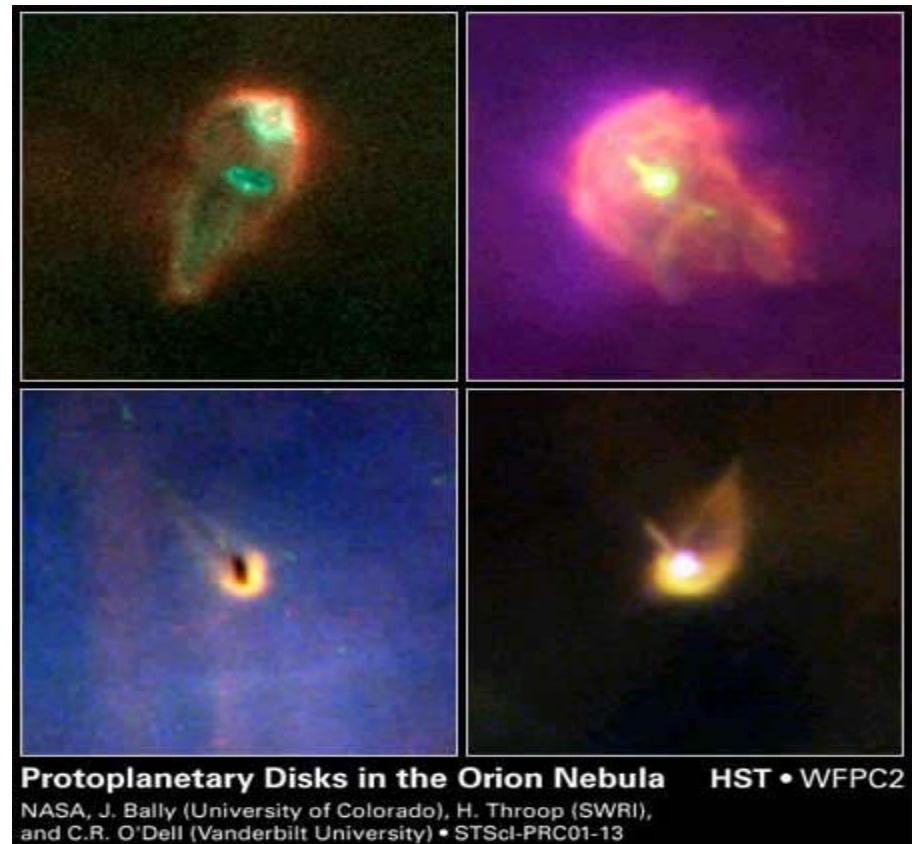


Comparison of Earth, Venus, Mars

To provide context of how unique or not our planet earth is, it helps to have a basic knowledge of the properties of our two nearest neighboring planets.

What is the biggest differences between these three planets?

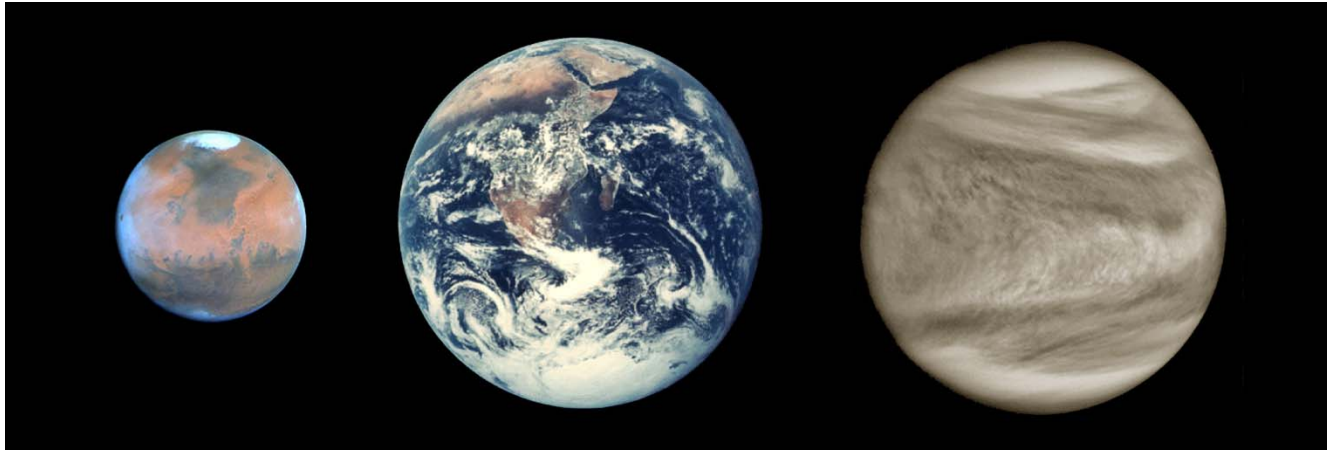
Planet	Mass	Radius	Density	Rotation	#Moons
Mercury	.05	.39	5.42	58d	0
Venus	.81	.95	5.25	243d	0
Earth	1	1	5.54	1d	1
Mars	.11	.53	3.94	1.02d	2



Protoplanetary Disks in the Orion Nebula HST • WFPC2

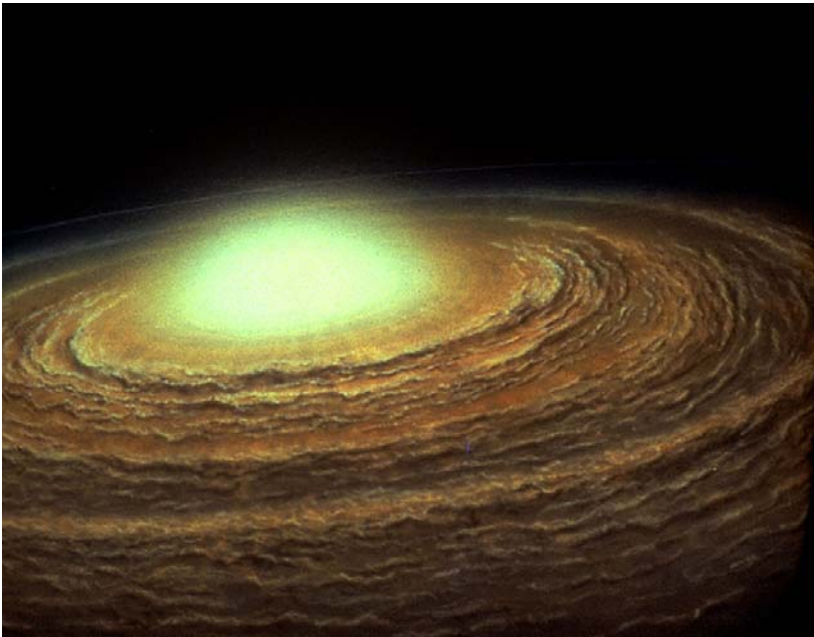
NASA, J. Bally (University of Colorado), H. Throop (SWRI), and C.R. O'Dell (Vanderbilt University) • STScI-PRC01-13

Venus, earth, mars



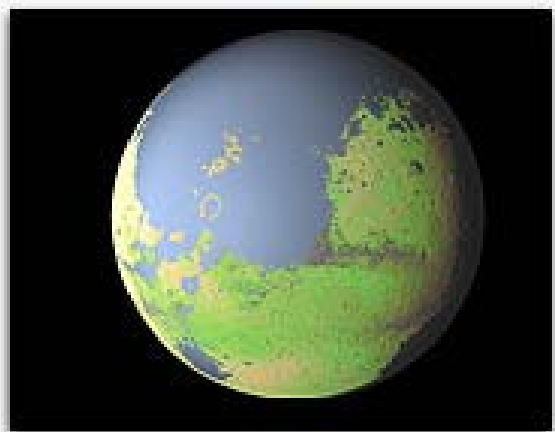
Making the inner rocky planets

- **Planets** formed in <50 Ma from proto-planetary nebula 4.57 Ga ago; this age is oldest age found in meteorites. Note that the sun's radiant output has increase 30% since the sun's fusion engine began at 4.57 Ga; so, the planets surface temperatures were cooler early on (all other things equal).
- Equilibrium condensation **nebula model** predicted all three planets had large amounts of water from de-gassing of hydrous minerals from mantle and late-veneer from comet impacts.



What happened to Mars ?

- **Mars** had liquid/gas/solid water cycle with easily seen rivers and maybe oceans first 500 Ma of history (maybe episodically turning warming events latter on). But, then its liquid iron core solidified due to cooling and hence the planetary magnetic field disappeared which lead to spallation of the atmosphere into space by impact of the solar wind.
- Also, smaller internal planet pressure mean a solid inner core didn't grow to stabilize a magnetic dynamo. Also, no formation of ozone layer to protect water from ultra-violet dissociation. Also, the $\frac{1}{2}$ gravity of Mars (wrt earth) also permits water to be spallated easier from the top of the atmosphere.



Cratering statistic show that mars is an old surface (4 Ga) and never had plate tectonics and is a one plate planet. This is because it cooled off very quickly due to its smaller diameter with respect to earth.

What happened to Venus?

On **Venus**, the atmosphere is so dense with CO₂ that light goes up and down and up and down, effectively heating the ground many times over so that the temperature goes from 297 K to 737 K! **Thus, the Greenhouse Effect increases the surface temperature on Venus by 440 K.** How did this happen?

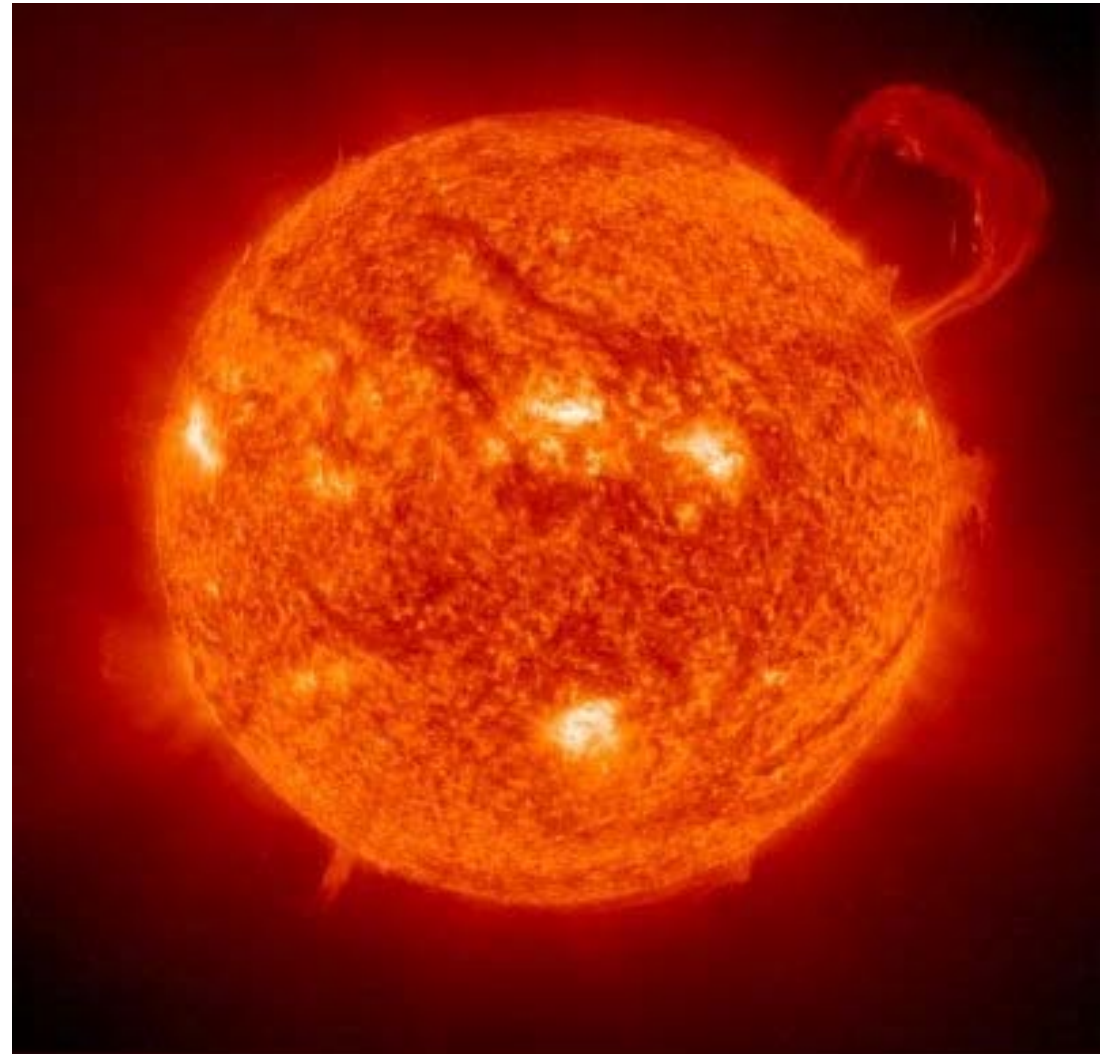
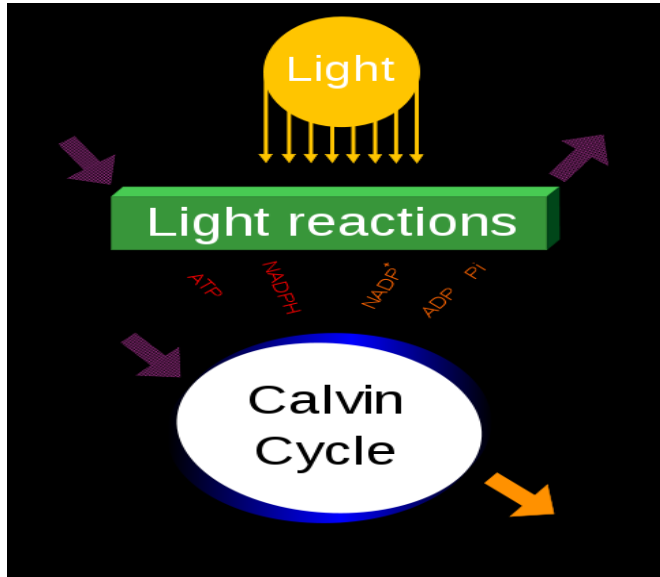
Venus shows no evidence in its landforms that manifest the flow of liquid water. But, it has a huge deuterium (heavy water) anomaly that is consistent with a primordial ocean that was boiled away into outer space after the planet hot-boxed to 800 deg F. Venus is only 1/3 closer to the sun and should only be about 90 deg F warmer than earth due to being closer to the sun. Why Venus hot-boxed is maybe because the 90 deg higher temperature caused the liquid water to evaporate which means the CO₂ in the atmosphere was not removed via precipitation of carbonate rocks, and buried non-oxidized biomass, as on the earth.

Cratering statistics of Venus show the surface is 300-800 Ma old: call it 600 Ma. The best model to explain this 'young' surface age (Moon and Mars have 4 Ga old surfaces) is that Venus's volcanism increase by a thousand times at 600 Ma which erased all the older craters. This would suggest an episodic form of convective motion of the planets surface.

What happened to Earth?

- A spectacular difference between the early history of Earth and Venus is that the Earth was struck in a glancing impact by a **Mars-size bolide** after 90% formation. The rubble thrown into space formed the moon; this impact-origin model explains the very large angular momentum of the earth-moon system (and other things). Note while the Earth spins once a day, Venus only spins once every 244 days. The Earth-moon angular momentum stabilizes earth's spin axis which helps stabilize climate extremes and maybe facilitate origin of life.
- The Earth formed oceans of liquid water by 4 Ga; Water is ultimate biochemical solvent.
- Why did the earth **not** hot-box due to **greenhouse** gas effects made by large quantities of CO₂ and water vapor in its atmosphere ? The stability of liquid water on Earth permitted the carbon cycle to operate to transfer the atmospheric CO₂ into carbonate rocks via precipitation in the liquid water oceans. Also, the moon forming boiled impact blew away the original CO₂ rich atmosphere (albeit, what atmosphere reformed after impact is difficult question). Less CO₂ in atmosphere means less trapping of outgoing infrared radiation == cooler planet!
- Liquid water was **subducted** into mantle to weaken the flow strength of mantle rocks so that **plate tectonics** could evolve.
- Organic based **life** form developed; albeit, the biologic seed could have come from Mars/Venus via meteorite transfer. Why here? Liquid water seem necessary.

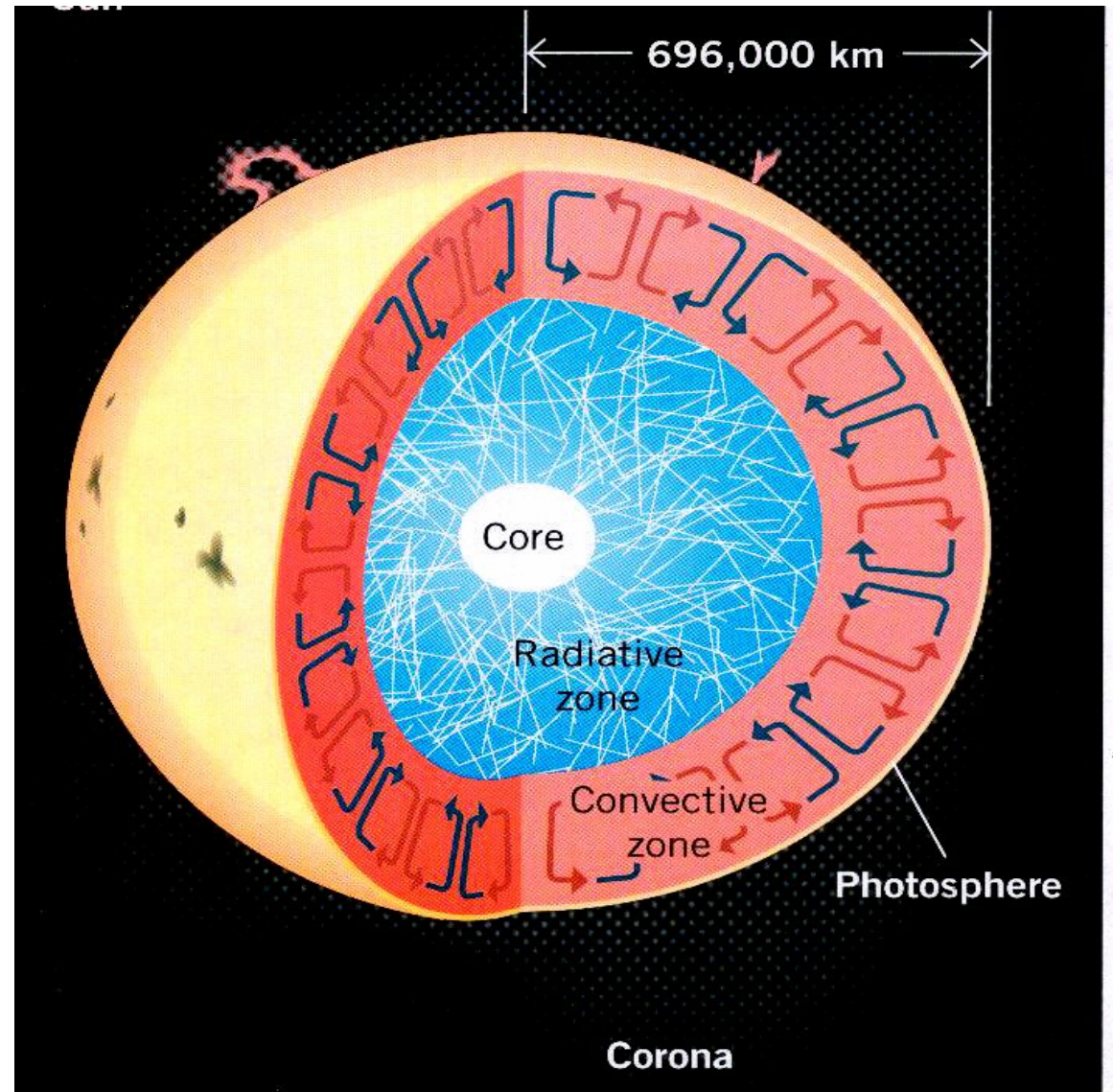
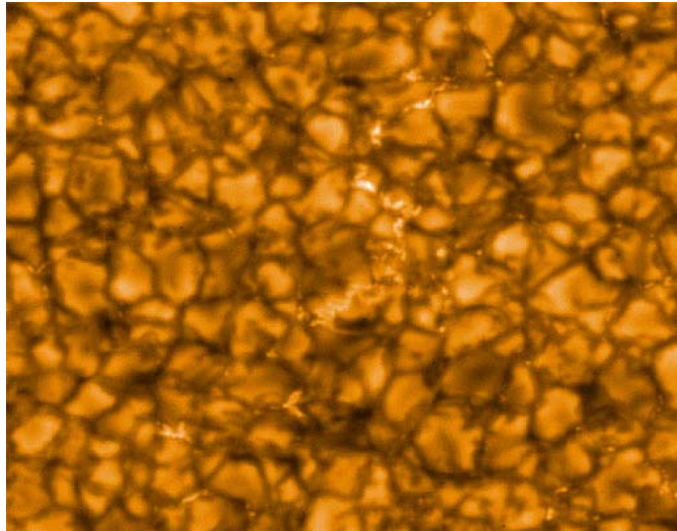
SUN: Electromagnetic energy from Sun warms earth and permits water splitting via photosynthesis to make Oxygen fuel and carbohydrate fuel



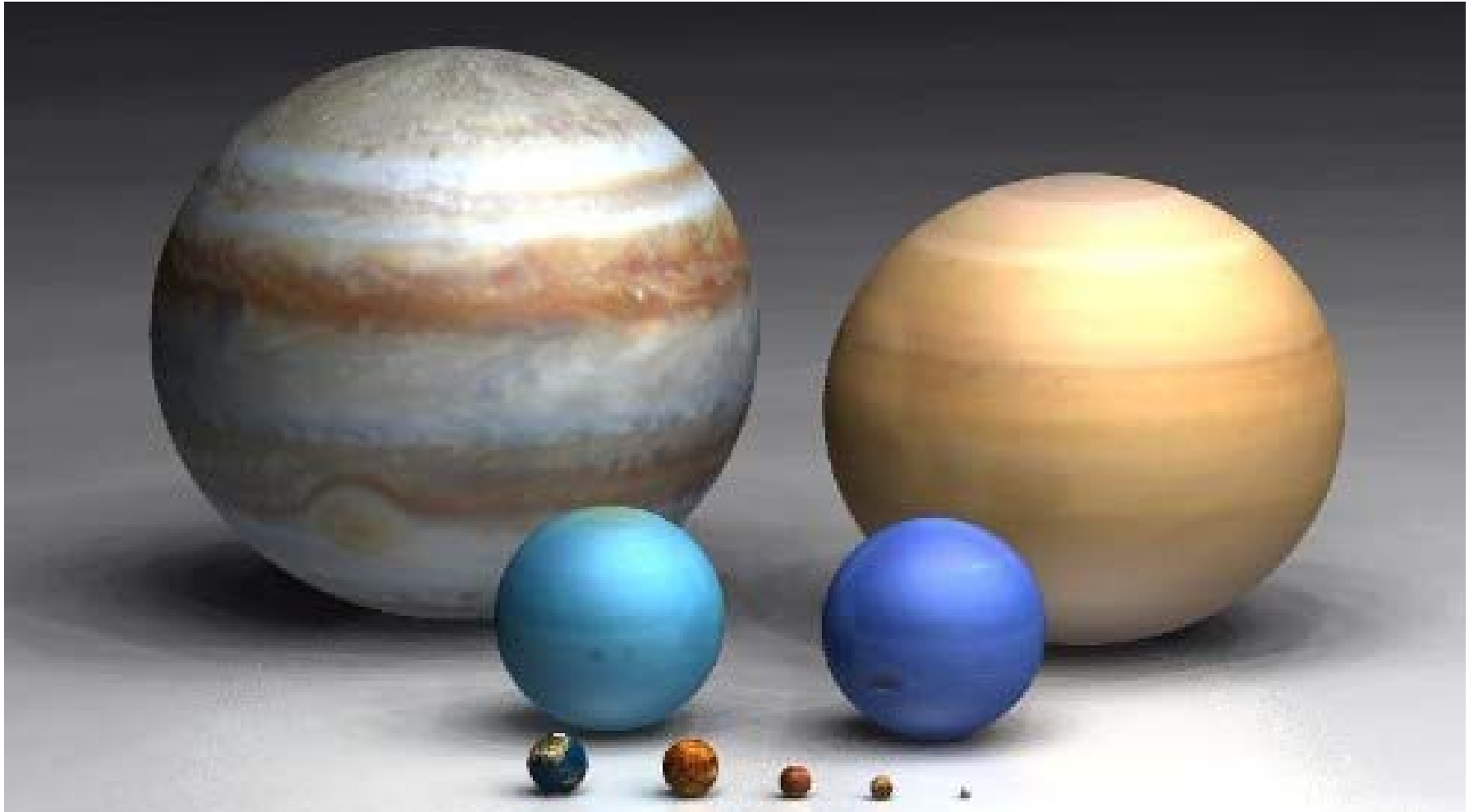
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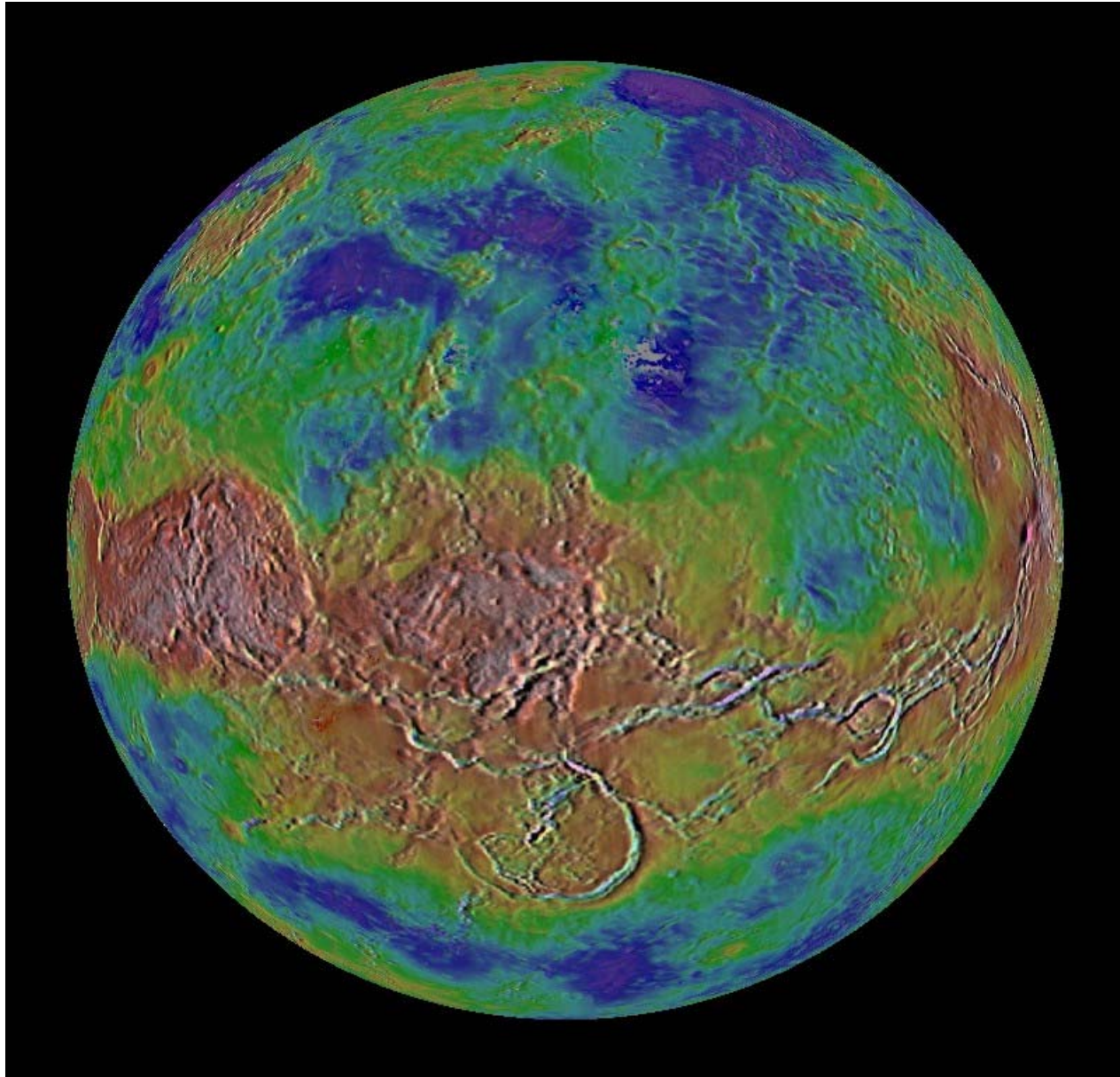
Convection in the Sun driven by Fusion



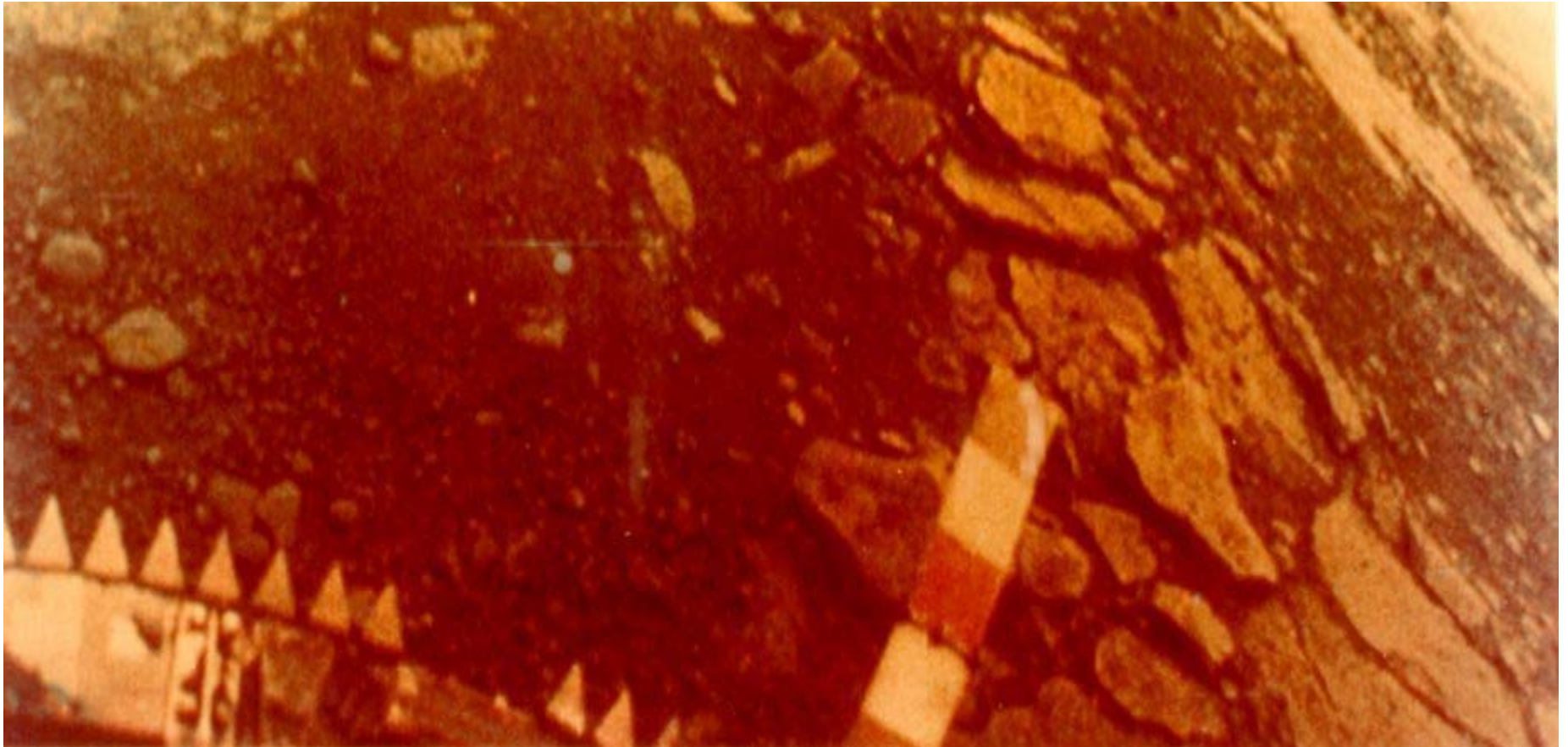
Planetary size comparison



VENUS Topography: 30,000 foot volcano mountains and big Rifts



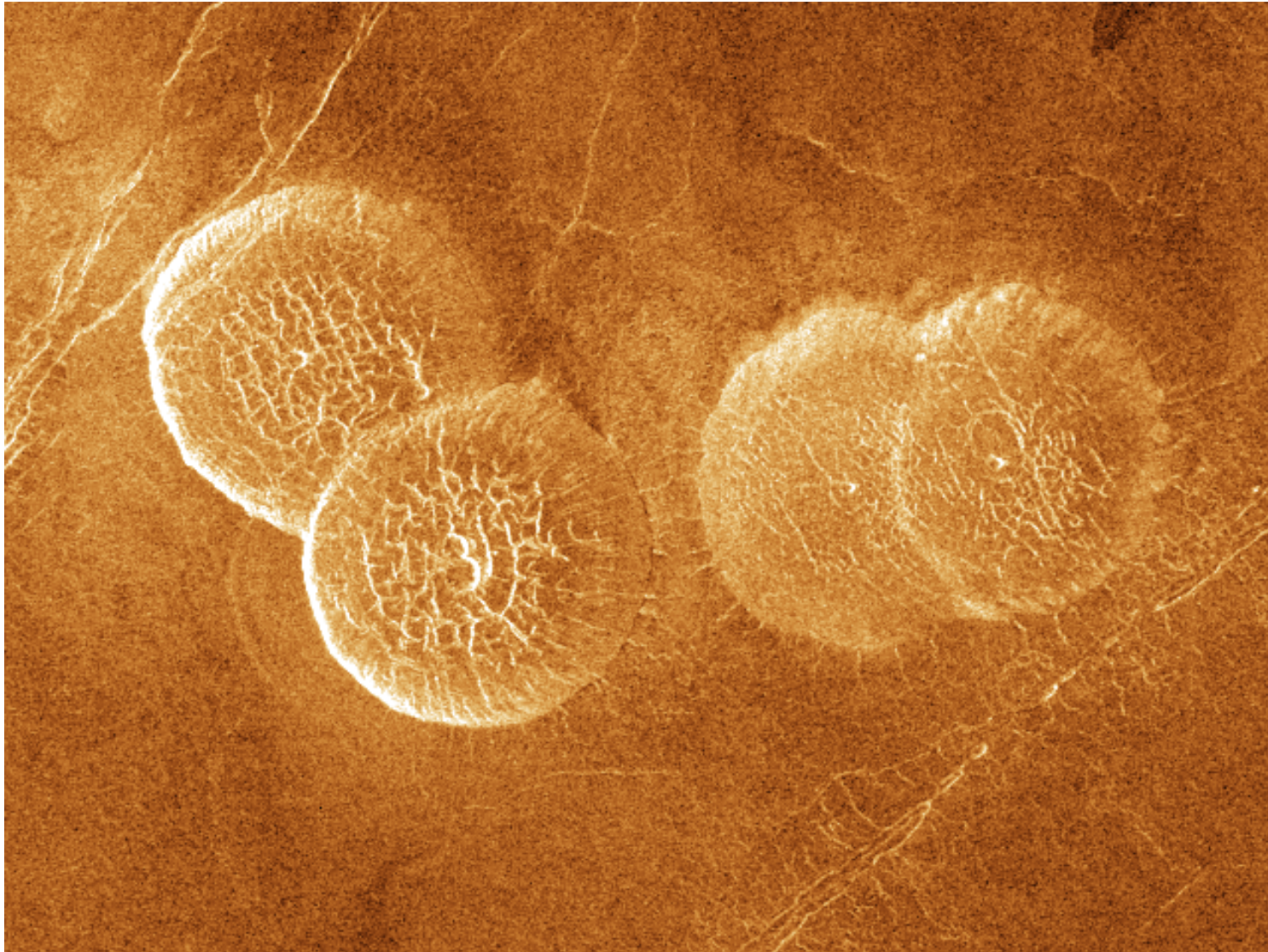
Venus surface from Soviet Venera lander



Venus and Moon



Volcanic pancakes (like Rhyolite domes on earth ?)



Clouds of Venus (infrared, heat band)



Atmospheric composition

- 99% carbon dioxide
- Very very little water vapor

Was there an original water ocean that diffused into space ?

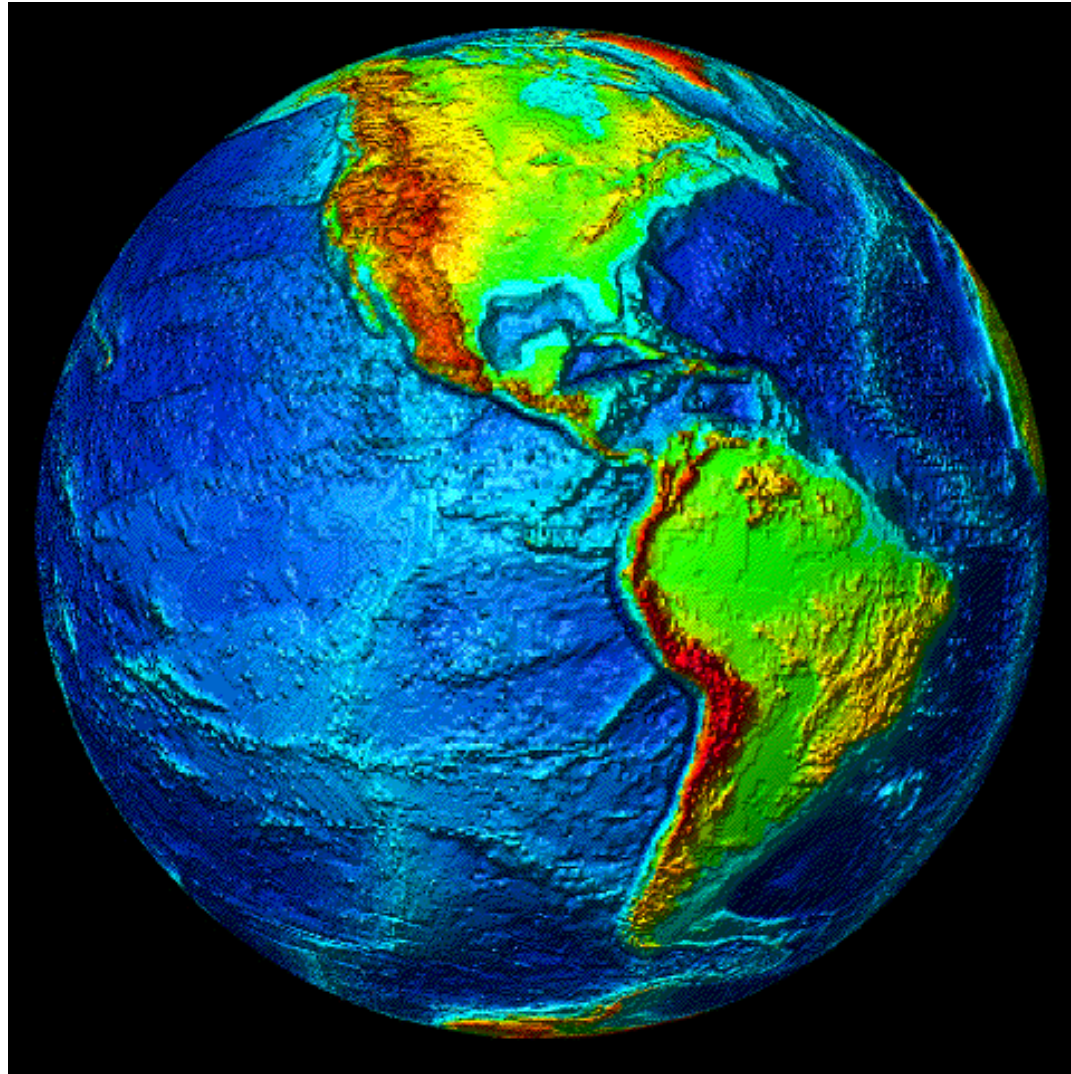
Why did Venus lose its original water and turn into a greenhouse 'hotbox'.

About 800 deg F at surface and 80 times earth's atmospheric pressure.

Earth (lotsa liquid water)



Area: 70% oceans and 30% continents



The blue water planet



Hydrologic cycle based on liquid/gas forms of water.

- Water evaporates.
- Clouds condense.
- Rain falls.
- Water flows to seas.
- Rinse and repeat.

Solid form (ice) also important.

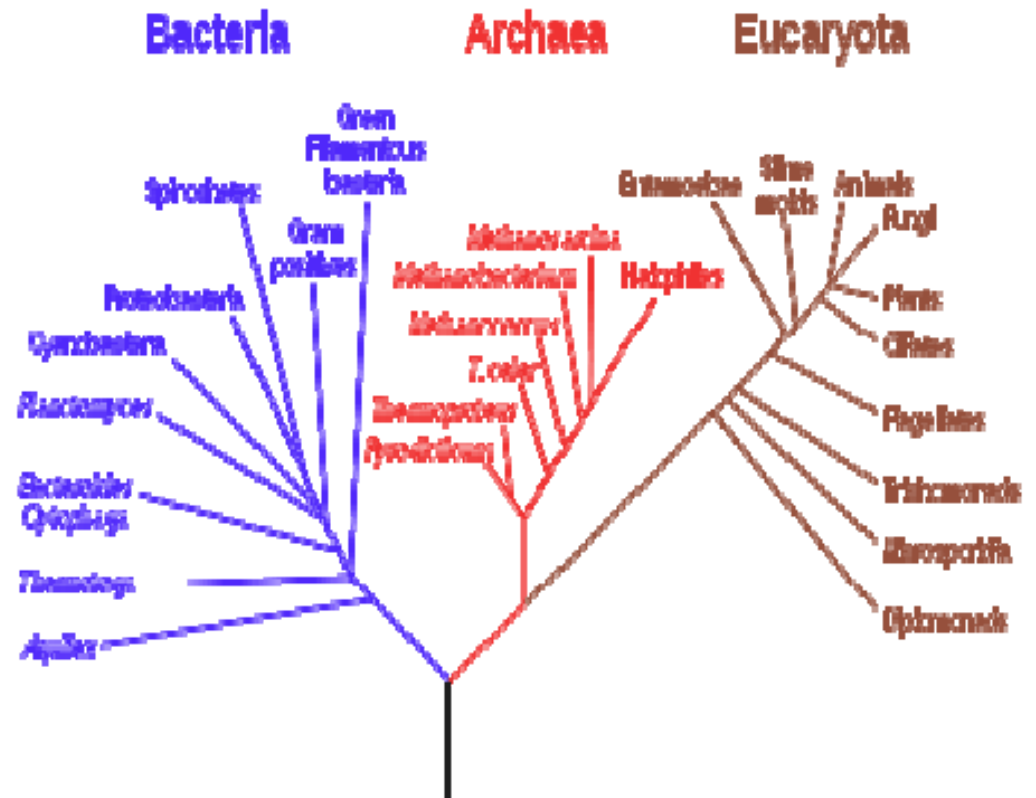
Liquid water and Life



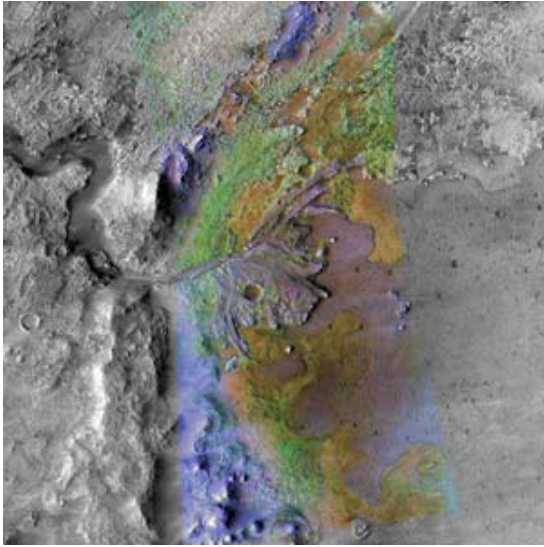
Water is best solvent that facilitates biochemical reactions.

Your cells are mostly all salty water.

Phylogenetic Tree of Life



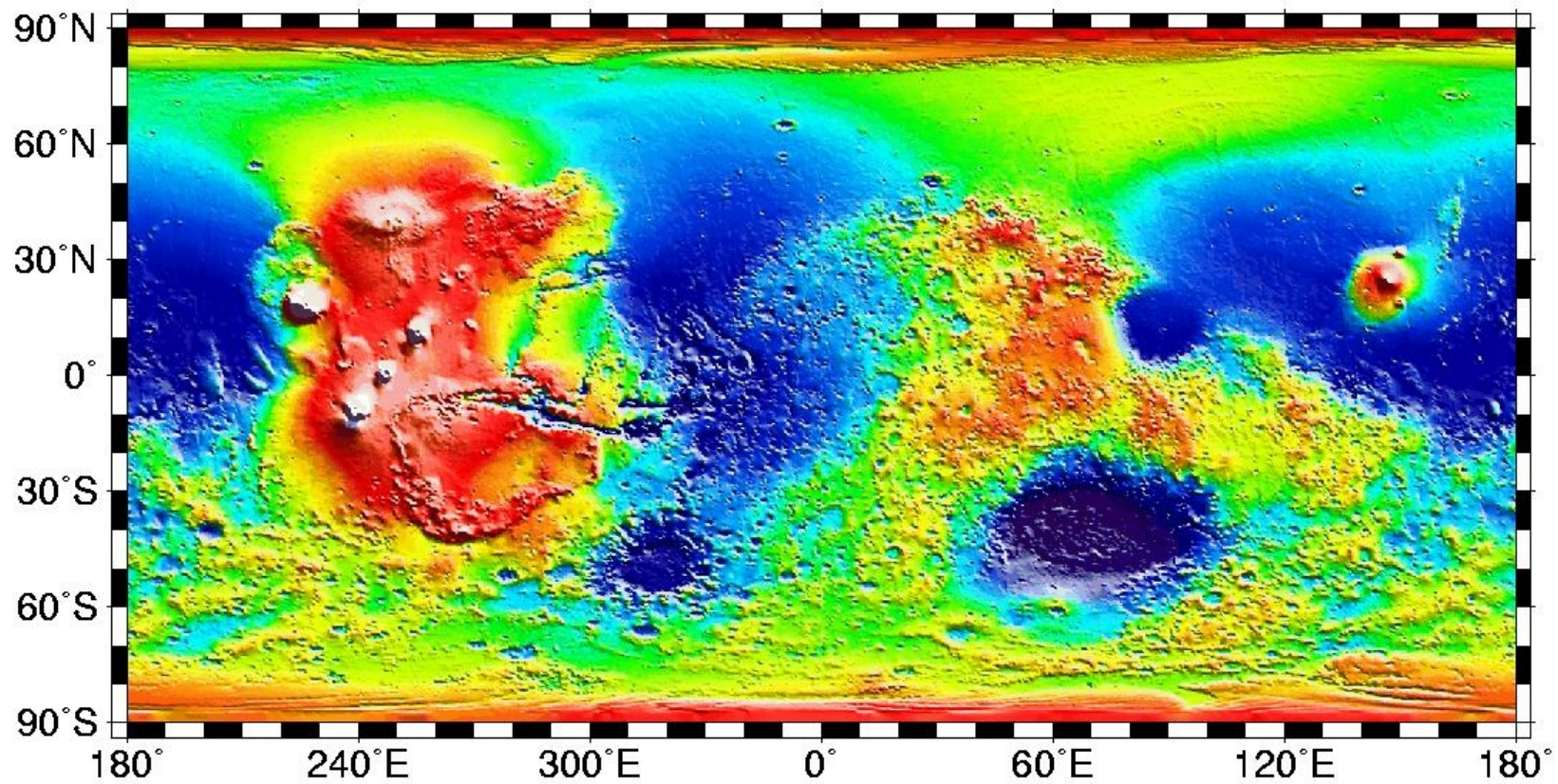
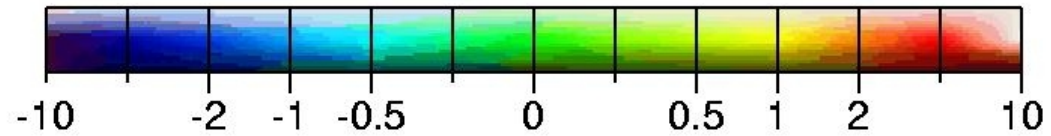
Mars: cold,windy,dead(?) now, but first 0.5 Ga it was wet, warm and verdant (microbial life?)



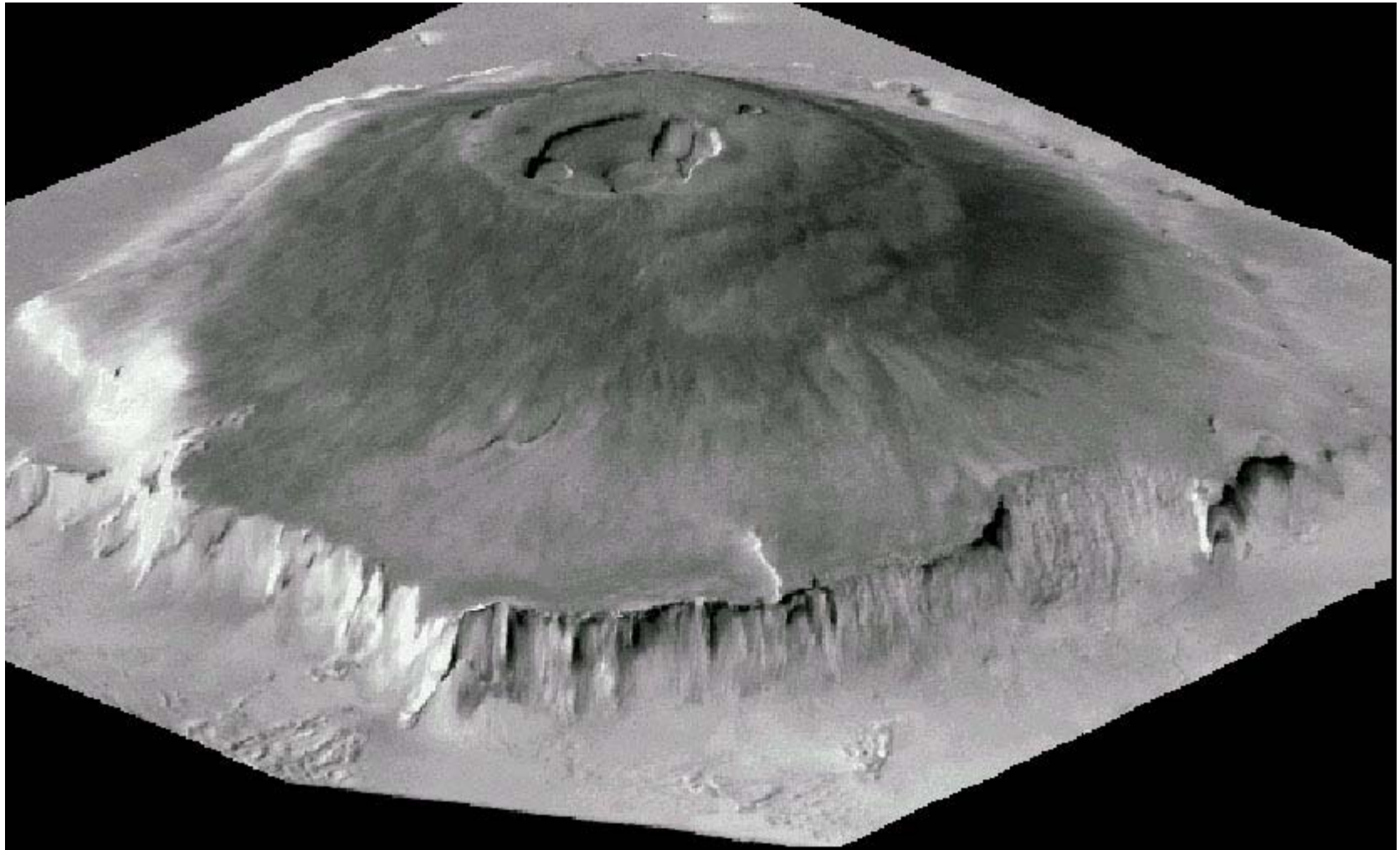
Surface Mars

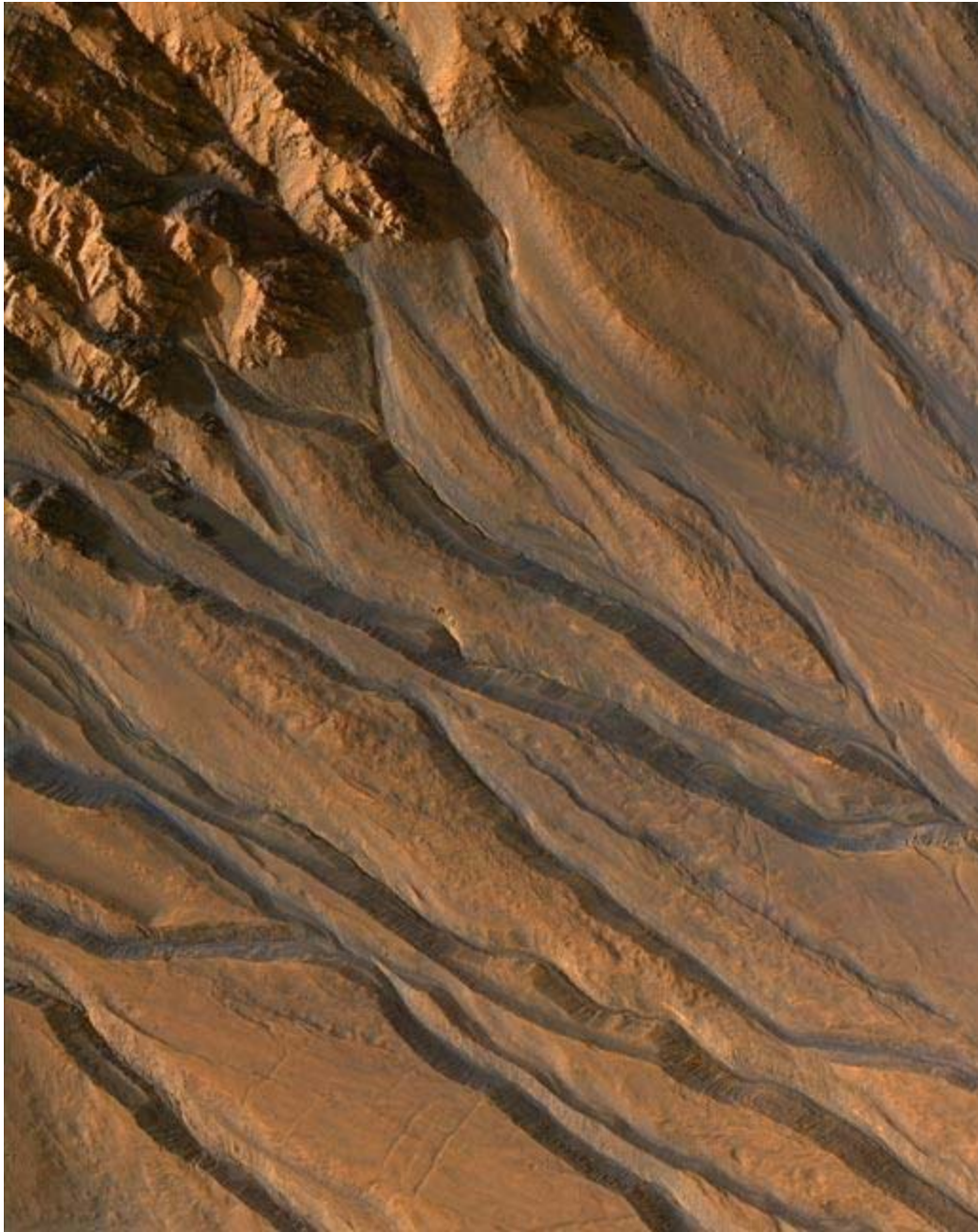


Mars Topography (km)



Olympus Mons (largest volcano)





Flow of
water?

Cautionary Tale of 3 Planets

The verdant liquid ocean life supporting planet earth maybe an anomaly.

Venus lost its water and green-housed to become hot dry and dead.

Mars lost its atmosphere and dried up to become cold windy and dead.

With respect the goldilocks 'bed testing' model of planetary tectonics: Mars is too hard (thick lithosphere), Venus is too soft (thin lithosphere), but the Earth is just right (30-150 km thick lithosphere).

