Mars

- Venus is too hot. Why did greenhouse fail on Venus? Brief review.
- Key Questions

1. What is the evidence that Mars has water?
2. What is the evidence that Mars had liquid water at one time?
3. Why did Mars become cooler (so that liquid water disappeared)?
4. What is the evidence that Mars used to have a hot interior?

- Homework 3 is due 6am on Wed. the 18th.

Goldilocks #1

- Venus is too hot; Mars is too cold. Why is the earth just right, not too cold and not too hot?
- Venus is too close to the sun, and Mars is too far.
  - This is part of the answer.
- Reflected light is 2nd ingredient.
- Greenhouse effect is 3rd ingredient.
  - Without the greenhouse effect, earth would be frozen.
  - Mars has a small greenhouse effect
  - Why did Venus evolve to have such a large greenhouse effect?
- History is 4th.

Planet	Pressure	Sunlight relative to Earth	Reflected	Temp w/o GH	Actual Temp	Greenhouse warming
Venus	90 atm	1.92	76%	-44 C	477 C	521 C
Earth	1 atm	1.00	30%	-18 C (0F)	15 C (59F)	33 C
Mars	0.006 atm	0.43	25%	-63 C	-55 C	8 C

Table from Rampino & Caldeira, 1994, Ann. Rev. Astron. & Astrophys, 32, p83.

The faint-sun paradox

- The sun was 30% fainter 3 Byrs ago. The earth received 30% less sunlight, but there was liquid water back then. Why did the earth stay just right, not too cold and not too hot?
- When the sun became brighter, the earth became warmer.
  - More evaporation ⇒ more rain
  - More rain ⇒ loss of more CO2, sequestered in rock
  - Less CO2 ⇒ less greenhouse effect
  - Less greenhouse ⇒ Earth cools, lessening effect of sun brightening
- When sun was fainter, the earth was cooler.
  - Less evaporation ⇒ less rain ⇒ more CO2 was released from rocks by volcanoes ⇒ more greenhouse effect ⇒ Earth warmed, lessening effect of sun dimming
- Walker, Hays, & Kasting (1981) discovered this effect, which provides negative feedback.

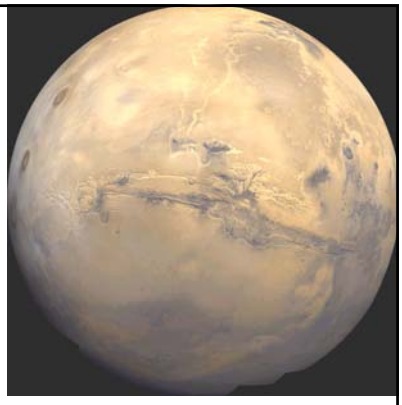
Why did greenhouse run amok on Venus?

- Key observation #1: Earth's ocean has 100,000 X more water than Venus' atmosphere.
- Deuterium
  - Normal H has 1 proton in nucleus
  - Deuterium D has 1 proton & 1 neutron
- At the same temperature, normal hydrogen gas moves faster than deuterium and is more likely to escape.
- Key observation #2 on deuterium abundance
  - On earth, H/D=5000
  - On Venus, H/D=50.
- Q4 Which hypothesis does KO#2 support?
  a. Venus formed without much water.
  b. Venus lost its water.
- On Jupiter, H/D=45000.
- Over the history of Earth, H/D dropped to 5000 because it is easier for H to escape than D. Earth has lost part of its hydrogen.
- Since H/D is higher on Venus, Venus has lost more of its hydrogen and therefore its water.

- Venus lost its water
  - Venus is hotter because it is closer to sun.
  - Water was in atmosphere.
  - Ultraviolet light broke water into oxygen and hydrogen. Hydrogen escaped.
- No rain $\Rightarrow$ no way to get rid of CO2.
- Models show Earth will suffer same fate if sunlight increases by 40%. CO2 cycle will not be sufficient to keep Earth temperate.

Mars

	Venus	Earth	Mars
Diameter	0.95	1	0.53
Mass	0.81	1	0.11
Semi-major axis	0.72	1	1.52
Density	0.96	1	0.71
Rotation (days)	-243	1	1.026
Orbit period (days)	224	365	687



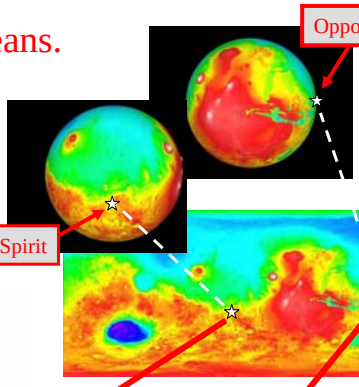
- Some of the 16 spacecraft that have gone to Mars:
  - **Mariner 9** orbiter (1971-72)
  - **Viking 1,2** landers (1976-80)
  - **Pathfinder** lander + rover (1997)
  - **Climate Orbitor**, **Polar lander** (crashed, 1999).
  - **Mars Global Surveyor**: orbiting Mars since March 1999.
  - **Odyssey**: orbiting Mars since October 2001.

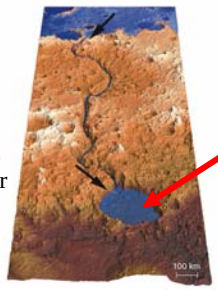
Rotating Mars

The Mars Rovers:

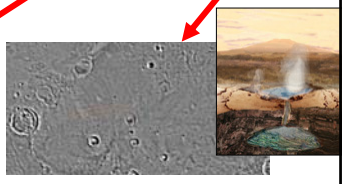
Searching for former lakes and oceans.

- Two separate missions.
- Arrived January 2004.
- Can travel 40 meters/day.
- Have far exceeded planned 3 month mission.
- Carry cameras, spectrometers, alpha-particle detector, grinder ➔ geology.



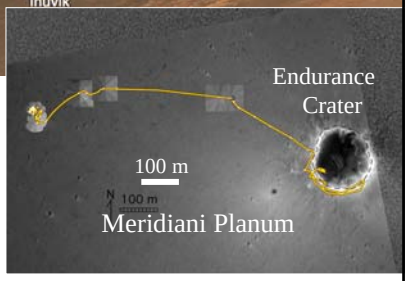


Gusev Crater
Former lake?



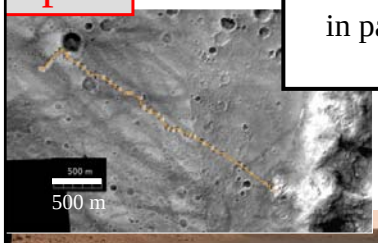
Meridiani Plain
Hematite (iron oxide = rust) deposits. Former hot spring?

Opportunity



Finding lots of evidence for water in past, at both sites.

Spirit

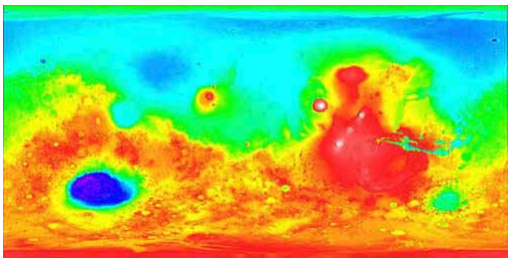


Geology

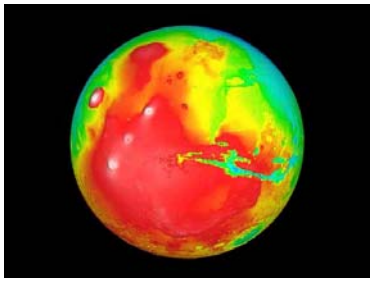
- Density suggests mostly silicates, but small metal core
- No detectable magnetic field
- Continental highlands
  - cover ~ 50% of planet.
- Low-lying lava plains
  - average of 4 km lower than continents.
  - Same age as lunar maria - 3-4 billion yrs old.

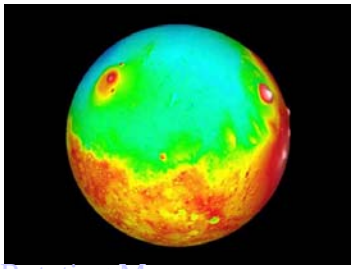
Topographic Map

From Mars Global Surveyor orbiter



Red = high areas.
Blue = low areas.



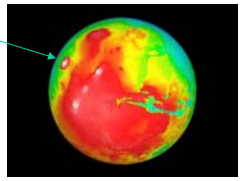


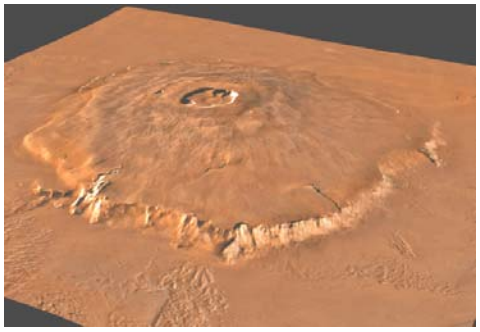
Rotating Mars

Tharsis bulge

- uplifted continent 10 km high.
- has 4 huge volcanoes, 15 km high.

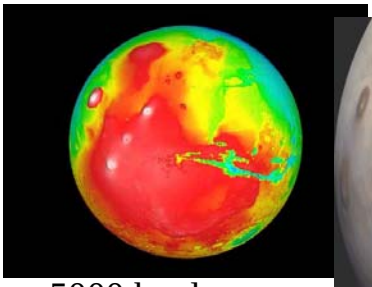
Olympus Mons





- 500 km diameter
  - would cover MI lower peninsula
- 25 km above surrounding plains
- largest mountain in Solar System.
  - 100 x volume of Mauna Loa
- < 100 million yrs old (impact crater counts)
  - so Mars is still geologically active.

Valles Marineris



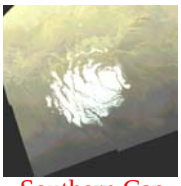
- 5000 km long
  - 1/4 way around Mars
  - would stretch clear across US.
- Huge tectonic crack in Tharsis bulge
  - 8-10 km deep
  - no outlet for water
    - but some minor role of water erosion in side canyons.

Martian Atmosphere

	Venus	Earth	Mars
Surface temperature	482° C	20° C	-100° C
Surface Air Pressure	92	1	0.007
CO_2	96%	0.03%	95%
N_2	3.5%	78%	2.7%

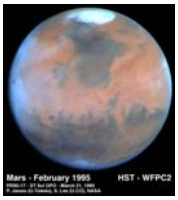
- Pressure is low
- Very cold
- (almost) no liquid water.
  - At Mars' low atmospheric pressure, water should go straight from ice to vapor.
- No Greenhouse effect because there is so little atmosphere.

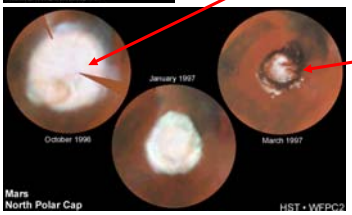
Polar Ice Caps



Southern Cap

- Always below 150° K (-279°F), so CO_2 frozen all year.
- Unknown mix of CO_2 and H_2O ice.





Frozen CO_2 layer in winter

Only underlying H_2O ice left in summer, 3 km thick

Northern Cap

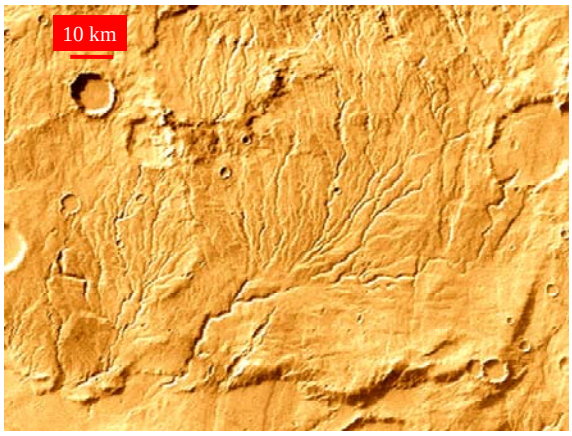
Rotating Mars

Climate change

Used to be *lots* of running water

- Runoff channels.
  - From rainstorms billions of years ago.

[Fig. 7.22]



What happened to Mars' greenhouse

- At one time Mars was warm enough for liquid water.
- CO2 reacts with silicate rocks to convert to carbonate rocks.
  - Q5 Why is sequestering of carbon in rocks not fatal on earth?
    a. The rocks are protected by vegetation.
    b. Because of plate tectonics, the carbon is released again.
    c. On earth, this does not happen as much because of the oceans
- CO2 produced by volcanoes & meteors
  - Meteor bombardment ceased
  - Being smaller, Mars cools faster & volcanoes decrease more rapidly.

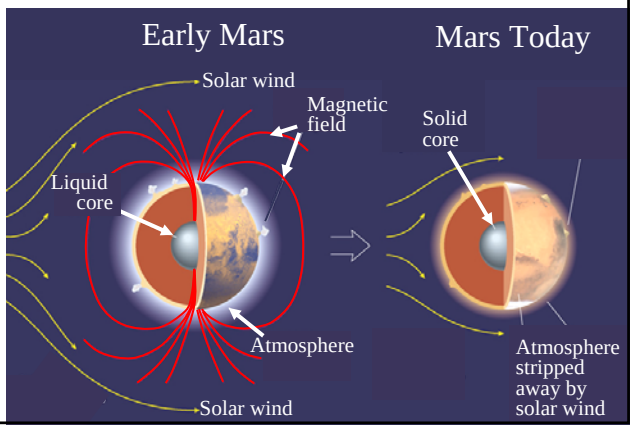
What happened to Mars' atmosphere

Mars did have H2O & CO2. Where did H2O go?

- H2O dissociates to O2 & H2 by UV light
  - Hydrogen escapes
  - Oxygen reacts with rock
- Stripping by solar wind
  - Core solidified ➔ magnetic field went away ➔ stripping of gas by *solar wind* particles.
- Low temperature freezes water

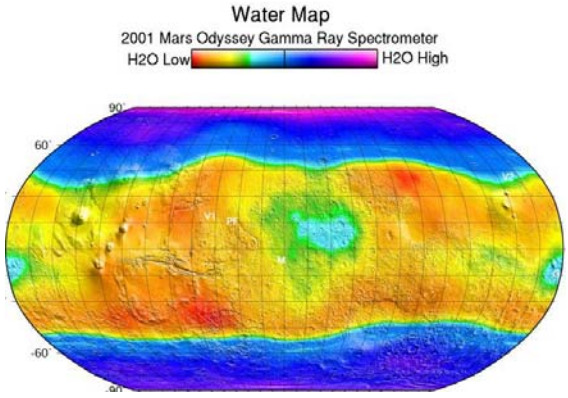
[Fig. 7.27]

	Venus	Earth	Mars
Escape velocity	0.93	1	0.45
Surface temperature	482° C	20° C	-100° C
Surface Air Pressure	92	1	0.007



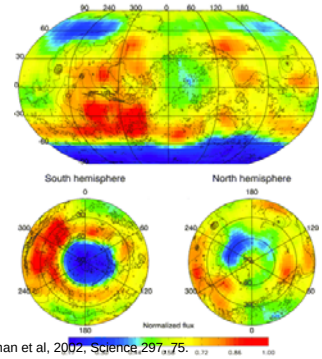
Gammy Ray Spectrometer & Neutron Spectrometer on Mars Odyssey

- "We have found that in the regions north and south of 60 degrees latitude, the surface is well over 50 percent water ice by volume. If just the top meter of ice deposits around the martian north pole were melted, there would be enough liquid water to fill Lake Michigan," Boynton (http://marsprogram.jpl.nasa.gov/spotlight/odyssey-mission-success.html)

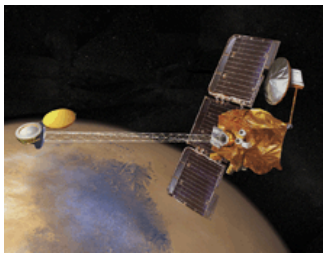


How could Odyssey see below the Martian surface?

- Cosmic rays hits Mars b/c there is no protecting magnetic field & atmosphere. Produce neutrons and gamma rays.
- Hydrogen (in top meter) absorbs energy of neutrons efficiently.
  - Energy of neutrons is transferred to hydrogen b/c masses are same.
  - Mass of Silicon, etc is much greater than that of neutron. Energy loss is small when neutron hits silicon.



Feldman et al, 2002, Science 297, 75.



Summarizing questions/ Q for reading

1. What is the evidence that Mars has water?
2. What is the evidence that Mars had <u>liquid</u> water at one time?
3. Why did Mars become cooler (so that liquid water disappeared)?
4. What is the evidence that Mars used to have a hot interior?

- Question for reading

1. Which is the principal reason the <u>interior</u> of Jupiter is hot?
   a. Material fell from a height and is therefore moving faster.
   b. Uranium decays and releases energy.
   c. The sun heats it.
   d. There is a lot of methane for burning.