

# ET: Astronomy 230



## This Class (Lecture 23):

Life in the Solar System

## Next Class:

Life in the Solar System

### **Midterm on Friday!**

**Presentations Monday Oct 24th**

**Jonathan Dellinger**

**Nathan Louer**

**Amit Behal**

**Presentations Tuesday Oct 26th**

**Jim Kestler**

**Melanie Kang**

**Brian Krutsch**

**Presentations Monday Oct 28th**

**Drew Sultan**

**Kurt Peterson**

**Jim Vorel**

Music: *Venus as a Boy* – Bjork

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# Midterm



- 1 hour exam in this classroom.
- It will cover material up to, but not including, “Life in the Solar System”
- Will consist of 17 multiple choice/ true-false questions (worth 2 points each) and 3 essay questions (6, 25, and 40 points each) .
- A total of 105 points, so 5 extra credit points.
- You can bring a normal-sized sheet of paper with notes on both sides.

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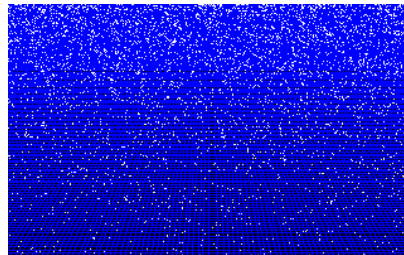
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# Big Bang



- Big Bang!
  - 13.7 billion years ago.
- Creation of primarily hydrogen & helium via BBN at  $t \cong 3$  minutes.
- Don't forget dark matter and dark energy.
- Still expanding and cooling
  - The rate of expansion is known
- It is BIG
  - As far as we are concerned, it is infinite in any direction
- Our place in the Universe is not special
  - Extension of the Copernican revolution
- The center of the Universe is everywhere or nowhere!



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# Galaxies



- Galaxies formed from the seeds of dark matter and hydrogen.
- The first stars formed from huge clouds of hydrogen.
- Fusion starts– turning hydrogen into helium,
- Remember that you have to have mucho heat and pressure to overcome the nuclear strong force.
- Hydrostatic equilibrium (gravity pressure pushes in – heat pressure pushes out).
- There are perhaps hundreds of billions of galaxies
  - Each with hundreds of billions of stars



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## But Life?



- As far as we know, we expect that we are typical in many ways to the other planets around other stars, in other galaxies.
- One aspect of the study of extraterrestrial intelligent life is to determine if *life* is a typical phenomenon.
- Our best guess is that most other galaxies have at least one planet with intelligent life on it
  - As the Milky Way has at least one planet with Intelligent Life.
- So, there ought to be hundreds of billions of intelligent civilizations in the Universe!
- But we focus on our Galaxy.



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## First and Second Stars



- Besides H into He, the first stars also create carbon and oxygen.
- As they age to the red giant phase, they produce sulfur, phosphorous, silicon, and finally iron.
- The star explodes and scatters the elements into the galaxy.
- The second stars form in the ashes of the first, forming most of the Universe's Nitrogen through the CNO cycle, then explode.
- Molecular clouds form from these elements.
- We are made from star stuff!

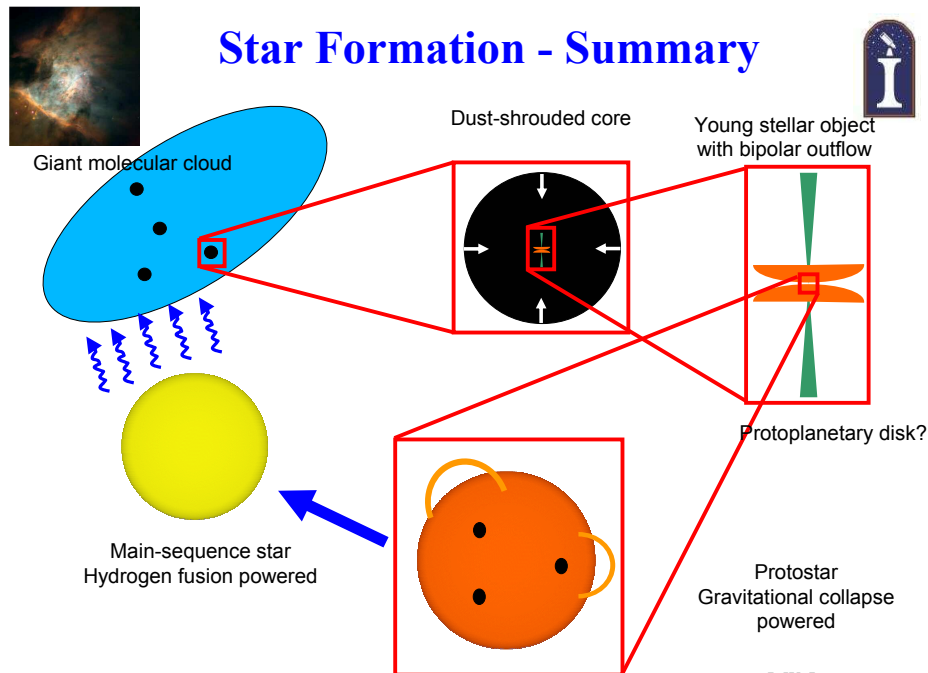


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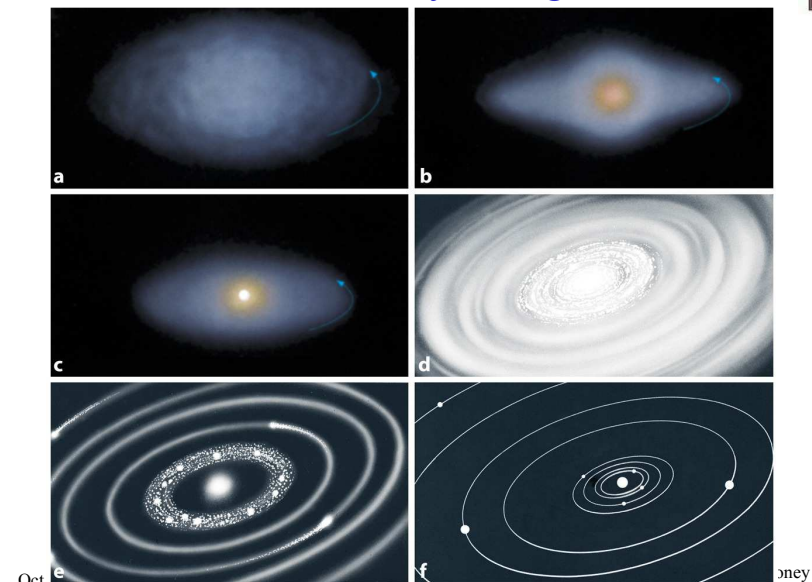
## Star Formation - Summary



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## Formation of the Solar System 4.6 billion years ago



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# Planet Formation in the Disk



Heavy elements clump

1. *Dust grains* collide, stick, and form planetesimals. All orbit in the same direction and in the same plane.
2. Gravity Effects: Big planetesimals attract the smaller planetesimals. Collisions build-up inner planets and outer planet cores.
3. Collisions can also account for odd motions of Venus (backwards), Uranus (rotates on its side), and Pluto (high inclination of orbit). Period of high collision in the system.



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# Outline



- Next stage– Is there life in our Solar System?
- Venus: Life in the clouds?
- Mars: Life in the ground?

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= 0.21

Life planets  
/year

# Drake Equation

Frank Drake



$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

# of advanced civilizations we can contact in our Galaxy today	Rate of star formation	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that communicate	Lifetime of advanced civilizations
10	stars/yr	0.38 systems/star	0.11 planets/system	0.5 life/planet	intel./life	comm./intel.	yrs/comm.

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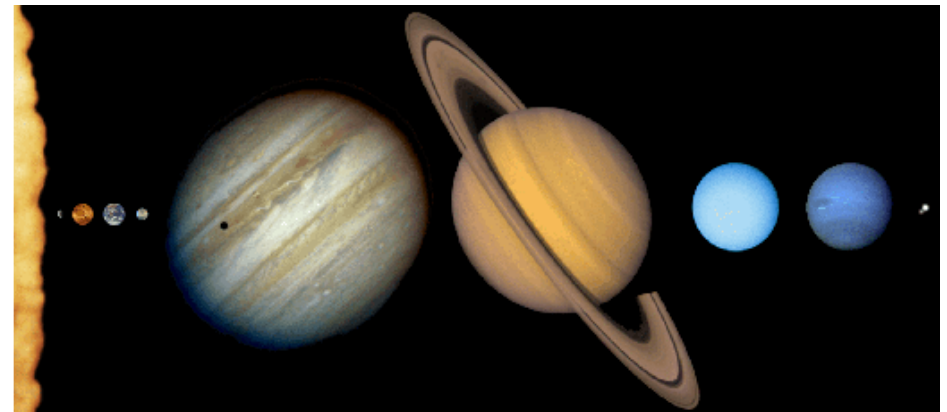
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# Life in the Solar System?

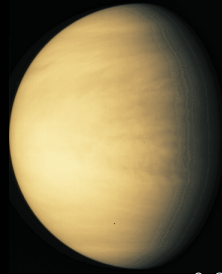


- We want to examine in more detail the backyard of humans.
- What we find may change our estimates of  $n_e$  or even  $f_l$ .





## Earth – Venus comparison



Venus is the hottest planet, the closest in size to Earth, the closest in distance to Earth, and the planet with the longest day.

Radius	0.95 Earth
Surface gravity	0.91 Earth
Mass	0.81 Earth
Distance from Sun	0.72 AU
Average Temp	475 C
Year	224.7 Earth days
Length of Day	116.8 Earth days
Atmosphere	96% CO <sub>2</sub>

## What We Used to Think



Venus must be hotter, as it is closer the Sun, but the cloud cover must reflect back a large amount of the heat.

In 1918, a Swedish chemist and Nobel laureate concluded:

- Everything on Venus is dripping wet.
- Most of the surface is no doubt covered with swamps.
- The constantly uniform climatic conditions result in an entire absence of adaptation to changing exterior conditions.
- Only low forms of life are therefore represented, mostly no doubt, belonging to the vegetable kingdom; and the organisms are nearly of the same kind all over the planet.

<http://www.daviddarling.info/encyclopedia/V/Venuslife.html>

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## Turns Out that Venus is Hell



- The surface is hot enough to melt lead
- There is a runaway greenhouse effect
- There is almost no water
- There is sulfuric acid rain
- Not a place to visit for Spring Break.



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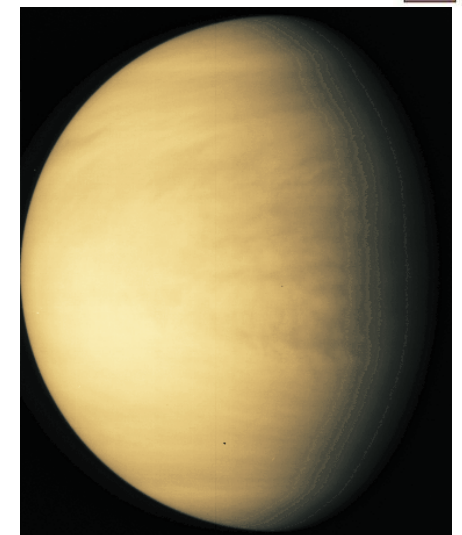
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## Our “Twin”



- Always covered in thick clouds of CO<sub>2</sub>, which make it the hottest planet in the Solar System.
- Pressure on surface is 90 times that on Earth— like 1 km under the sea
- Often called the morning star or the evening star. 3<sup>rd</sup> brightest object in the sky. Often mistaken for UFO.
- Retrograde rotation – Sun rises in west
- No moons, no magnetic field

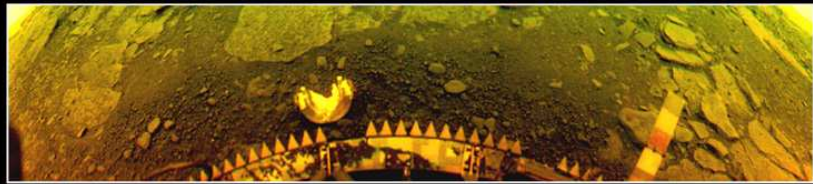


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<http://antwrp.gsfc.nasa.gov/apod/ap060923.html>  
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# Soviet Satellites on Venus



Color as seen on the surface of Venus

Venera 13

Color with atmospheric effects removed



USSR Academy of Sciences / Brown University

Mostly Basalts-like rocks, indicative of volcanoes

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# The Venusian Surface Revealed



- We can't see Venus' surface in visible light, clouds block the view
- Magellan's Radar showed the surface
- Most of surface is smooth lava flows
- Many large volcanoes
- Probable ongoing volcanism

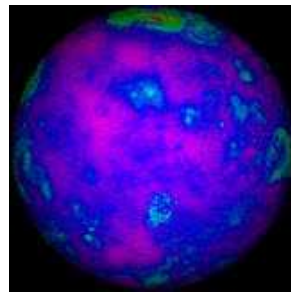


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# Surface of Venus: Radar



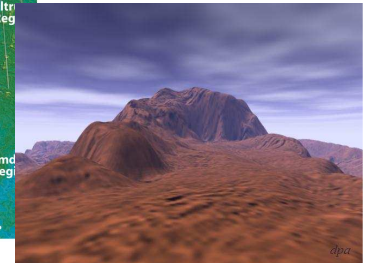
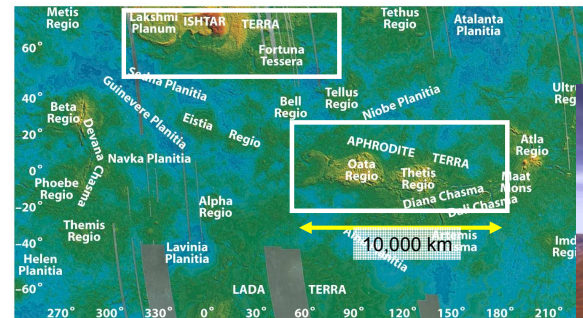
<http://www.solarviews.com/raw/venus>

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# Venus: surface features



Maxwell Montes (65N 5E)  
(Highest mountain range in the solar system  
11km high- Everest is 8km)

Images of Venus  
from radar data collected by the  
NASA Magellan Spacecraft

<http://www.geology.smu.edu/~dpa-www/venus.html>

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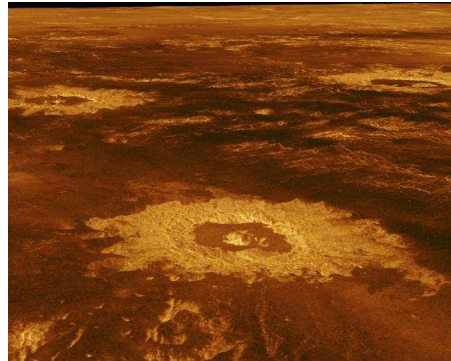
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## Impacts on Venus



- Venus has about 1,000 craters, often clustered
- No trace of heavy bombardment
- Cratering rate indicates Venus' surface about 500 million yrs old
- Why?
  - Possibility: Extreme temperatures soften rock, making the surface subject to catastrophic volcanic upheaval



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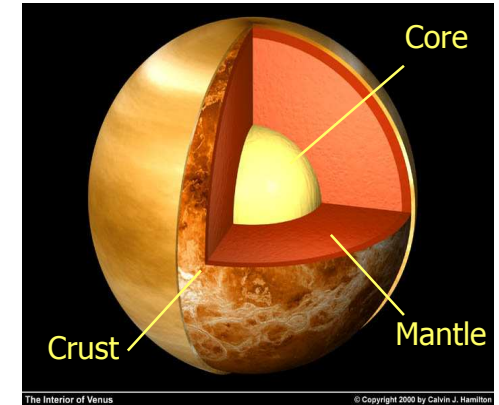
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## Venus' Interior



- Venus' size and density are roughly equal to Earth's
  - Indicates iron core of similar size
- No magnetic field
  - Very slow rotation - 243 Earth days



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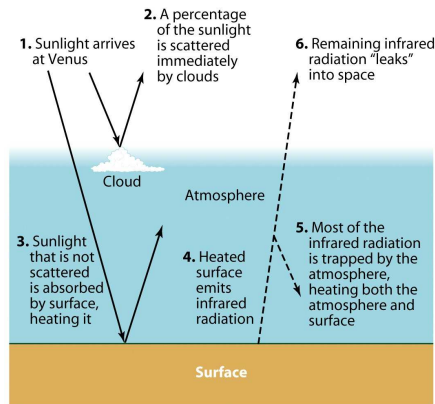
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## Runaway Greenhouse



- On Earth, greenhouse gasses insulate us
  - Keep Earth 35 K warmer than it would be otherwise
- On Venus, massive amounts of CO<sub>2</sub> keep it incredibly hot
  - Almost 300 K warmer!
  - The hottest planet in the Solar System



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## What Happened to Venus?



- It really should have been more like Earth, but the atmosphere is much different.
- Earth's atmosphere is mostly O<sub>2</sub> from life, but early Earth was N.
- Earth and Venus have similar amounts of carbon & nitrogen, but Venus's carbon is loose in the atmosphere.



<http://www.digitalart.ab.ca/art/ren/images/birth-of-venus.jpg>

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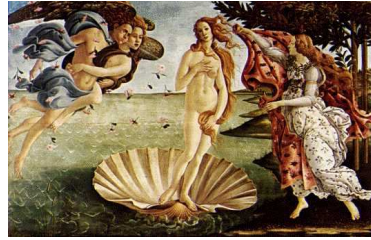
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## Why So Different?



- Earth's carbon is locked up
  - Dissolved in the oceans
  - Locked into rocks and life
- Venus' carbon is in its atmosphere
  - Too close to the Sun for liquid water
  - No oceans to trap the carbon dioxide
  - No life to process the carbon into sedimentary rocks



<http://www.edgechaos.com/MECA/WALLART/VR89/venus.jpeg>

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## What Happened to Venus?



- Apparently Venus lost its H<sub>2</sub>O— no oceans and no sediments.
- Probably the atmospheric temperature was hot enough for water to travel high enough to be broken apart by UV radiation, the H was lost and the O reacted with something else.
- Irreversible procedure!
- Which is why greenhouse effect is worrisome here too!
- The Earth traps water vapor in the cool tropopause at 14km.



<http://photos1.blogger.com/blogger/4103/1148/1600/Venus%20Wimbeldon05.jpg>

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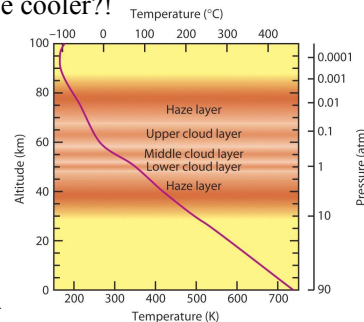
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## Life on Venus?



- Surface is far too hot
  - If lead is liquid, think of what heat would do to complex organic polymers
  - No cooler polar regions exist
    - Heat is uniform!
    - But, high in the clouds it should be cooler?!
- Maybe life can still exist in the clouds?
- At 50 km up, the temperature is not too hot and the pressure is 1 atmosphere.



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## Chemical Disequilibrium



- High clouds in the atmosphere contain chemicals that hint at the presence of some kind of biological activity.
- Hydrogen sulfide and sulfur dioxide - two gases that react with each other— exists in the clouds.
- Something is probably producing them.
- Hardly any carbon monoxide. So something is perhaps removing the gas.



[http://www.manson-valley.de/fotogalerie/manson/images/acess/acess\\_32.jpg](http://www.manson-valley.de/fotogalerie/manson/images/acess/acess_32.jpg)

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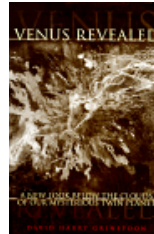
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# Life on Venus?



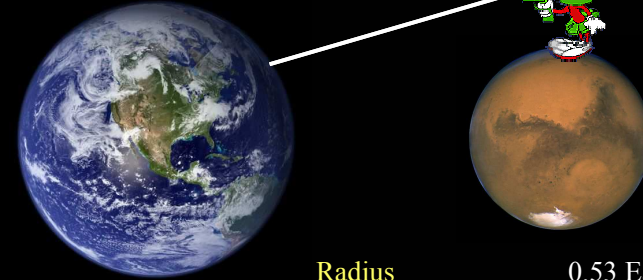
- One possibility is that microbes living in the clouds could be combining sulfur dioxide with carbon monoxide and possibly hydrogen sulphide or carbonyl sulphide in a metabolism similar to that of some early terrestrial micro-organisms.
- Given that the temperature on Venus was once much cooler, there may once have been oceans on the planet. Life could have started there and retreated to stable niches once the runaway greenhouse effect began.
- Maybe a mission to scoop up some atmosphere?



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## Earth – Mars comparison



Mars has the Solar System's largest Volcano, Olympus Mons – 27 km tall.

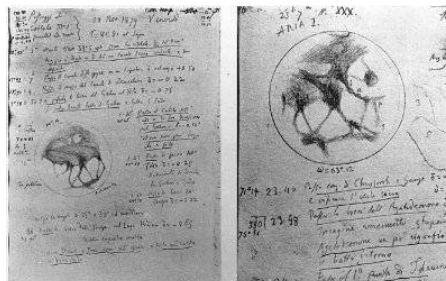
Radius	0.53 Earth
Surface gravity	0.38 Earth
Mass	0.11 Earth
Distance from Sun	1.5 AU
Average Temp	-63 C
Max Temp	20 C
Year	687 Earth days
Length of Day	24 hours 39 minutes
Atmosphere	CO <sub>2</sub> 95%

# What we used to think.



Giovanni Virginio Schiaparelli

- Was thought to be similar to the Earth in many ways.
- Life was argued to exist on Mars by many astronomers.
- The astronomer Schiaparelli announced that he saw regular linear markings on the surface, which he named *canali*.
- Technically, in Italian means channels, but it was mistranslated to canals.



Pages from Schiaparelli's observing notebook, 1879

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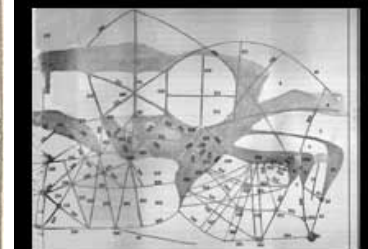
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# Percival Lowell's Canals



- Evidence for intelligent life?
- Mapped the civilization.
- Influenced culture.



Martian "canals" as mapped by Percival Lowell in the late 1800s.

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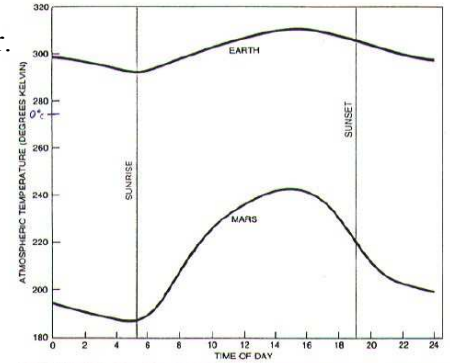
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## The Martian Atmosphere



- 95% carbon dioxide
- Atmospheric pressure 0.6% of Earth's – like 40 km altitude on Earth
- But too thin for significant greenhouse effect.
- Pressure is too low for liquid water.
- Not protected by a global magnetosphere like Earth's
- Large daily and seasonal swings in surface temperature

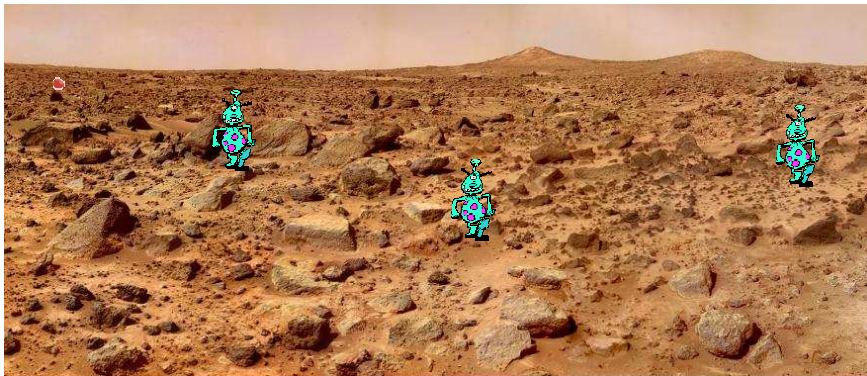


DAILY VARIATIONS IN ATMOSPHERIC TEMPERATURE at the *Viking 1* landing site (color) are qualitatively similar to those at China Lake, Calif., a desert site (black). In both cases the temperature reaches a minimum around sunrise and reaches a peak about 10 hours later. The daily range, however, is about three times greater on Mars than it is on the earth. At Viking site range is 55 degrees, from about 187 to 242 degrees Kelvin (-86 to -31 degrees Celsius). At China Lake range is 18 degrees, from 292 to 310 degrees K. (19 to 37 degrees C).

## The Surface of Mars

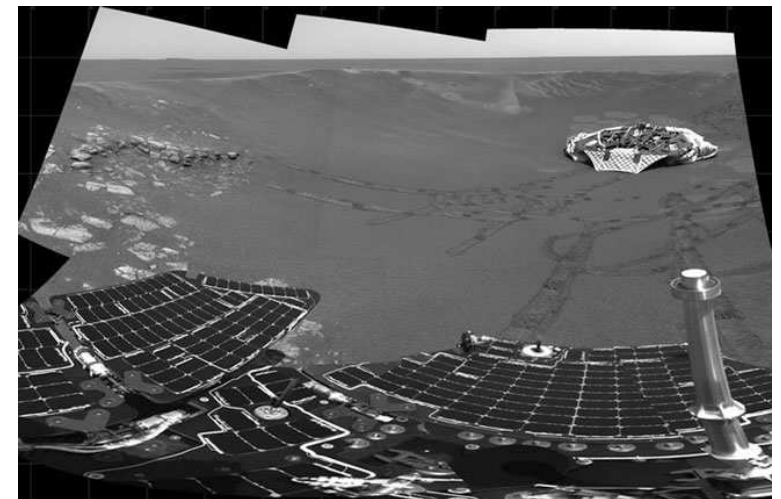


- Mars is a desert!
- Iron oxide in soil gives reddish cast.



View of "Twin Peaks" from Mars Pathfinder

## The Surface of Mars: Opportunity



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<http://www.grc.nasa.gov/WWW/PAO/16000/marspath.htm>

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<http://antwrp.gsfc.nasa.gov/apod/ap041017a.html>

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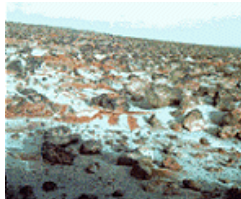
## Water on Mars



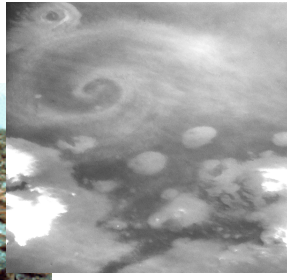
- There **is** water on Mars
  - North and south polar caps (mostly CO<sub>2</sub>)
  - Some water vapor in the air
  - Frost on rocks
  - Clouds (ice crystals)
- No *liquid* water now



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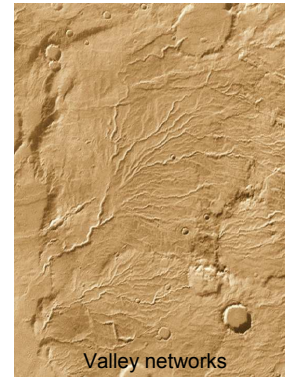


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## Liquid water on Mars?

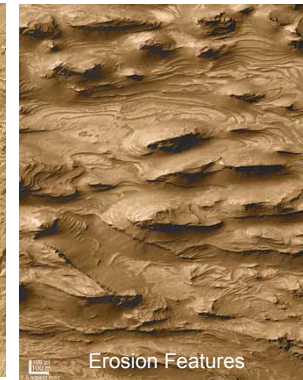


- Water erosion features visible from space
- Atmospheric pressure too low for liquid water to exist
- Perhaps at some point in the past?



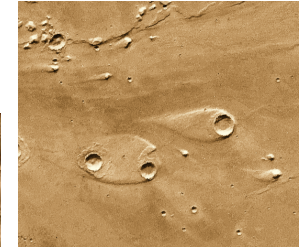
Valley networks

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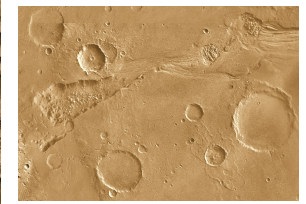


Erosion Features

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"Islands"

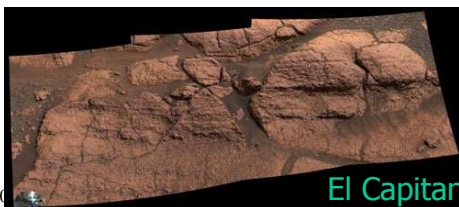
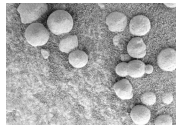


Flood erosion

## Standing Water on Mars

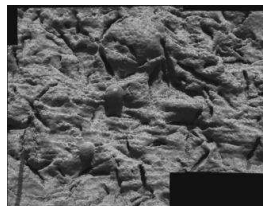


- The new data from the rovers are highly suggestive of ancient standing water on the Meridiani Planum.
- 3 pieces of evidence:
  - Physical appearance of rocks
  - Rocks with niches where crystals appear to have grown
  - Rocks with sulfates left after the water evaporated
- Is it a former sea floor or just an area that had groundwater?



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El Capitan



## Mars' Watery Past



Image Courtesy of Kees Veenbos

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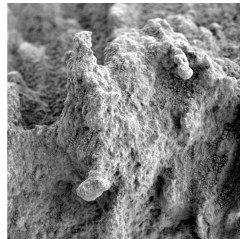
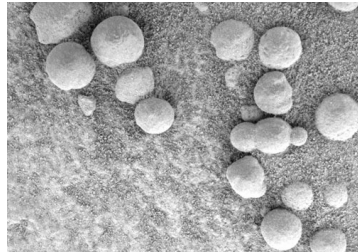
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# What Happened to the Water?



- That is the big question
  - Both Opportunity and Spirit have found evidence of water
  - Did the water escape to space with the air?
  - Is it frozen beneath the surface?
- The rovers are continuing their exploration
- More missions are planned

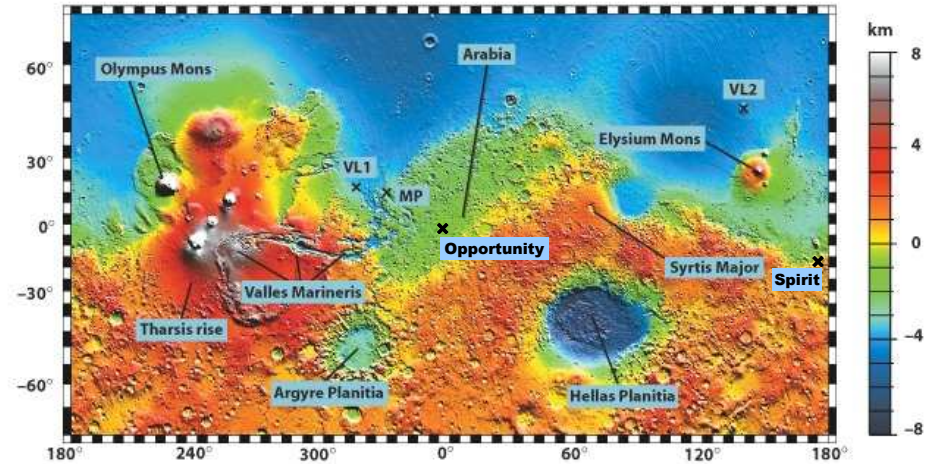


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# The Geology of Mars

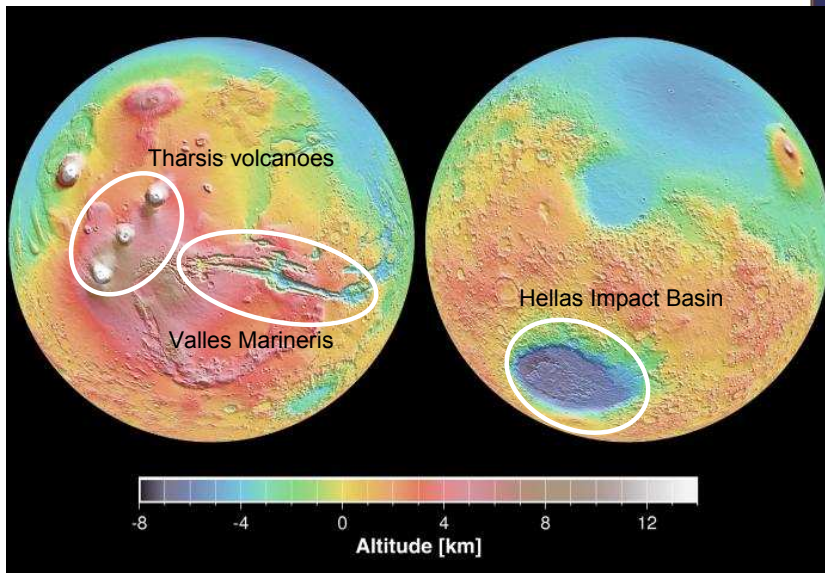


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# The Surface of Mars



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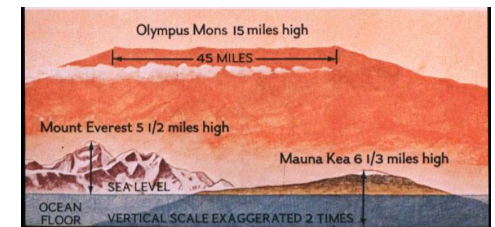
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Mars Global Surveyor

# Olympus Mons



- The largest mountain in the Solar System rising 26 km high
- A shield volcano, like Hawaii on Earth
- Its caldera is 90 km across



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## Olympus Mons



- Its base is more than 500 km in diameter
- As long as the entire Hawaiian island chain
- Rimmed by a 6 km high cliff
- Last erupted 25 million years ago
- Probably so big, due to lack of plate tectonics



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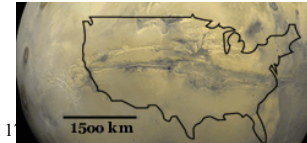
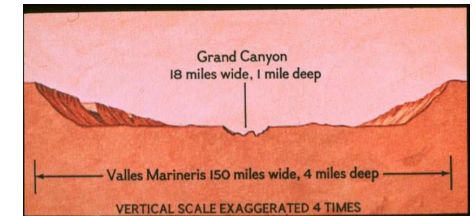
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## Valles Marineris



- A series of fault canyons
- 5000 km long
  - A big as the U.S.!
- A giant crack in the crust of Mars
  - Formed as the planet cooled
  - Expanded by water flow



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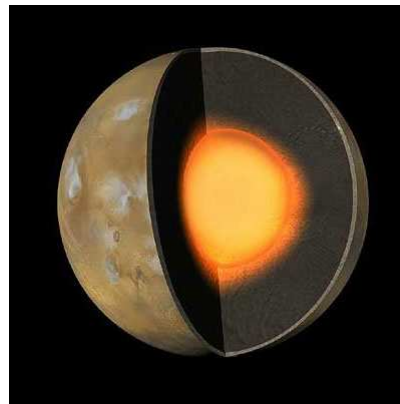
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## Mars' Interior



- Like Earth, Mars has an iron core
  - About half of the planet's radius in size
  - Heavily contaminated with sulfur
  - Weak magnetic field suggests a thin layer of liquid iron, mostly solid



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## Mars' Past



- Early in Mars' history it was likely more Earth-like
  - Geologically active
  - Volcanic eruptions created a thick carbon dioxide, nitrogen atmosphere
  - Greenhouse effect made it warm enough for liquid water
  - Oceans? Rivers? Glaciers by the poles?
  - Life?



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## What Happened?



- Mars was too small
  - Not enough internal heat
- Plate tectonics stopped
  - Volcanoes sat over “hotspots” grew to immense sizes
- Volcanic activity slowed as the interior cooled
- The atmosphere escaped
- The planet froze
- Did life move underground?

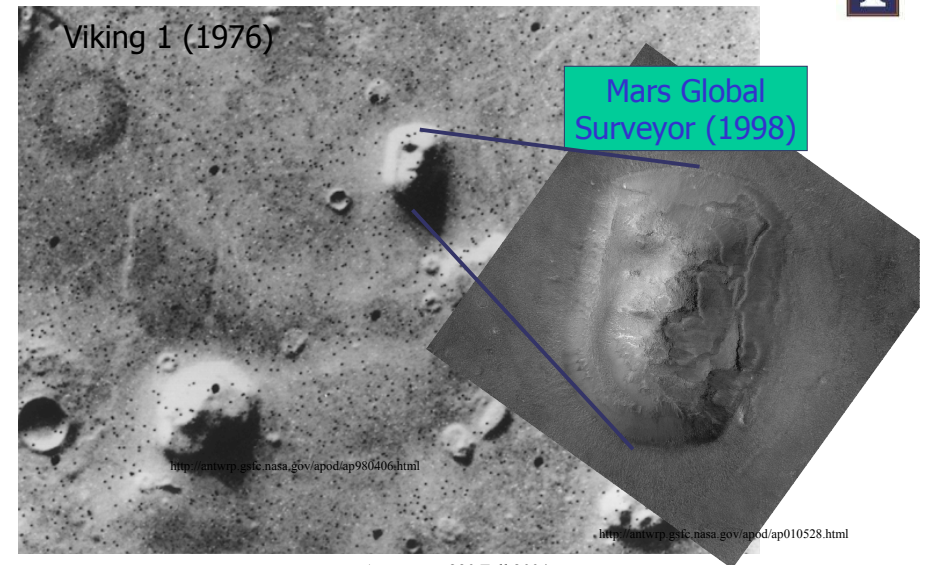


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## The “Face” of Mars?



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## Other Faces

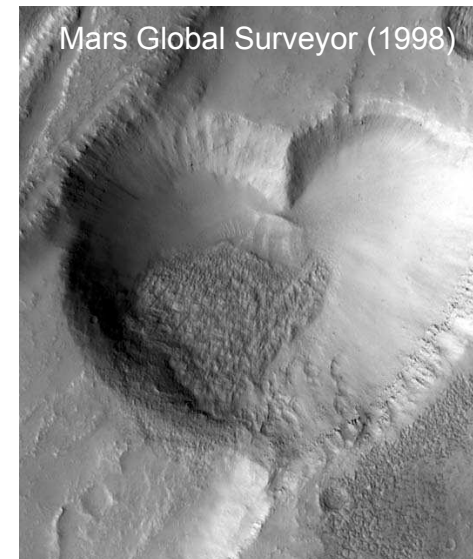


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<http://antwrp.gsfc.nasa.gov/apod/ap990109.html>

## Other Places



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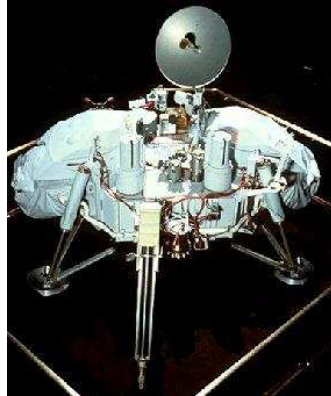
<http://www.solarviews.com/cap/mars/face.htm>



## The Search for Mars Life



- Viking 1 and 2 carried several experiments to detect life
- The results were ambiguous. The soil reacted vigorously with the Viking nutrients, then tapered off in activity.
- The conclusion of most scientists is that the reactions were due to inorganic chemical reactions.



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## Martians?



- In August 1996, evidence for microbial life was found in a Martian meteorite.
  - ALH84001 (3Gyrs): Found in Antarctica, composition suggests it was knocked from Mars
  - About 14 such Mars rocks have been found on Earth
- David McKay *et al.* suggested that there was fossil evidence for bacteria in the meteorite.



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## Martian Microbe Fossils?



- Microscopic shapes that resemble living and fossil bacteria on Earth—nanobacteria, but much smaller than on Earth.
- Microscopic mineral grains like some produced by living and fossil bacteria on Earth
- Organic chemical compounds that resemble the decay products of bacteria on Earth.
- In the end, not impelling enough. Non-biological processes can probably produce the observed features



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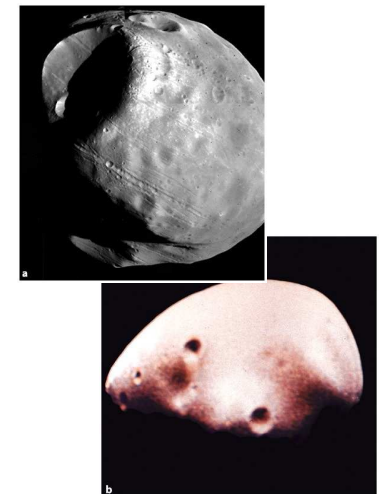
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## Phobos & Deimos



- Mars' moons
- Likely captured asteroids
- Very small
  - About 15-25 km in size
  - Shaped like potatoes



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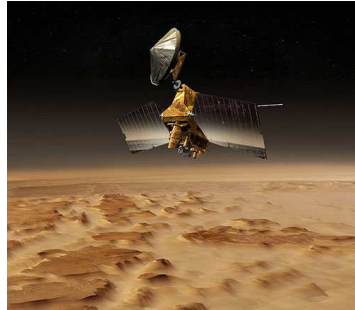


## Future Mars Missions



- Mars Reconnaissance Orbiter (2005)

- Will study the geology and climate of Mars
- Look for ancient sea shores
- Survey potential landing sites



- Phoenix (2007)

- Will analyze water ice at Mars' north pole

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## Manned Mars Exploration



- NASA's plans to send a manned expedition to Mars

- Timetable:

- Complete Space Station by 2010
- Return to Moon by 2020
- Then, on to Mars (no date)

- No cost estimates

- Some funds from to-be-retired shuttle fleet



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