Astronomy 230

Section 1– MWF 1400-1450
106 B1 Eng Hall

<u>This Class (Lecture 20):</u>

Life in the Solar System

HW#4 Due today.

Midterm Friday!!!!

<u>Next Class:</u>

Life in the Solar System

Music: *Venus as a Boy* – Bjork

Outline

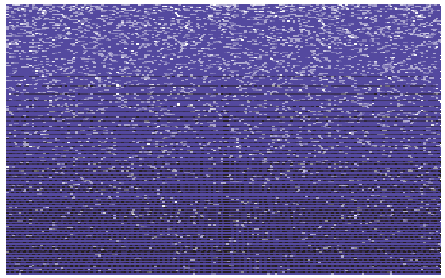
- Discuss the Midterm + Review Part 1
- Venus
  - Hot
  - Life in the clouds?
- Mars
  - Martian microbes?
- Jupiter
  - Big planet with possibly interesting chemistry.
  - Floaters?

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.

Big Bang

- Big Bang!
  - 13.7 billion years ago.
- Creation of primarily hydrogen & helium via BBN at t=3 seconds.
- 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!



Galaxies

- Galaxies formed from the seeds of dark matter, mostly 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

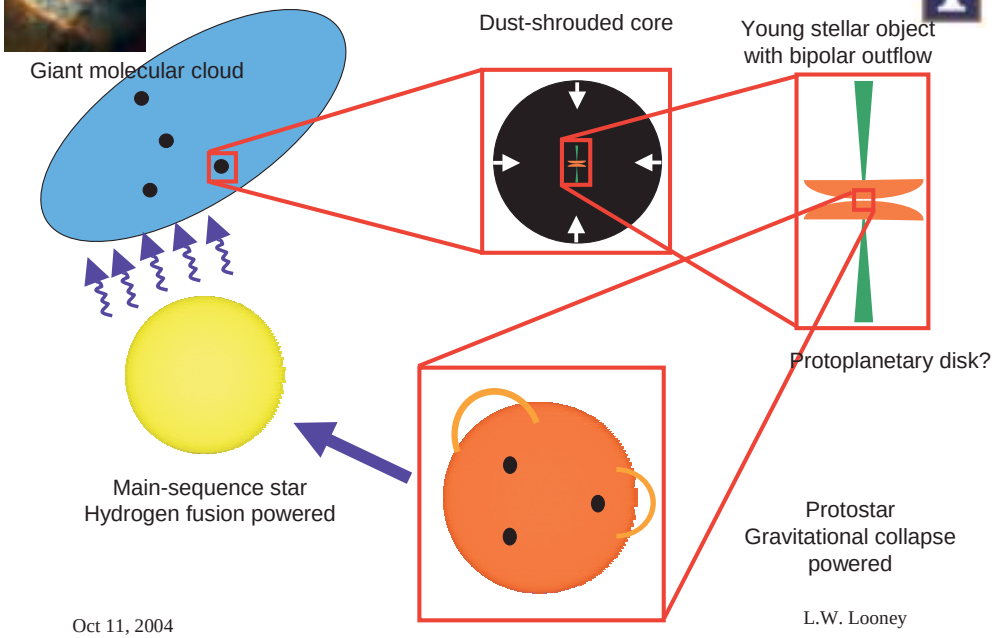
But Life?

- 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 <u>at least one</u> 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.

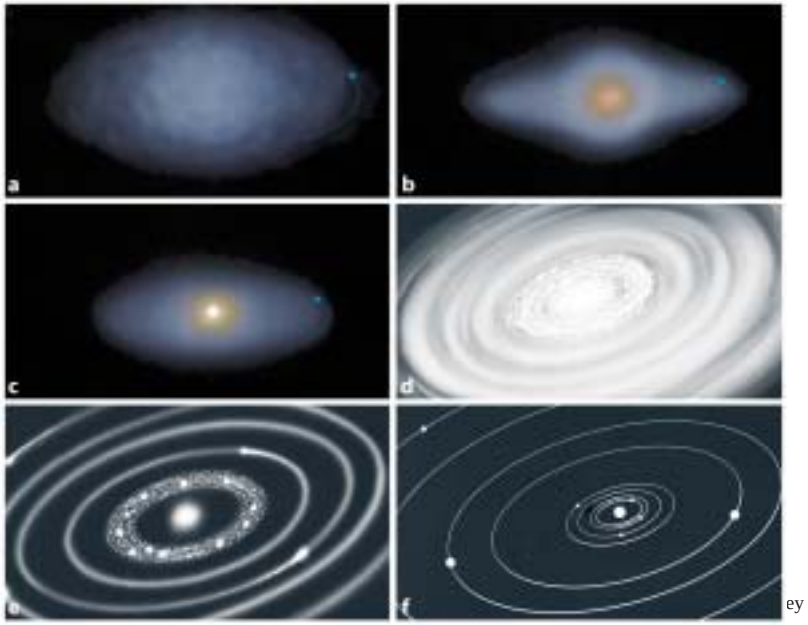
First and Second Stars

- 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!

Star Formation - Summary



Formation of the Solar System 4.6 billion years ago



Our Sun

- Is a fairly typical star
  - Has lived for 5 billion years
  - Will probably live another 5 billion

Planet Formation in the Disk

Heavy elements clump

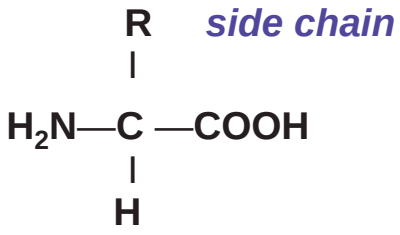
1. *Dust grains* collide, stick, and form planetesimals. All orbit in the same direction and in the same plane.
2. Gravity Effects: Big planetesimals attract the smaller planetesimals. Collisions build-up inner planets and outer planet cores.
3. Collisions can also account for odd motions of Venus (backwards),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

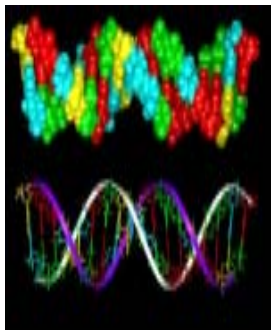
Proto-Earth

- The hot proto-Earth heated up the ices on dust grains– mostly water, carbon dioxide, and nitrogen– the Earth's first atmosphere.
- The water condensed to form oceans and much of the CO_2 was dissolved in the oceans, unlike Venus and Mars.
- No oxygen, no ozone layer.
- UV light, lightning, radioactivity, and geothermal heat, provided energy for chemical reactions.
- Perfect place for carbon chemistry.

Life on Earth

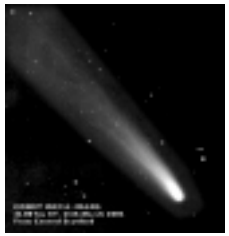
- Most important components are
  - Proteins or enzymes
    - Polymers made of amino acids strung together.
  - Nucleic Acids (DNA or RNA)
    - Polymers made of sugars (deoxyribose or ribose), a phosphate, and nitrogenous bases.
- In life on Earth, they are so closely linked that it is hard to figure out which came first.
- We do know that life began about 3.8 billion years ago, soon after the large bombardment.





Synthesis of Monomers

- Miller-Urey experiment? Could be, but atmosphere probably not a heavily reducing atmosphere.
- Area around undersea hot vents might work.
- Interstellar space?

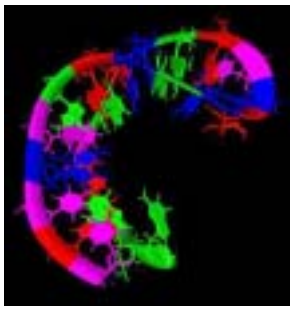


Synthesis of Polymers

- With monomers around, then you have to make the polymers.
- Maybe easier if the primordial soup quickly evaporates into a condensed soup.
- Polymerization in clay soils?
- An evaporating pool with geothermal energy?
- Polymerization of amino acids on the early Earth is plausible.
- Synthesis of nucleic acids seems to be much harder.

Transition to Life

- Most favored concept is the RNA world.
  - Dominance of the nucleic acids first.
  - An ecosystem of self-replicating RNA, but without capability for protein synthesis.
  - Naked genes.
  - Some RNA evolve enzyme ability, produce proteins
  - Eventually better protein enzymes are produced
  - Life.
- Or the proteins could have dominated– no info storage.
- Or life could have just happened with both nucleic acids and proteins together– primitive cells.



Drake Equation

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

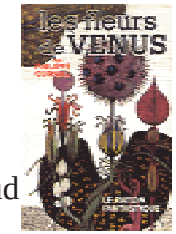
# of advanced civilizations we can contact	Rate of star formation	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that commun-icate	Lifetime of advanced civilizations
	25	0.34	.396	0.54		= 1.8	
	stars/ yr	systems /star	life planets /system	life /planet		Life /year	

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.

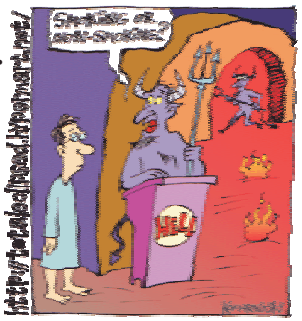
In 1918, a Swedish chemist and Nobel laureate concluded:

- 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.

http://www.daviddarling.info/encyclopedia/V/Venus_life.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.

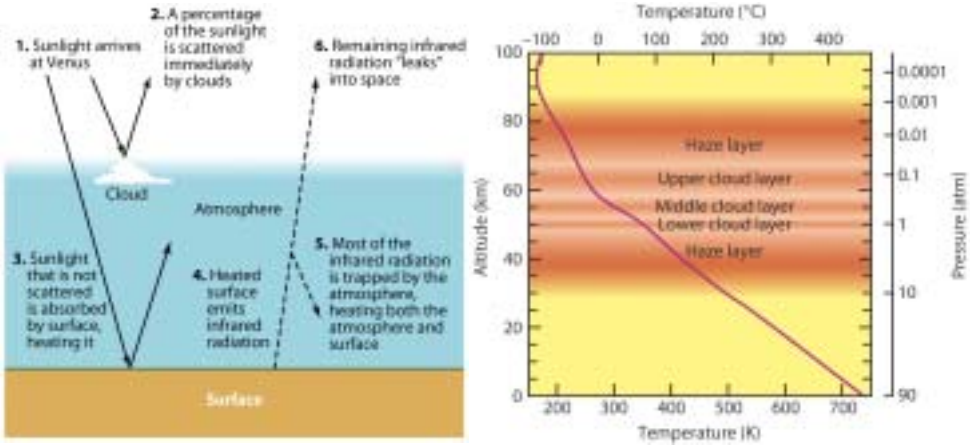


Venus

- Always covered in thick clouds of CO_2, 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

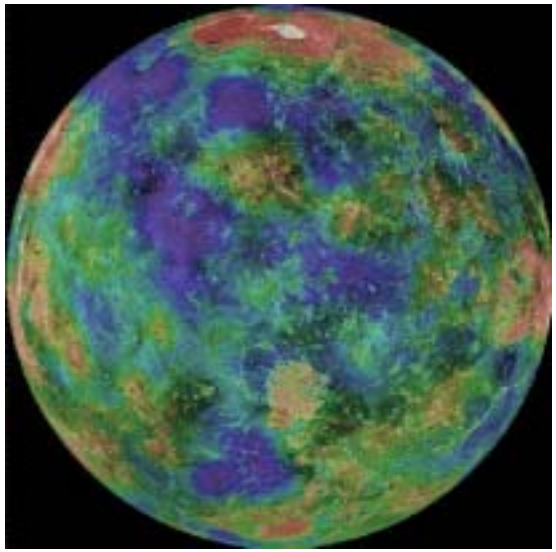
The Greenhouse Effect

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

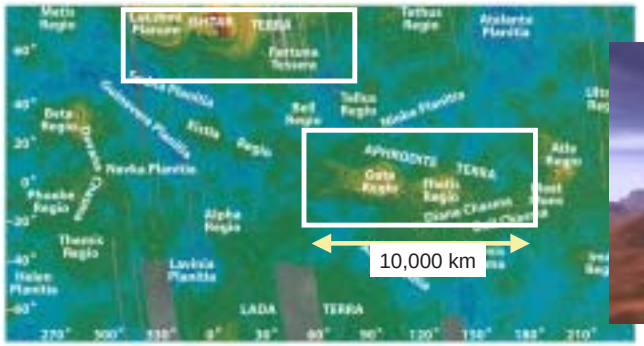


Venus: Surface

- 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



Venus: surface features

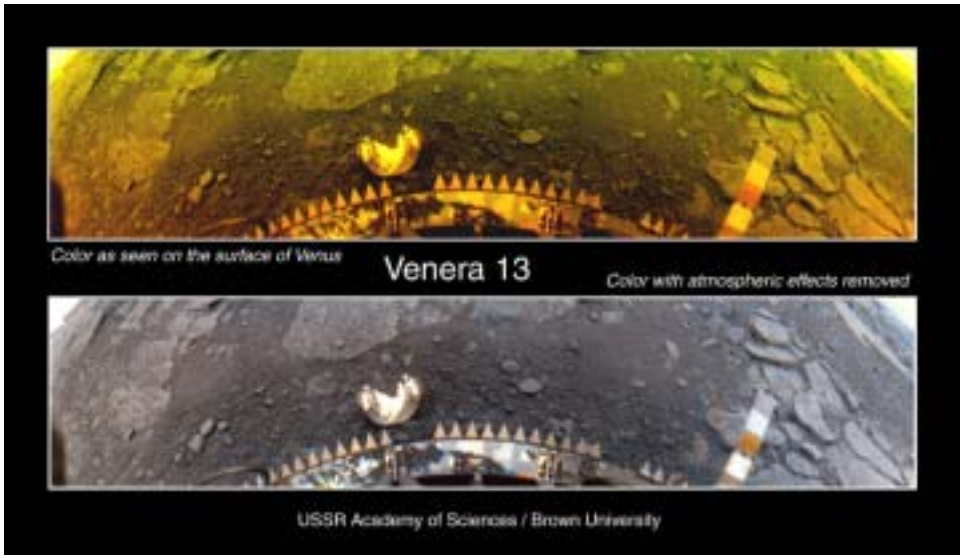


Maxwell Montes (65N 5E)
(Highest mountain range in the solar system
11km high– Everest is 8km)

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

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

Images from the Surface of Venus (Soviet Venera probes)

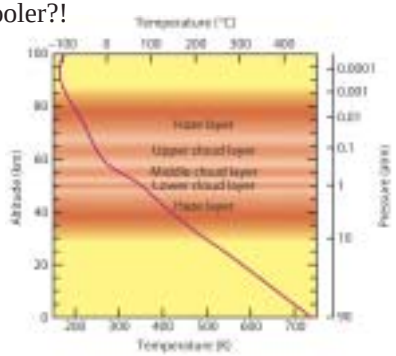


What Happened to Venus?

- It really should have been more like Earth, but the atmosphere is much different.
- Earth's atmosphere is mostly O_2 from life.
- Venus has some N,and if the CO_2 was buried in sediments like it is on Earth, then N_2 would have dominated its atmosphere too.
- Apparently Venus lost its H_2O– 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.

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?!



Chemical Disequilibrium

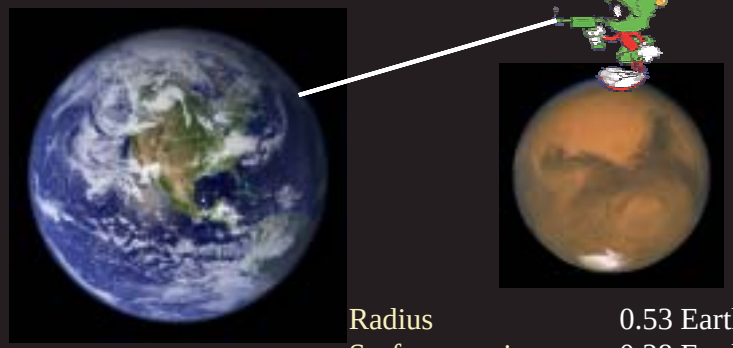
- Maybe life can still exist in the clouds?
- At 50 km up, the temperature is not too hot and the pressure is 1 atmosphere.
- High clouds in the atmosphere contain chemicals that hint at the presence of some kind of biological activity.
- Hydrogen sulfide and sulfur dioxide - two gases that react with each other– exists in the clouds.
- Something is probably producing them.
- Hardly any carbon monoxide. So something is perhaps removing the gas.

http://www.manson-valley.de/fotogalerie/manson/images/acss/acss_32.jpg

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?

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_2 95%

What we used to think.

- 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

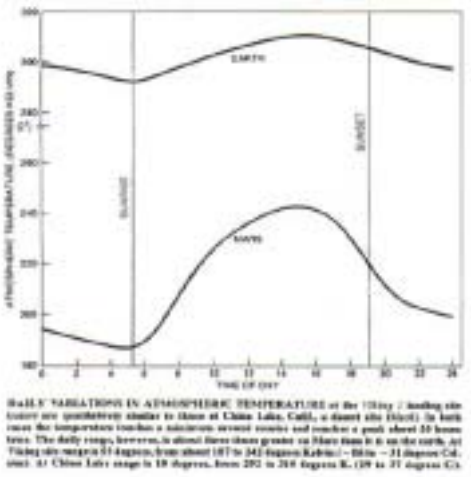
Percival Lowell's Canals

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


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

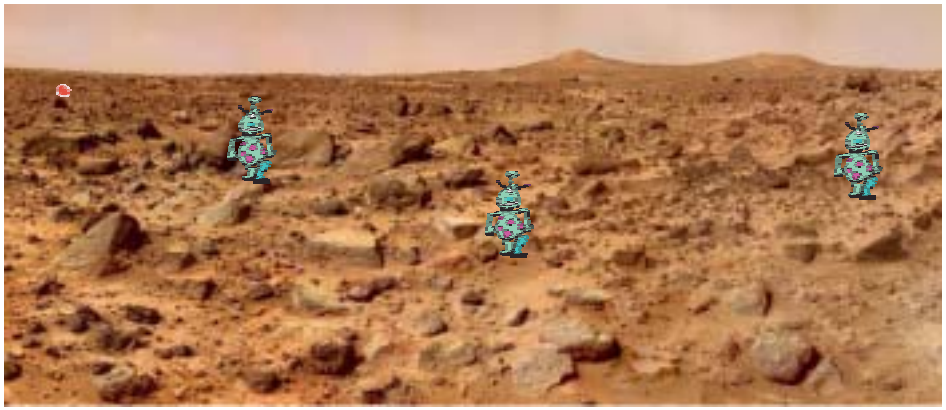
The Martian Atmosphere

- 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



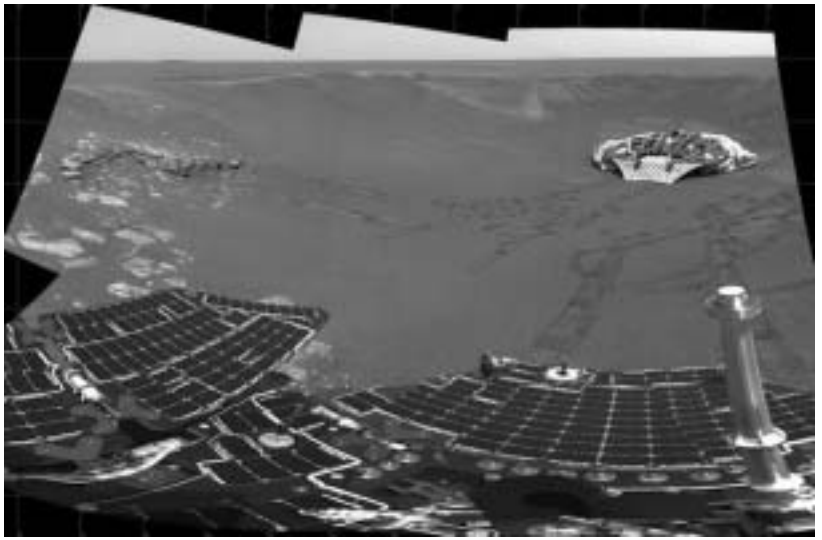
The Surface of Mars

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



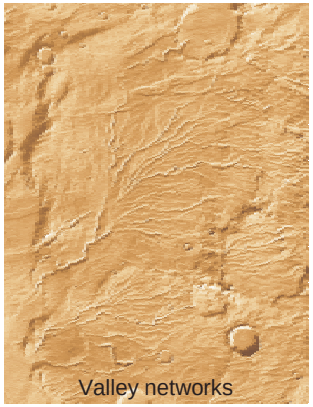
View of "Twin Peaks" from Mars Pathfinder

The Surface of Mars: Opportunity



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?

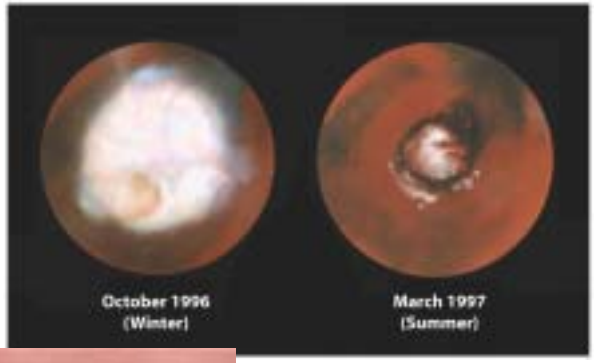


"Islands"

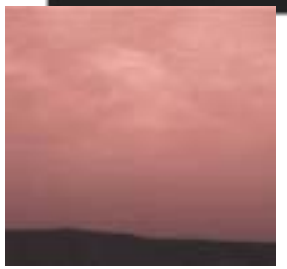
Flood erosion

Water on Mars

- North and south polar caps is mostly frozen CO_2, but maybe some ice water too.
- Frost
- Clouds (ice crystals)



http://www.solarviews.com/eng/marscld.htm

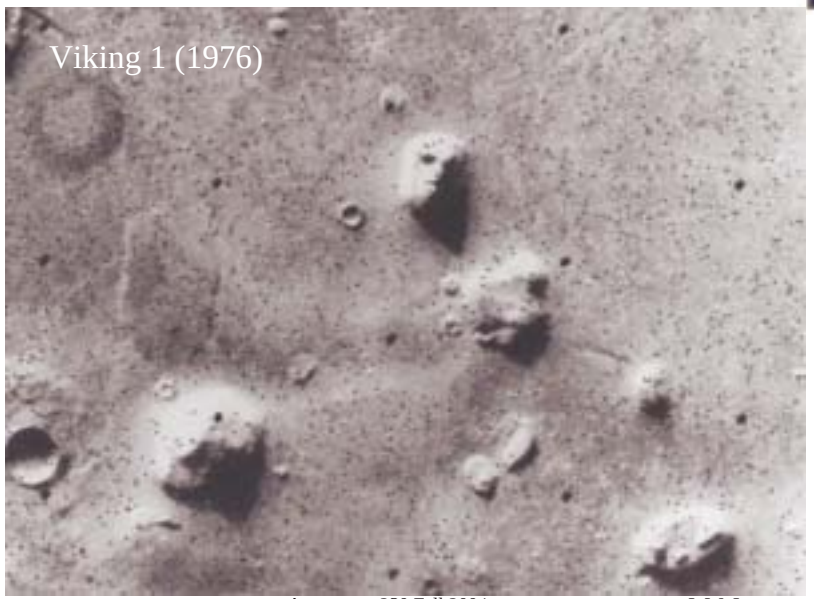


NASA Spacelink

Standing Water on Mars

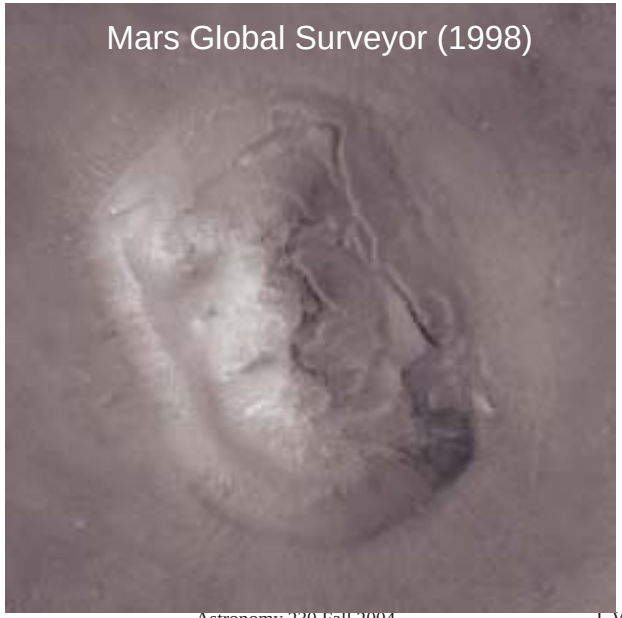
- The new data from the rover Opportunity highly suggestive of ancient standing water on the Meridiani Planum.
- 3 pieces of evidence:
  - Physical appearance of rocks
  - Rocks with niches where crystals appear to have grown
  - Rocks with sulfates.
- Does not mean there was necessarily a standing ocean. But maybe.

The Surface of Mars



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

The Surface of Mars

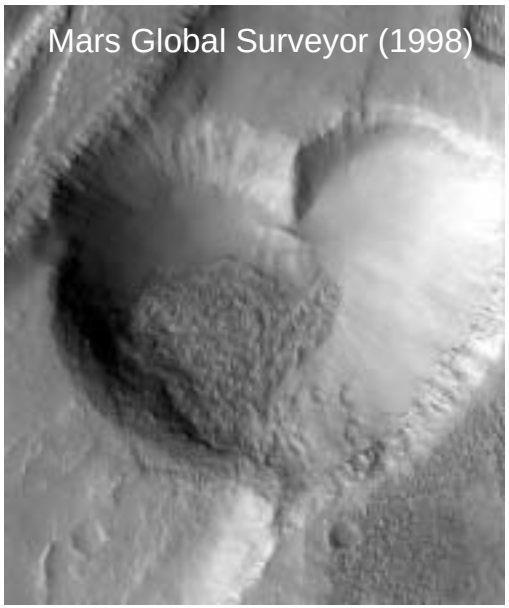


http://antwrp.gsfc.nasa.gov/apod/ap010528.html

The Surface of Mars

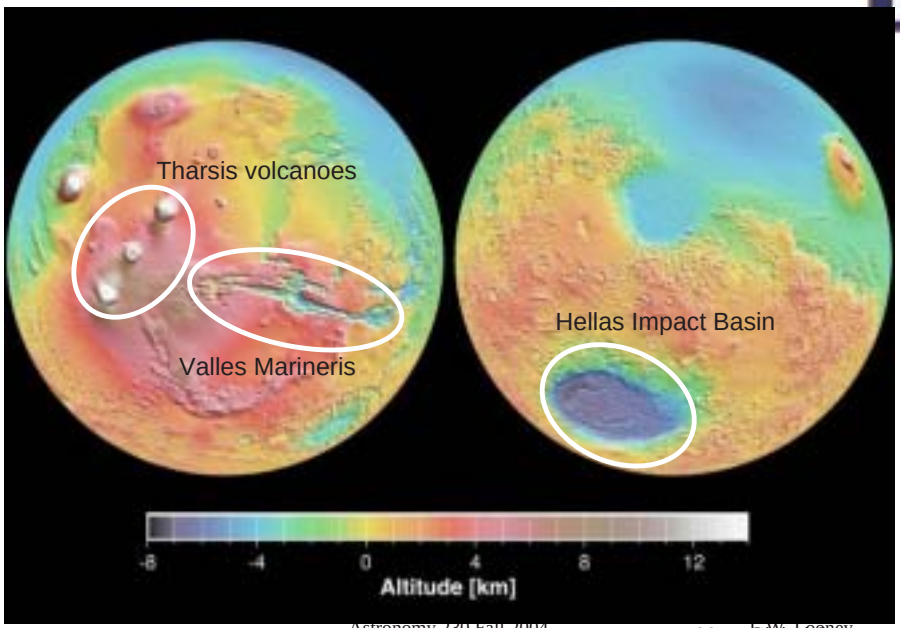
http://antwrp.gsfc.nasa.gov/apod/ap990315.html

The Surface of Mars



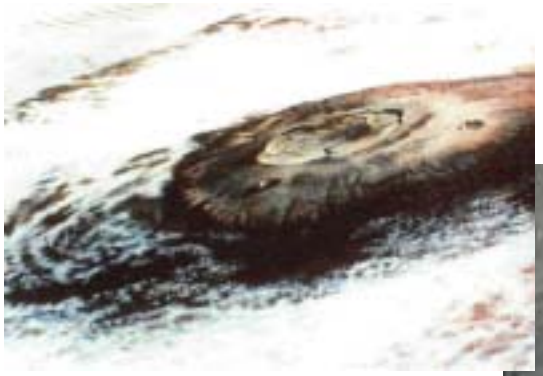
http://www.solarviews.com/cap/mgs/heart.htm

The Surface of Mars



Mars Global Surveyor

Olympus Mons



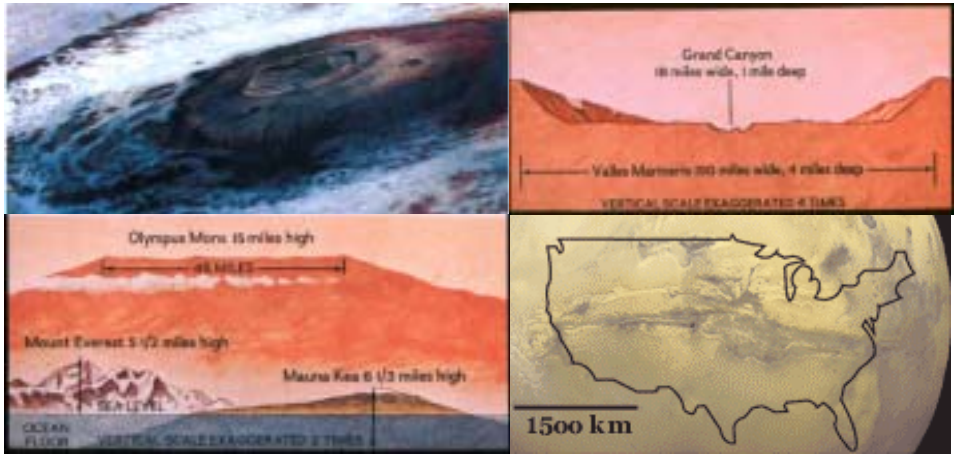
- The largest mountain in the Solar System rising 24 km (78,000 ft.).

- Its base is more than 500 km in diameter and is rimmed by a cliff 6 km (20,000 ft) high (right).
- Last erupted 200+ years ago.

http://hyperphysics.phy-astr.gsu.edu/hbase/solar/marsoly.html

Volcanoes and Chasms

Olympus Mons Valles Marineris



The Search for Mars Life

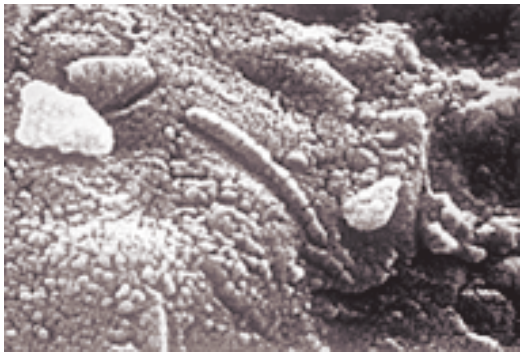
- Viking 1 and 2 carried several experiments to detect life
- The results were ambiguous. The soil reacted vigorously with the Viking nutrients, then tapered off in activity.
- The conclusion of most scientists is that the reactions were due to inorganic chemical reactions.

Martians?

- In August 1996, evidence for microbial life was found in a Martian meteorite.
  - ALH84001: 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.

Martian Microbe Fossils?

- Microscopic shapes that resemble living and fossil bacteria on Earth– nanobacteria.
- 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



Life in the Solar System

- Venus may have life in the clouds.
- Mars might still have life under the soil.
- But what about the outer solar system?
- It isn't in our definition of the habitable zone, but it still is interesting.
- We will focus on Jupiter, Io, Europa, and Titan in this class.