

Astronomy 230

Section 1 – MWF 1400-1450
106 B1 Eng Hall



This Class (Lecture 19):

Alternatives

HW#4 Due on Oct 11th

Next Class:

Life in the Solar System

Midterm On Oct 15th!

Music: *Black Hole Sun* – Soundgarden

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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 20 multiple choice/ true-false questions (worth 2 points each) and 2 essay questions (one worth 40 points and one worth 25 points) .
- 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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Outline



- Exotic Life
- What is f_1 ?
- Venus
 - Hot
 - Life in the clouds?
- Mars
 - Water in Mars’s past.
 - Martian microbes?

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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	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
	25	0.34	.396				
	stars/ yr	systems /star	life planets /system				
				= 3.4			
				Life Planets			
				/year			

Exotic Life



- We have spent a long time with Earth Chauvinism, but ET life would be very different? Probably very alien!
- If other options are possible, then that gives a more optimistic value of f_1 .
- As we just discussed, there are options for life based on other molecules than amino acids, some have been shown to sort of work in the lab.

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Silicon Based Life?



- Silicon makes 4 bonds like Carbon
- It is 135 times more abundant than carbon on Earth.
- But there are 4 arguments against it:
 - C-C bonds are twice as strong as Si-Si
 - Si-O or Si-H is stronger than Si-Si, so harder to make long stands
 - Si does not usually make multiple Si bonds
 - C with O makes CO_2 , but Si with O makes silicates (SiO_2), which are large solid crystals.
- Still it is a possibility that can not be ruled out.



<http://www.decipher.com/startrek/cardlists/mirror/images/horta.gif>
<http://soundwavs.trekkieguy.com/25.html>

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Other Solvents



Molecule	Freezes (K)	Boils (K)
Water (H_2O)	273	373
Ammonia (NH_3)	195	240
Methyl alcohol (CH_3OH)	179	338
Methane (CH_4)	91	109
Ethane (C_2H_6)	90	184



Water is about twice as good as ammonia or methyl alcohol. Water also has a high energy of vaporization, so it is very good at evaporative cooling (sweat).

<http://www.talisman-activities.co.uk/winter/images/ice%20climbing.jpg>
<http://web.media.mit.edu/~fletcher/tags/boiling.jpg>

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Non-Chemical Life



Life is based on chemical energy. Thinking is an electrochemical activity. What about a life form that uses electromagnetic energy instead, perhaps without a body.

The Black Cloud (1957) by Fred Hoyle

The story describes a small interstellar molecule cloud that is alive. The organism is half a billion years old, as big as the orbit of Venus, and as massive as Jupiter. The brain is a complex network of molecules. Once it discovers the Earth it communicates with us:



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The Black Cloud Speaks

Paraphrased "badly"



- It is most unusual to find animals with technical skills inhabiting planets
- Living on a planet, greatly limits your size, thus the scope of your neurological activity.
- Living on a planet, forces you to possess muscular structures to promote movements.
- Your very largest animals have been mostly bone and muscle with very little brain.
- One only expects intelligent life to exist in a diffuse gaseous medium. At the moment, I myself am building basic chemicals at about 10,000,000,000 times the rate as your whole planet.

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Cloud Problems



- How would such a cloud evolve?
- The most dense clouds are 10^{13} times less dense than our atmosphere, which makes molecule interactions very rare.
- In space, interstellar clouds are torn apart in about 10^7 years. It took 10^9 years for intelligent life to form on Earth.
- Still it is a cute idea.



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Other Voices, Other Energies



- Life based on nuclear energy (put forward by Drake)
 - Life on the surface of a neutron star?
 - Gravity and temperature too high for normal life.
 - Life made of closely packed nuclear matter instead of molecules
 - They interact quickly 10^{-21} seconds, much faster than chemical reactions.
- It has been fictionalized by Robert Forward in *Dragon's Egg*
 - Talking to these beings would be difficult.
 - Their Biology uses the strong nuclear force.
 - A time difference of a million to one.
 - In the time it takes to say "Hello" - would be the equivalent of a week to a star creature. It would hear "He . . ." on Sunday and ". . . lo" on the following Saturday.

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Or Too Big



- Life based on gravitational energy?
- In this creature, the gravity force would dominate– very large!
- The monomer of life would have to be a star.
- Perhaps individual stars play the role of individual atoms or molecules in Earth life.
- Could galaxies be alive?
- Stars interact with one another on a time scale of many millions of years, so if life is to originate from such interactions it would take longer than the age of the Universe.
- If life is occurring, it is only at the stage where life was when the Earth was a few years old.



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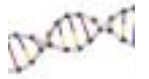
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Summing



- Existence of organic molecules in space implies that amino acid complexity is common.
- On Earth polymers arose and evolved to life.
- Life it seems evolves naturally through a number of intermediate steps if conditions are right.
- That means that $f_l = 1$
- But how often are the conditions right.
- Nonetheless, even with only a vague notion of how life on Earth evolved, it seems that there are possible pathways that take the mysterious polymerization to transition to life steps.
- Still a number of questions:

Summing for f_l



- Is life a natural occurring consequence of the laws of nature?
- Will each planet from n_e outgas and produce water?
- Will it have a reducing atmosphere?
- Will it have the right energy sources to produce life's monomers?
- Monomers from space?
- Will polymerization occur?
- Are tides necessary to wash polymers back into liquid water?
- Will basic life occur? Protolife or life?
- Alternative life?
- Maybe the conditions that produced life on Earth are unusual or maybe common.
- That means f_l can range from small numbers 0.0001 to 1.

Drake Equation



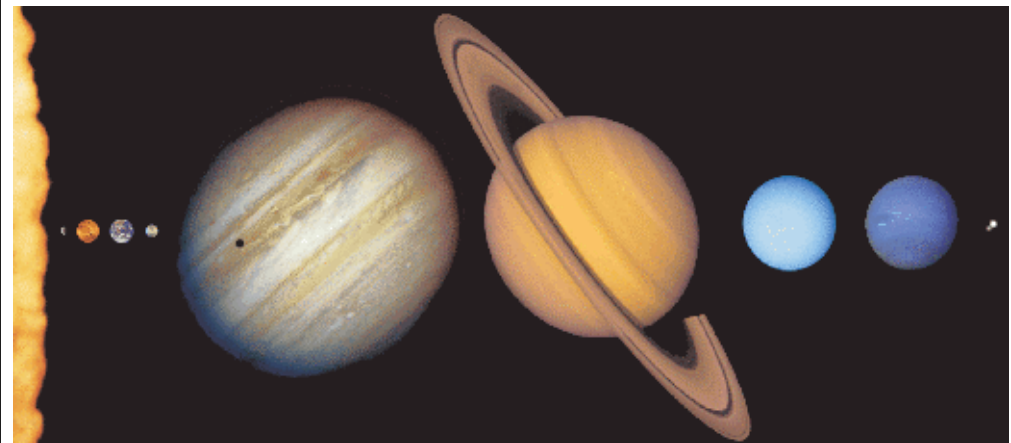
$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

# of advanced civilizations we can contact	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
25	0.34	0.396	?				
stars/yr	stars/yr	systems/star	life planets/system	life/planet			Life /year

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 .



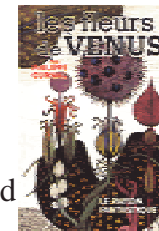
Earth – Venus comparison



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 ₂

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.

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<http://www.daviddarling.info/encyclopedia/V/L.W.Looney.html>

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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Venus



- Always covered in thick clouds of CO₂, 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. 3rd brightest object in the sky. Often mistaken for UFO.
- Retrograde rotation – Sun rises in west
- No moons, no magnetic field



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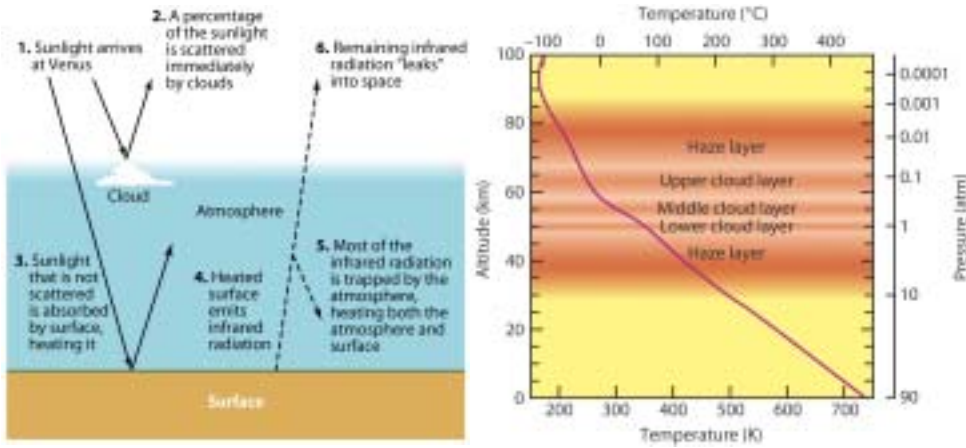
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<http://antwrp.gsfc.nasa.gov/apd/060923.html>

The Greenhouse Effect



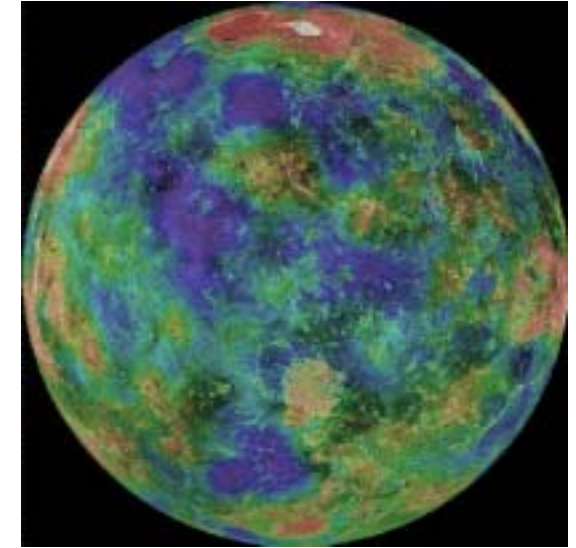
- Surface completely covered by clouds
- Atmosphere mostly carbon dioxide and nitrogen
- Sulfuric acid clouds
- Runaway greenhouse effect – surface temperature > 700 K



Venus: Surface



- Blue is lowest and Red is highest– there is trace amounts of water
- Most of surface is smooth lava flows
- Many (> 1,000) large volcanoes
- Probable ongoing volcanism
- Slow wind erosion of impact craters
- Craters are clustered

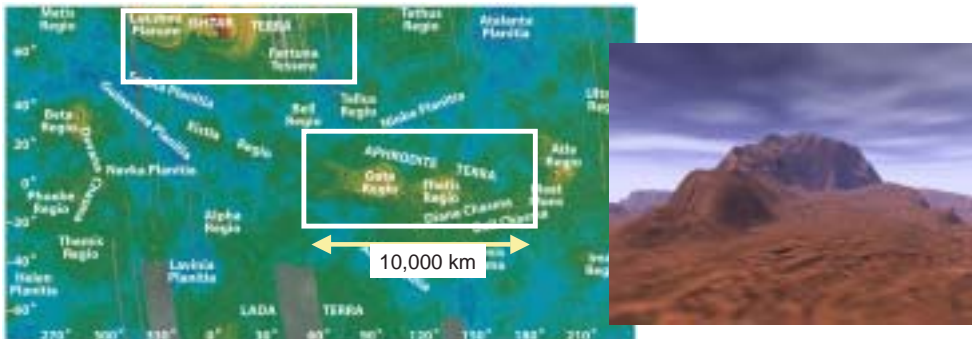


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<http://antwrp.gsfc.nasa.gov/apod/ap041008.html>

Venus: surface features



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

<http://www.solarviews.com/raw/venus/vidven2.mpg>

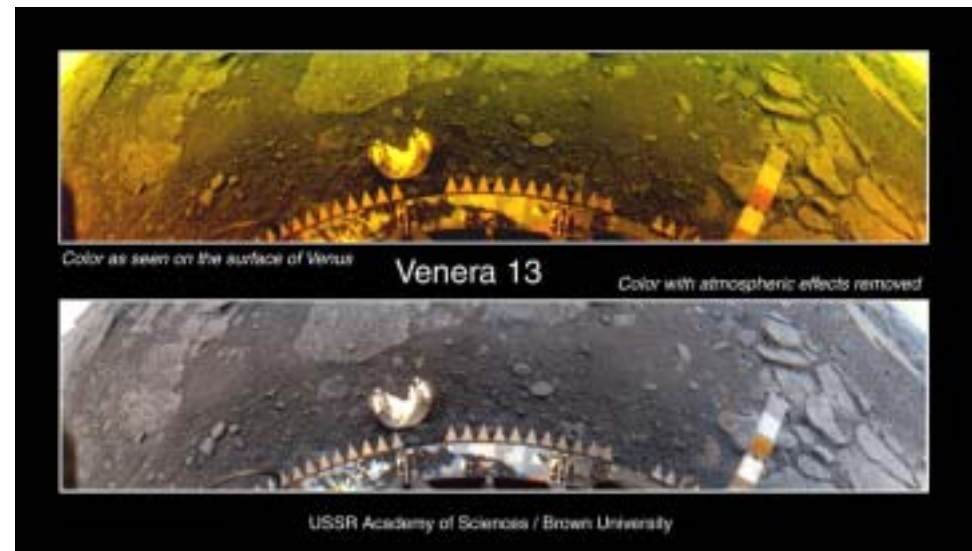
<http://www.geology.smu.edu/~dpa-www/venus/mpeg/max.mpg>

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Images from the Surface of Venus (Soviet Venera probes)



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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 O₂ from life.
- Venus has some N, and if the CO₂ was buried in sediments like it is on Earth, then N₂ would have dominated its atmosphere too.
- Apparently Venus lost its H₂O— 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.
- The Earth traps water vapor in the cool tropopause at 14km.

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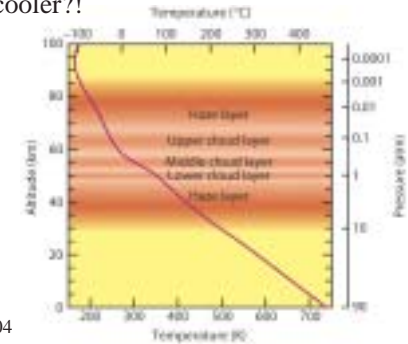
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Life on Venus?



- 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?!



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Chemical Disequilibrium



- Maybe life can still exist in the clouds?
- At 50 km up, the temperature is not too hot and the pressure is 1 atmosphere.
- 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.

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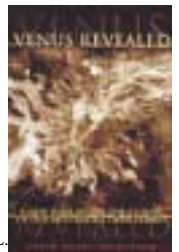
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<http://www.daviddarling.info/encyclopedia/V/Venuslife.html>
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Life on Venus?



- 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 microorganisms.
- 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



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 ₂ 95%

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

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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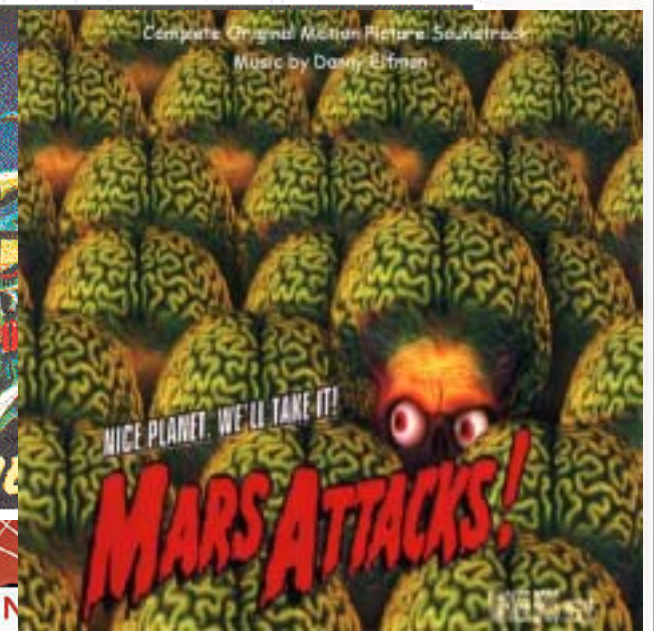
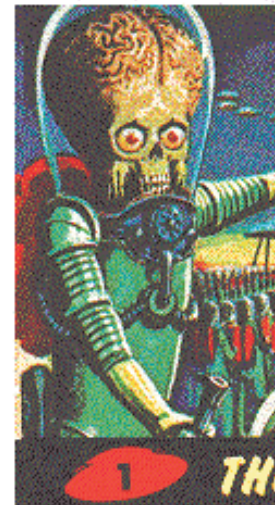
Percival Lowell's Canals

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



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

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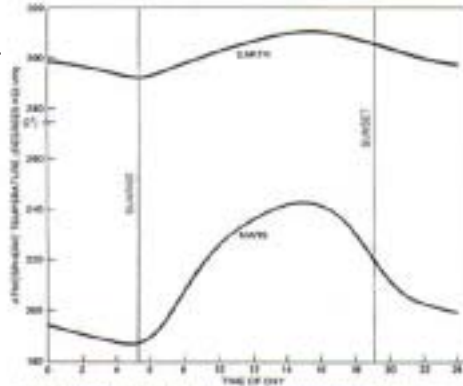


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The Martian Atmosphere



- 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

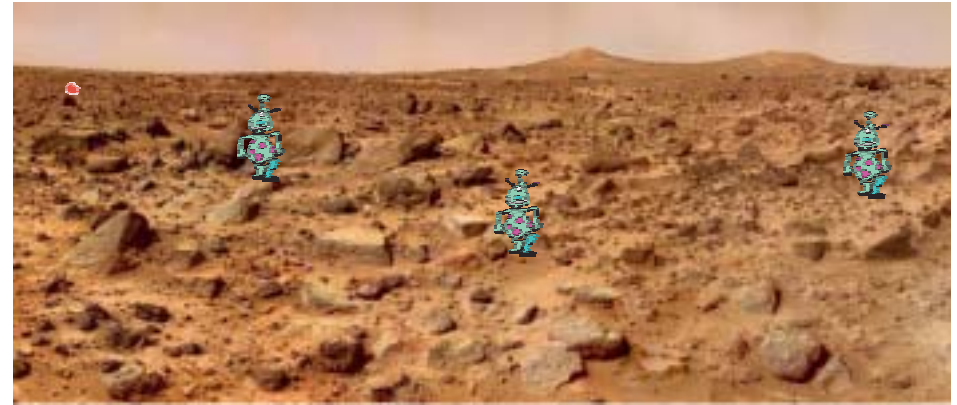


DAILY VARIATIONS IN ATMOSPHERIC TEMPERATURE on the Viking 1 landing site (near the equator) are similar to those at Chino Lake, Calif., a desert site (left). In both cases the temperature reaches a minimum around sunrise and reaches a peak about 30 hours later. The daily range, however, is about three times greater on Mars than it is on the earth. At Viking site ranges 57 degrees, from about 187 to 242 degrees Kelvin (- 88 to - 21 degrees Cel.) over 24 hours. Chino Lake ranges to 18 degrees, from 292 to 268 degrees K. (19 to 27 degrees Cel.)

The Surface of Mars



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



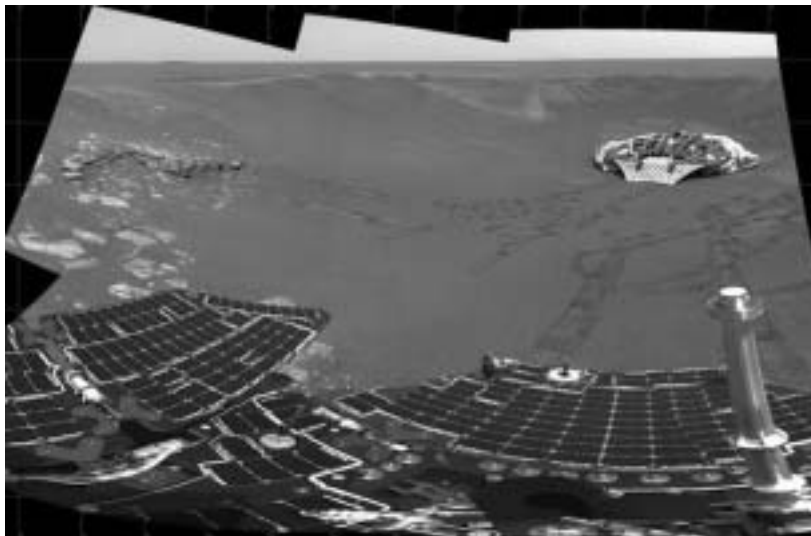
View of "Twin Peaks" from Mars Pathfinder

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<http://www.grc.nasa.gov/WWW/PAO/html/infarspath.htm>

The Surface of Mars: Opportunity



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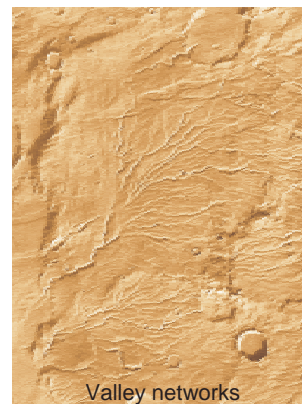
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<http://antwrp.gsfc.nasa.gov/apod/ap040903.html>

Liquid water on Mars?

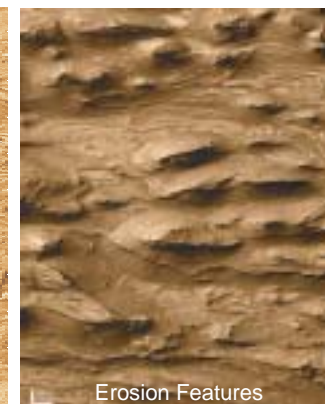


- Water erosion features visible from space
- Atmospheric pressure too low for liquid water to exist
- Perhaps at some point in the past?



Valley networks

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Erosion Features

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"Islands"



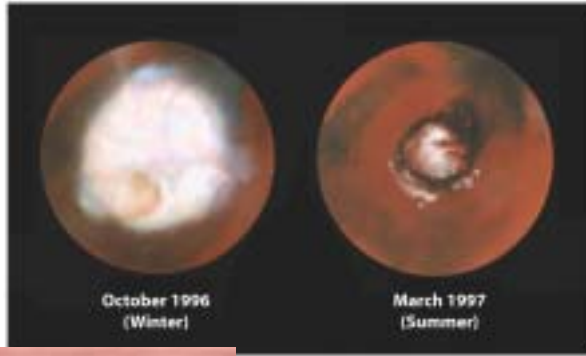
Flood erosion

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Water on Mars



- North and south polar caps is mostly frozen CO₂, but maybe some ice water too.
- Frost
- Clouds (ice crystals)



<http://www.solarwinds.com/eng/marsfld.htm>

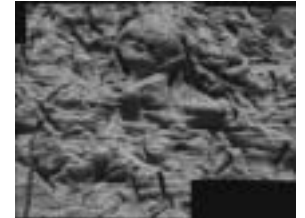


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NASA Spacelink

Standing Water on Mars



- The new data from the rover Opportunity 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.
- Does not mean there was necessarily a standing ocean. But maybe.



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The Surface of Mars



Viking 1 (1976)

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<http://antwrp.gsfc.nasa.gov/apod/ap980406.html>

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The Surface of Mars



Mars Global Surveyor (1998)

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<http://antwrp.gsfc.nasa.gov/apod/ap010528.html>

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The Surface of Mars



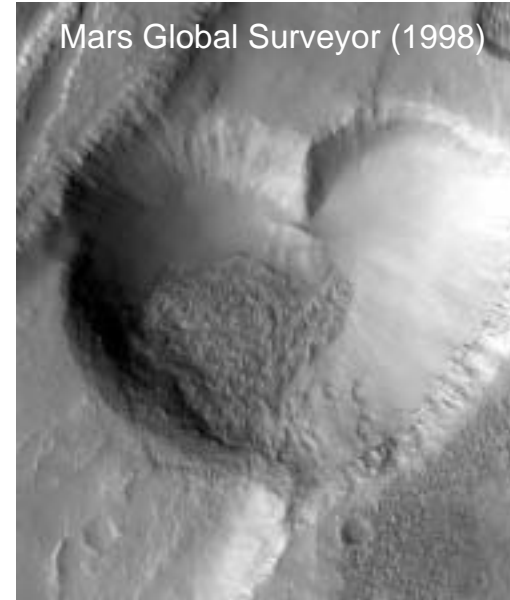
Mars Global Surveyor (1998)

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<http://antwrp.gsfc.nasa.gov/apod/ap990315.html>

The Surface of Mars



Mars Global Surveyor (1998)

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<http://www.solarviews.com/cap/mgs/heart.htm>