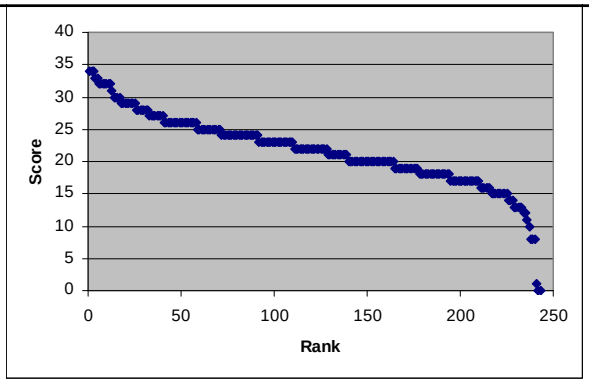
Atmosphere of Earth & Venus

- Test1
- Processes that shape earth
  - Losing gases in atmosphere
  - Gaining gases in atmosphere
- Venus
- Goldilocks Paradox

Test 1



- How am I doing?
  - Good job, if I am in the top quartile (rank <60, score >24)
  - Need improvement, if I am at the bottom (rank >220, score <15.
  - Cuts are on Angel. Test 1 only represents 1/6 of course grade.
- How to do better on the next test. Aim to understand ideas.
  - Purpose of homework & practice test is to check your understanding.
    - Think about key idea for each question.
  - Ideas are important; answers are not. Do not memorize the answers.
  - Models are important; answers are not. Do not memorize the answers.
  - Do not memorize questions: For some questions, the ideas are the same as on homework or practice test, but the wording is different.

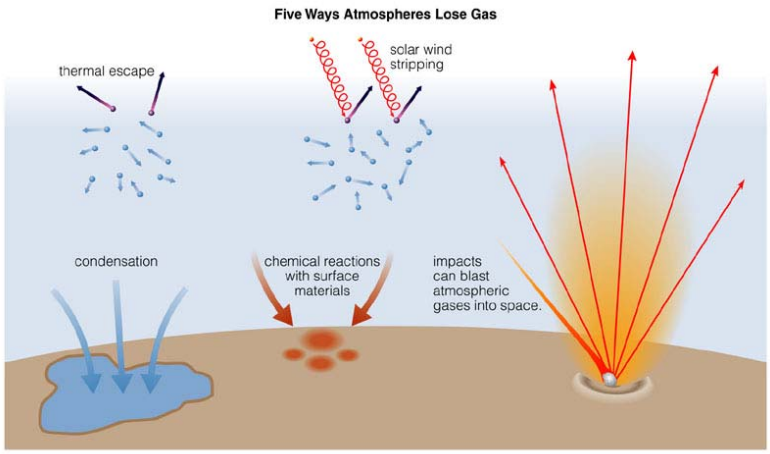
Atmosphere of planets: loss of gases

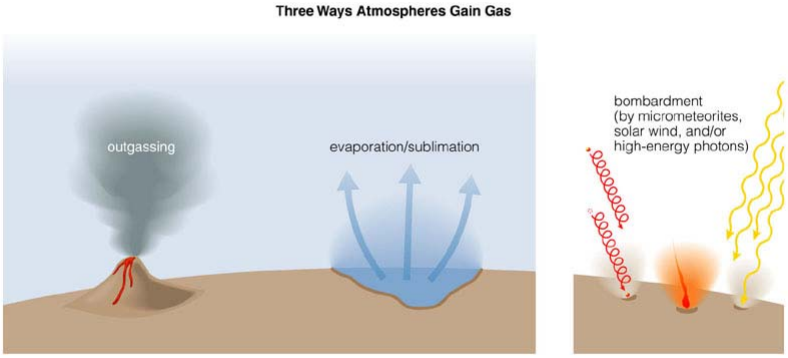
- Planets formed from the same material but now have very different atmospheres.
  - Earth has little helium; Jupiter has a lot of helium
  - Mercury has little atmosphere
- Think of gas molecules as baseballs moving and colliding. How do baseballs escape from the earth's gravity?
- Average kinetic energy of gas molecule
  - KE = 3k/2 Temperature
  - KE = ½ mass speed^2

Important: Hotter means more kinetic energy.
Not important: 3k/2

- Q: Oxygen molecules (m=32) in the air move at an average speed of 300m/s. Helium (m=4) moves at an average speed of
  a. 40 m/s
  b. 300 m/s
  c. 850 m/s
  d. 2400 m/s
- Baseball can escape if Kinetic Energy > Potential Energy
  - speed^2 > $2GM_{Earth}/R_{Earth}$
  - Escape speed from earth is 11,000 m/s. How can helium escape?

- How can helium escape from earth? By chance, a helium atom gets much more speed than the average and escapes.
  - Average 850 m/s
  - Very rare 12,000 m/s
  - On earth, each molecule get a new try every billionth of a second.
- Q: S1: It is easier to lose a lighter gas. S2: It is easier to lose gas from a hotter planet. S3: It is easier to lose gas from a more massive planet.
  a. T T T
  b. F T T
  c. T F T
  d. T T F
  e. Two are false





Life & the Earth's Atmosphere

- Life started in CO_2 atmosphere, roughly 4 billion yrs ago.
- Life initially only in sea… converted CO_2 to oxygen through *photosynthesis*.
- The released oxygen was swallowed up in interactions with surface material until ~ 2 billion yrs ago.
- After 2 billion yrs ago, oxygen able to build up in atmosphere.
  - + geological activity buried much of the free carbon.
- Atmosphere then converted to today's mix:
  78% nitrogen, 21% oxygen, 1% everything else.
- Free oxygen ➔ ozone

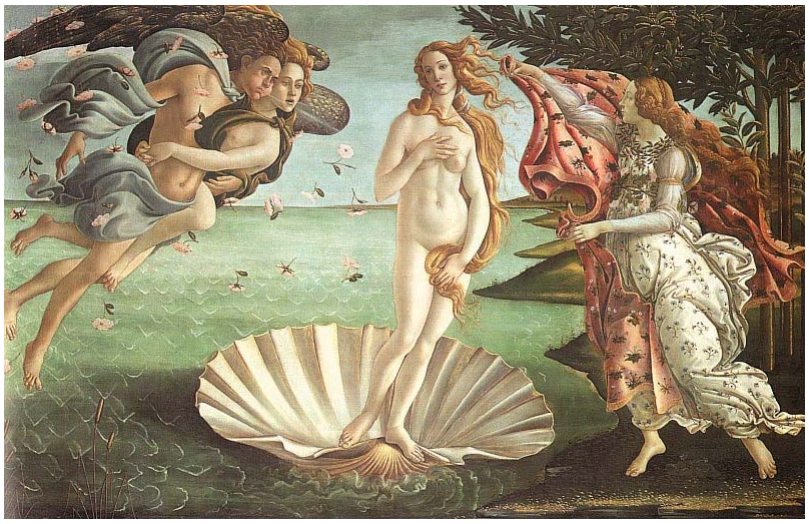
  ➔ protection from ultraviolet light➔ land animals

Life converted Earth's atmosphere from CO_2 to N_2, O_2

Venus is too hot for life. What went wrong?

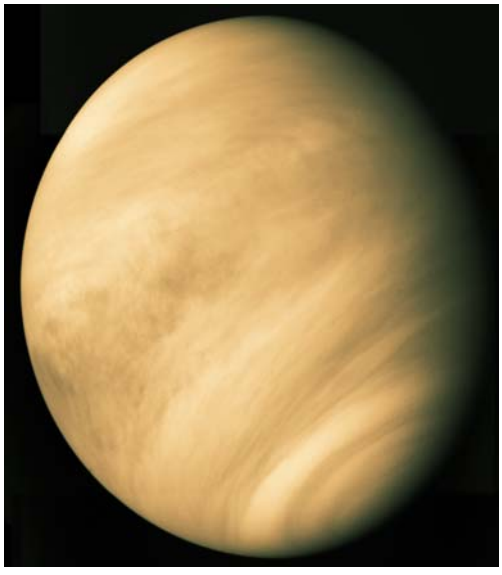
- Description of Venus
- Atmosphere of Venus
- Why did Venus get too hot, even though Earth, its twin, remained temperate?

Venus
(according to Botticelli)



Venus, our sister planet

	Venus	Earth
Diameter	0.95	1
Mass	0.81	1
Semi-major axis	0.72	1
Density	0.96	1
Rotation (days)	-243	1
Orbit period (days)	224	365



Venera 7 (1970)
Venera 10,11 (1975)
Venera 11,12 (1978)
Venera 13,14 (1981)

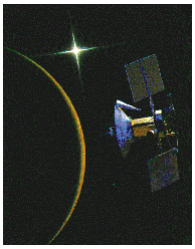
Venera Landers
(USSR)

Venera 13, 14 soil samples: basalts

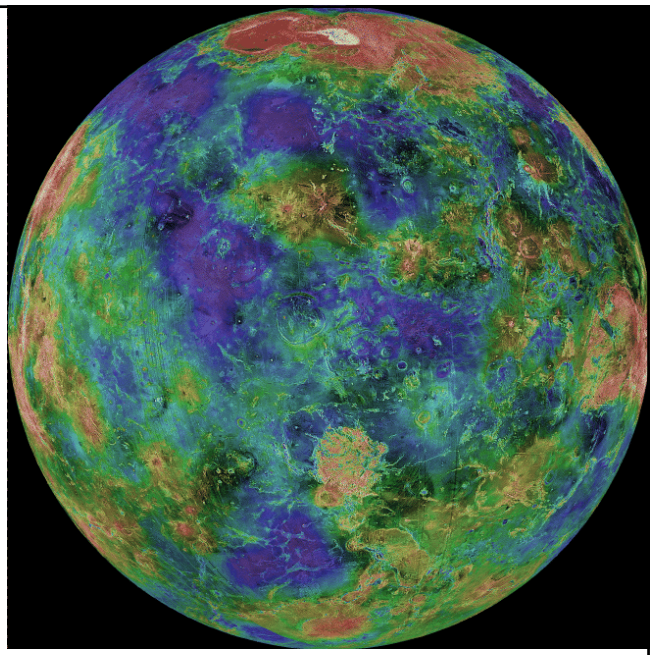
The view from Venera 14

Radar Map of Venus

Made by Magellan orbiter in 1991-93.



Blue = lower
Brown/red = higher.



The surface of Venus [7.4]

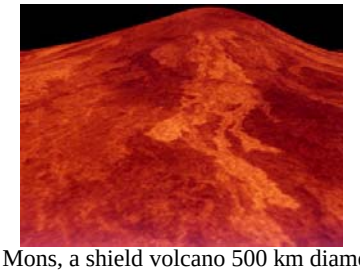
Magellan Radar Imaging.

- Impact craters
  - ➔ age dating of surface
    - only 15% as many craters as lunar maria.
- ➔Oldest terrain only 800 million yrs old
  - compare to 3.8 billion yrs on Earth
- Constant resurfacing by volcanic action.
  - but appears to have ceased ~ 500 million yrs ago

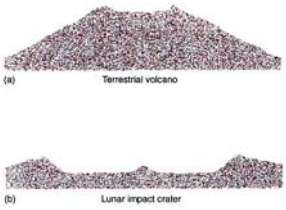
Rotating Venus

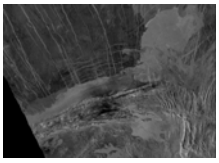
Volcanic Activity on Venus

Radar Imaging: 100 m resolution

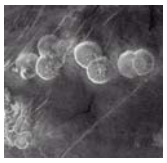


Sif Mons, a shield volcano 500 km diameter x 3 km high.





Lava flow



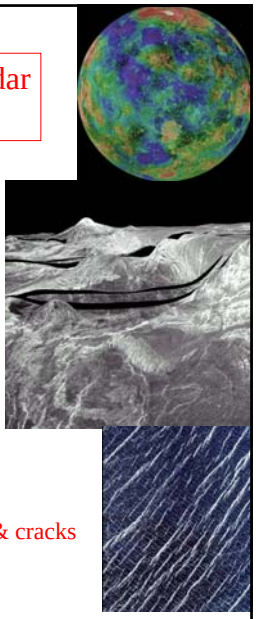
"Pancake" volcanoes, due to very thick lava.

Corona: a collapsed dome over a magma chamber.

Interior Structure

- Similar to Earth
- Iron core 3000 km in radius
- Molten mantle
- Crust

Magellan Radar Images



Lakshmi Planum
Hilly area on Ishtar

Ridges & cracks

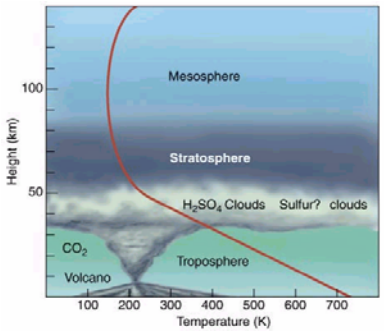
Tectonics

- No plates as on earth
- But much shearing, compression and stretching of crust by convection currents in mantle.
- Has pushed up “continents”
  - Aphrodite and Ishtar
- Rift valleys and cracks

The Atmosphere of Venus

- Surface Pressure = 92 x Earth’s
- Surface Temperature = 482º C
  - melting point of lead: 327º
- Sulfuric acid cloud layer at 30-60 km

	Venus	Earth
CO_2	96%	0.03%
N_2	3.5	78.1
Ar	0.006	0.93
O_2	0.003	21.0



Some Surface Temperatures in ^{o}F

- Mercury (Mariner 10) 800F
- Venus (Mariner 2; Venera landers) 900F
- Hell (Revelations 21:8) 832F
  - "But the fearful and unbelieving shall have their part in the lake which burneth with fire and brimstone"
  - boiling point of brimstone (sulfur); 832F

Goldilocks #1

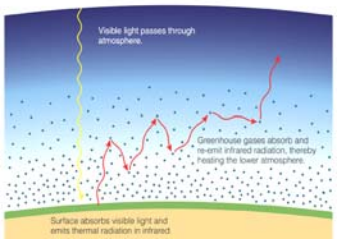
- Venus is too hot; Mars is too cold. Why is the earth just right, not too cold and not too hot?
- Venus is too close to the sun, and Mars is too far.
  - This is part of the answer.
- Reflected light is 2nd ingredient.
- Greenhouse effect is 3rd ingredient.
- History is 4th.

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.

Greenhouse effect

- Greenhouse effect
  - Sunlight is absorbed by the planet's surface
  - Surface emits infrared radiation
  - Infrared radiation is absorbed by CO2 & H2O and reradiated many times before it escapes into space. CO2 & H2O acts like a blanket.
- 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?



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Why did greenhouse run amok on Venus?

- When the sun becomes brighter, the earth becames 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

1. Which is <u>not</u> a possible reason why greenhouse ran amok on Venus?
   a. Too hot to rain
   b. Type of rocks cannot sequester CO2
   c. There is no plate tectonics
   d. Venus was born without water.

Why did greenhouse run amok on Venus?

- Deuterium
  - Normal H has 1 proton in nucleus
  - Deuterium D has 1 proton & 1 neutron. Mass of n & p same.
- Q1 Suppose I had a pound of normal hydrogen. I trade a deuterium for every hydrogen atom. How much would I have?
  - A: 1lb, B: 2lb, C: ½ lb, D: 4 lb.
- Q2 At the same temperature, which gas moves fastest and is more likely to escape?
  - A: normal H; B: deuterium; C: H2O, D: DHO
- Key observation of water: Earth's ocean has 100,000 X more than Venus' atmosphere.
- Key observation on deuterium abundance
  - On earth, H/D=5000
  - On Venus, H/D=50.
- Q3 Which hypothesis is wrong?
  a. Venus formed without much water.
  b. Venus lost 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.

Why did Mars become so cold?

- Read & think.