

Midterm Topics

Nuclear particles: *protons, neutrons, electrons, alpha particles, neutrinos.*

Nuclear fusion

Astronomers: *antiquity, renaissance, modern era (late 1800s to present).*

Astrolabe –ancient instrument

Refractive Telescopes

Reflecting Telescopes: *Single mirror, segmented, liquid, interferometric, space, radio.*

Diffraction & angular resolution

Adaptive optics, CCD cameras

Space probes & instruments

Structure of the Solar System

Density of planets

Solar nebula hypothesis

Density of materials: *liquids, ices, rocks, metals.*

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Differentiation, planet structure
Planetesimals, frost line
Why do planet lie in orbital disk?

Radioactive dating: *half life, exp. decay.*
Crater counting dating

Earth's structure
Element abundances
Tectonic plates
Magnetosphere
Aurora
Atmosphere: structure, composition
Greenhouse effect
Temperature of the Earth, ice core dating

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Blackbody radiation
Light pressure
Photon energy, photon momentum
Doppler shift

Today's Topics

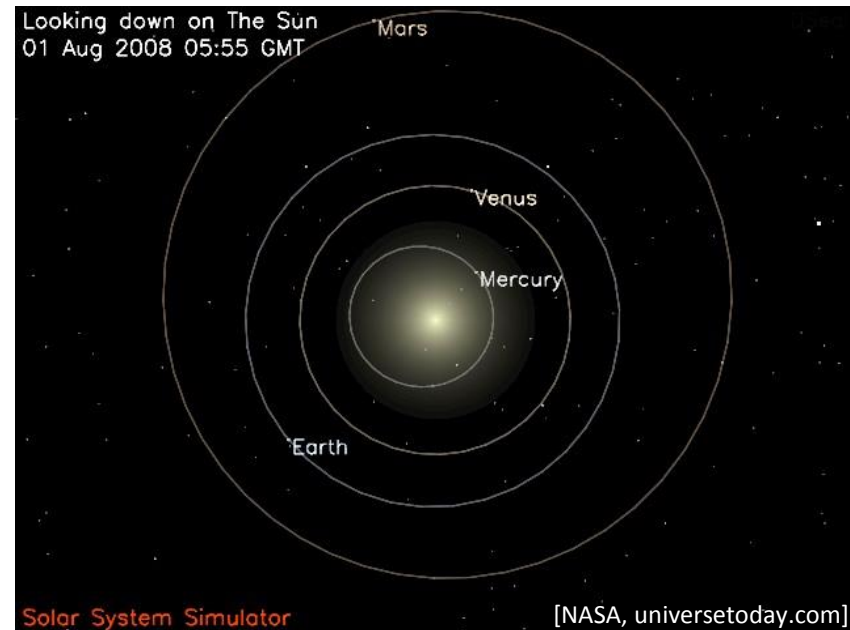
Friday, October 18, 2019 (Week 7, lecture 20) – Chapters 10, 11, 12.

Mars

1. Basic properties
2. Moons
3. Surface features
4. Internal structure
5. Atmosphere
6. Water

Mars

- Fourth planet from Sun.
- Second closest planet to Earth.
- 687 day orbit, somewhat eccentric $\epsilon = 0.093$.
- Receives ~40 % of the sunlight that Earth does, i.e. 60 % less sunlight than Earth.
- Martian day is 24.6 hrs, very similar to Earth's.



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- Second closest planet to Earth.
- 687 day orbit, somewhat eccentric $\epsilon = 0.093$.
- Receives $\sim 40\%$ of the sunlight that Earth does, i.e. 60% less sunlight than Earth.
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➤ Physical features

→ $R_{\text{Mars}} = 53\%$ of Earth's.

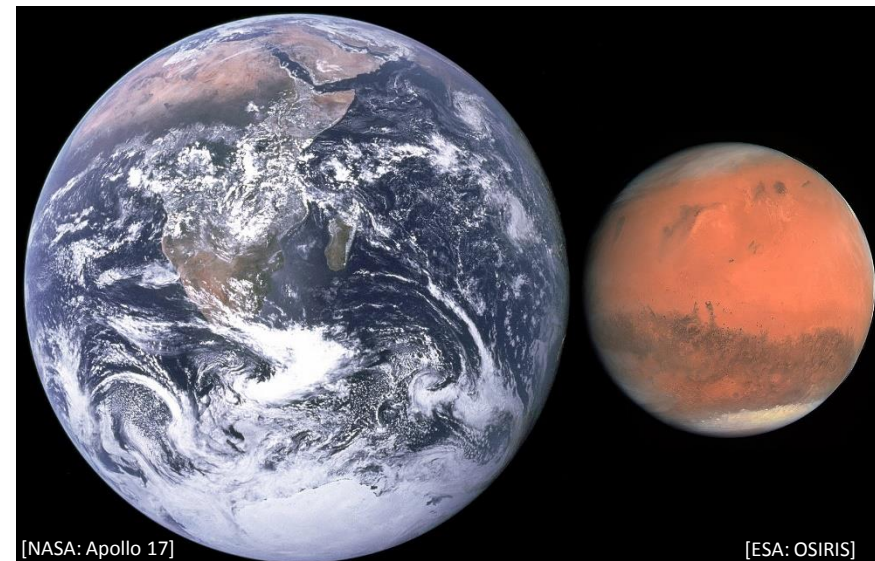
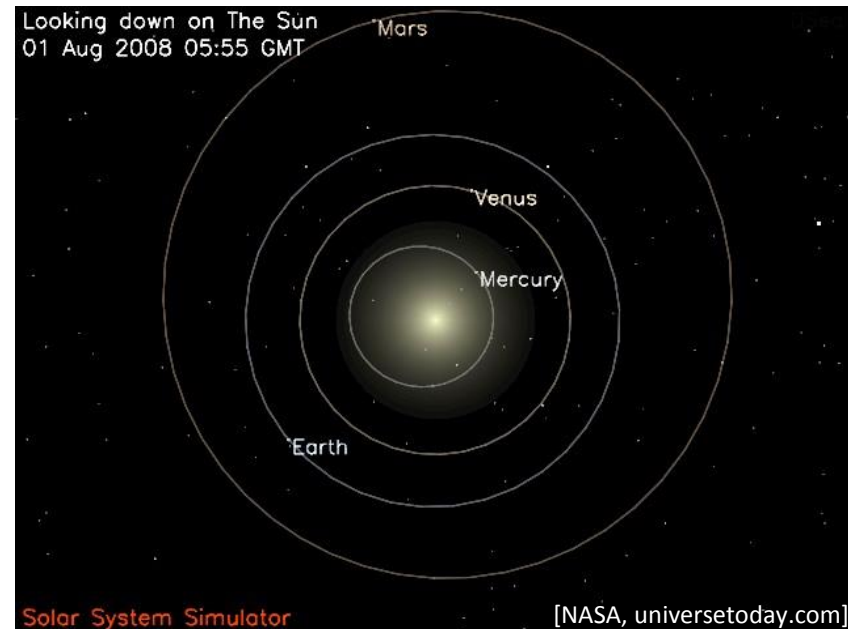
→ $M_{\text{Mars}} = 11\%$ of Earth's.

→ $g_{\text{Mars}} = 38\%$ of Earth's.

→ Density: 3.9 g/cm^3 .

➤ Temperature range: -143° to 35° C .

➤ No magnetosphere.



Martian Moons

Phobos & Deimos



Phobos, diameter \approx 22 km.
(11 hour orbit)



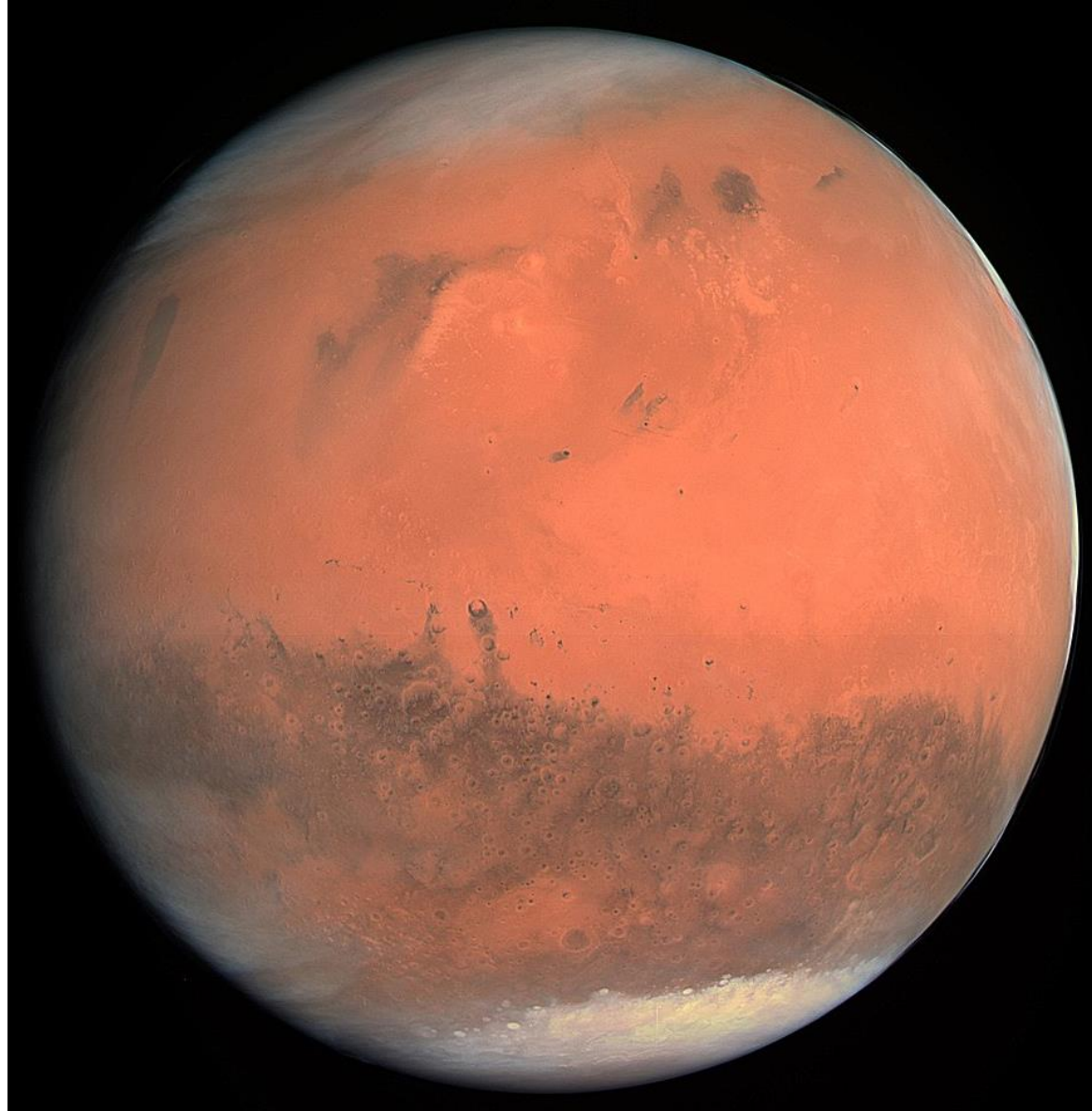
Deimos, diameter \approx 12 km.
(30 hour orbit)

Origin hypotheses: orbital capture of asteroids ... accretion after collision with Mars.

Mars: first glance

Data collection

- Visited by many landers (2 active).
- Several permanently orbiting spacecraft (6 active).
- The surface is clearly visible from space.



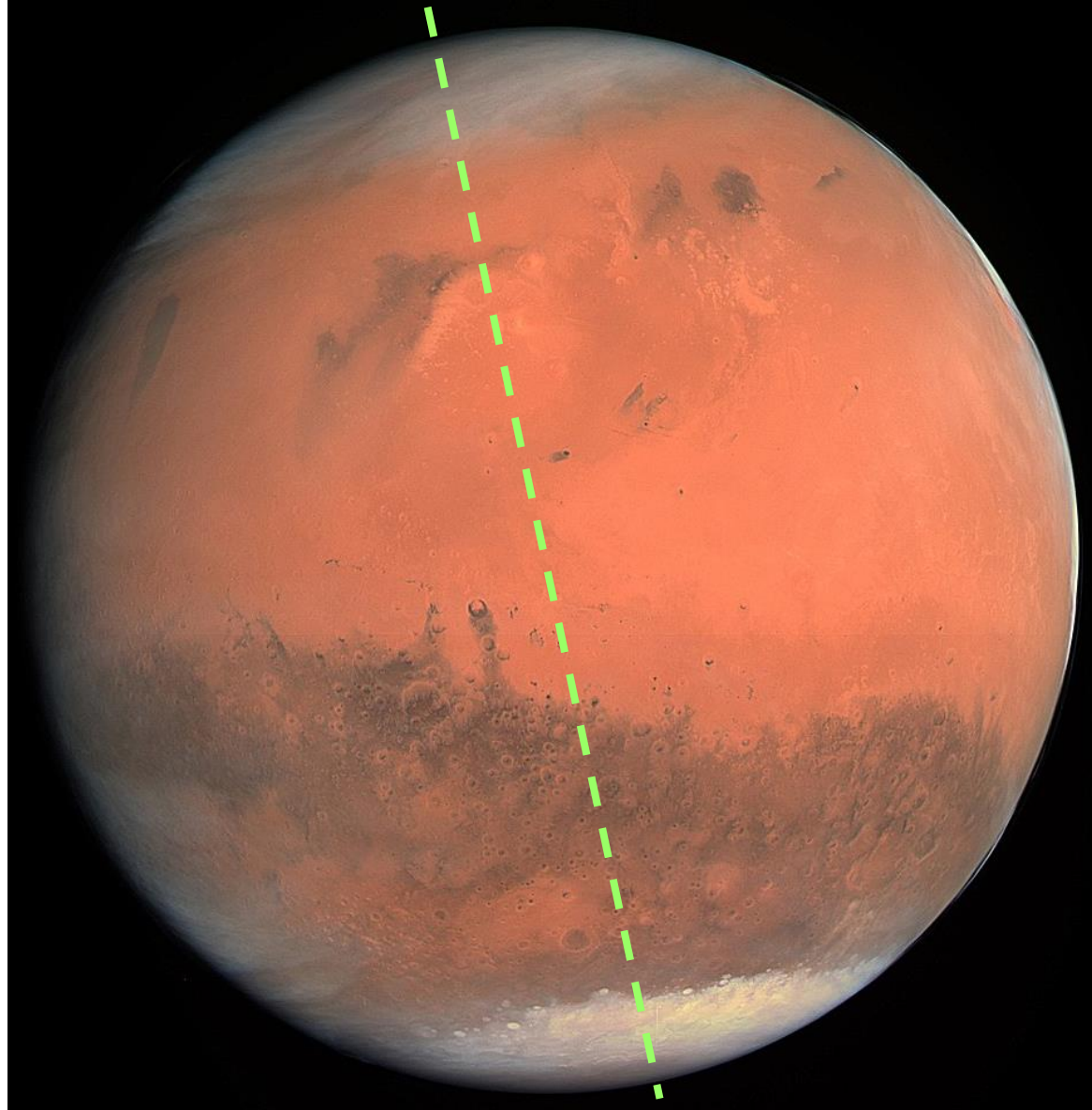
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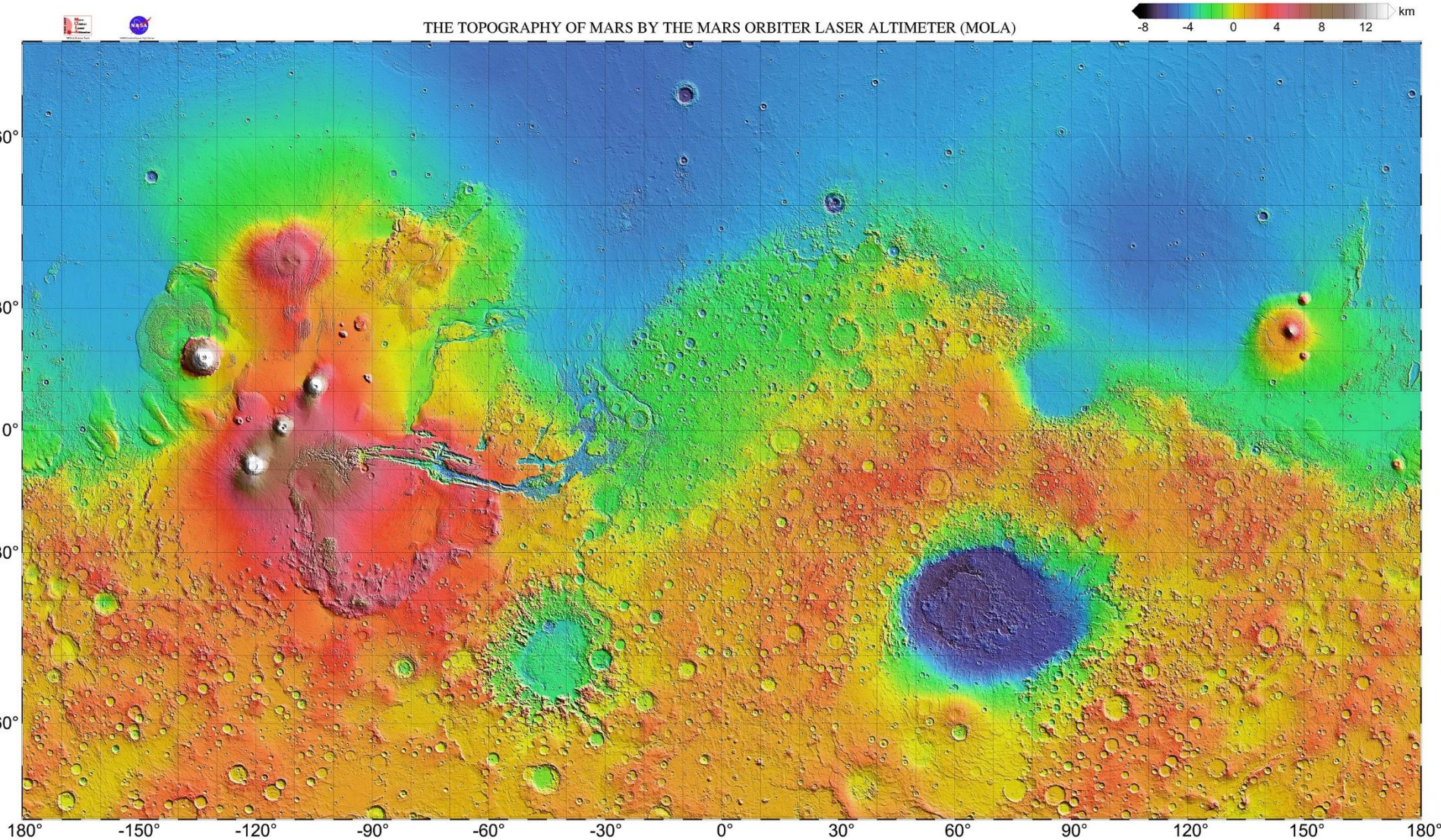
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Major surface features

- **Seasons:** rotation axis is at 25° (similar to Earth's 23°).
- Polar **ice caps** (CO_2 & H_2O).
- **North hemisphere** is smoother and 1-3 km lower.
- **South hemisphere** is bumpier, older, and 1-3 km higher.



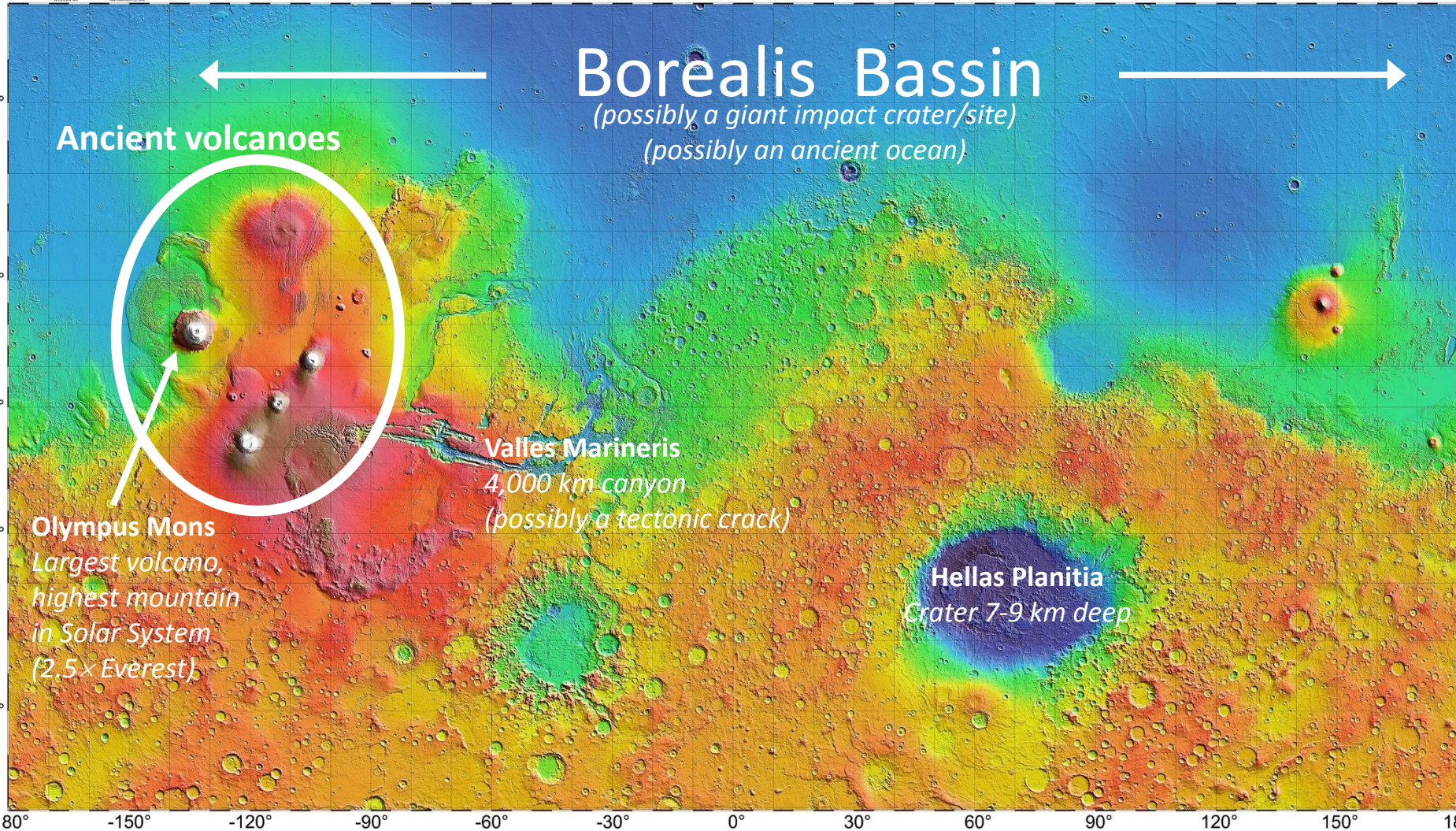
Mars: topology



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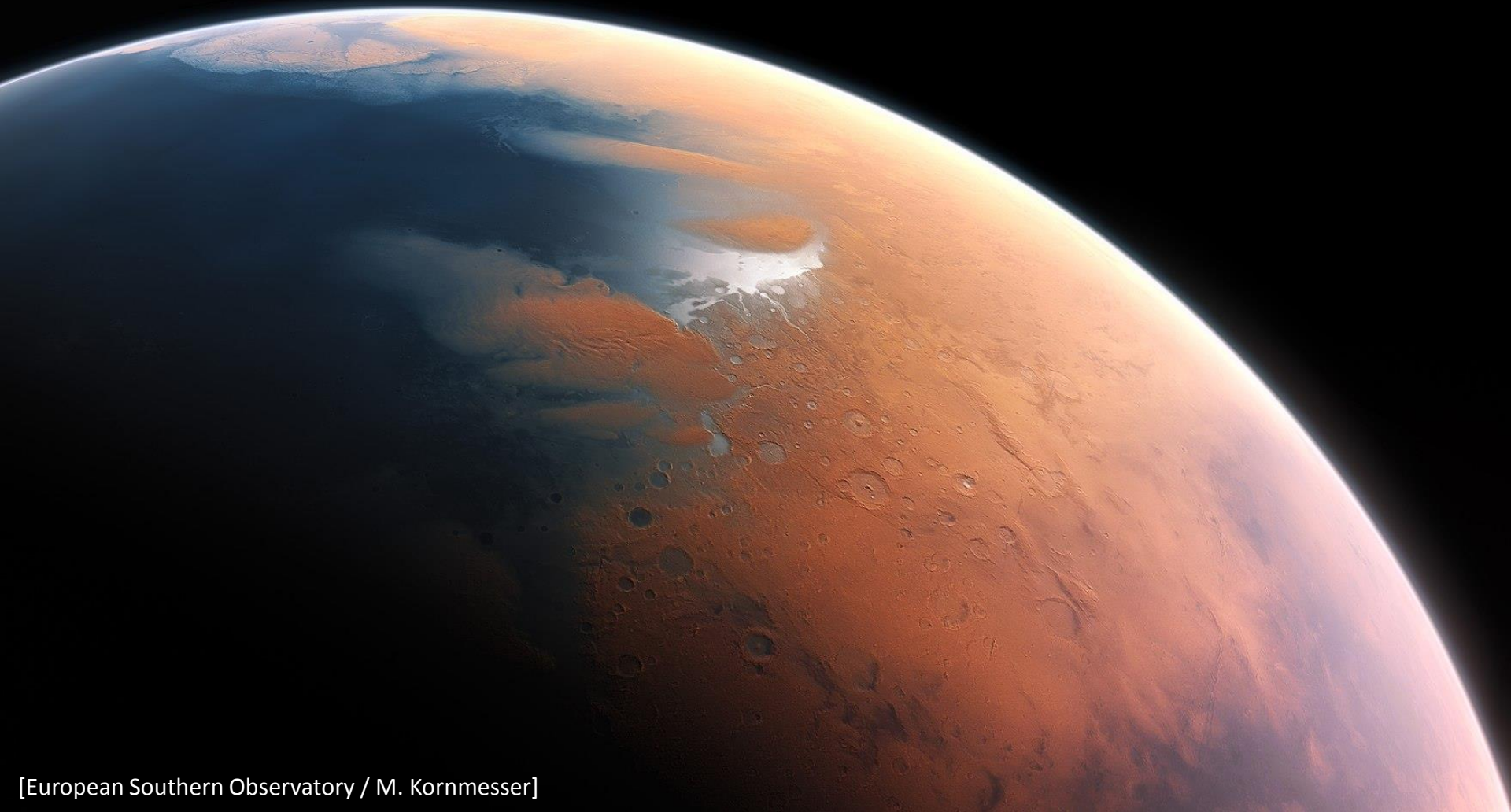


THE TOPOGRAPHY OF MARS BY THE MARS ORBITER LASER ALTIMETER (MOLA)



Mars: ancient ocean ?

Artist's depiction of a possible ancient ocean (water)
4 billion years ago.



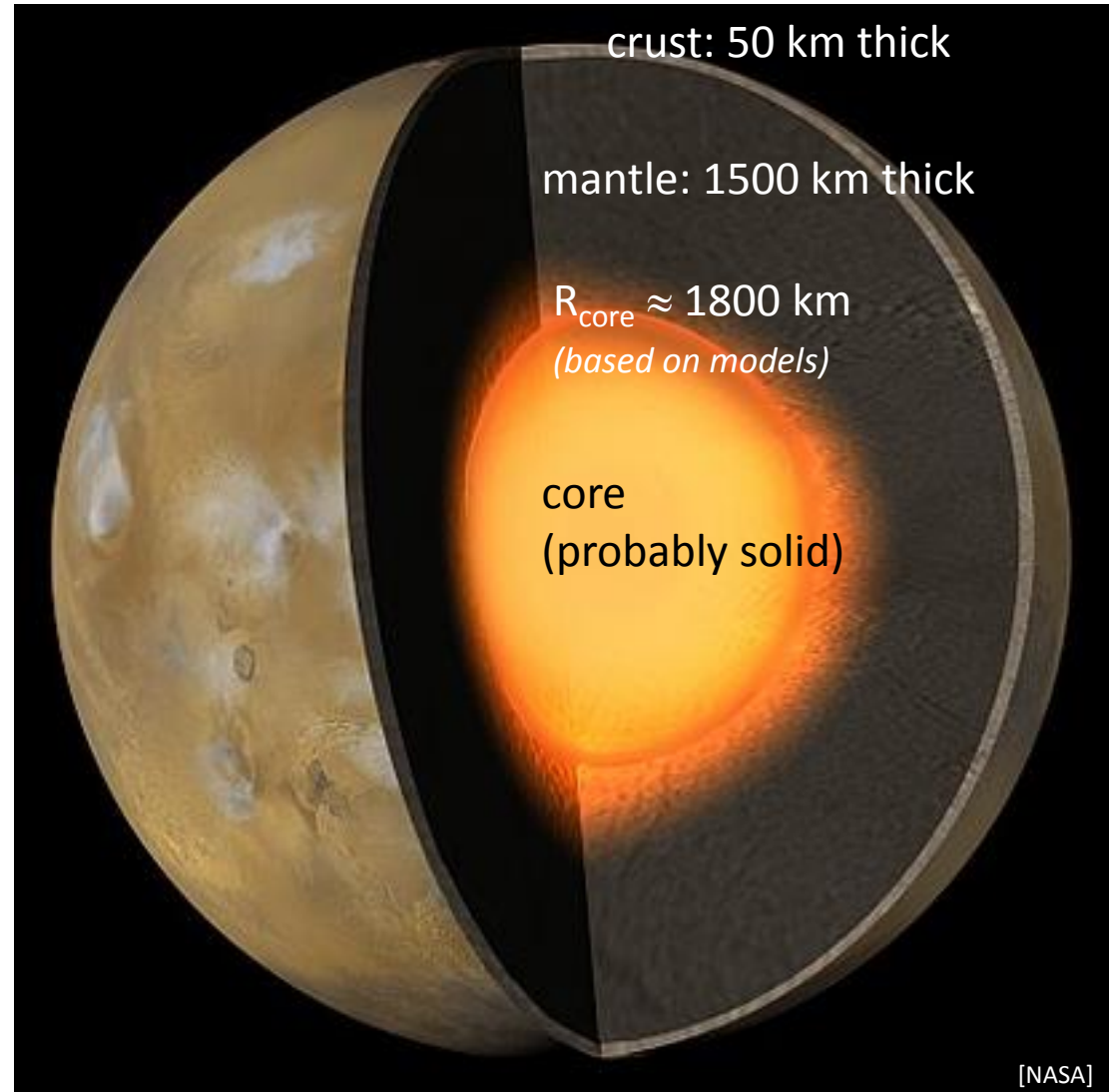
Mars: internal structure

Composition

Crust: Silicon, oxygen, iron, magnesium, calcium, potassium.

Mantle: Silicates.
(model based)

Core: Iron, nickel, and some sulfur.
(model based)



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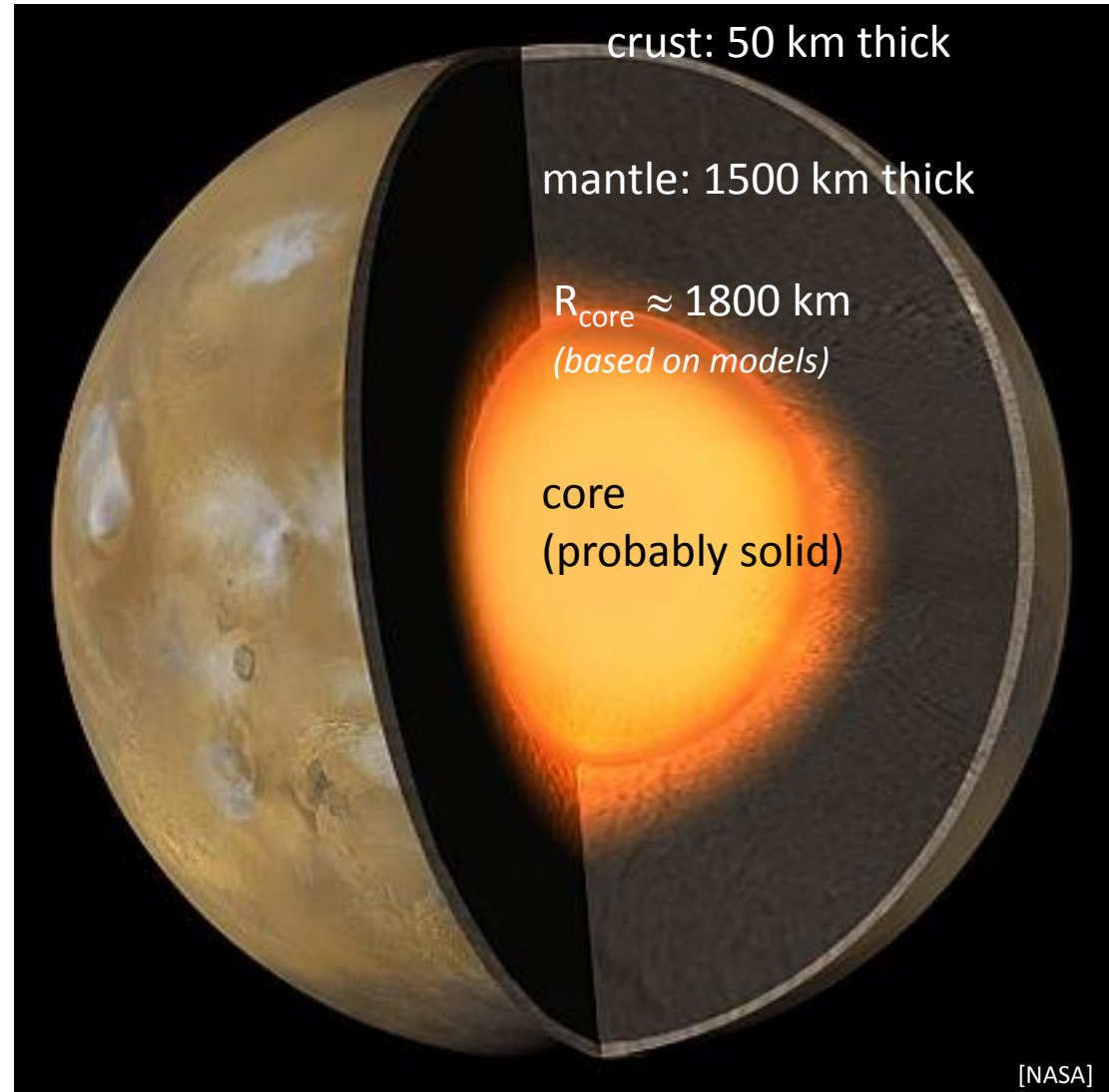
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Q: Why is Mars red-ish?

A: Martian soil has a lot of iron oxide dust in it (rust-like particles).

*This **dust** is often in the atmosphere as well.*



Martian sky with dust



[NASA:Pathfinder mission + sojourner]

Clear Martian Sky



[NASA: Curiosity rover, Gale crater]

Mars: global dust storms

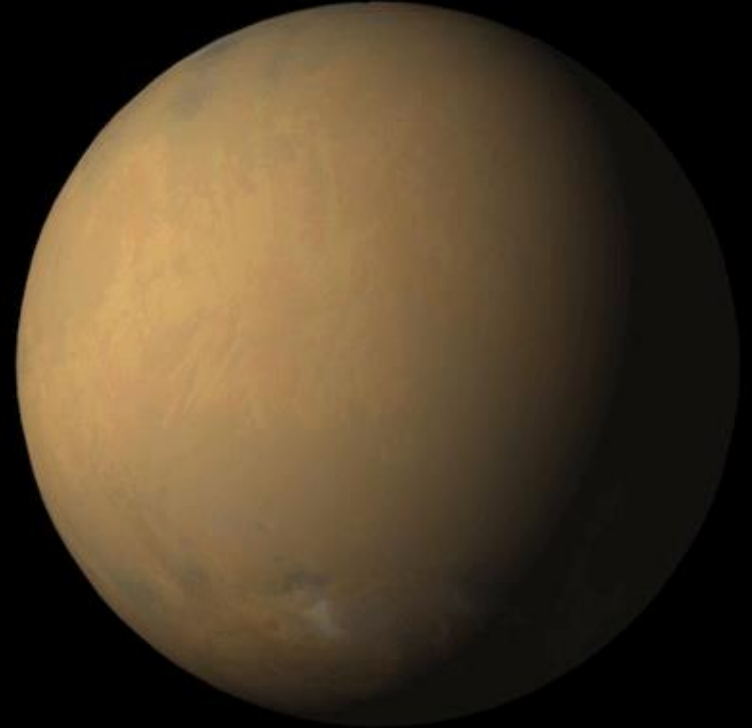
Mars has the biggest dust storms in the Solar System.

→ They can be planet-wide with winds up to 160 km/h.

clear sky



global dust storm



Martian Atmosphere

Pressure

Mars has a very dilute atmosphere.

→ Pressure is **0.6 %** of Earth's.

→ **Greenhouse effect is weak.**

Composition

Carbon dioxide (CO₂): 95.3 %

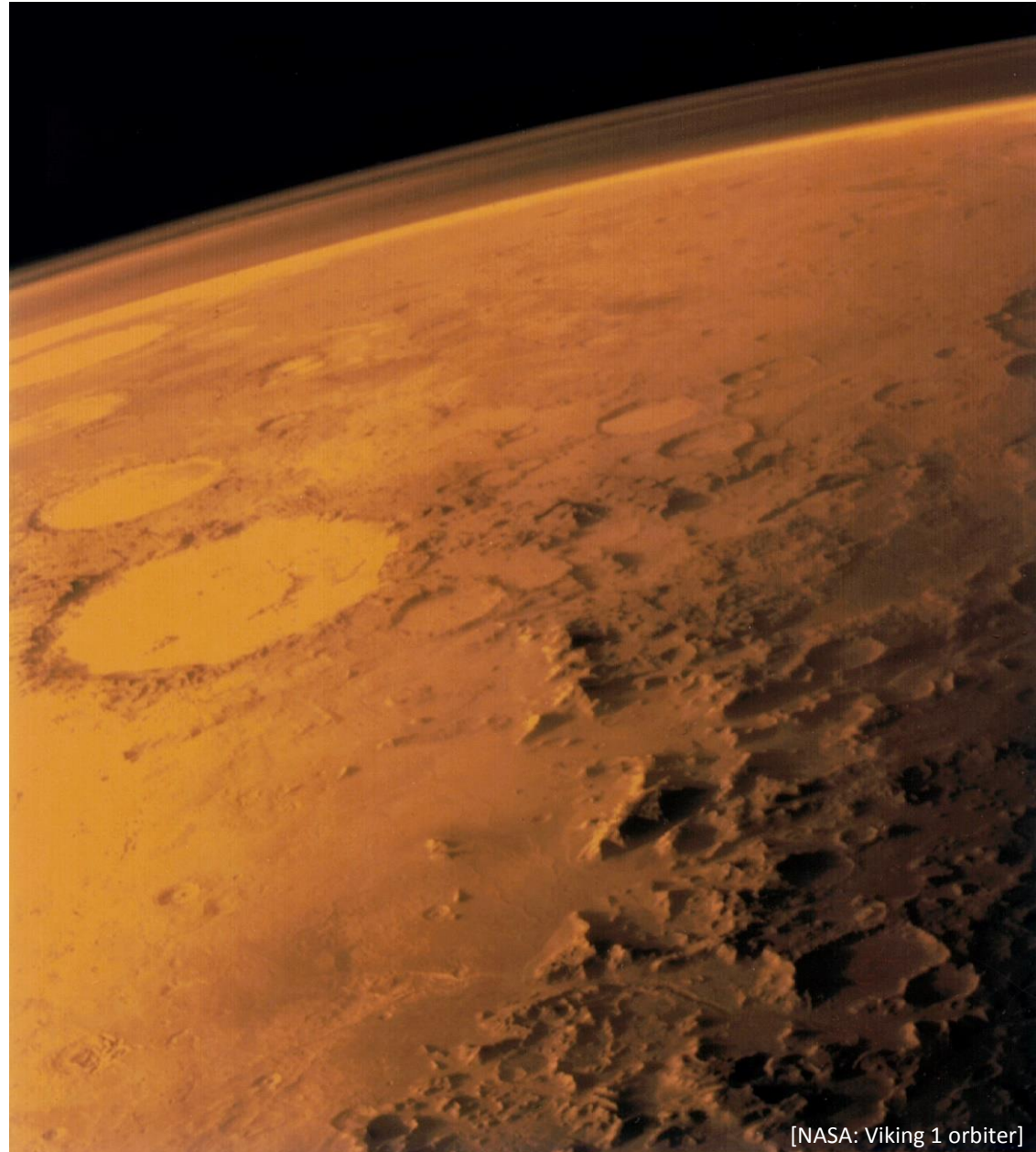
Nitrogen (N₂): 2.7 %

Argon (Ar): 1.6 %

Oxygen (O₂): 0.15 %

Water (H₂O): trace

(occasional water ice clouds)



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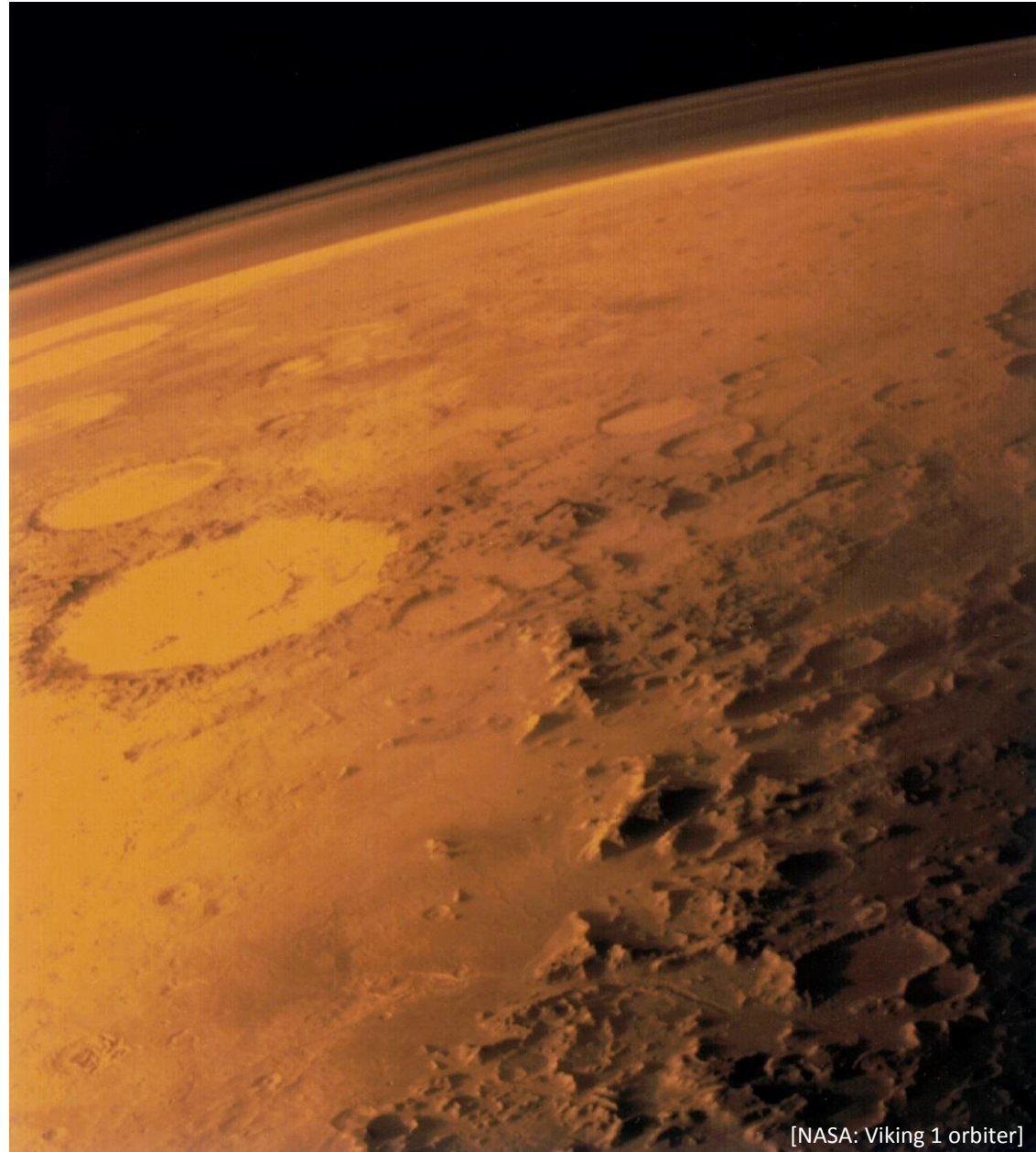
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Water in atmosphere

Water ice sublimates in low pressure atmosphere.

Note: Water vapor escapes Mars into space.



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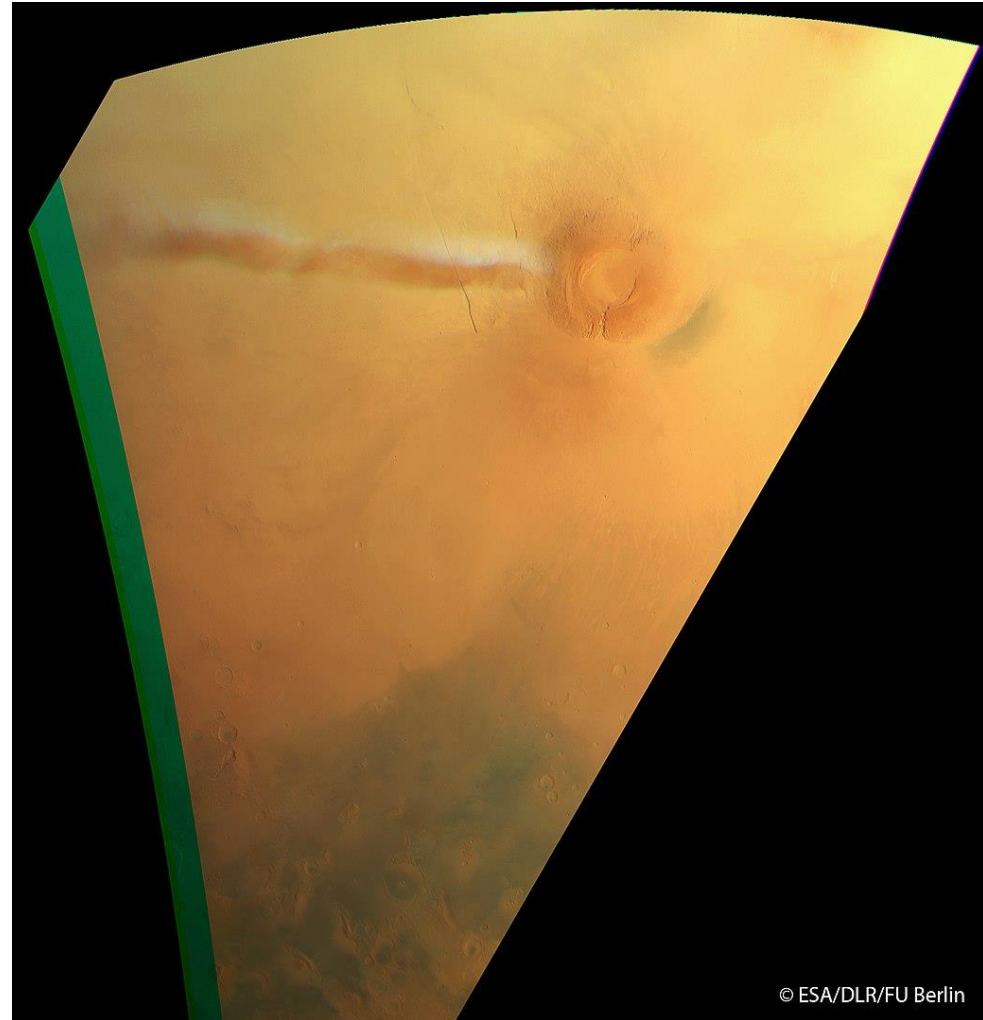
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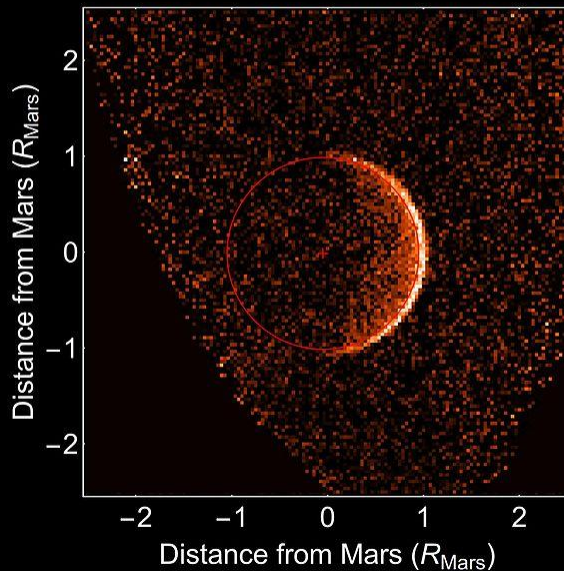


Water ice clouds above Arsia Mons volcano, 2018.

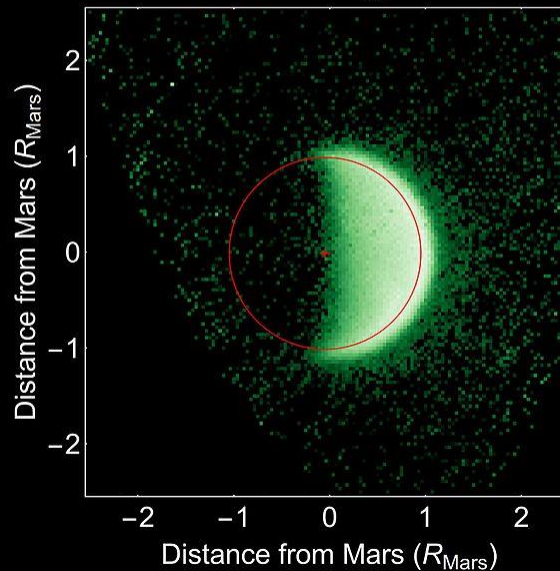
Why can't Mars keep its water?

- **Solar wind & UV radiation** from the Sun break up water molecules high in the atmosphere:
- **Mars's gravity is not sufficient** to hold onto the resulting hydrogen atoms (and oxygen atoms).

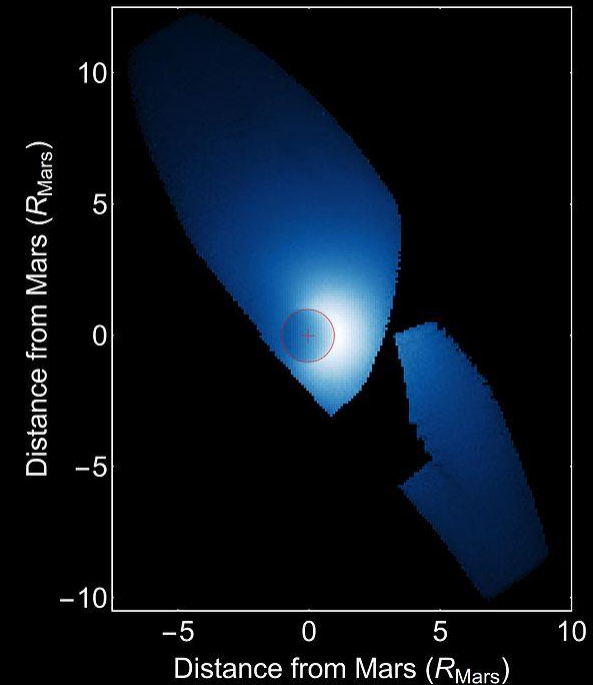
Atomic Carbon



Atomic Oxygen



Atomic Hydrogen



[NASA: MAVEN probe]

→ Mars is constantly losing its atmosphere.

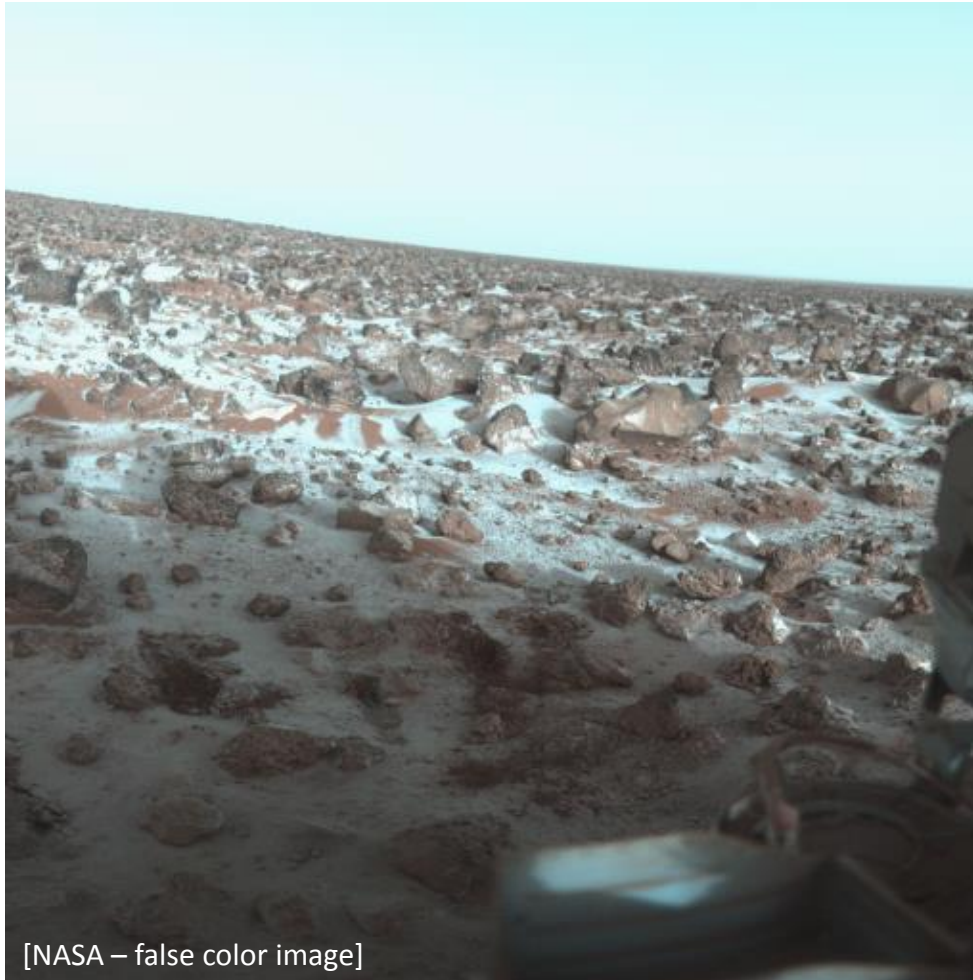
Water Ice on Mars



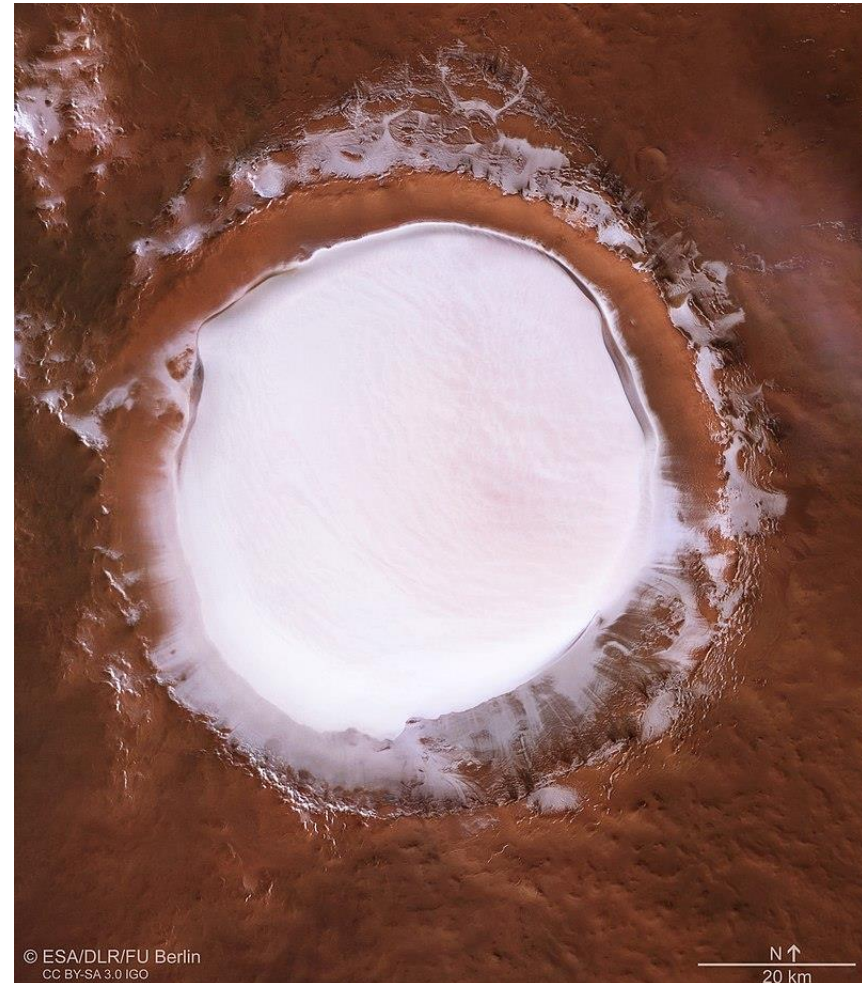
[NASA – false color image]

Water frost from the atmosphere (northern hemisphere) as seen by Viking 2 lander (1979).

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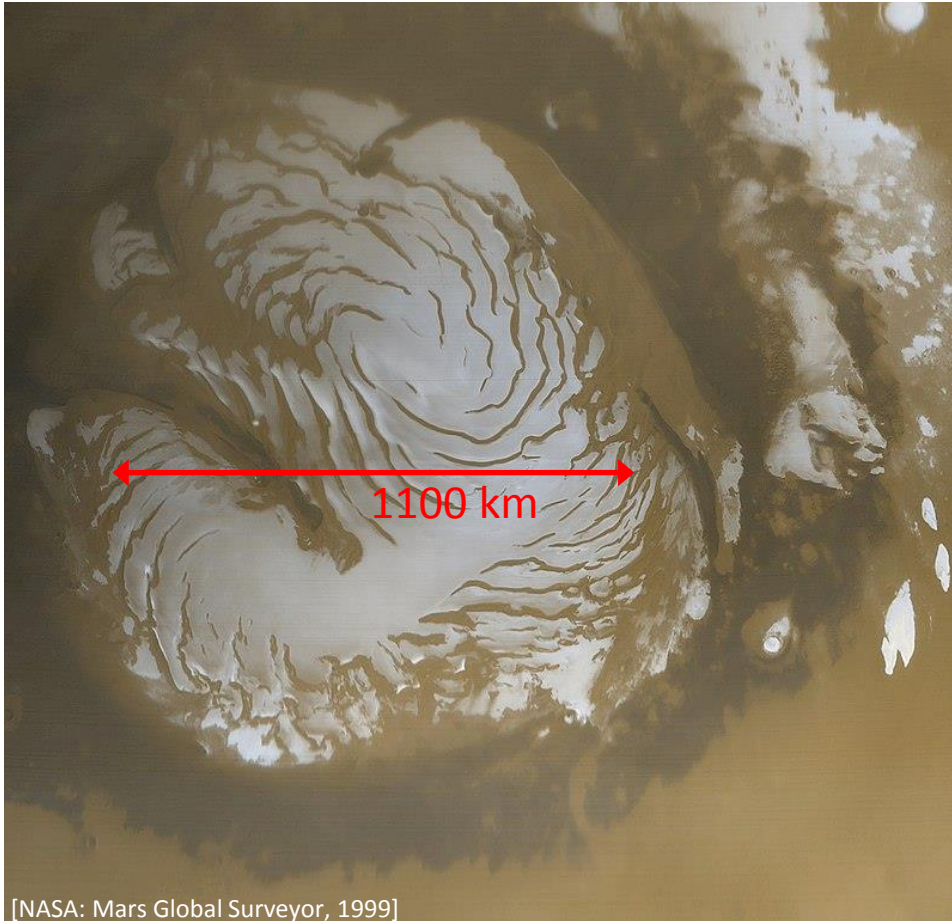
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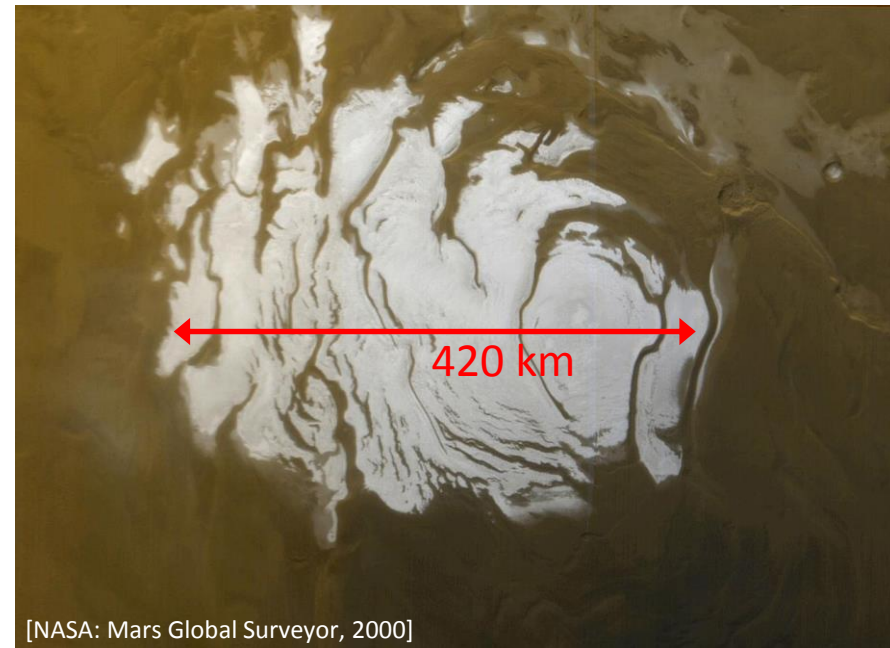
Korolev crater filled with water ice (cold trap) as seen by Mars Express orbiter (2018).

Water Ice on Mars: Polar Caps

Polar ice caps acquire a dry ice (CO_2) layer in the winter, but in the summer they are primarily water ice.



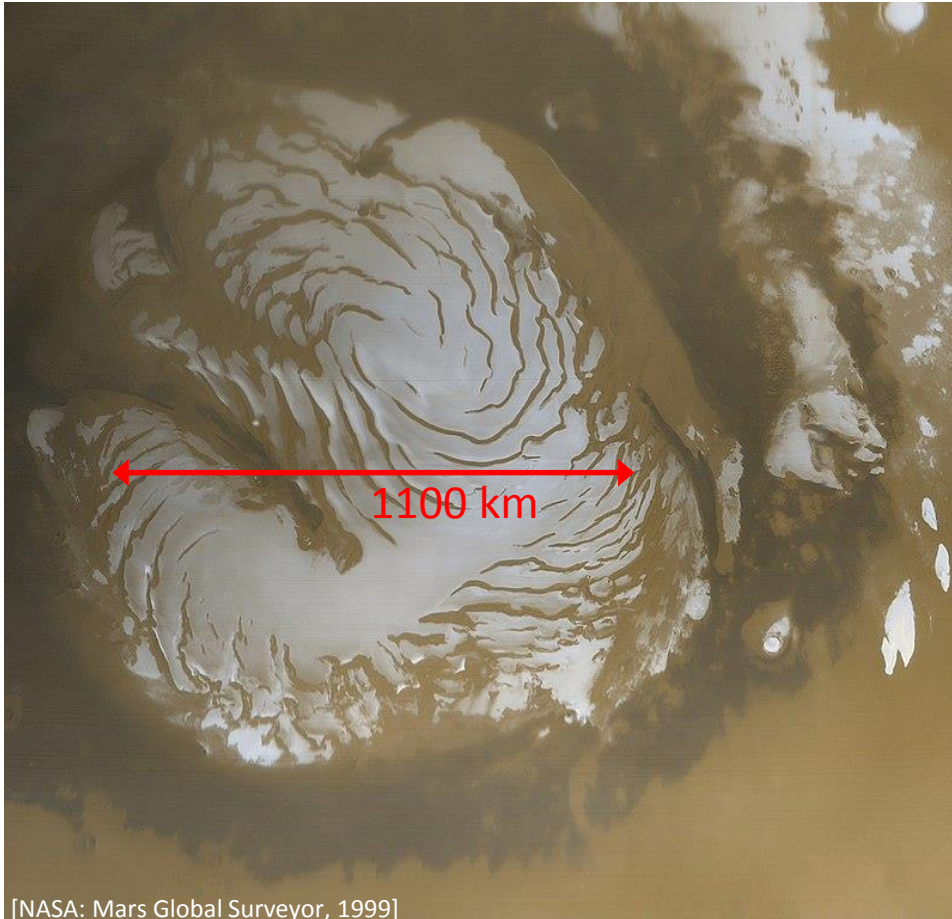
Northern ice cap, summer 1999.
→ Water ice, 2-3 km thick.



Southern ice cap, summer 2000.
→ Water ice with some CO_2 ice.

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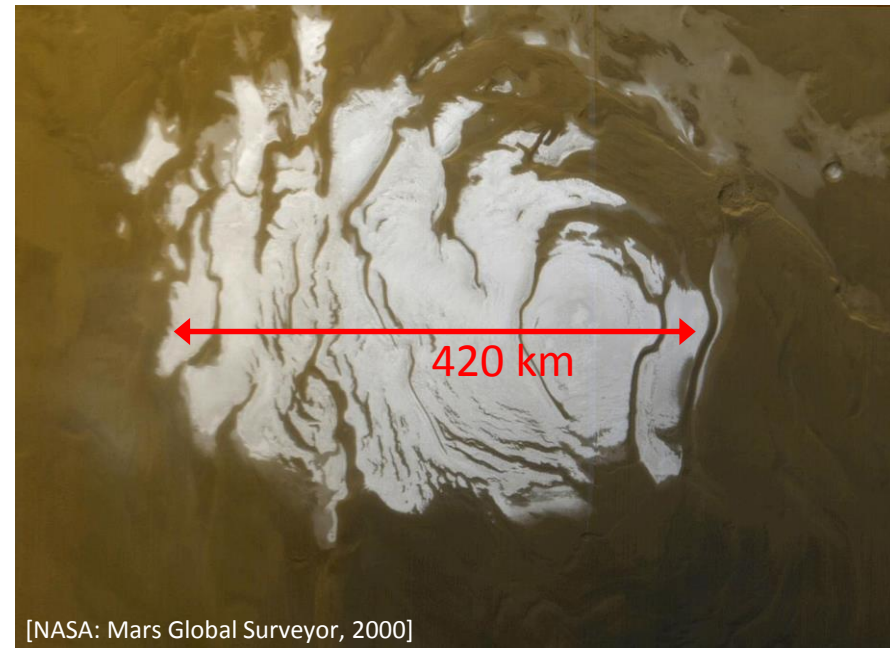
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Mars Reconnaissance Orbiter radar measures 820,000 km³ of water ice ... other estimates put it at 1.6×10^6 km³.



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→ Water ice with some CO_2 ice.

Life on Mars ?

TBD: To Be Determined ...