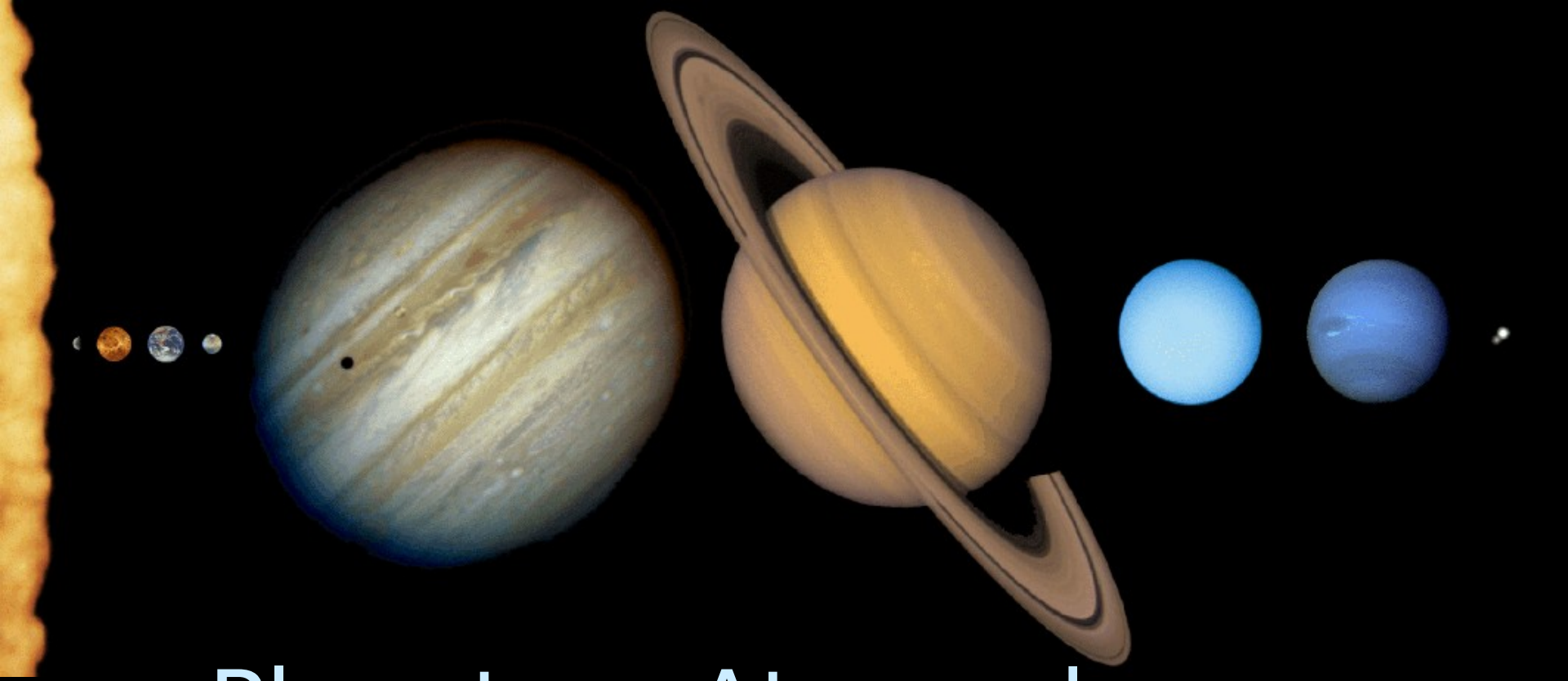
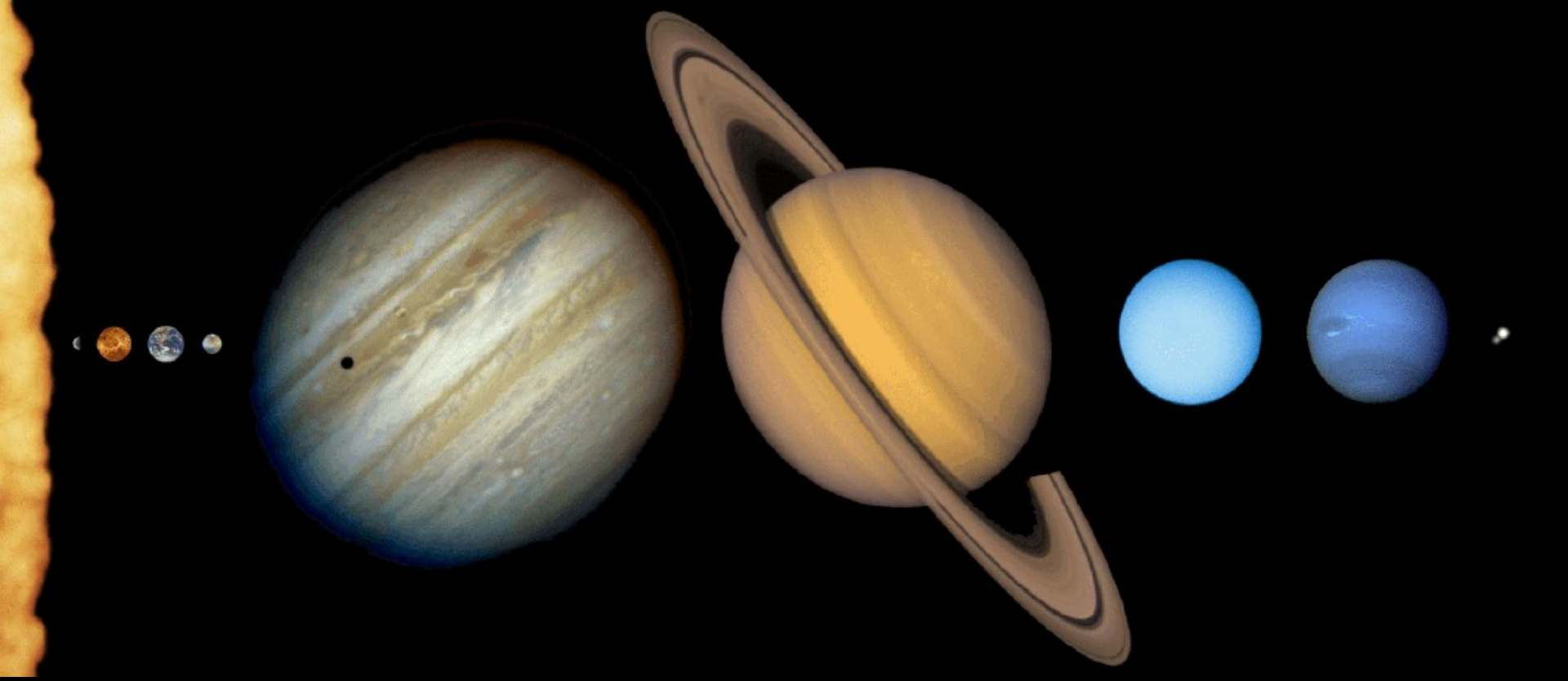


Planetary Atmospheres: What do they tell us?

Melissa Trainer

CU Center for Astrobiology



“Earth’s atmosphere today is the end-point of an evolution that started about 4.6 billion years ago… by examining other parts of the solar system that have evolved to a lesser degree, we may deduce what the early Earth might have been like.”

-Yuk Yung

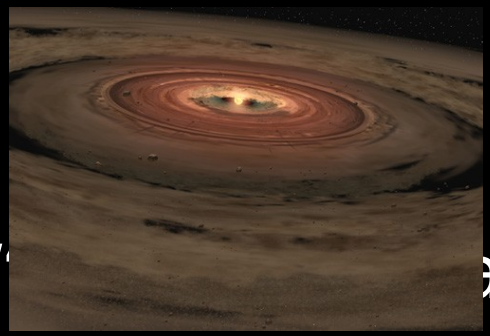
Types of Atmospheres

Hardly anything

Mercury

Moon

Where do planetary atmospheres come from?



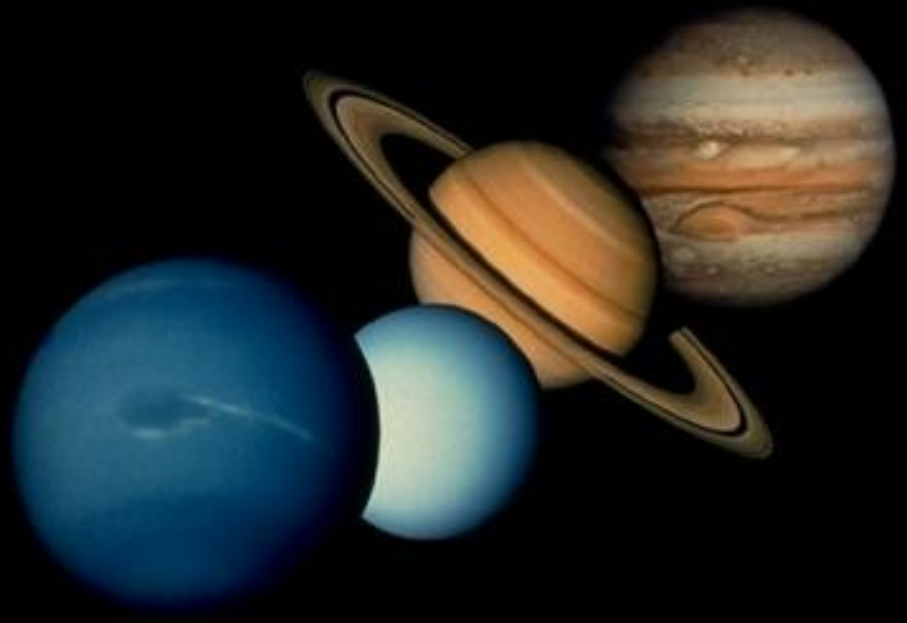
Planets form from

“ ary disk”

- Terrestrial planets accrete planetesimals, may lose volatiles (escape, etc.)
  - Secondary atmospheres from mantle degassing, impactors
- Giant gas planets capture nebular gas, like solar content
- Noble gases (He, Ne, Ar, Kr, Xe) give clues
  - Abundance, Patterns, Isotopes
  - Also D/H ratio of water gives clues to origin

“Planets” with Atmospheres

- Venus
- Mars
- Titan
- Enceladus

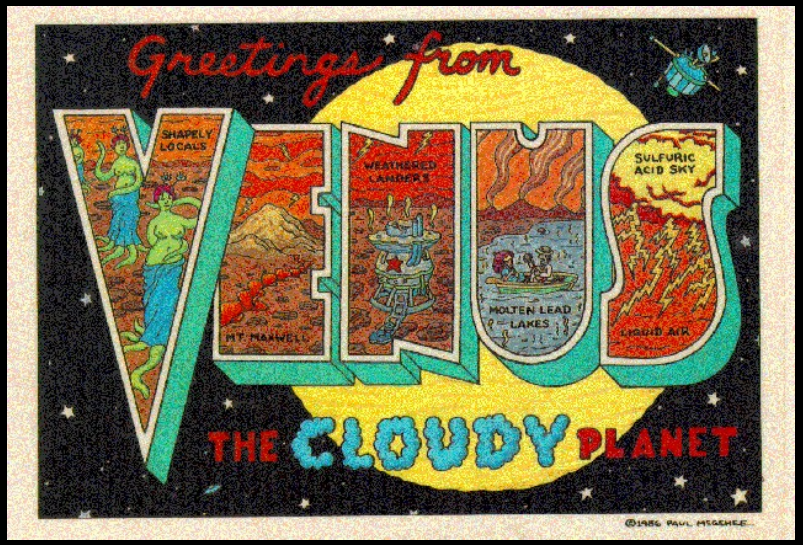


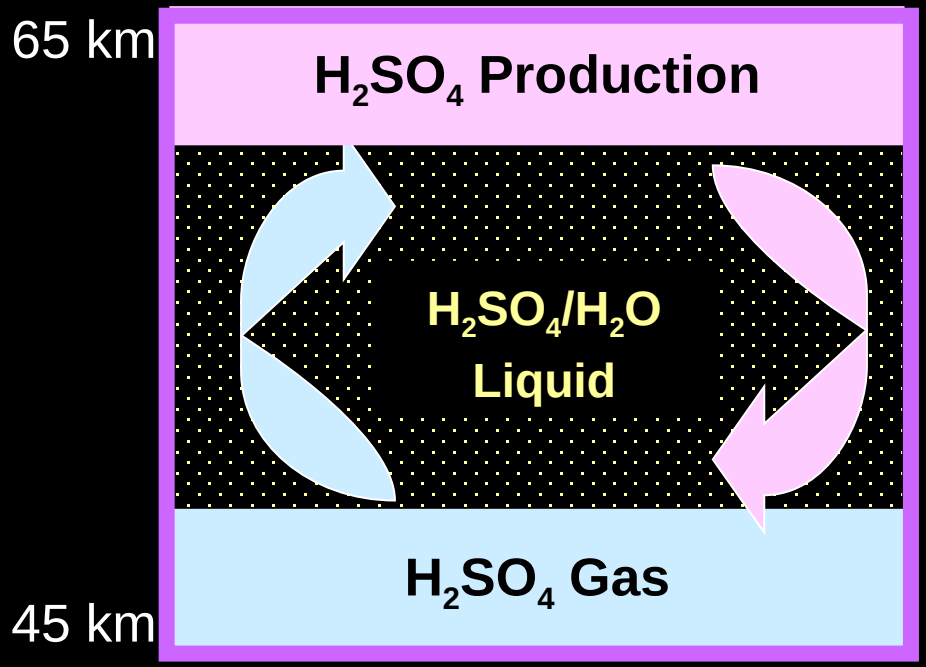
Venus
Early Vision = Prehistoric Rainforest

- In 1930s astronomers knew
  - High CO_2
  - Intense cloud cover
- Thus, warm temperatures and heavy rain: prehistoric Earth
- Data from the fly-bys and radio astronomy from the ’60s pointed to a hot, dry Venus

→ but as late as 1964, Soviet scientists were

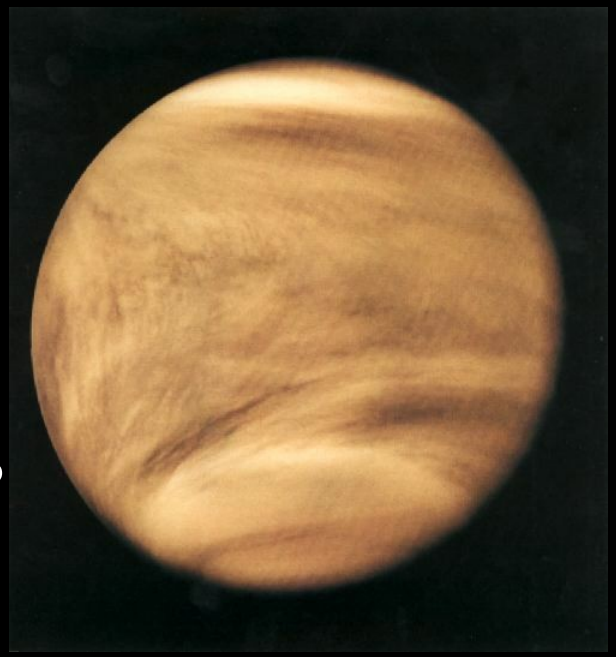
Sulfuric Acid Clouds





- Clouds are sulfuric acid
- Planet actually dry, hot
- Why are they yellow? What is UV absorber?
- Why are there holes in clouds for Near-Infrared observation of surface?

Orbit



- Venusian “day” = 243 days
- Venusian “year” = 225 days
- But, not much diurnal (day-night) temperature difference!

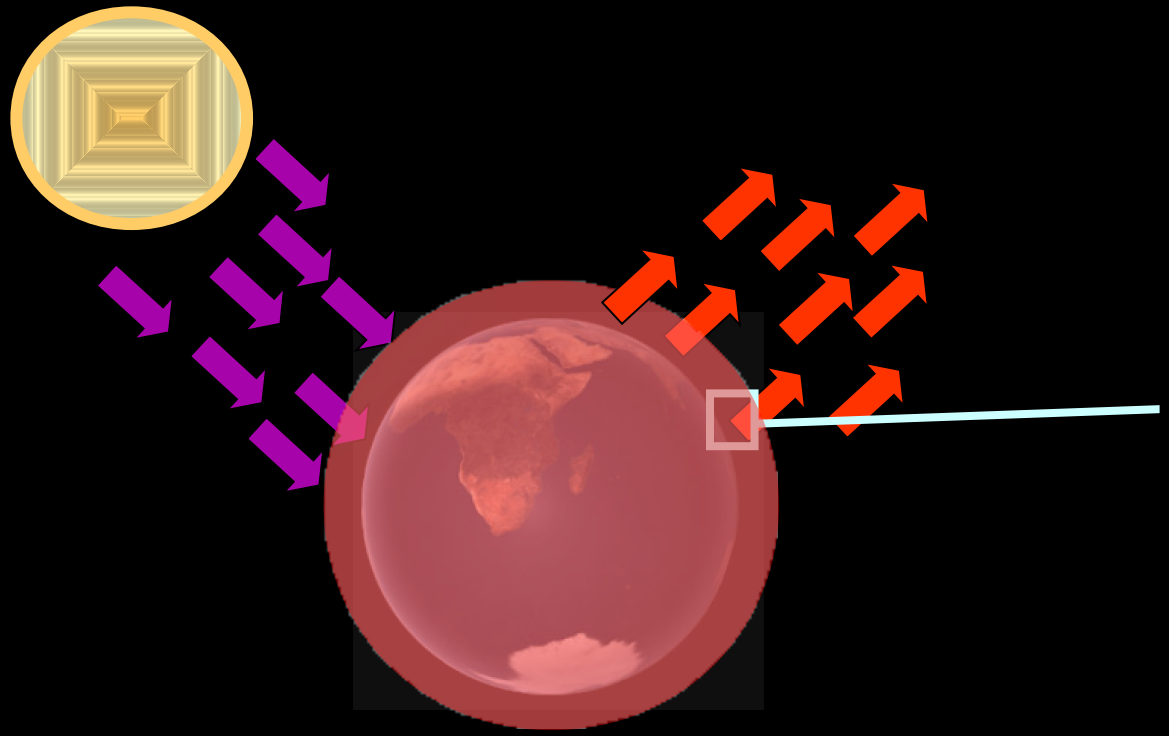
- Retrograde (clockwise) rotation:
  - Mystery when first measured
  - May be result of tidal forces and thick atmosphere

Hot, Hot, Hot

- Mercury (T_{max} ~ 420°C)
- Venus (T_{max} > 700°C)
  - Due to high CO_2 atmosphere

- Greenhouse effect on Earth = +33°C
- Greenhouse effect on Earth = +500°C

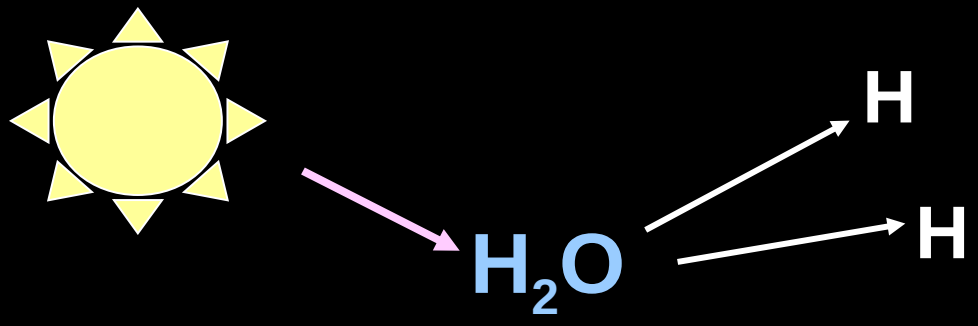
The Greenhouse Effect



With current atmosphere = 59°F

No Atmosphere = 0°F

D/H Ratio on Venus



H then escapes to space

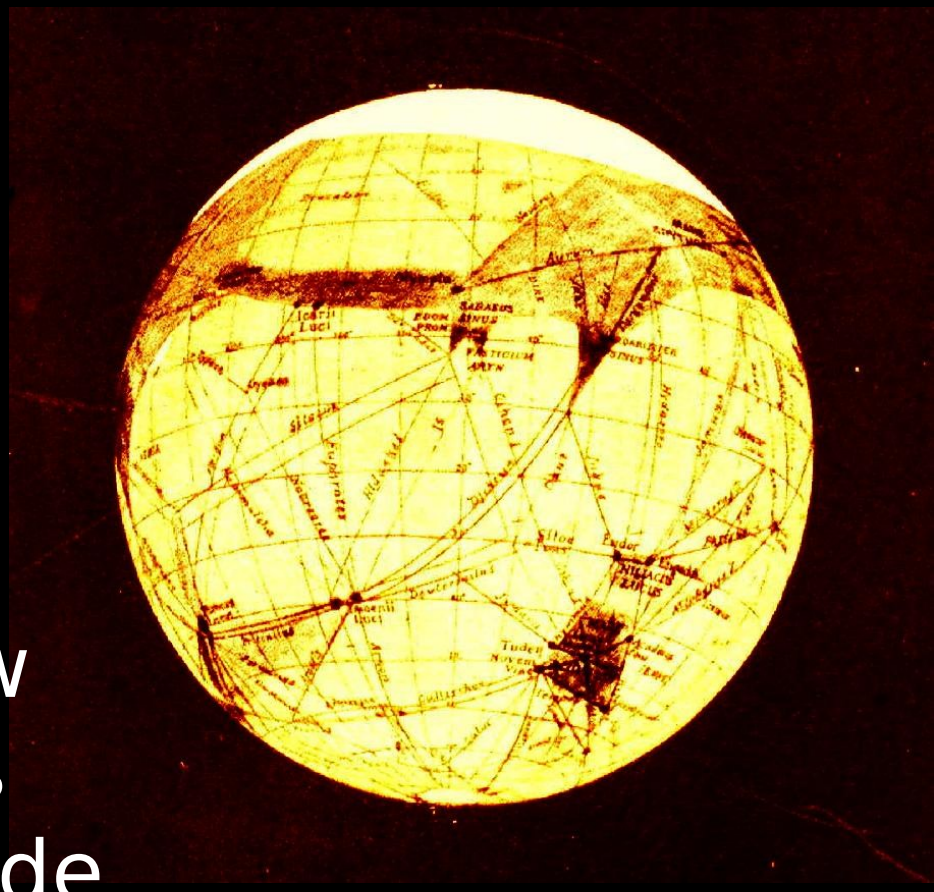
^{1}H loss preferential to heavier ^{2}D

- Early Venus may have been cool enough for water to condense on surface
- Yet, warm Temps may have led to a runaway greenhouse, where H_2O accelerates its own loss
- D/H ratio on Venus 100x greater than Earth ocean
  - HDO >> H_2O (ppm)

Mars

Mars
Home of the Canali

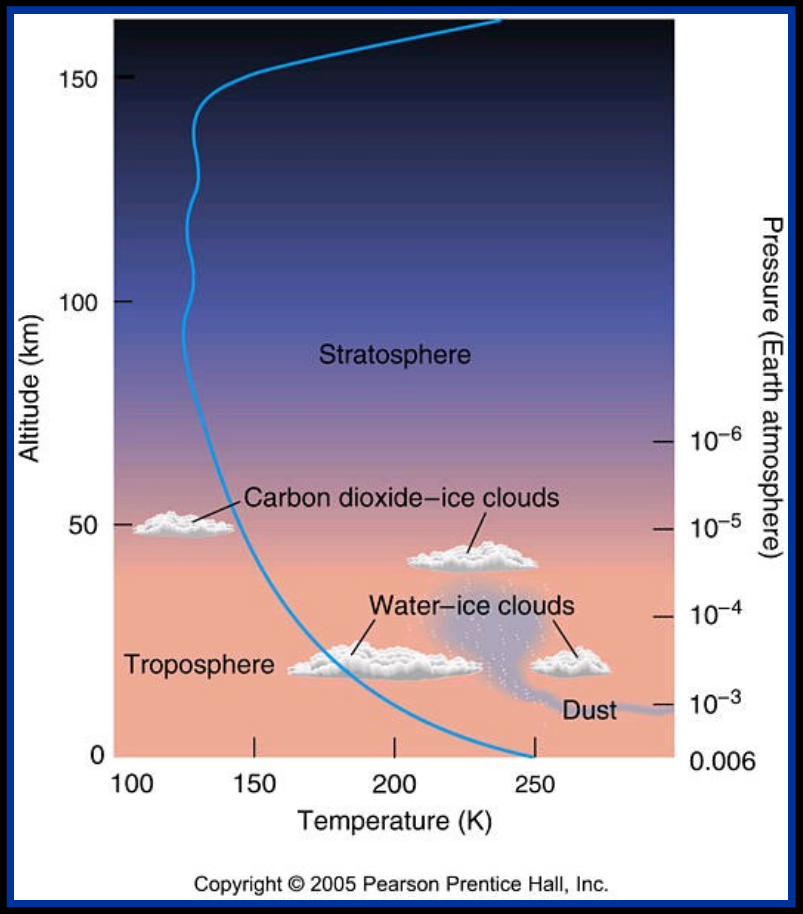
- Giovanni Schiaparelli reported seeing “canali” on Mars in 1877…this was mistranslated as “canals” (not channels)
- Percival Lowell drew a map of the canals in “Mars as the Abode of Life” in 1908



The Atmosphere of Mars

Major and Minor Components

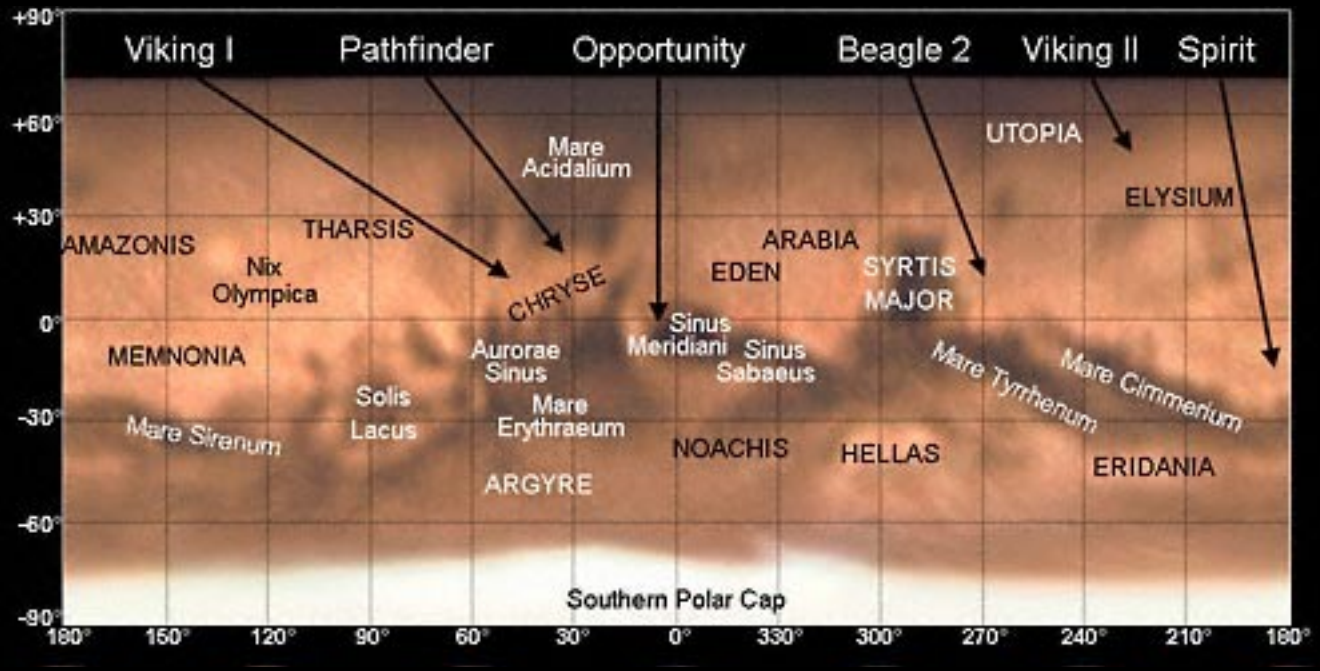
CO_2	~ 95.3 %	6.39 mbar
N_2	2.7	0.18
Ar	1.6	0.11
O_2	0.13	0.0087
CO	700 ppmv	0.0047
H_2O	350	0.0023
Ar Ne Kr Xe	< 10 ppmv	< 6×10^{-5}
H_2O_2 O_3 CH_4	< 1 ppmv *variable*	< 6×10^{-6}



Owen, in *Mars* (1992)

Encrenaz *et al.*, *Planet. Space Sci.* (2004)

Mars Exploration

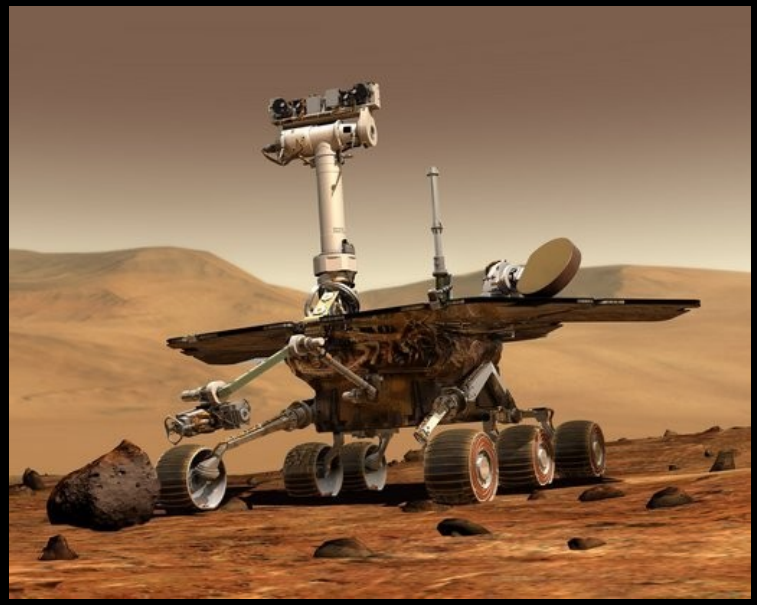


- Studies have focused on looking for water, organics
- Current Orbiters include:
  - 2001 Mars Odyssey
  - Mars Express
  - Mars Reconnaissance Orbiter

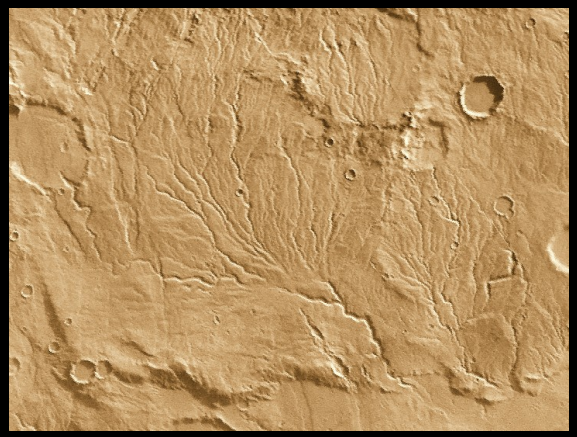
Mars Missions: Dangerous Work!

Mission Log

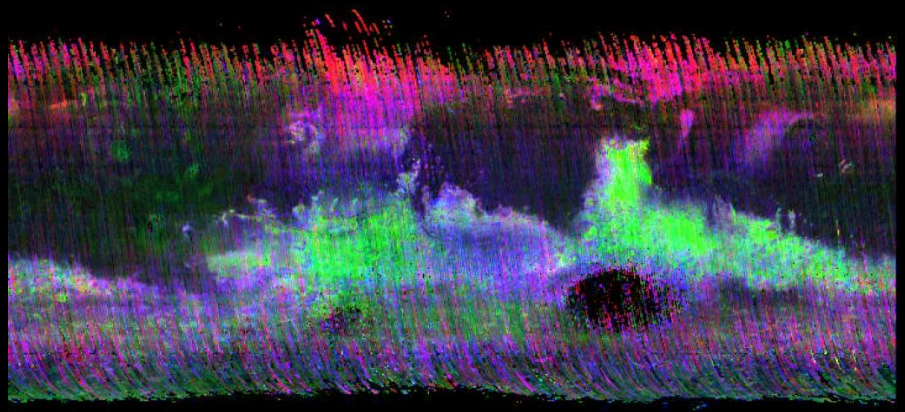
http://mars.jpl.nasa.gov/missions/log/



Water on Mars

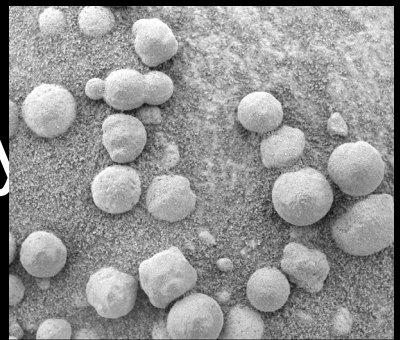


- Orbiters
  - Images of outflow channels
  - Evidence of water ice
  - Evidence of evaporite mineralogy

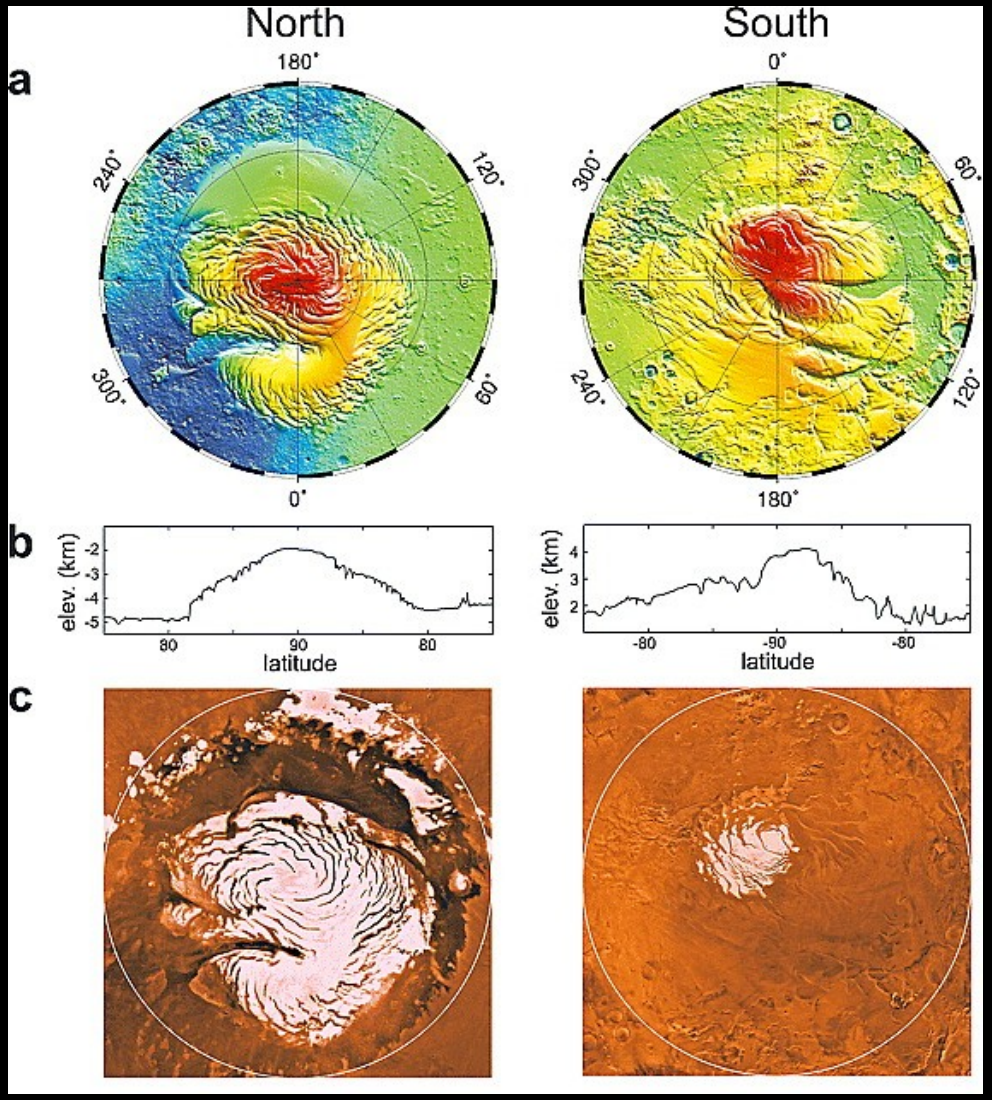


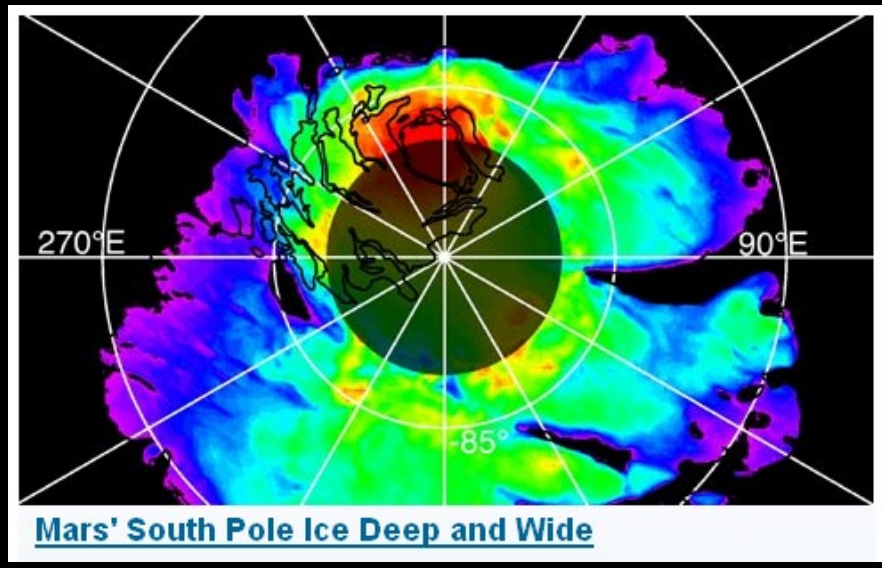
Sulfates: such as gypsum, barite, and anhydrite

- Rovers (Spirit and Opportunity)
  - Hematite spherules, formed in water?

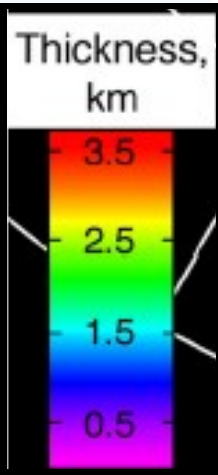


Water on Mars





- Enough water to cover the surface in a liquid water layer 11m deep



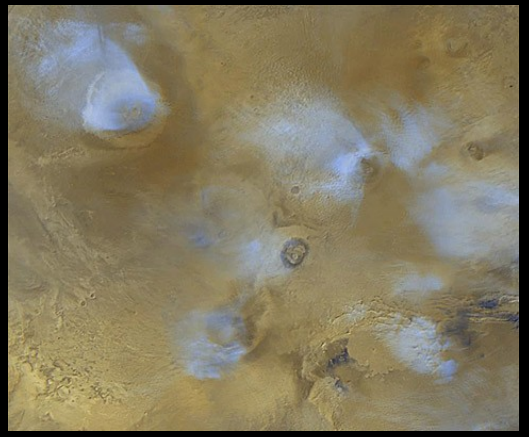
Plaut et al., *Science* (2007)

Weather on Mars

- Dust Devils and Global Dust Storms

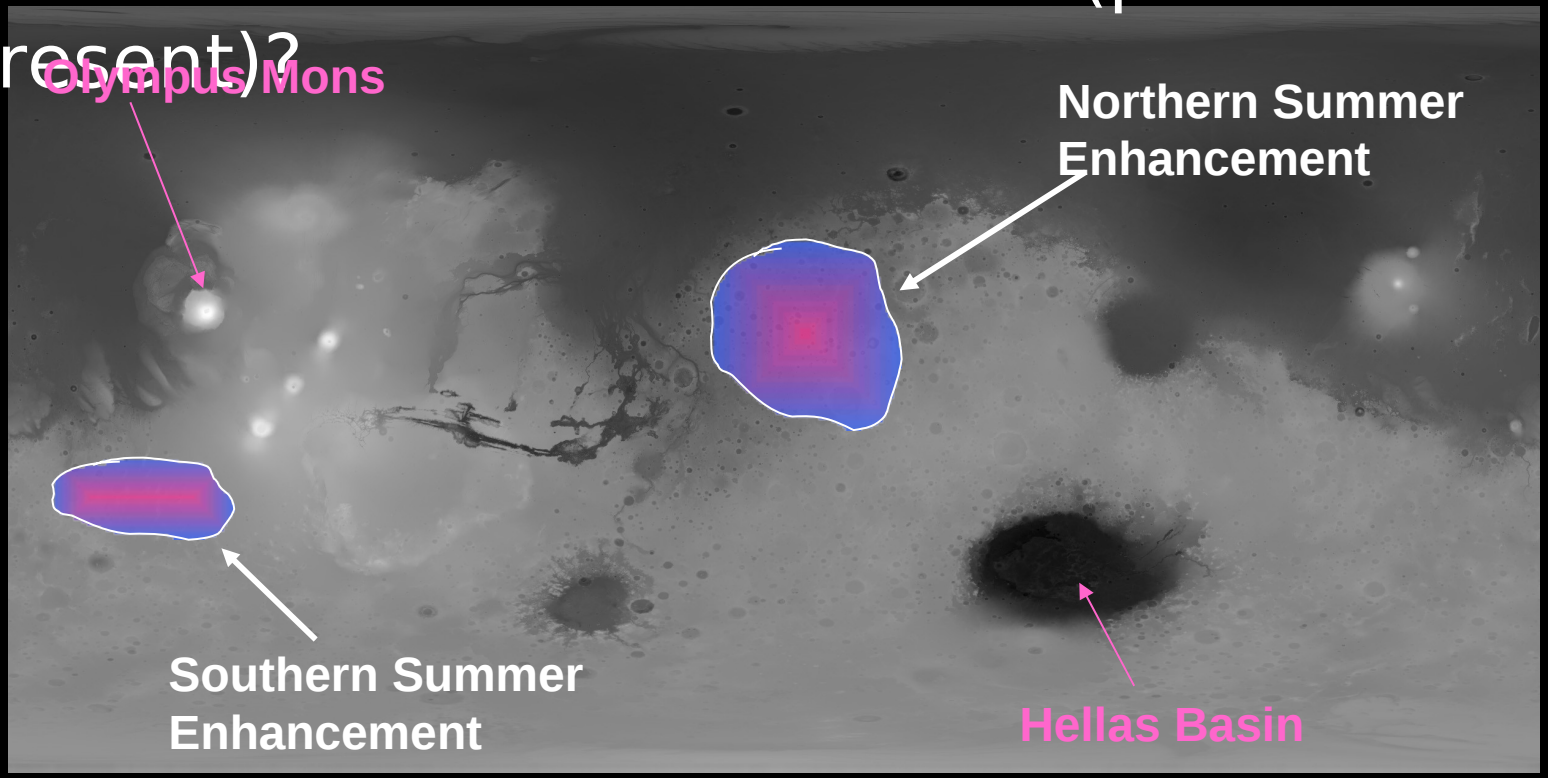
dust storm

- Mars has clouds (water ice and CO_2 ice)



CH_4 on Mars?

- Detection of CH_4 on Mars in small amounts
  - 10 ppb, 1/100th of Earth atmosphere
  - CH_4 varies in space and time
- Could it be an indicator of life (past or present)?



The Goldilocks Principle

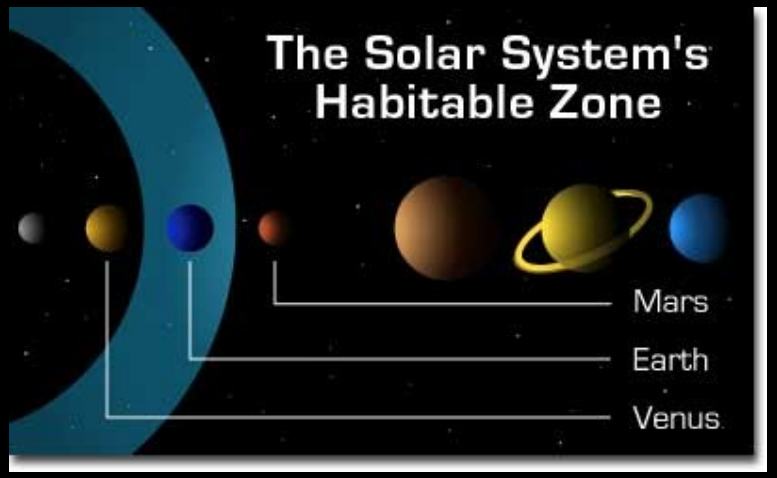
Venus is too hot, Mars is too cold, but Earth is *just right* !

Venus: Runaway Greenhouse

Mars: All water is frozen

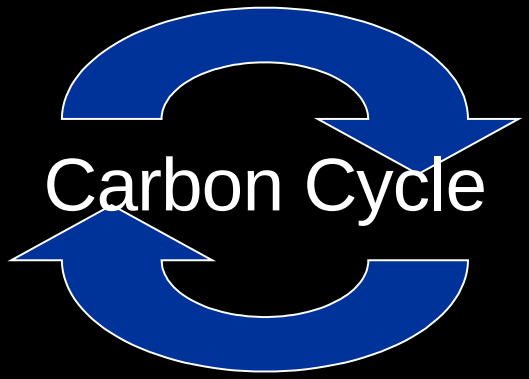
Why is Earth “just right”?

- Distance from Sun



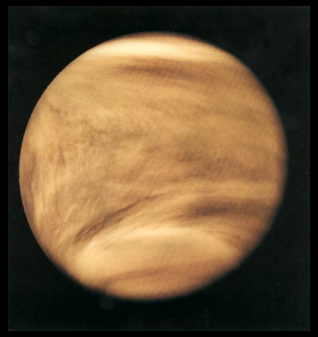
- Moderate and stable obliquity (Moon)
- Clouds/cold trap keep H_2O from rising
- Carbon cycling

Climate Stabilization



Carbonate metamorphism is <u>source</u> of Carbon dioxide

Weathering is <u>sink</u> for Carbon Dioxide



<u>Venus</u>

Lack of water prevents weathering (sink)

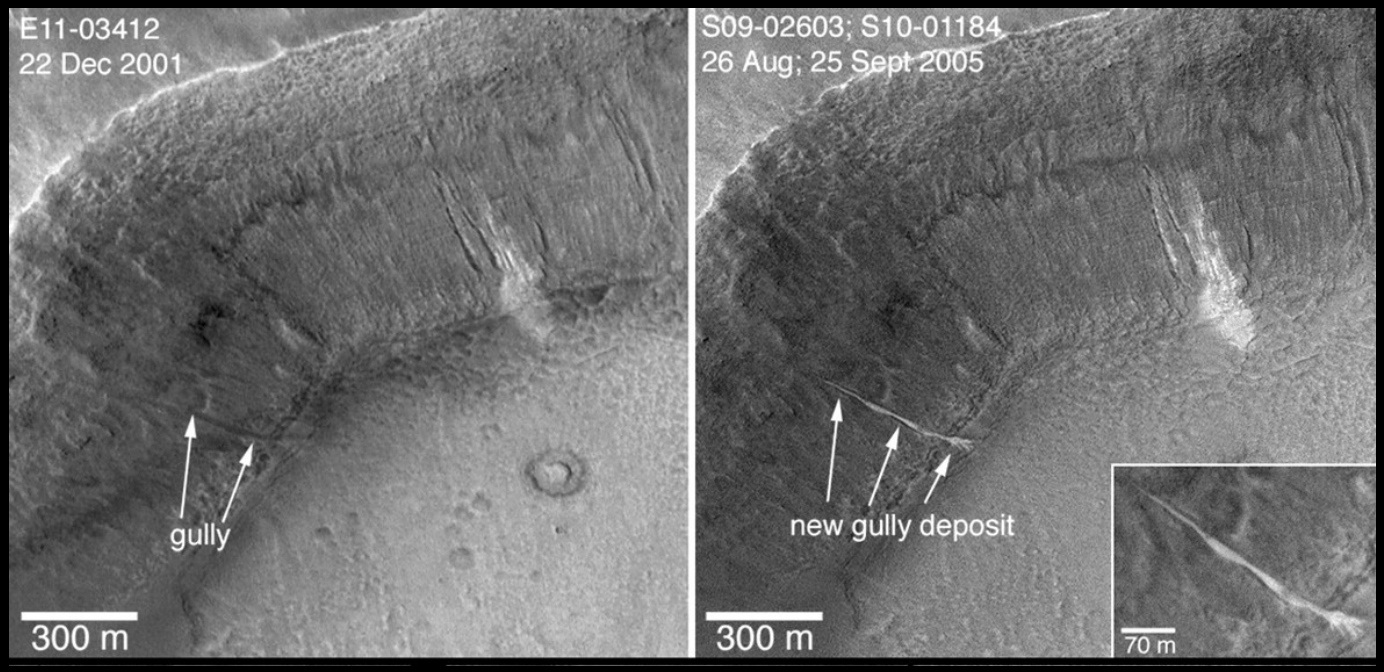
<u>Mars</u>

Small size stopped tectonic/volcanic activity (source)

Mars: Was there more CO_2?

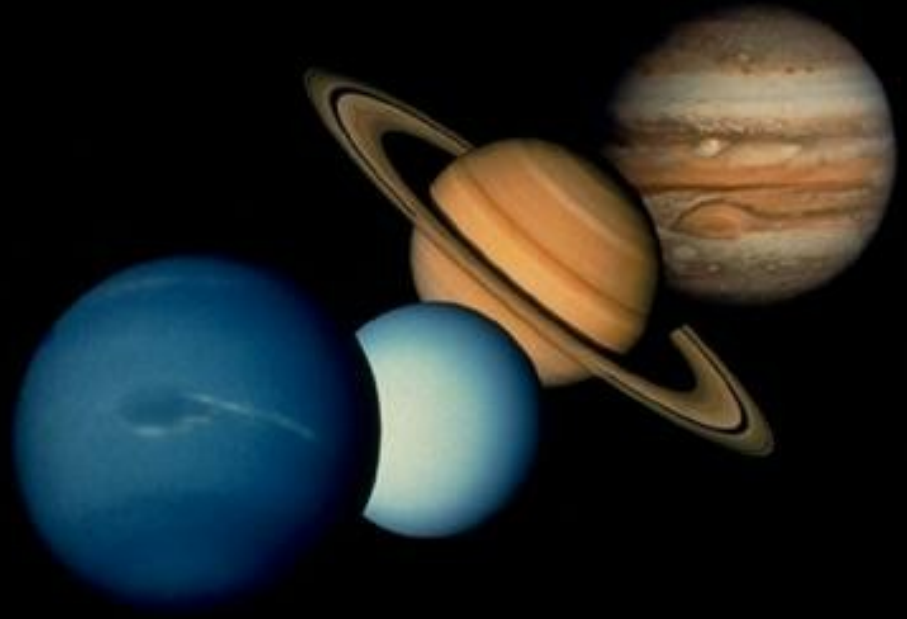
- **Evidence of past water on Mars begs the question:**
  ***when* and *how* was Mars warmer?**
- **CO_2 trapped in ices?**
  - **CO_2 can be trapped in H_2O ice, stable under high pressures (and undetectable)**
- **Obliquity changes may release more CO_2 into atmosphere**
- **Impacts may have temporarily**

Recent Evidence of Mars Processes



- Would be amazing discovery if caused by water
- Gullies may have been formed from debris-

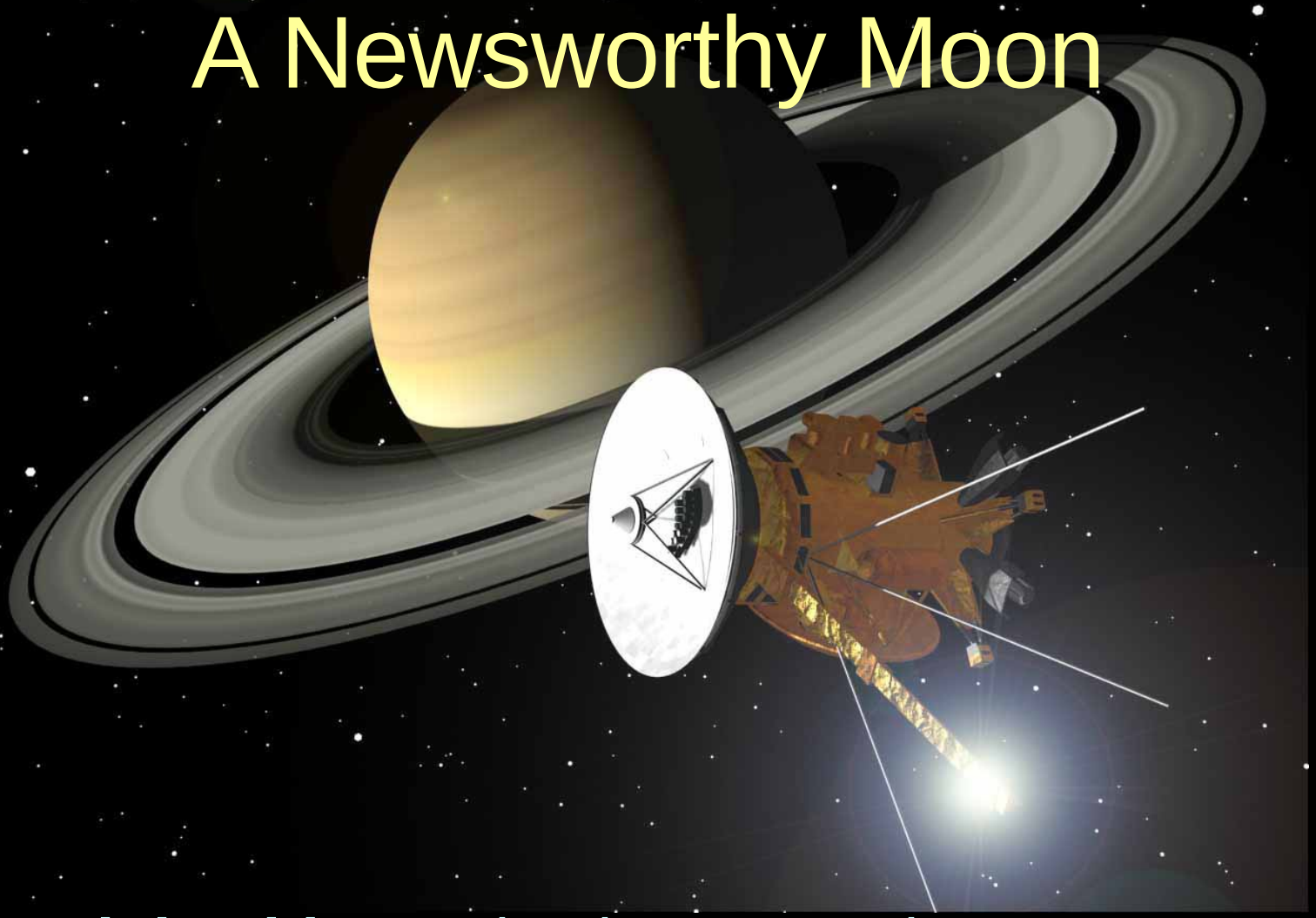
Titan



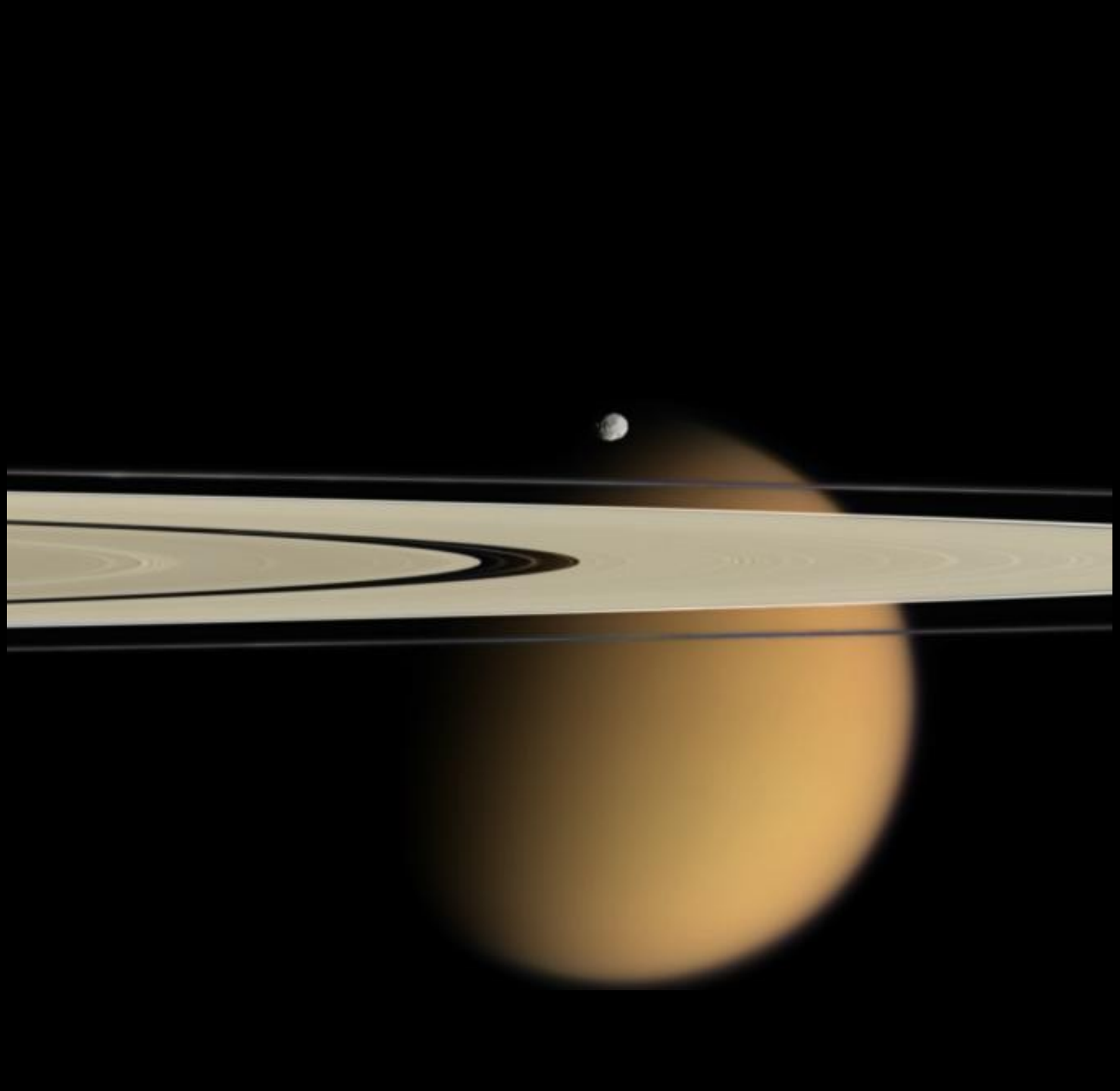
Titan

Largest Moon of Saturn

A Newsworthy Moon



- **Cassini Orbiter** arrived at Saturn in June, 2004
- **Huygens Probe** released into Titan’s atmosphere in January, 2005



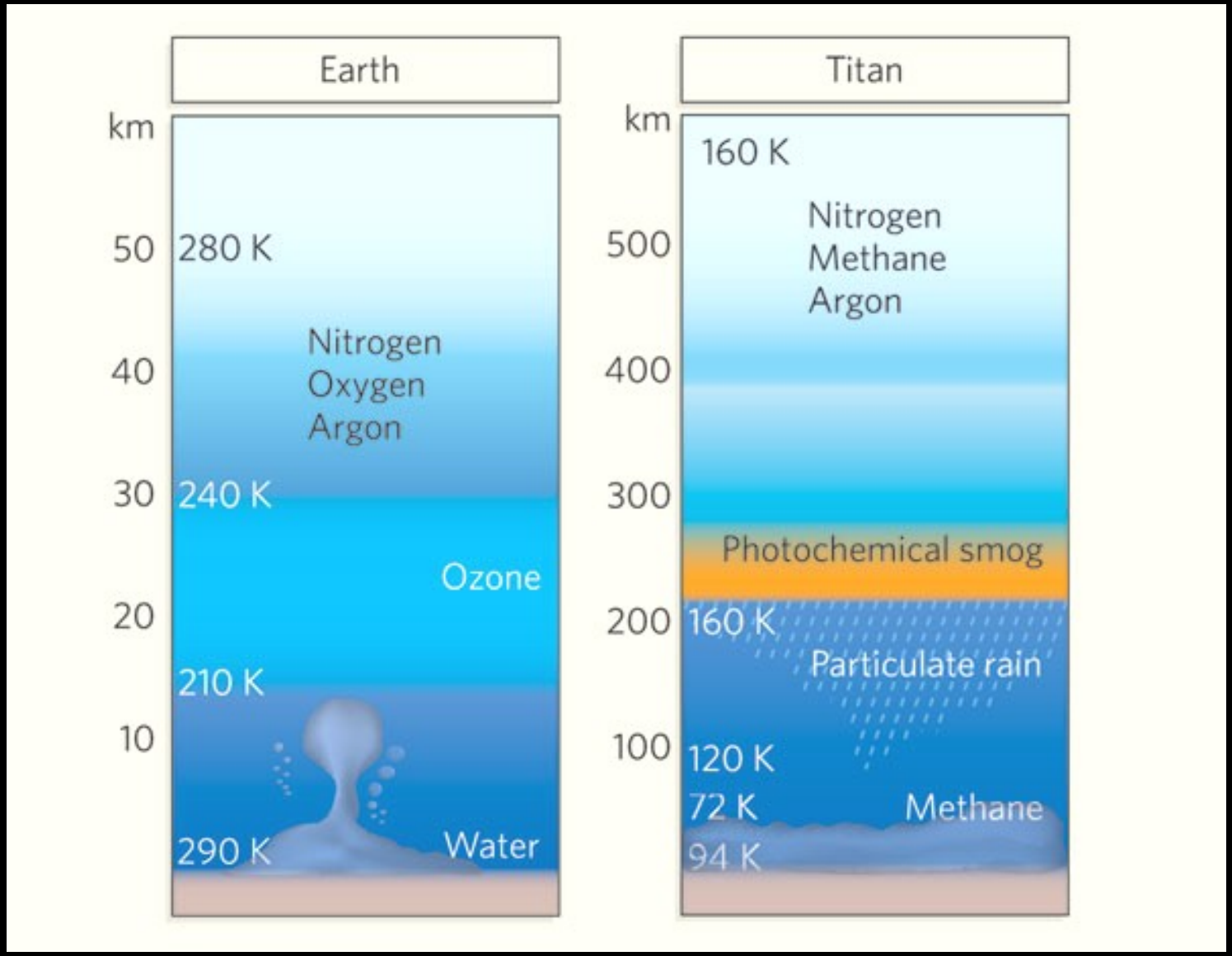
Saturn and Titan are 10x further from the Sun than Earth!

- 800 million miles from Earth
- Took Cassini 7 years to get there

Titan vs. Earth

- Size and Gravity
- Surface Temperature
- Atmosphere

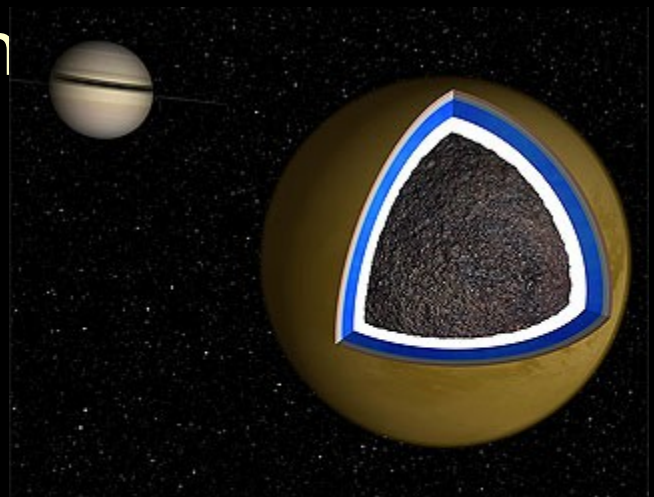
Titan vs. Earth



From Owen, (2005) *NATURE* **438** (7069): 756-757.

Origin of N_2 on Titan?

- A mystery of Titan
- Huygens data show:
  - Primordial argon (^{36}Ar) is several orders of magnitude below that expected if nitrogen accreted as N_2
- Implies N_2 was converted from nitrogen-bearing compounds - ammonia (NH_3)
- NH_3 then dissociated back in
(photochemistry)

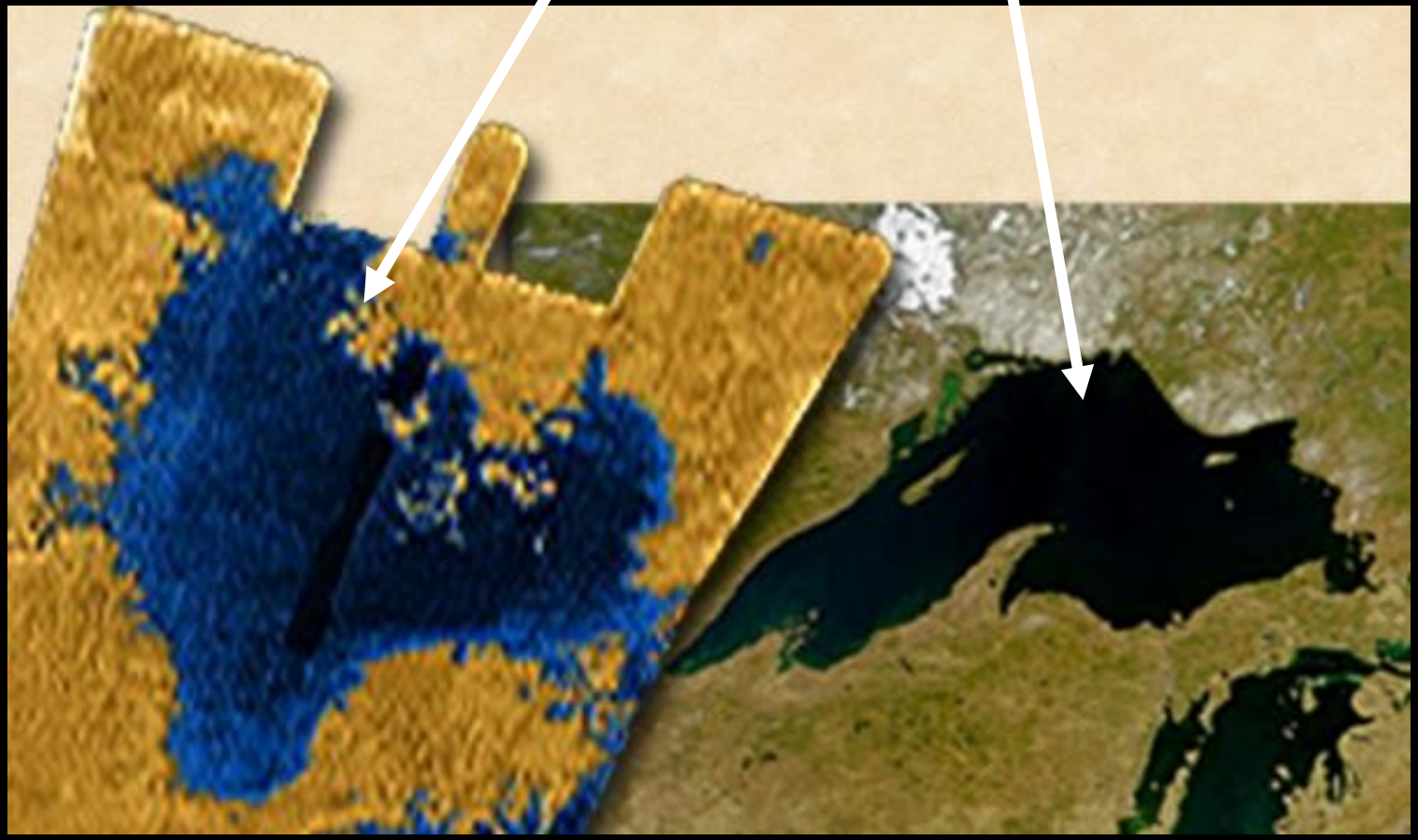


Internal Ocean of H_2O/NH_3

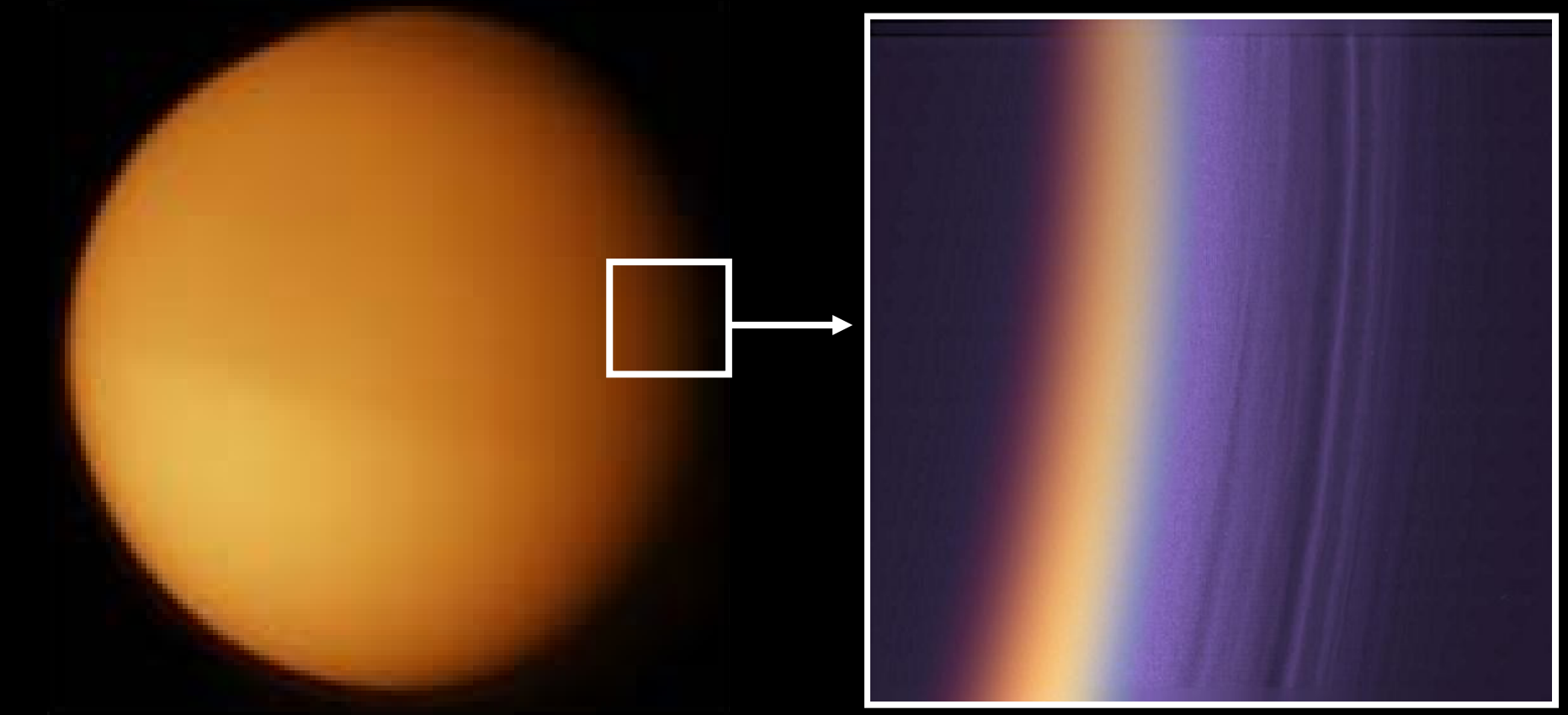
Titan's Surface

- Landing probe found a "soggy" surface strewn with pebbles
- Light is very dim, sky appears orange because of haze in atmosphere
- COLD!
  - H_2O ice would be solid as rock
  - Lakes and rivers could be CH_4

“Lake” at Titan’s North Pole as big as Lake Superior



Why does Titan look so hazy?



Organic particles produced by CH_4 photochemistry

(LA smog)

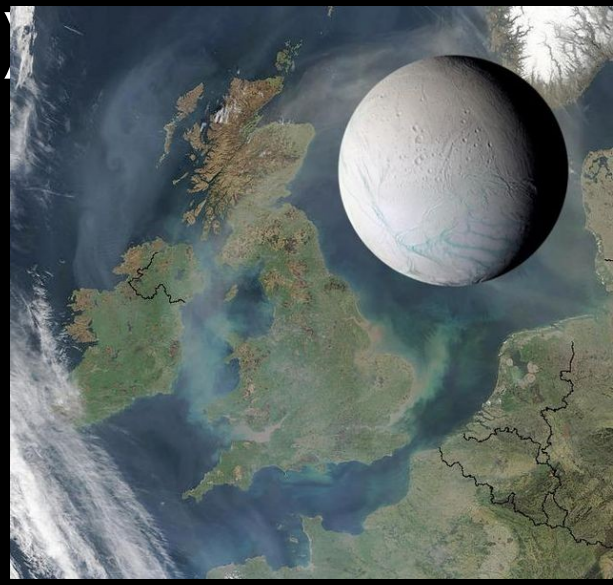
Titan → Like Prebiotic Earth?

- High production rate of organic material
- Titan is too cold for chemistry to advance
- If “Early Earth” had CH_4, may have been hazy

Enceladus

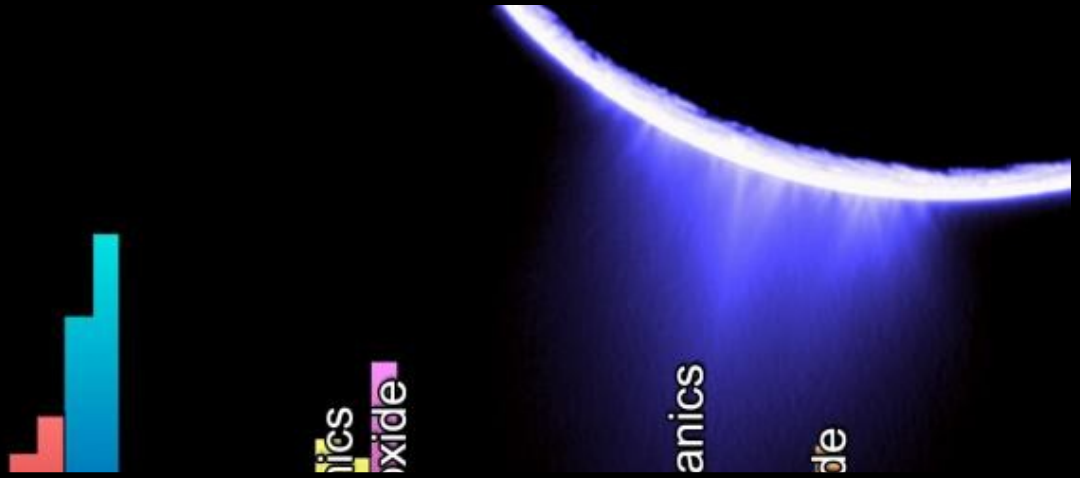
Enceladus

- Moon of Saturn
- Different surface ages (some surfaces more cratered than others) gives evidence of cryo-volcanism
  - Temperature ~ 75 K (-198°C)



Water-Organic Rich Geyser

- Cassini witnessed plume being ejected from Enceladus during flyby



What is source of material?

Trapped in ices, then subject to internal heating?

As we explore other planets, we learn more about our own...

- Where did it come from?
- Where is it going?
- What will other habitable planets look like?

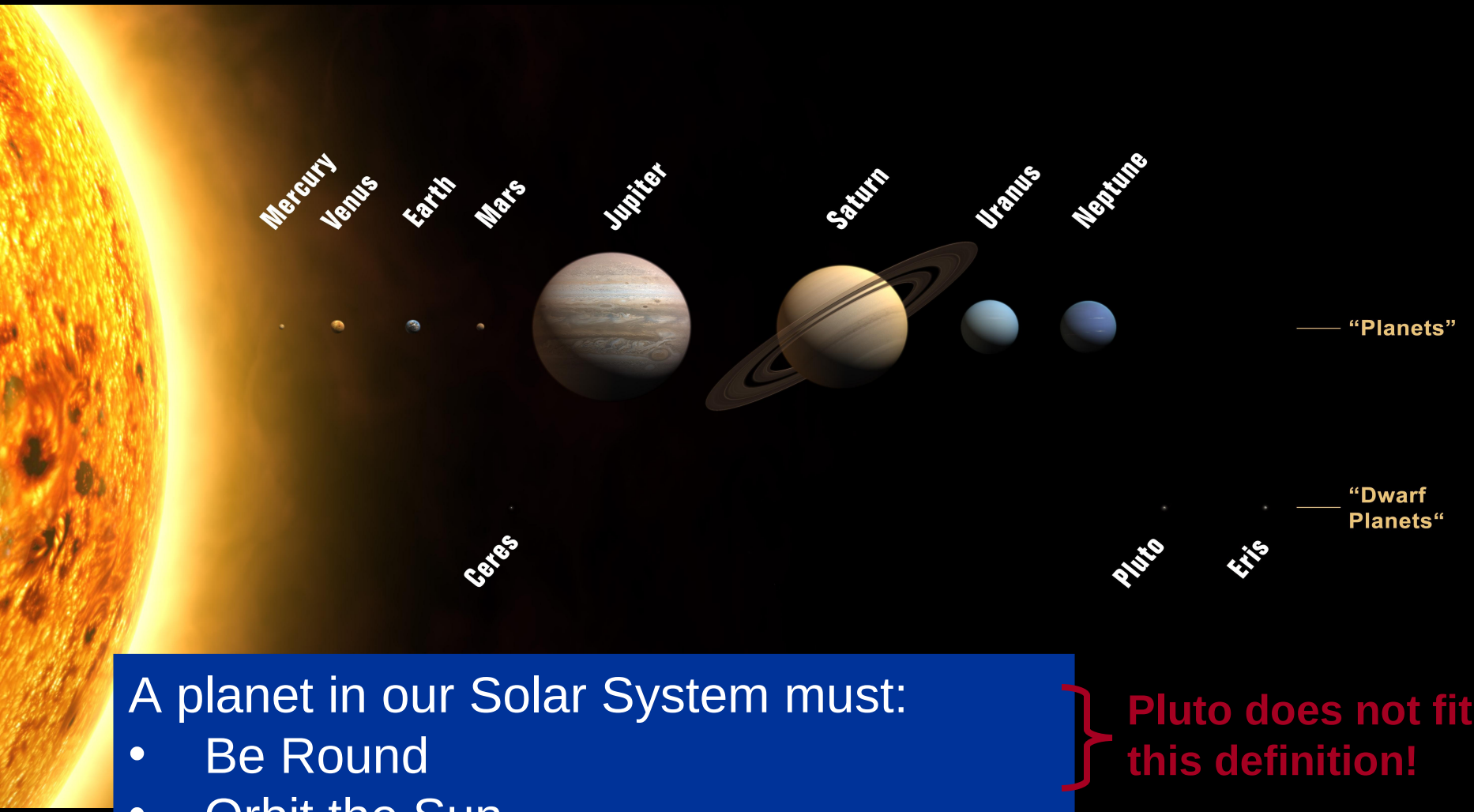
Questions?

trainer@lasp.colorado.edu

Our Solar System

- Europa (moon of Jupiter)
  - Water ice, maybe liquid
  - Hydrothermal energy?
  - Organics?

What is a planet?



A planet in our Solar System must:

- Be Round
- Orbit the Sun
- Be the biggest object in its orbit

Pluto does not fit this definition!


2003 UB313
2600 km
Sedna
1500 km?
Quaoar
1290 km
Pluto
2320 km
Moon
3480 km
Earth
12,800 km
Pluto is NOT a planet because it is not the largest object in its orbit