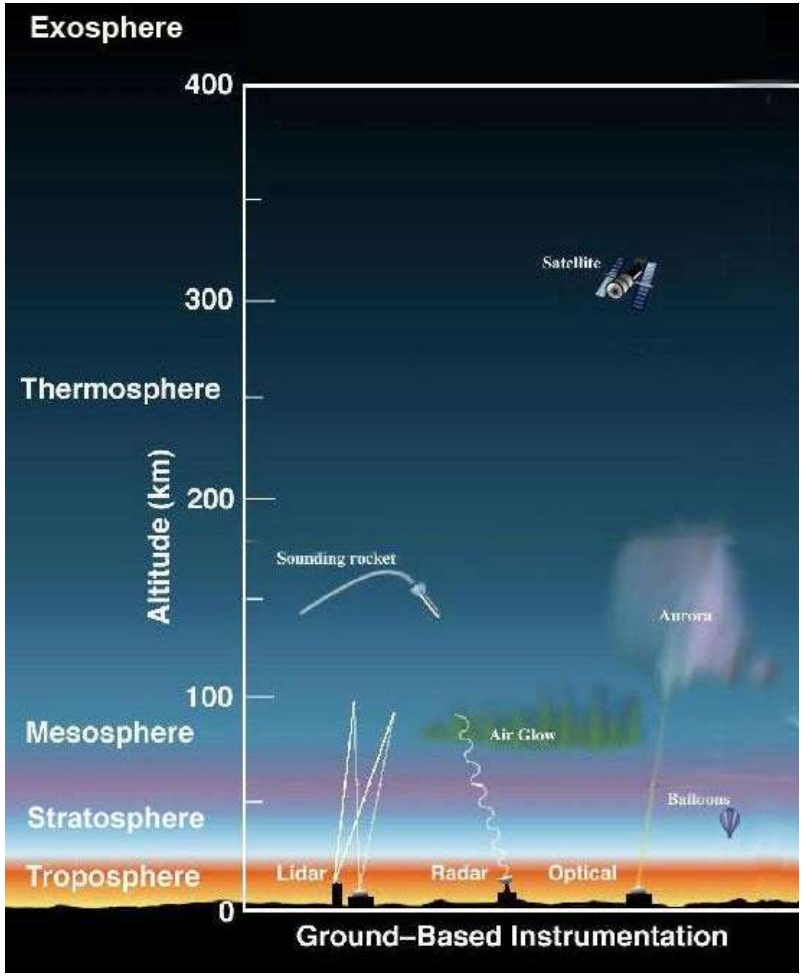
Earth



1 A.U. from Sun – *Differentiated* planet with rocky surface and >71% water cover

Complex surface and interior processes

Earth



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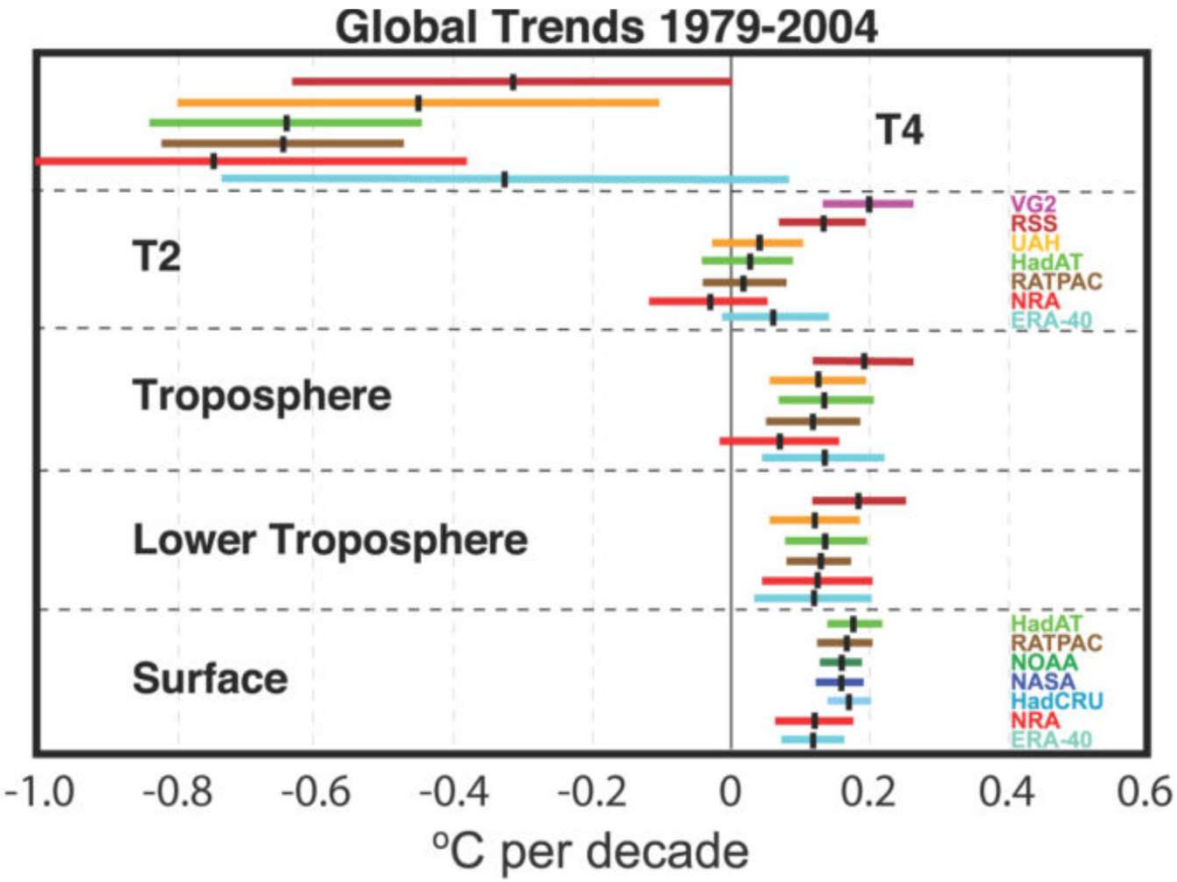

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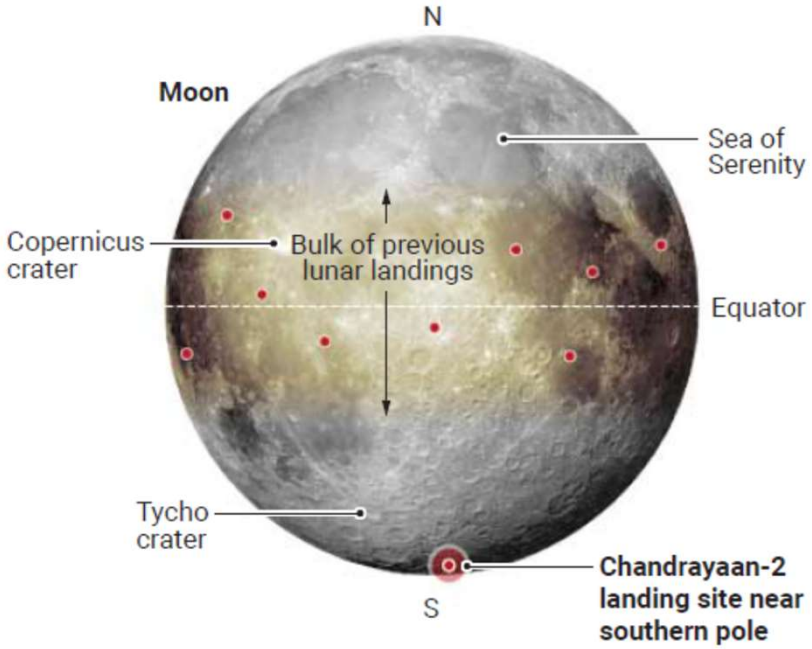
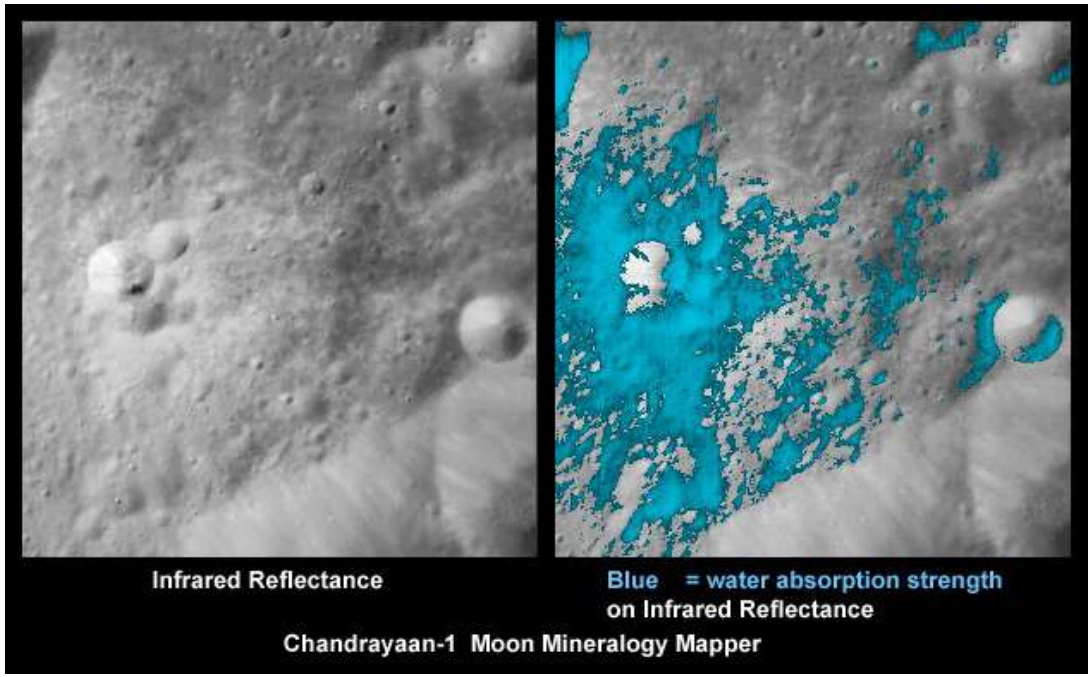
Atmosphere: 78% N_2, 21% O_2, 1% others

Complex and variable atmosphere – Undergoing significant changes *(including in the oceans)*

Variable magnetosphere

Moon





1,737 km diameter – Differentiated and same age as Earth?

12 "Moon-walkers", 100+ robotic missions

Tenuous atmosphere: He, Ar, Ne, CH_3, CH_4, CO_2 + sodium, potassium

Complex and variable atmosphere – Variable magnetosphere

From चन्द्रयान to 玉兔

Chandrayaan 3 (India): launch 2021, repeat of Chandrayaan 2 (2019)

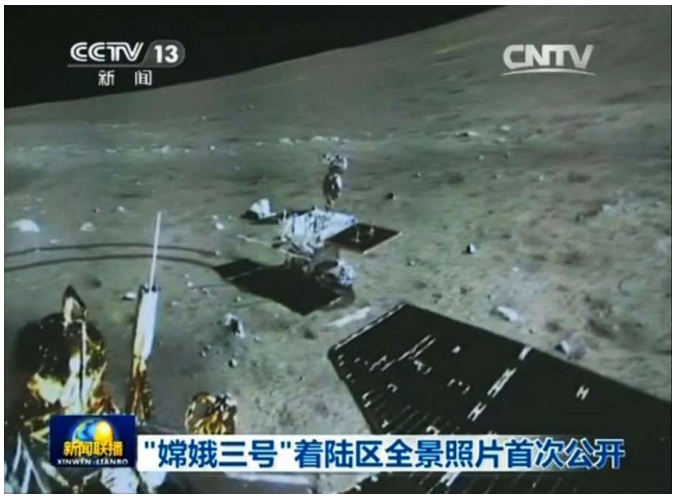
Orbiter on far side
Water mapper

Lander and rover (600 km from south pole)
Langmuir probe: plasma and electric charge in regolith
Seismometer for moonquakes

More missions in next decade – ~~Google Lunar X Prize (March 2018)~~

Far-side observatory? South Pole Base? Sample return to Earth (Chang'e 5): December 2020

Jade Rabbit missions (China)
2014



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Chang'e 4 2019

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Still many questions about:

the formation of the Moon,

its mineral deposits,

and the presence of water …

Artemis Gateway

Mars – Next stop ?

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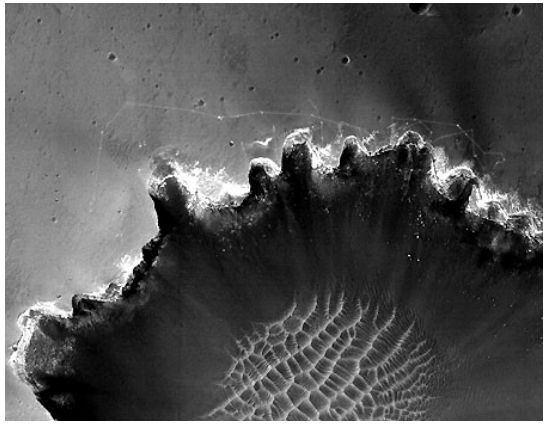

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½ size of Earth – 1.5 AU from Sun
Many robotic expeditions, some on-going

Orbits the Sun in 687 Earth days
1 Mars day = 24.6 hours

Thin atmosphere: mostly CO_2, N_2, Ar
Complex atmosphere (winds, dust storms)

Surface: -89 ºC to -31 ºC – 9 mb pressure

Rocky planet – Strong weather (planet-scale storms) – Polar caps
Large volcanoes – Flat plains

No (current) magnetosphere

Mars

© NASA

Open questions:

Free-flowing water?

Deposits and habitability

Atmosphere circulation
Methane anomaly

Structure of the core

NASA Mars Reconnaissance Orbiter (MRO) – 50,000 orbits in Oct. 2017

ExoMars 2016 Trace Gas Orbiter (since Oct. 2016) – Lander Schiaparelli lost on descent

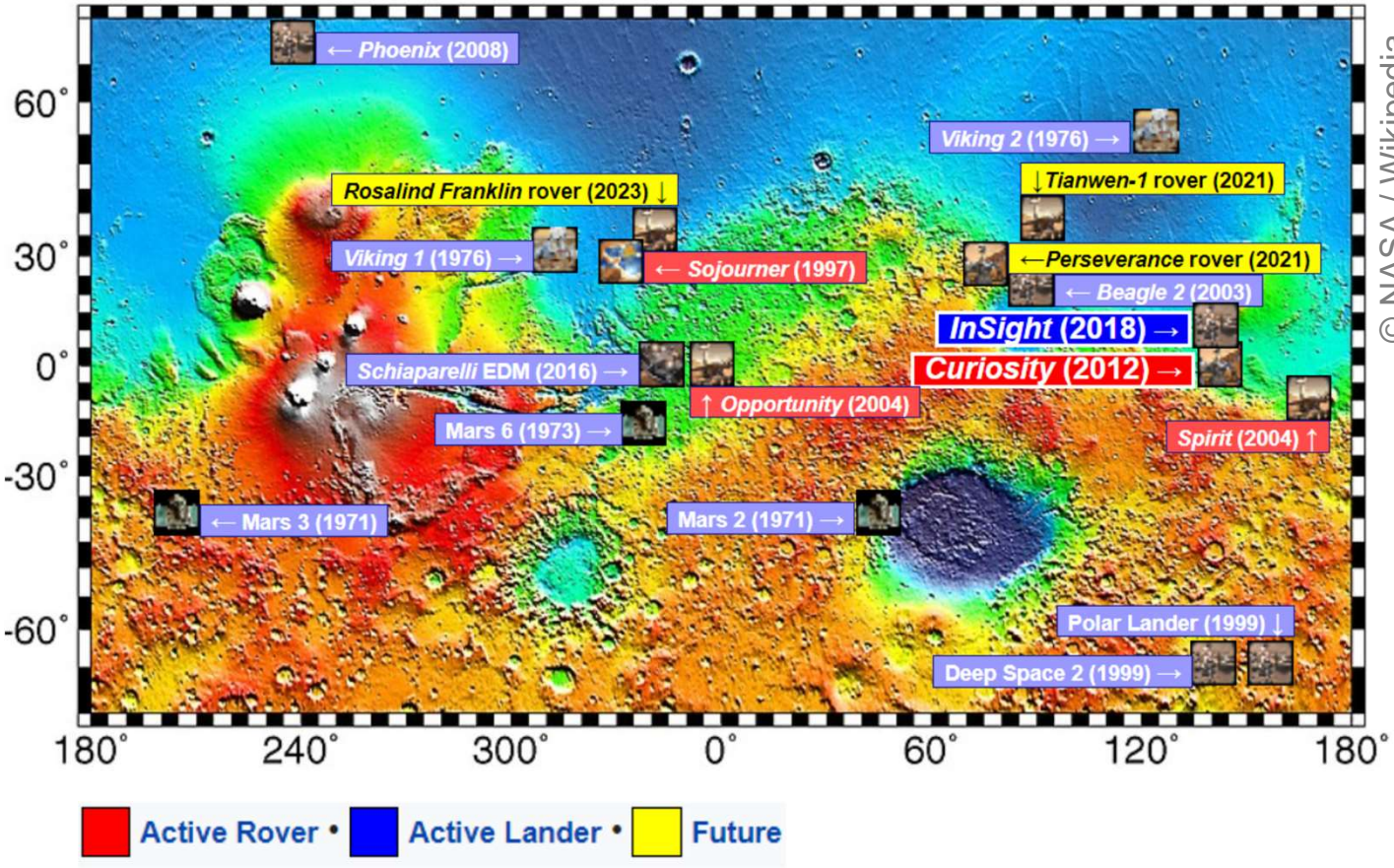
Search for methane and other trace atmospheric gases
(signatures of active biological or geological processes)

NASA InSight (Nov. 2018) – Sub-surface mapping (heat flows and marsquakes)

ESA ExoMars Rover (launch Summer 2022) – and more missions planned …

Tianwen-1 (China) – Orbit insertion scheduled 10 Feb. 2021 – Rover landing in July

Mars missions in 2021



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Perseverance (NASA)
Landing 18 Feb. 2021

Rosalind Franklin/ExoMars
(ESA/Roscosmos)
To be launched 2022
Landing June 2023

中国行星探测
mars

Tianwen-1 (China)
Landing 10 Feb. 2021

مشروع الإمارات لاستكشاف المريخ ✦ EMIRATES MARS MISSION
مسبار الأمل
HOPE

Hope (مسبار الأمل) (UAE)
Orbit insertion 9 Feb. 2021

Rocky planets - Summary

Planetary bodies within the frost line

(point between the orbits of Mars and Jupiter where the material is cool enough for volatile icy compounds to remain solid)

All bodies have been mapped and explored:
Only manned missions on Earth and Moon.
Only samples from Earth and Moon.

Great variety: sizes / surfaces
atmospheres
magnetospheres

Water present on:
Mercury
Earth + Moon
Mars

New discoveries still coming in …
Solar system formation: still debated