The Cosmos

Planets & Life

PHYS 214

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Please start all class related emails with "214:"

Few more midterm details

- Walter Light Hall Rm 205 9:30 – 10:25
  - 55 minutes, as there is a class coming in after us.
  - There isn't a class in before us – aim to be there at least 10 minutes early if you can
- 30 multiple choice questions, 2 short answer (choose from 4)
- You won't be tested on today's lecture

Phys 214 - Midterm - 2007

This exam contains two parts, Part I (multiple choice) and Part II (short answer)

Useful formulae, information and constants

Stephan-Boltzmann Law (luminosity per surface area): $L = \sigma T^4$, $\sigma = 5.67$ W m^{-2} K^{-4}

Wein's Law for Black-body emission: $\lambda_{max} = \frac{2.898 \times 10^6}{T}$, where λ_{max} is in nm.

Parallax distance estimate: $d = 1/p$ where p is in arc seconds

Apparent brightness: $F = \frac{L'}{4\pi r^2}$, where L' is the total luminosity

Apparent magnitude: $m = -2.5 \log(\frac{L'}{4pir^2}) + constant$, Absolute magnitude, M, is the apparent magnitude at 10 pc

Distance modulus: $(m - M) = 5 \log(D) - 5$

Energy of a photon: E=hf, velocity of wave: $v = f\lambda$

Doppler shift in wavelength: $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$

Surface area of sphere: $4\pi r^2$, area of a circle: πr^2

Luminosity of star is given by: $L \propto M^4$

Magnitude of angular momentum in rotating body: $l = mr^2\omega$

Small angle formula: $\theta = D/d$

60 arc minutes in a degree, 60 arc seconds in an arc minute

Planck's constant $h = 6.62 \times 10^{-34}$ m^2 kg s^{-1}
Speed of light: $c = 3.00 \times 10^8$ m s^{-1}
Astronomical unit: 1 AU $= 1.50 \times 10^{11}$ m
Light year: 1 ly $= 63240$ AU
1 parsec $= 3.26$ ly
Mass of Sun $= 1.99 \times 10^{30}$ kg

Today's Lecture

- The terrestrial planets
  - Brief discussion of the space-craft we have sent to the terrestrial planets
  - Physical characteristics
  - Possibility of life?

The Terrestrial Planets

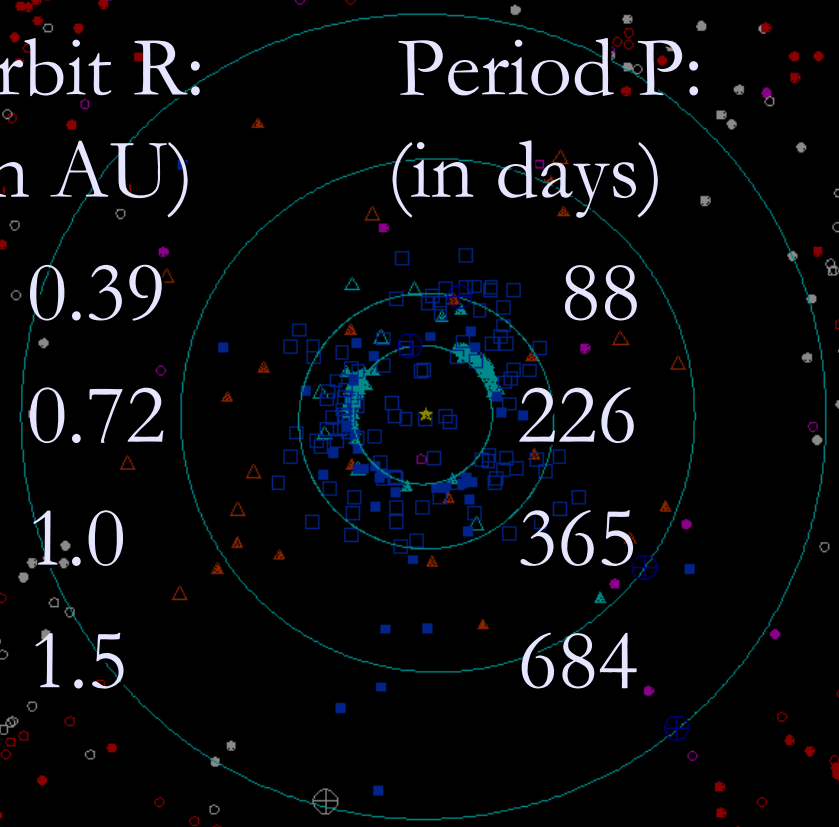
- In our discussions of habitable zones we've seen that the greenhouse effect can make the habitable zone quite large
- Increasing luminosity as the star ages drives the HZ outward
- Other than Earth could other terrestrial planets have haboured life (however primitive)?

Mercury *Venus* *Mars*

Comparison: Orbital data

	Orbit R: (in AU)	Period P: (in days)	Mass M: (× Earth)
Mercury	0.39	88	0.055
Venus	0.72	226	0.82
Earth	1.0	365	1.0
Mars	1.5	684	0.53

Mercury gets $1/0.39^2 = 7\times$ the radiation that the Earth gets



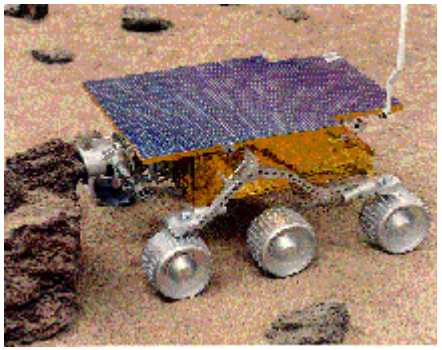
Plot prepared by the Minor Planet Center (2002 Feb 7).

Mariner 10

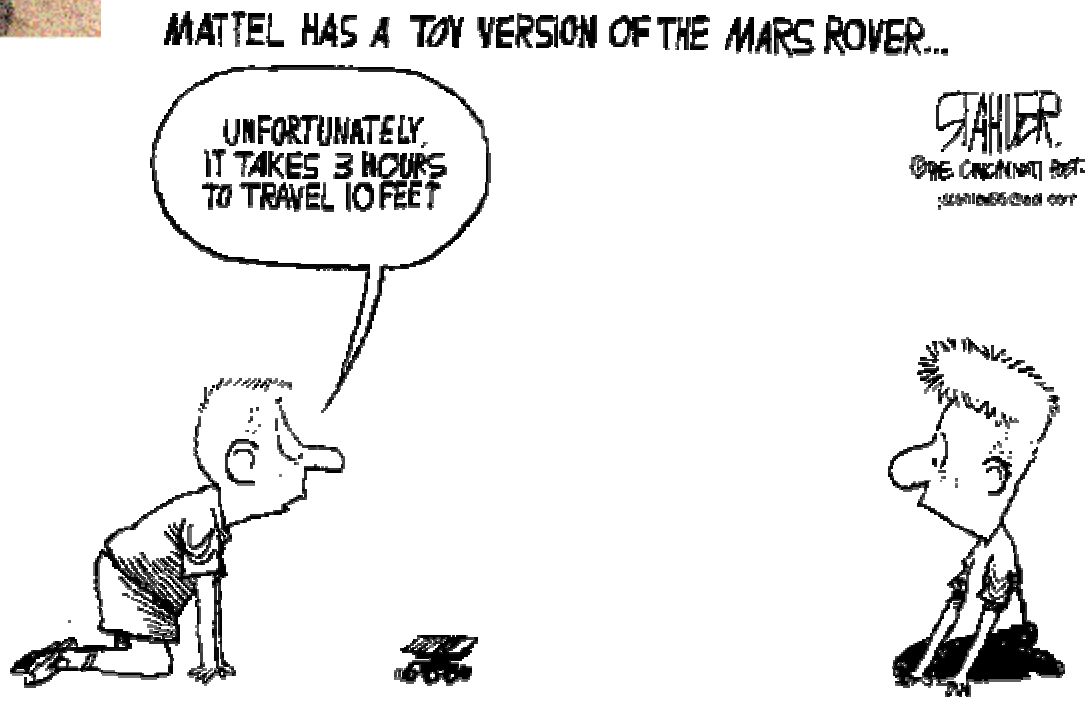
- Launched in 1973, is still the only probe to have visited Mercury
  - MESSENGER probe will visit in 2008
- Mariner 10 was the first probe to use a gravity assist (from Venus to Mercury)
- We discovered more about Mercury in a few days worth of data from Mariner 10 than we did in 300 years of using telescopes

Venera Program

- The USSR took great interest in Venus and sent 16 probes there over 20 years
- All of the surface telemetry we have from Venus comes from Venera probes
  - The longest survival time for a probe on the surface is 110 minutes!
  - Surface temperature 470° C, pressure 90 Earth atmospheres (like being under 900 meters of water!)
- The exceptional temperatures and pressures on the surface of Venus requires that probes be "armoured"

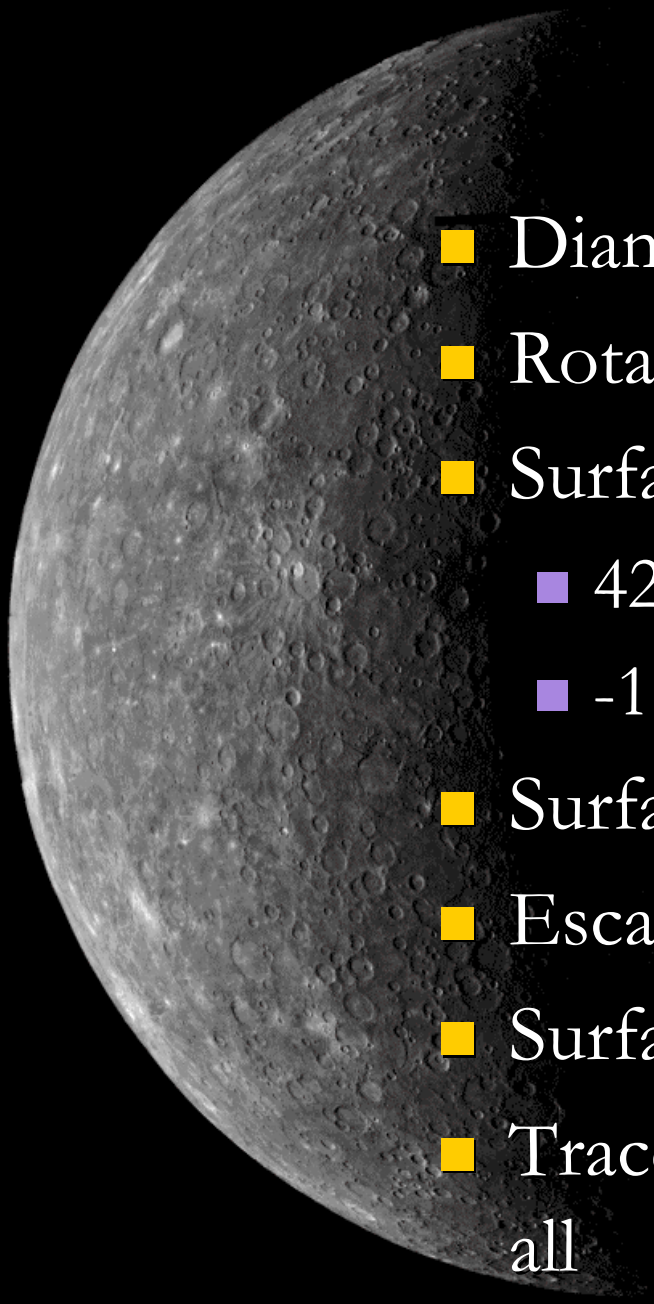


The Mars Rover



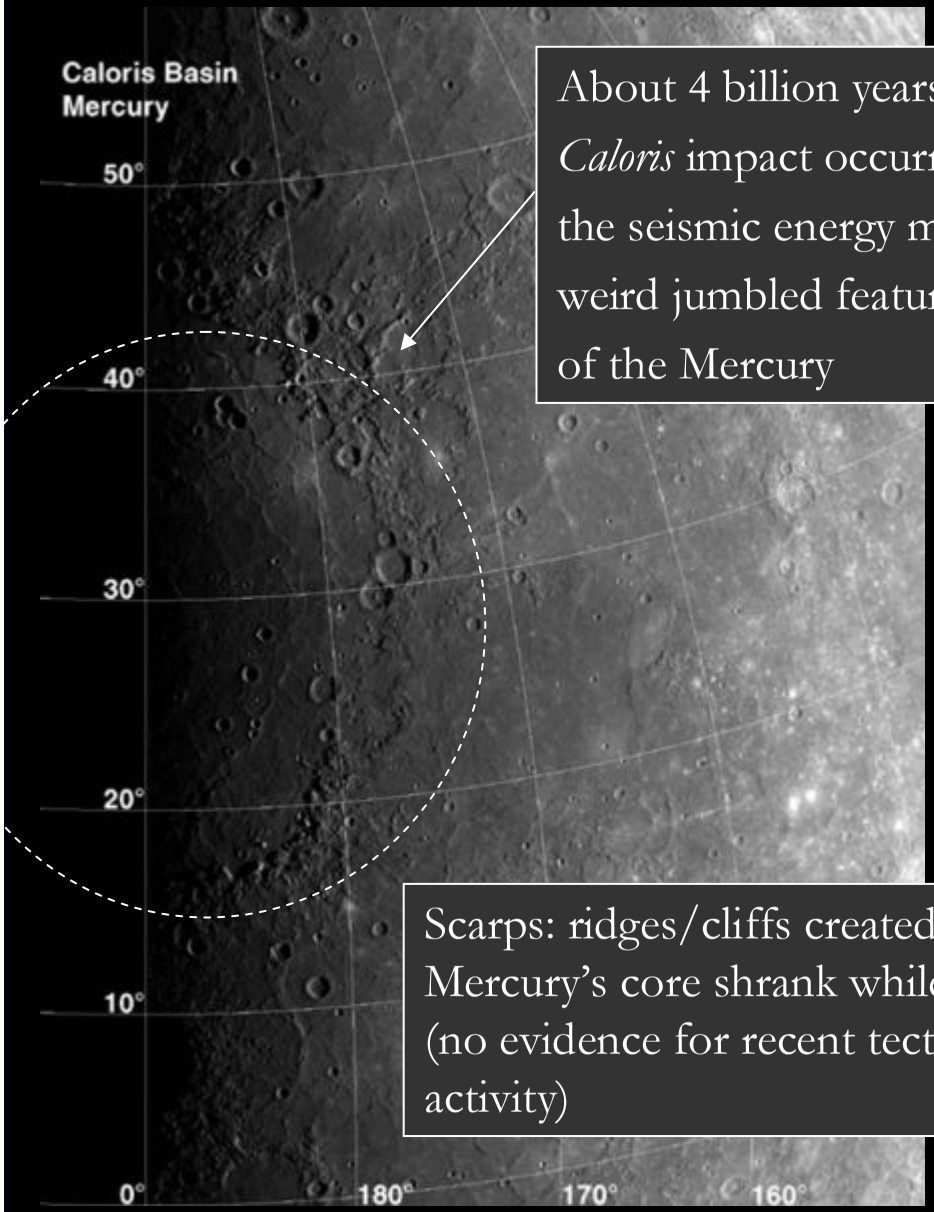
- and you can't use it at night!
- NASA circa 2000: great PR!

Mercury

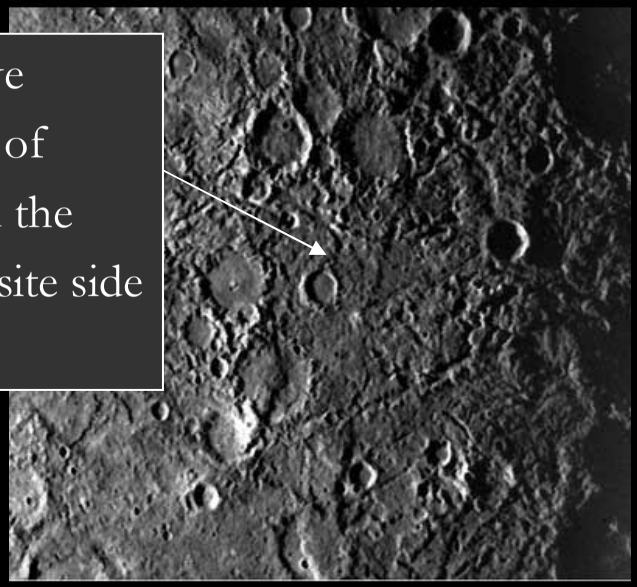


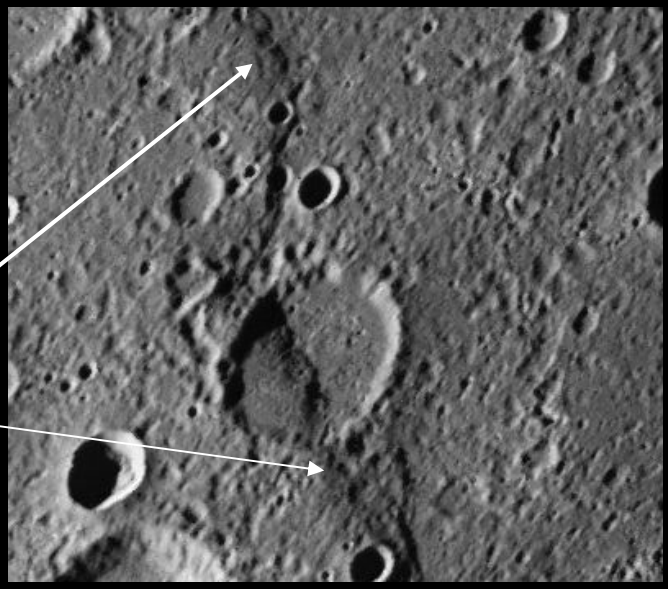
- Diameter: 4,880 km (0.38× Earth)
- Rotation period is 58.6 days
- Surface temperature max
  - 420° C (day side)
  - -180° C (night side)
- Surface gravity is 1/3 that of Earth
- Escape velocity is 1/3 times that of Earth
- Surface appears very similar to the Moon
- Trace atmosphere, no probability of life at all

Caloris impact



About 4 billion years ago the massive *Caloris* impact occurred. Refocusing of the seismic energy may have created the weird jumbled features on the opposite side of the Mercury

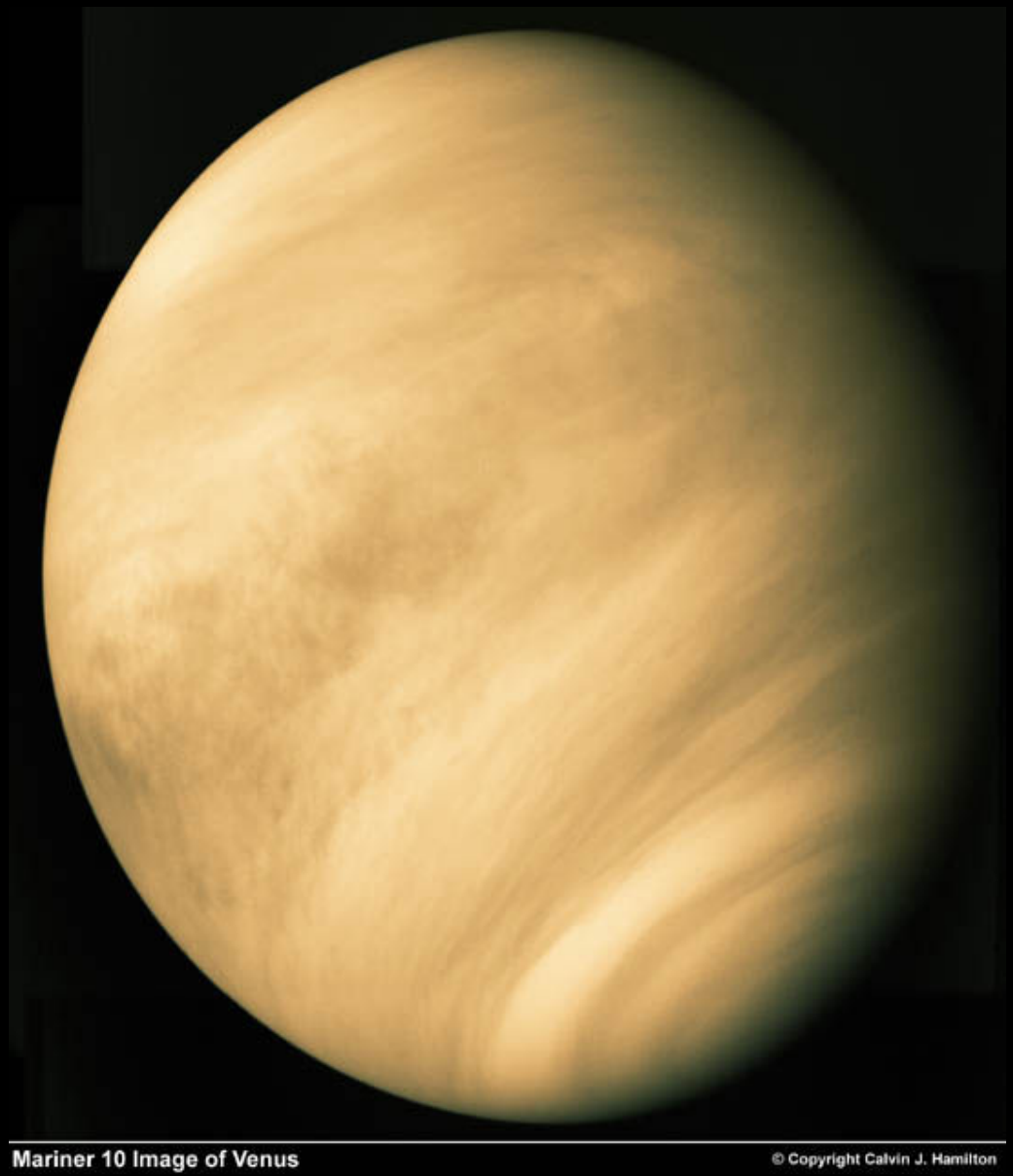




Scarps: ridges/cliffs created as Mercury's core shrank while cooling (no evidence for recent tectonic activity)

Distant view of Venus

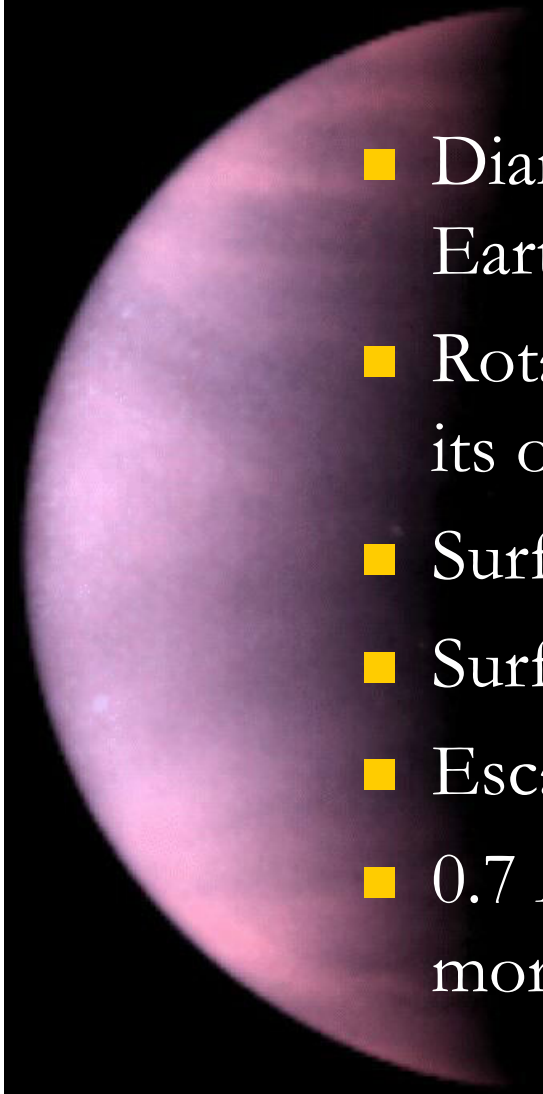
(*Planet of Love and Sulfuric acid rain!)*



Mariner 10 Image of Venus

- Cloud systems are very visible
- These clouds are actually sulphuric acid
- Precipitation never actually reaches the surface – too hot

Venus



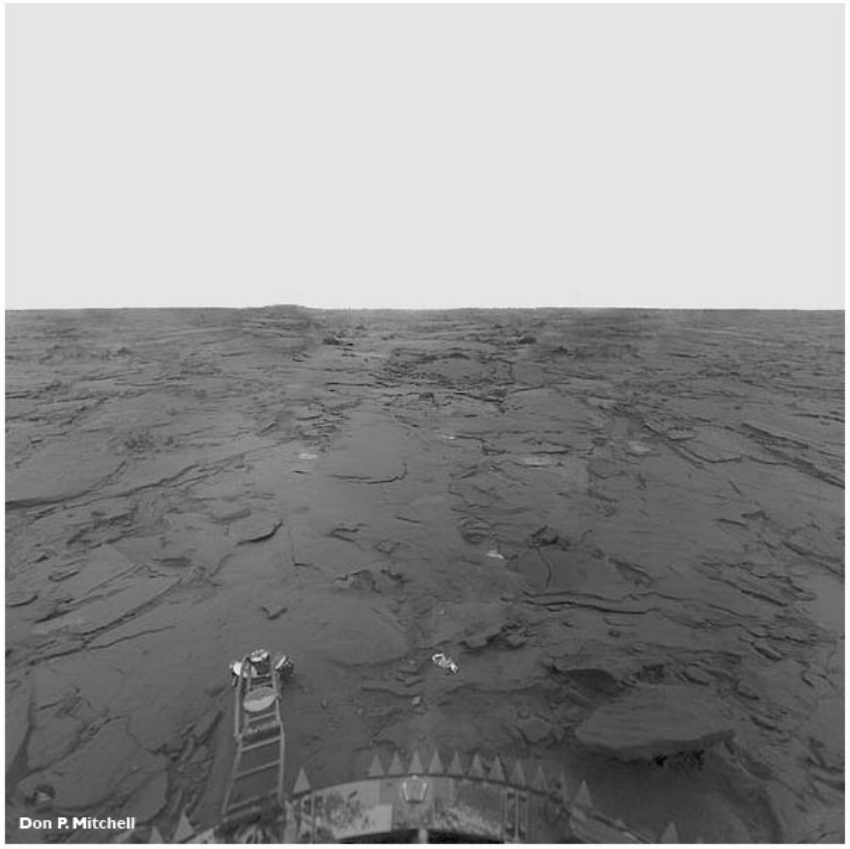
- Diameter: 12,200 km (almost same size as Earth)
- Rotation period: 243 days, it rotates slower than its orbital period
- Surface temperature: 480° C
- Surface gravity: 90% of the Earth
- Escape velocity: 93% of the Earth
- 0.7 AU from Sun, so receives $1/0.7^2 = 2$ times more solar radiation

Surface of Venus

- Surface of Venus from *radar imaging* by the Magellan probe
- No clear evidence for ridges associated with plate tectonics
- Small number of impact craters

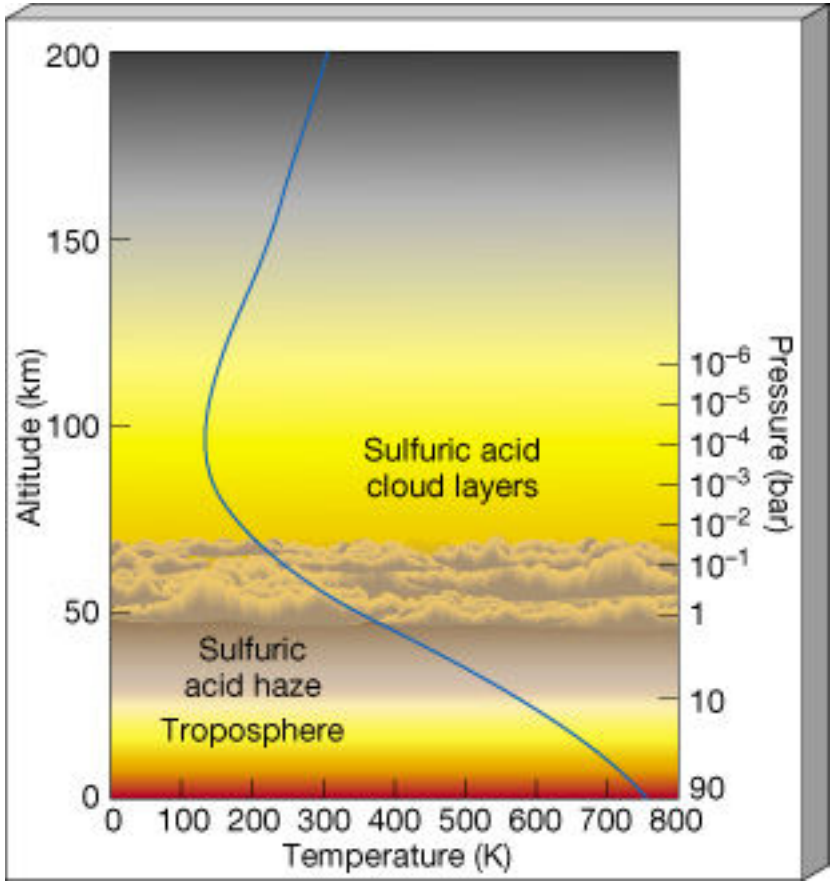
Venus Flyover

Venusian surface



These images were produced by Don P. Mitchell by compositing (and mipulating) images from the Russian Venera 13 probe

Venusian Atmosphere



- 96.5% Carbon dioxide, 3% nitrogen
- Pressure at surface = 90× Earth's
  - Equivalent to water pressure at ½ mile depth
- Above 30 km the atmosphere is dominated by sulphuric acid
- Cloud layer is visible from space

No carbonate-silicate cycle on Venus

- Venus has only trace amounts of water
  - CO_2 cannot precipitate out of the atmosphere by forming carbonic acid
- On Earth: greenhouse effect traps enough energy to increase temp by 40^{o} C
- On Venus: Atmosphere is 96% CO_2 , so the greenhouse effect *dominates*
- 99% of emitted IR radiation is trapped
- Almost *no difference* in temp between poles and dark side

Earth

Messenger's view of the Earth as it left in 2005

We'll look at Mars in more detail later in the course, today let's look at a few interesting features

Mars

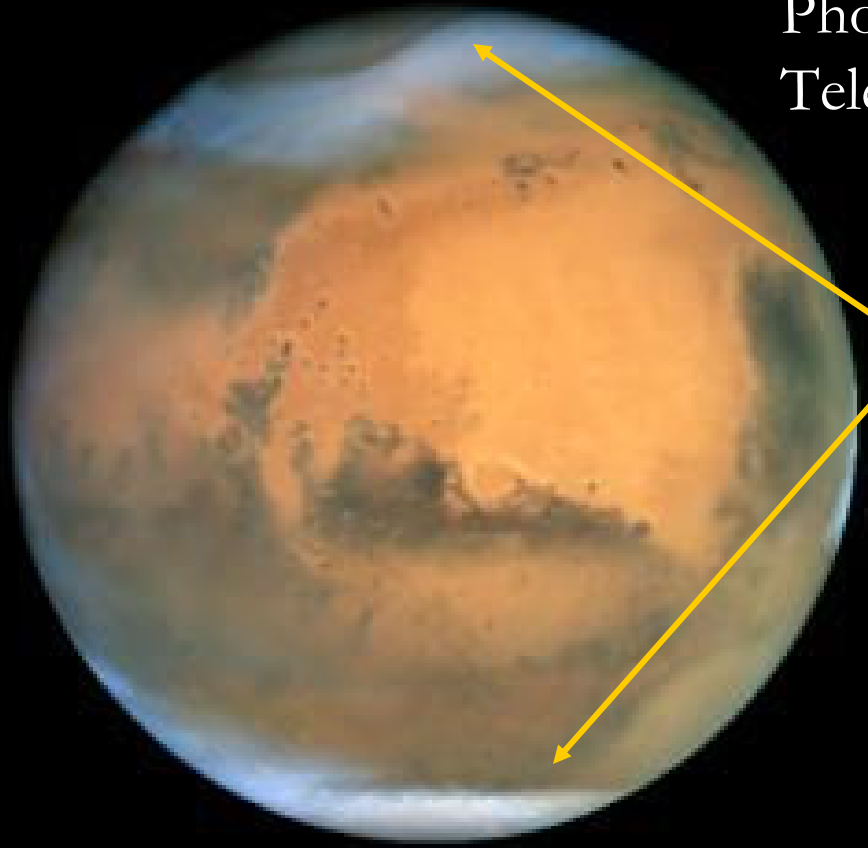
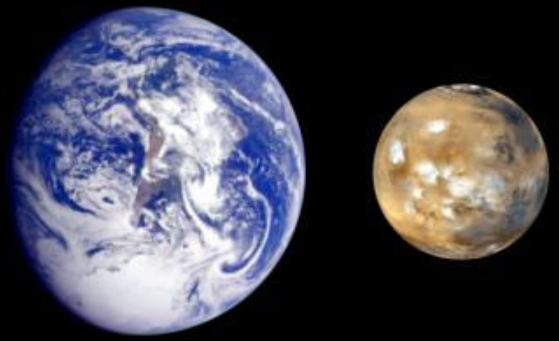


Photo from the Hubble Space Telescope

Polar caps

To scale with the Earth



Dust, CO_2 and water clouds can appear in the atmosphere

Mars

- Diameter: 6800 km (about 1/2 Earth's)
- Rotation period: 24.6 hours
- Surface temperature: -93 to -3^{o} C
- Surface gravity: 38% of that of Earth
- Escape velocity: 45% of that of Earth
- 1.5 AU from the Sun, so surface radiation is $1/1.5^2=1/2$ that of Earth's
- Axial tilt of 25° - shows seasons like the Earth

Martian Atmosphere

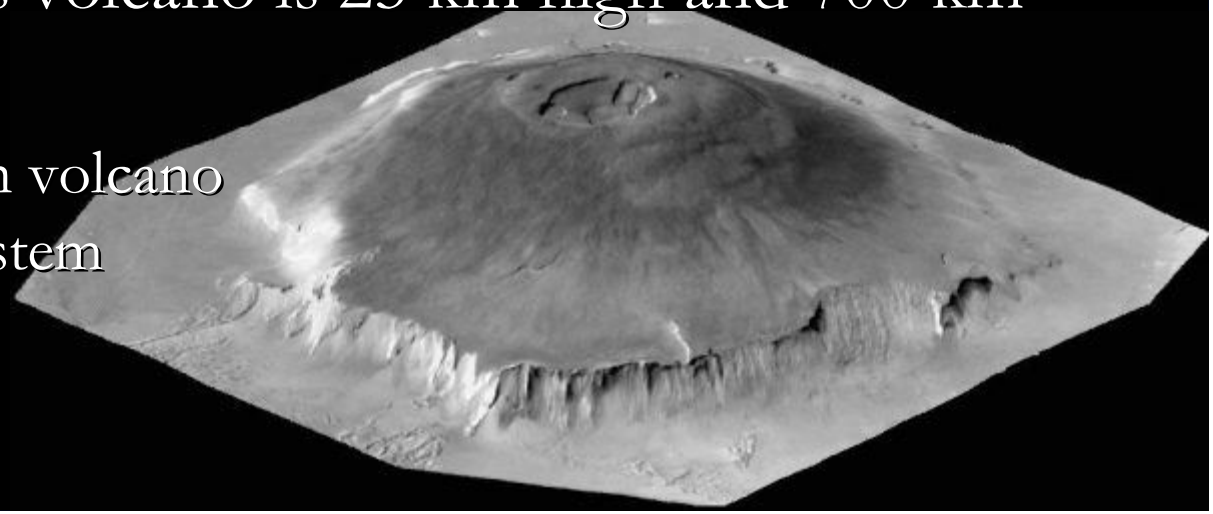
- *Very* thin (1% of the Earth's by mass)
- 95% CO_2 , 3% Nitrogen, 1.5% Argon, traces of other stuff
- *Possibly* billions of years ago the Martian atmosphere was similar in mass to the primordial Earth's
- What happened to reduce the levels of gases though?

`Reverse' Greenhouse/Runaway Refrigerator

- *If* Mars had a lot of surface water then almost all the atmospheric CO_2 may have been converted into carbonates via the creation of carbonic acid and sequestration into calcium carbonates
- Result: less and less CO_2 is available for maintaining the greenhouse effect
- Result: runaway cooling of the atmosphere
  - Water freezes
  - When temperature becomes sufficiently low CO_2 will also freeze out
- End result is that there is little CO_2 left in the atmosphere and the planet has cooled dramatically

Martian Geography

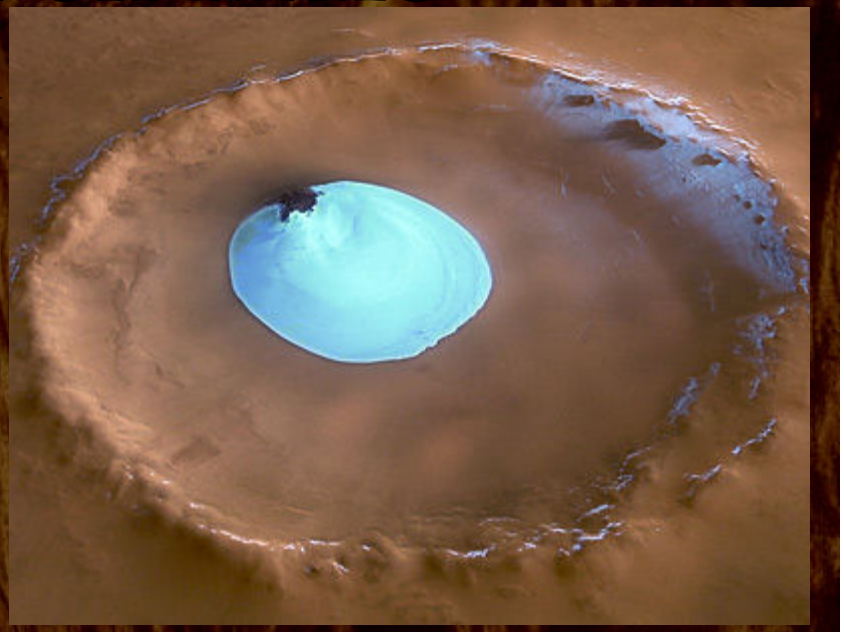
- Really interesting – the largest features are disproportionately large compared to those on Earth
  - Mariner Valley is as long as N. America is wide, 7 km deep
  - Olympus Mons volcano is 25 km high and 700 km in diameter
    - Largest known volcano in the solar system



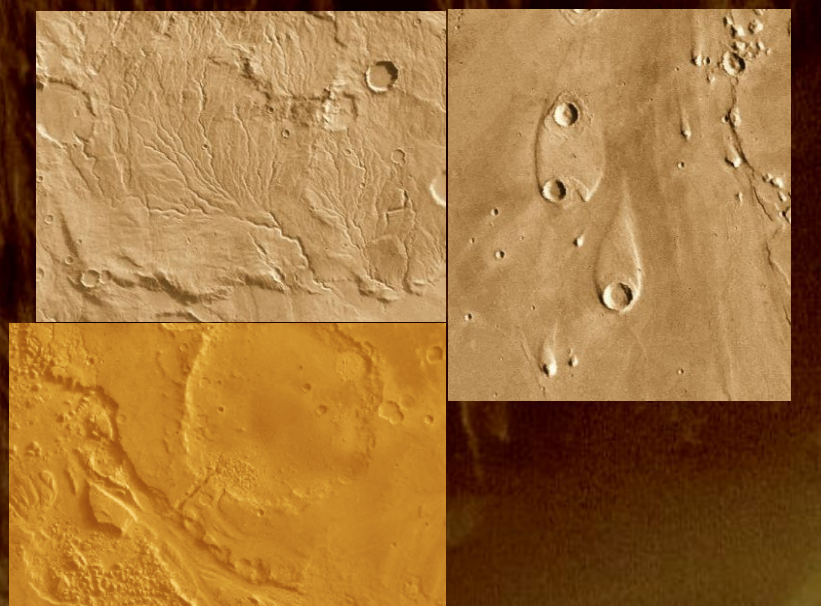
Mariner Valley Flyover

Water & erosion on Mars

- Frozen ice has been pictured by the Mars Express probe
  - Not CO_2 ice since the temperature is too high

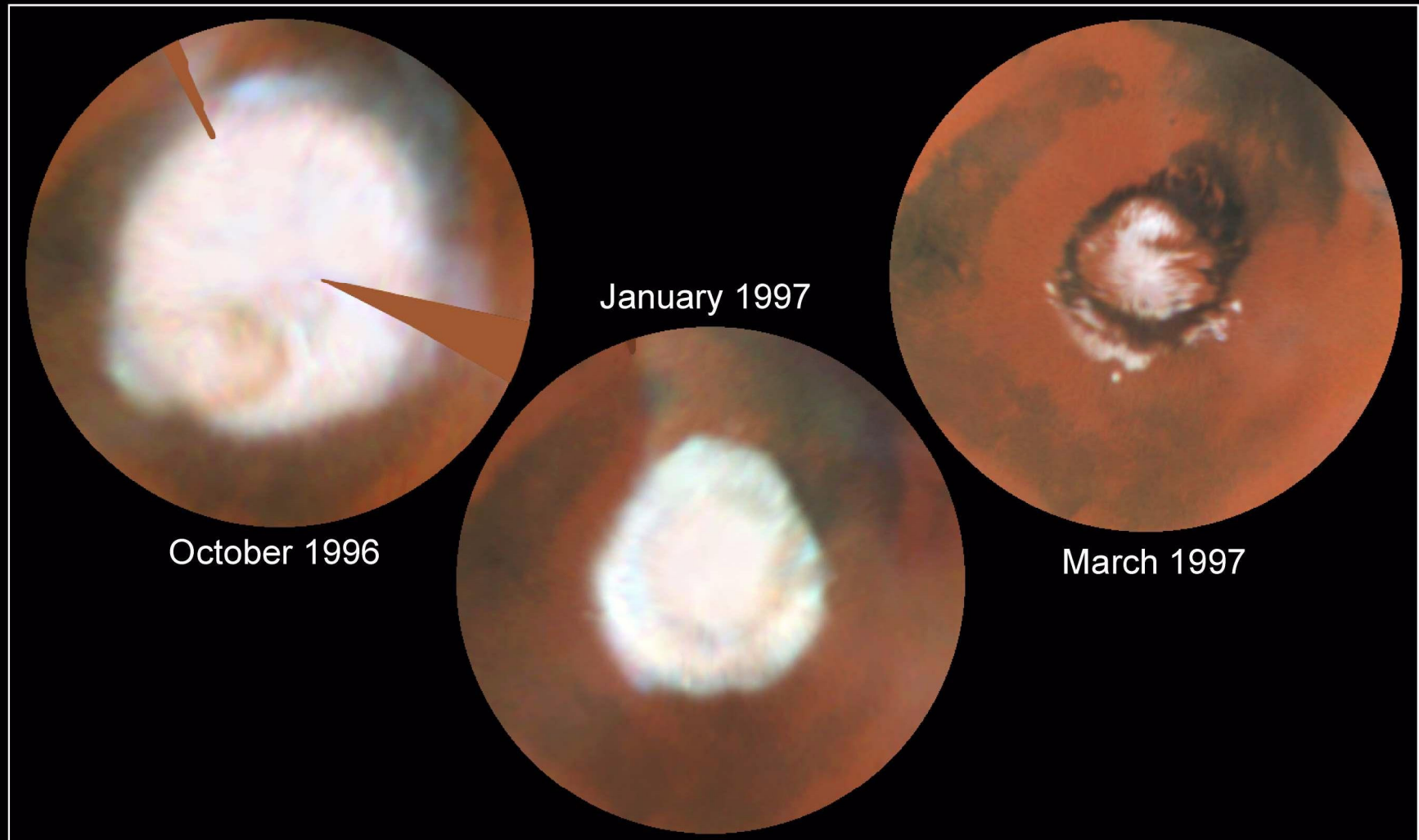


- Large *erosion* features on Mars *suggest* that water was present in liquid form billions of years ago



Martian Polar Caps

- Mainly frozen H_2O, covered with a layer of frozen CO_2
  - This is a very recent hypothesis and is still debated (2003)
- Wax and wane during (Martian) winter and summer (same as Earth's)
- *Residual* caps are there all year long (mostly water)
- Temperatures are seldom greater than -120° C on South Pole (freezing point of CO_2)
  - North Pole can reach -70° C



Mars • North Polar Cap

Hubble Space Telescope • WFPC2

PRC97-15b • ST ScI OPO • May 20, 1997 • P. James (Univ. Toledo), T. Clancy (Space Science Institute), S. Lee (Univ. Colorado) and NASA

Summary of lecture 14

- Other than Earth, Mars is the only real candidate for life on the terrestrial planets
- Mercury and Venus are both far too hot

Next lecture

- Midterm!