The Earth-Moon System

Earth/Moon radius: **¼**

Earth/Moon mass: **1/81**

Earth-Moon distance:

384,000 km

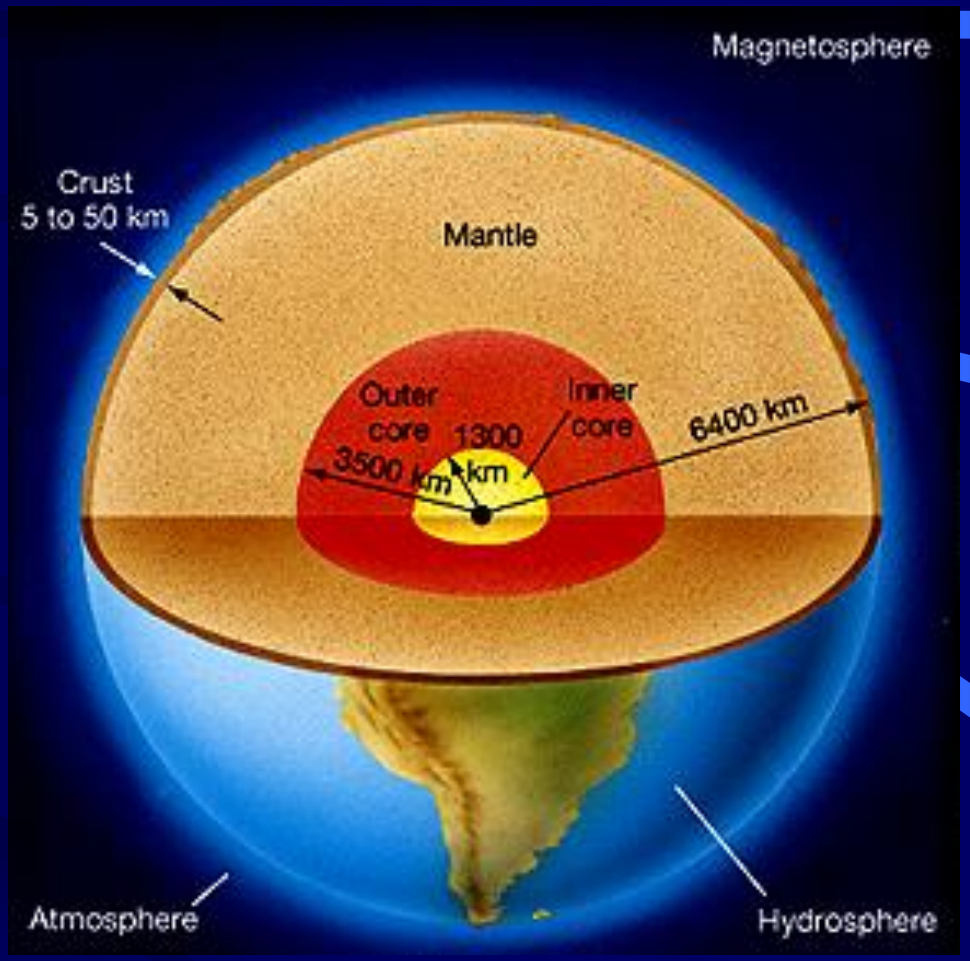
Features of the Earth & Moon

- Mass: Earth: 6×10^{24} kg — Moon: 1/81 Earth's
- Radius: Earth: 6400 km — Moon: 1/4 Earth's ra
- Density: Earth: 5500 kg/m^3 — Moon: 3300 kg/m^3
  - 5.5 times that of water
  - About 2 times that of a rock
- Gravity: Earth: 9.8 m/s^2 — Moon: 1/6 Earth's gravity

(about the same as in water)

Structure of the Earth

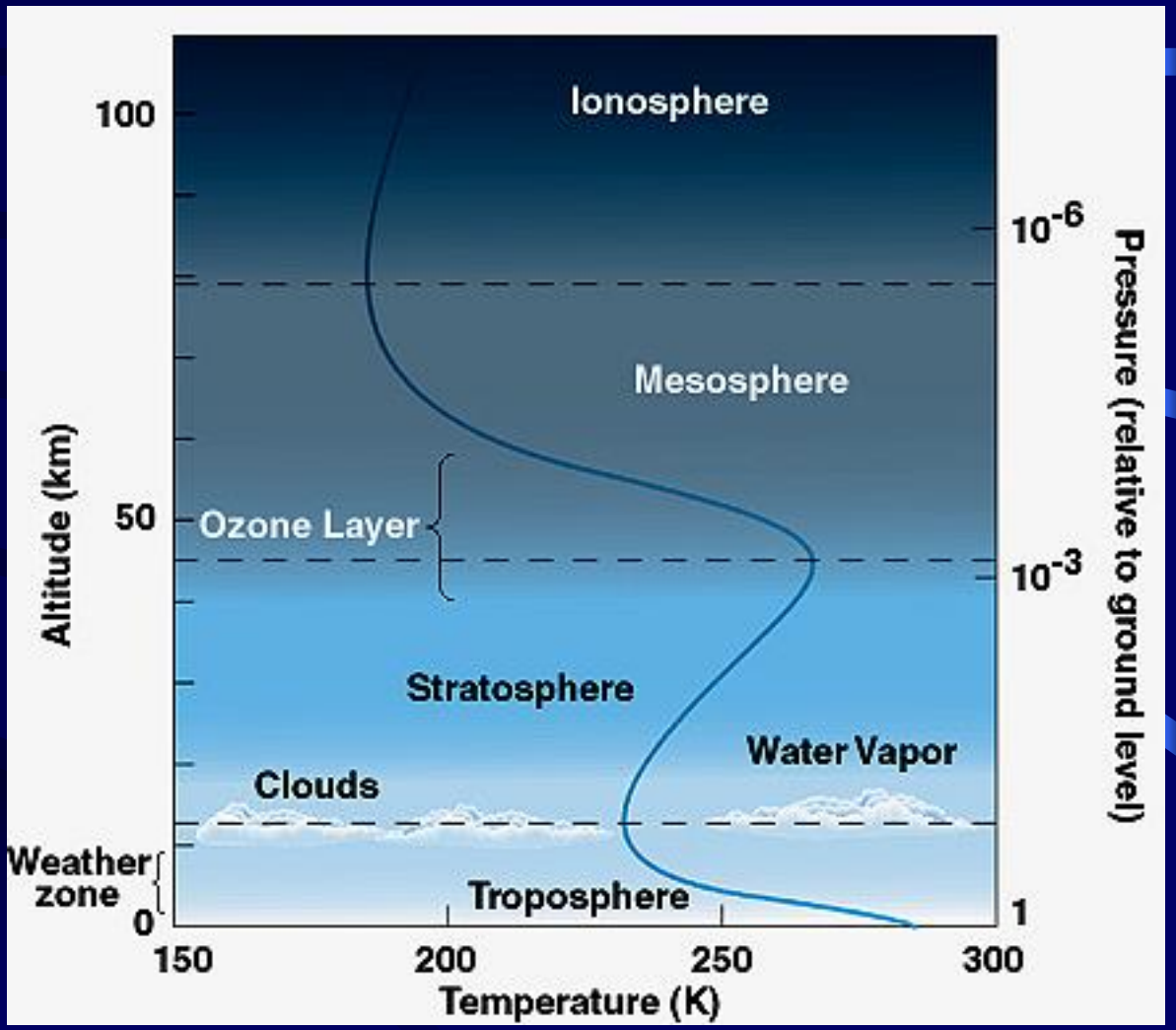
- Core
  - Mostly iron and nickel
  - Inner core solid, outer core liquid
- Mantle
  - Mostly basalt, a heavy mineral containing iron and magnesium
  - Soft; can flow even though it is solid rock
- Crust
  - Solid surface layer; “floats” on the mantle



- Density and temperature both increase with depth

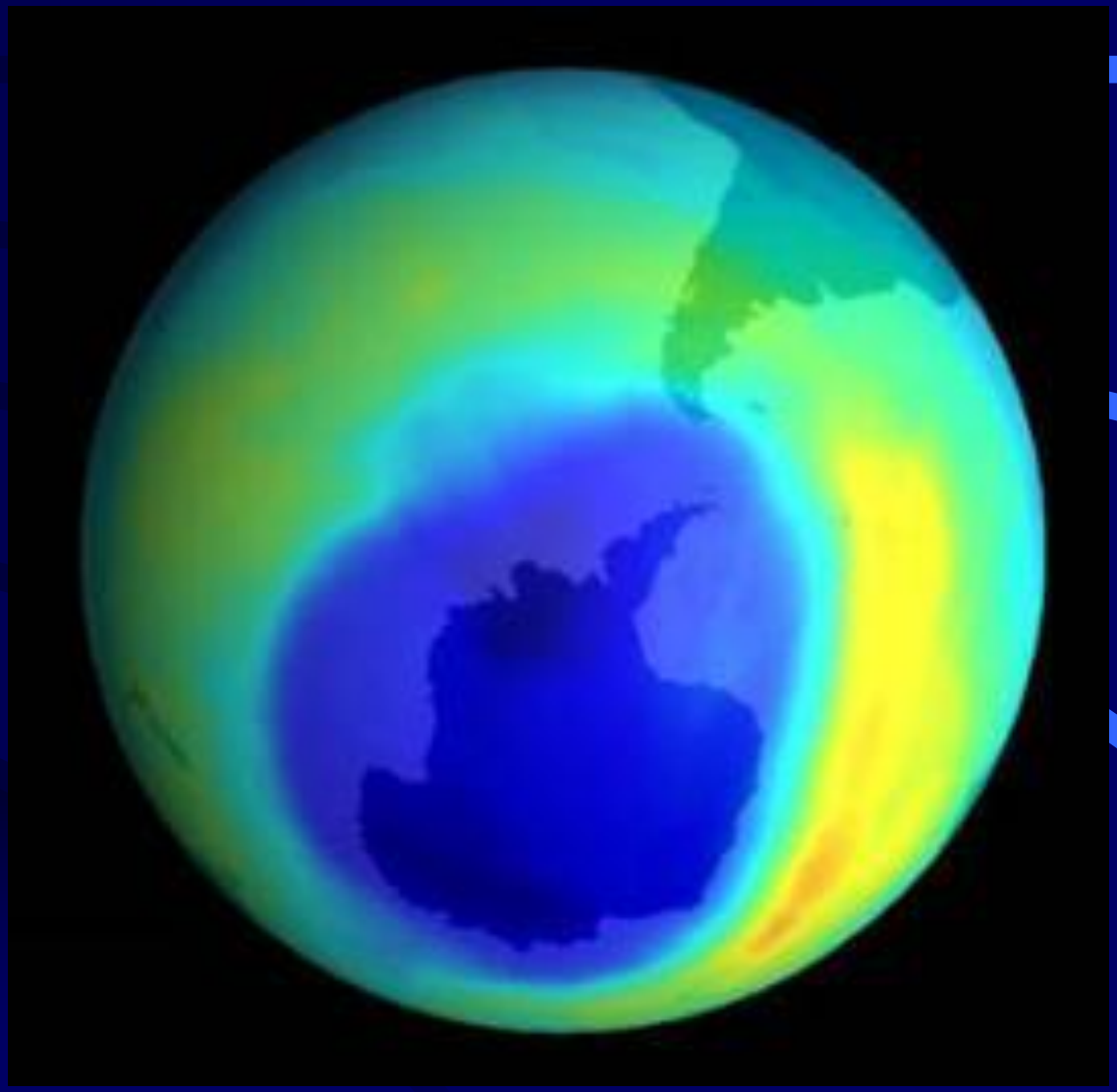
Earth's Atmosphere

- 78% Nitrogen, 21% Oxygen, 1% Other
- Troposphere – region of weather
- Stratosphere – stable and calm
- Ionosphere – gases charged by interaction with radiation from space



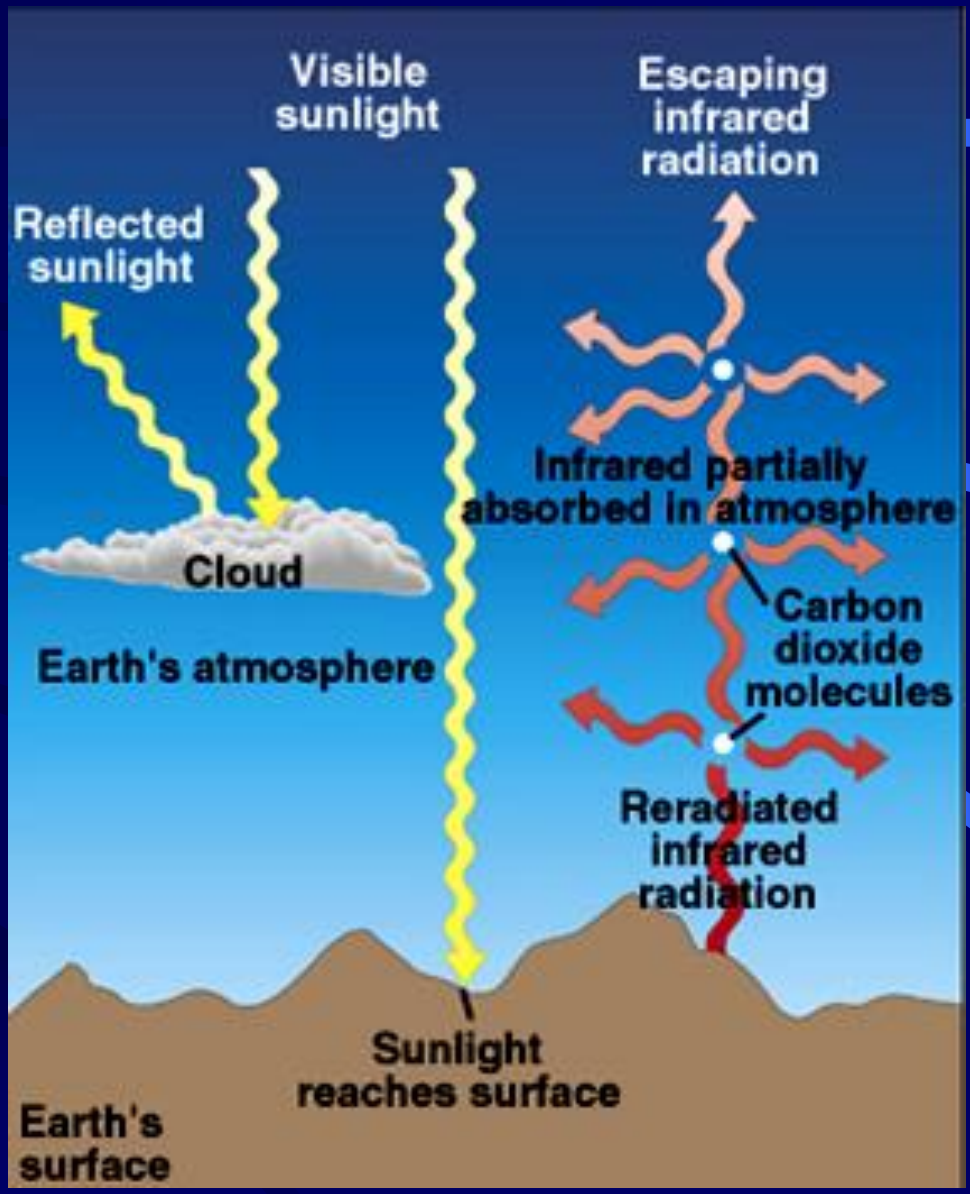
Ozone Layer (O_3)

- Absorbs most UV radiation from the Sun
- Hole over Antarctic
  - *Chlorofluorocarbons* (CFC's) – released by spray cans, refrigerators



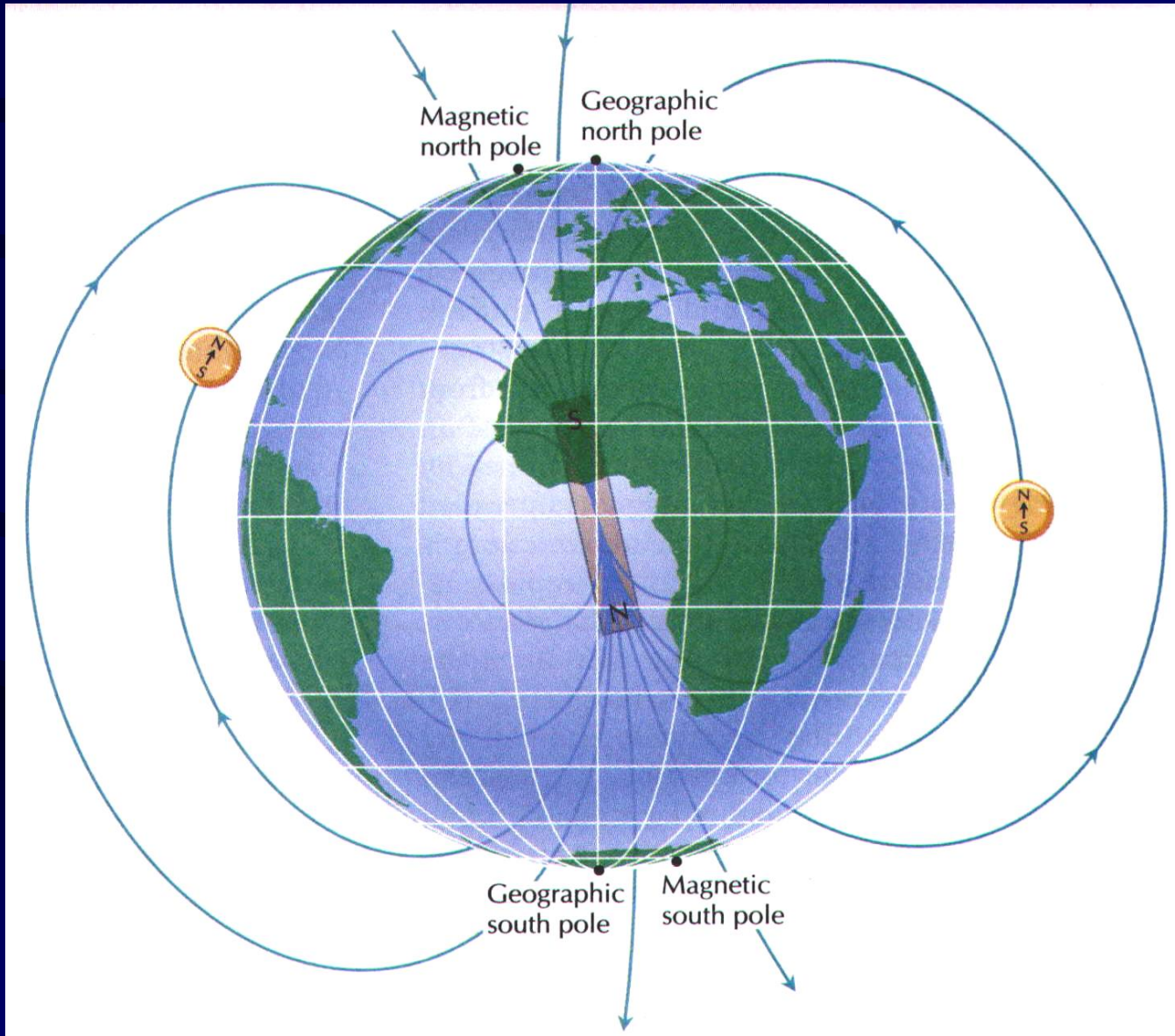
Greenhouse Effect

- Earth absorbs energy from the Sun and heats up
- Earth re-radiates the absorbed energy in the form of infrared radiation
- The infrared radiation is absorbed by carbon dioxide and water vapor in the atmosphere



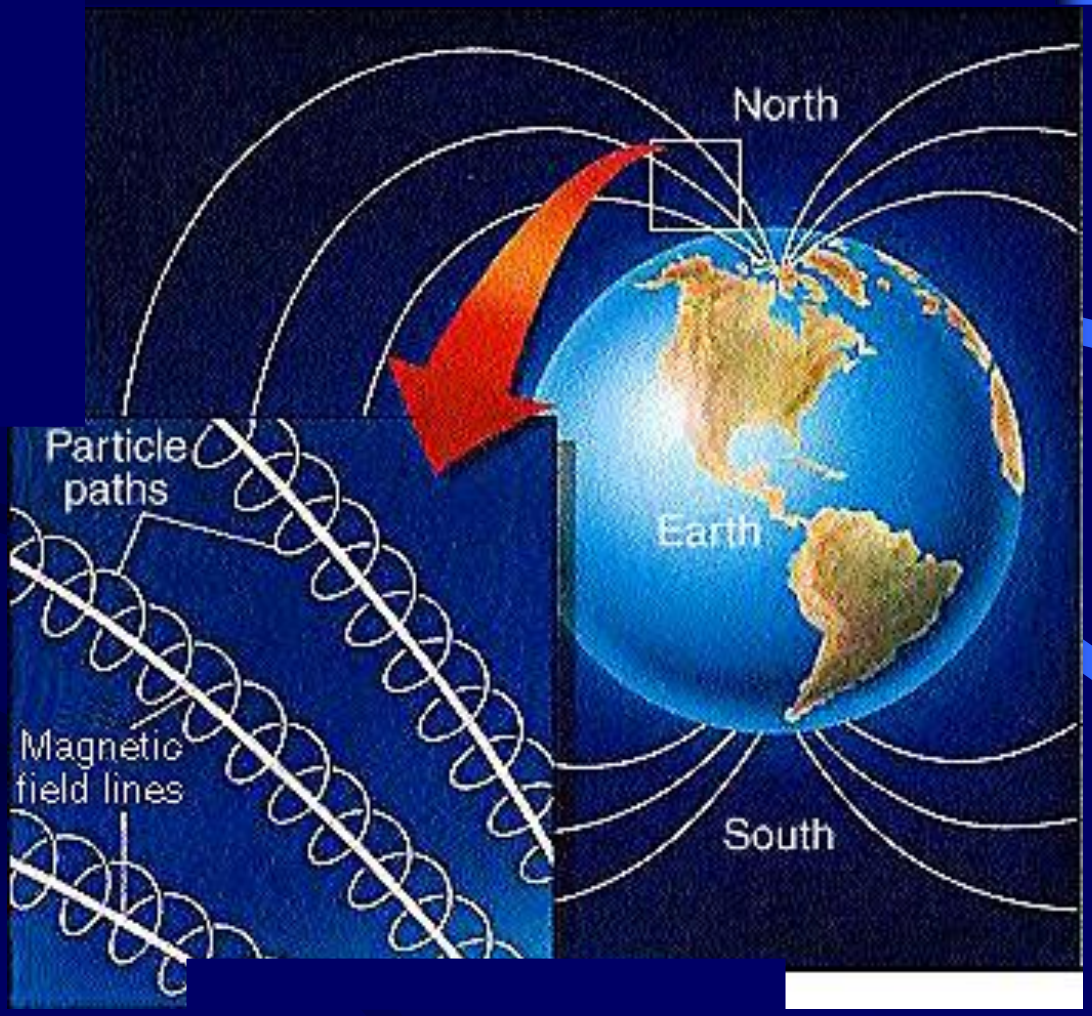
Magnetosphere

- Magnetic north pole about 7° west of geographic north pole
- Driven by motion of molten metals in core



Magnetic field/shield: Motion of Charged Particles

- Charged particles "trapped" by magnetic fields
- Origin of the Van Allen radiation belts
- Protects us!



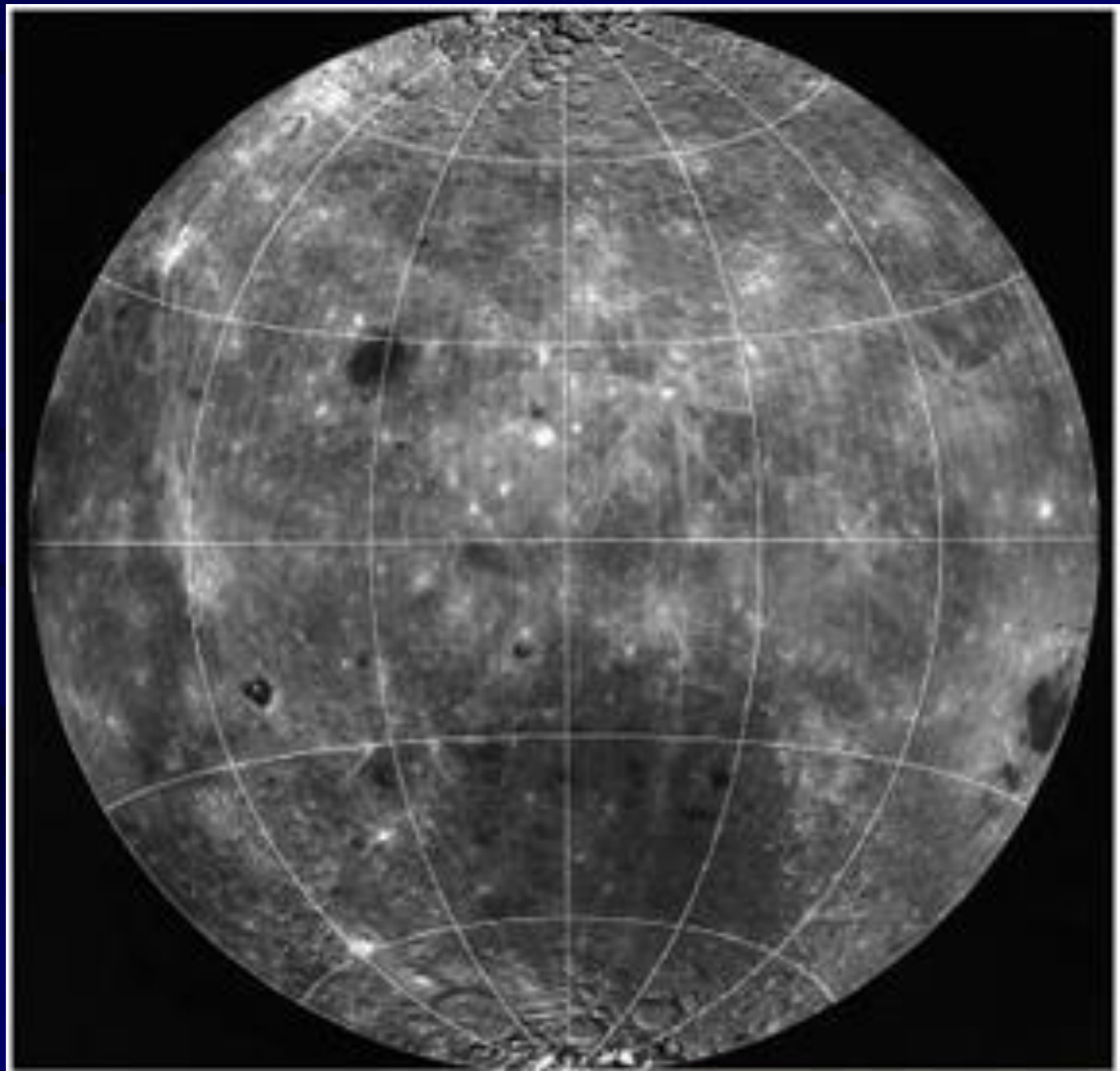
Aurora Borealis

Moon: Large-Scale Features

- "Maria"
  - Dark areas resembling oceans
  - Plains of solidified lava
  - Part of the lunar mantle
  - About 3.2–3.9 billion years old
- Highlands ("Terrae")
  - Light-colored, resemble continents
  - The lunar crust
  - More than 4 billion years old

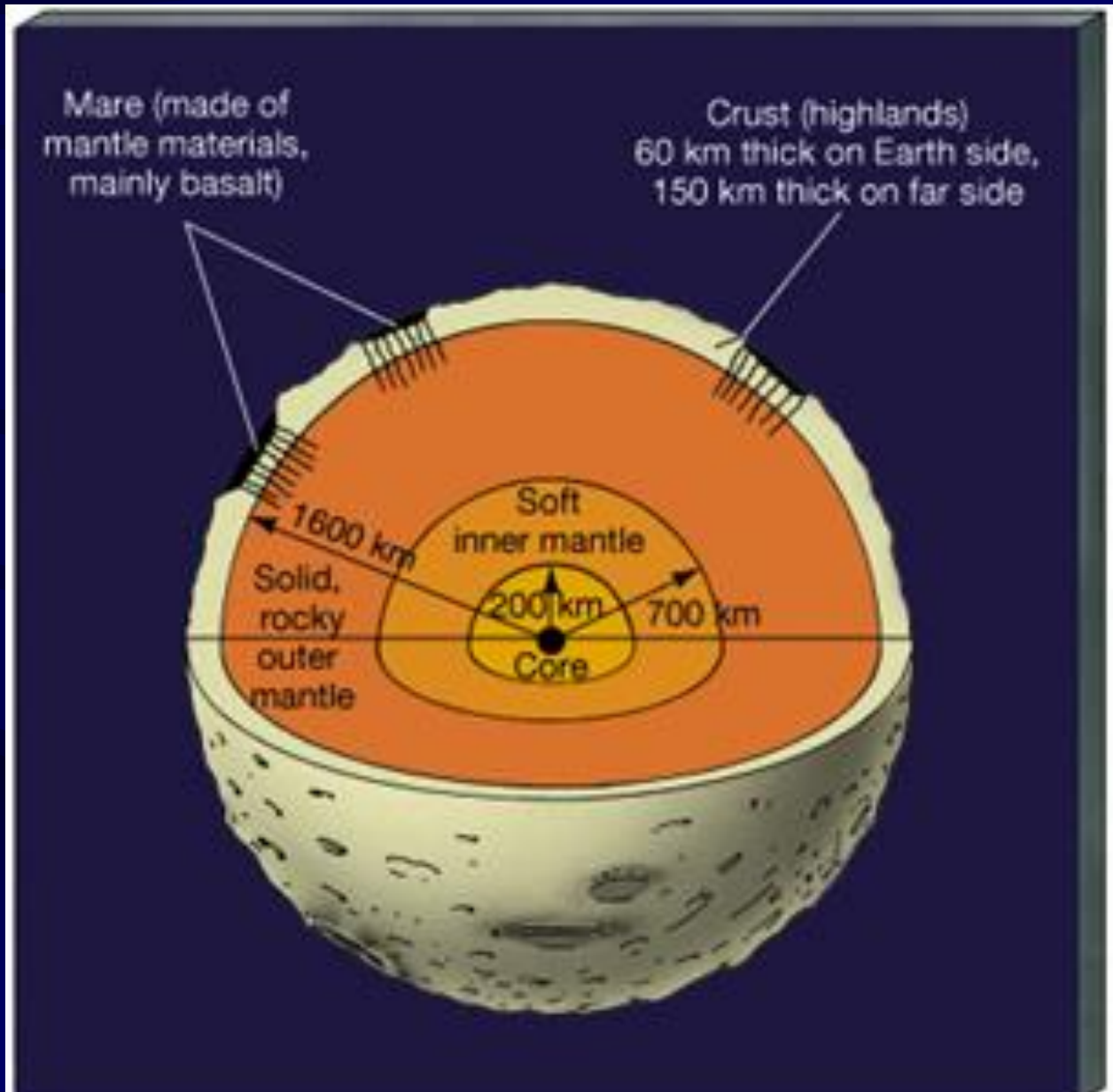
The Moon – Far Side

- Can be seen by satellites only

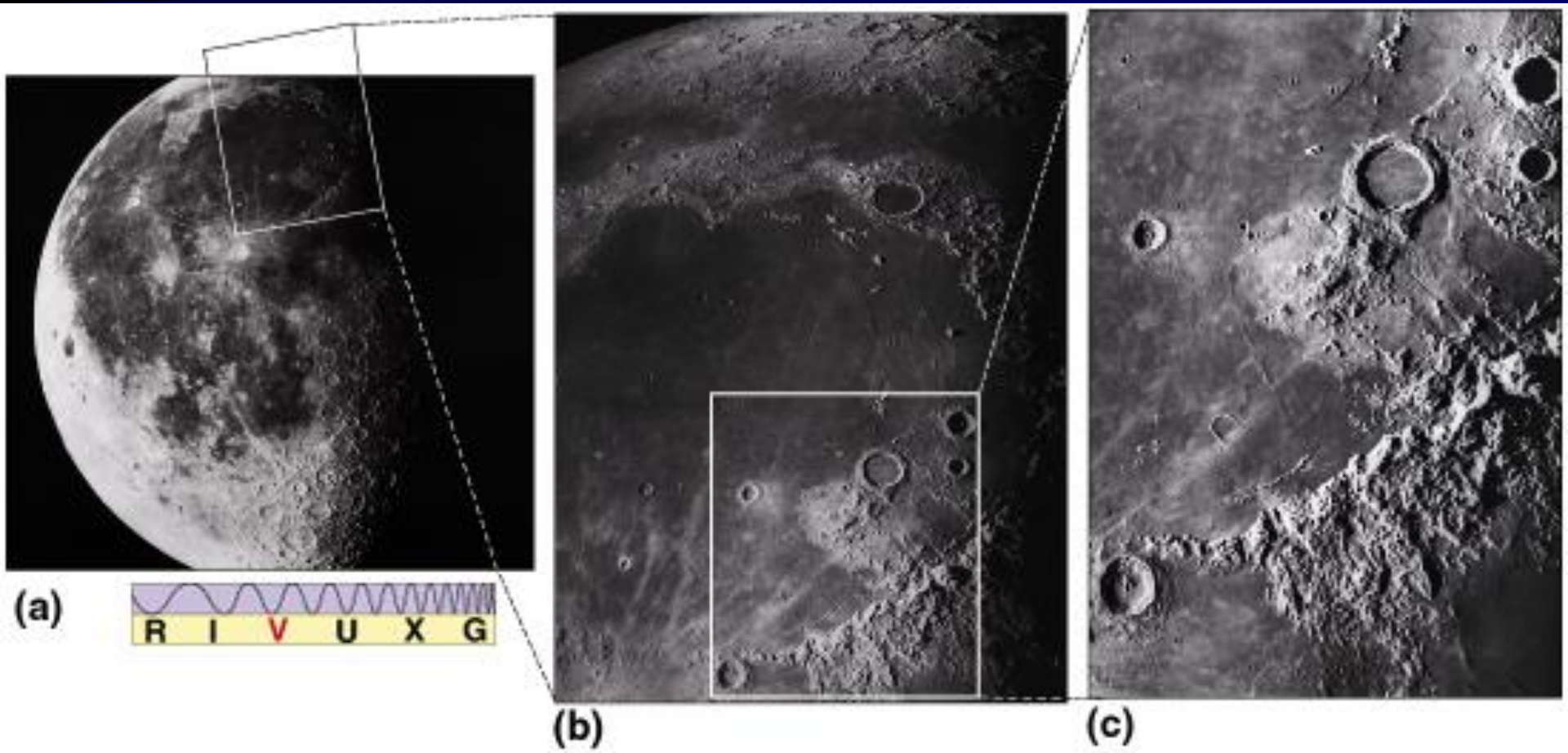


Structure of the Moon

- Also consists of crust, mantle and core
- **No** hydrosphere, magnetosphere or atmosphere
- Little seismic action



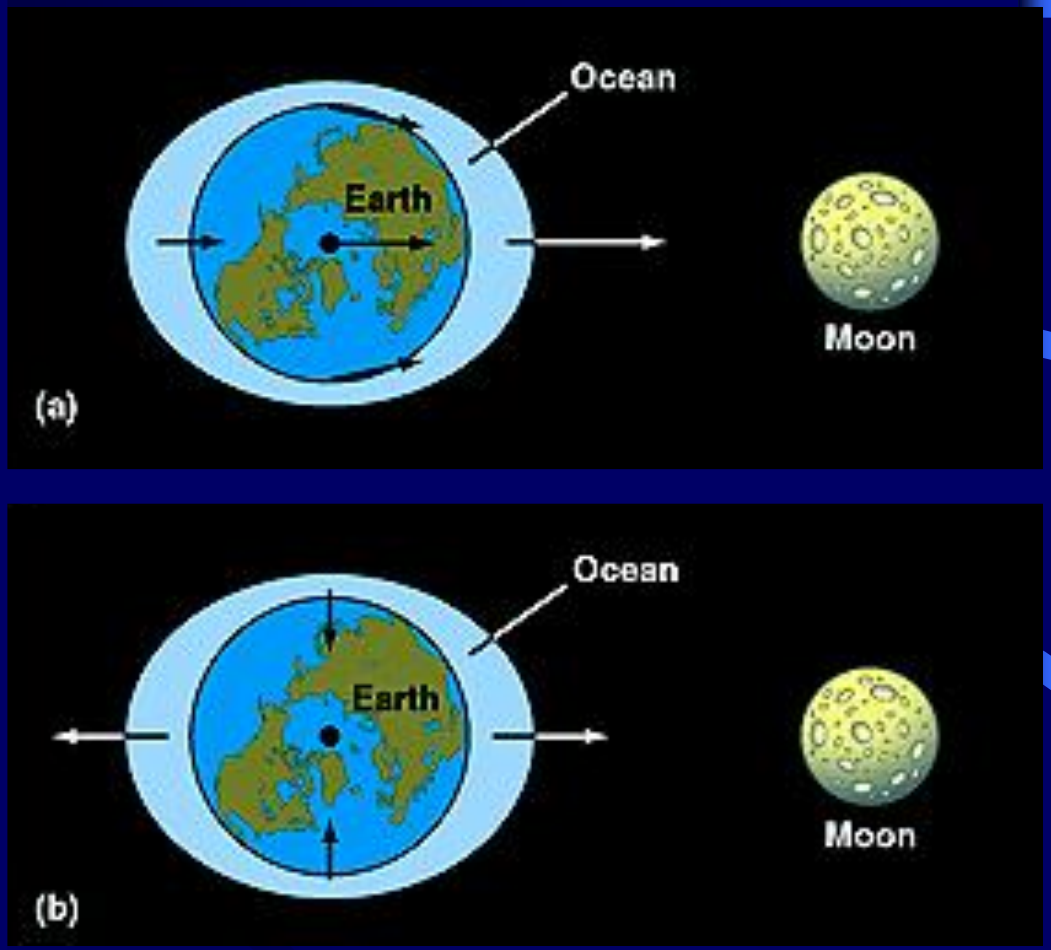
The Mountains of the Moon



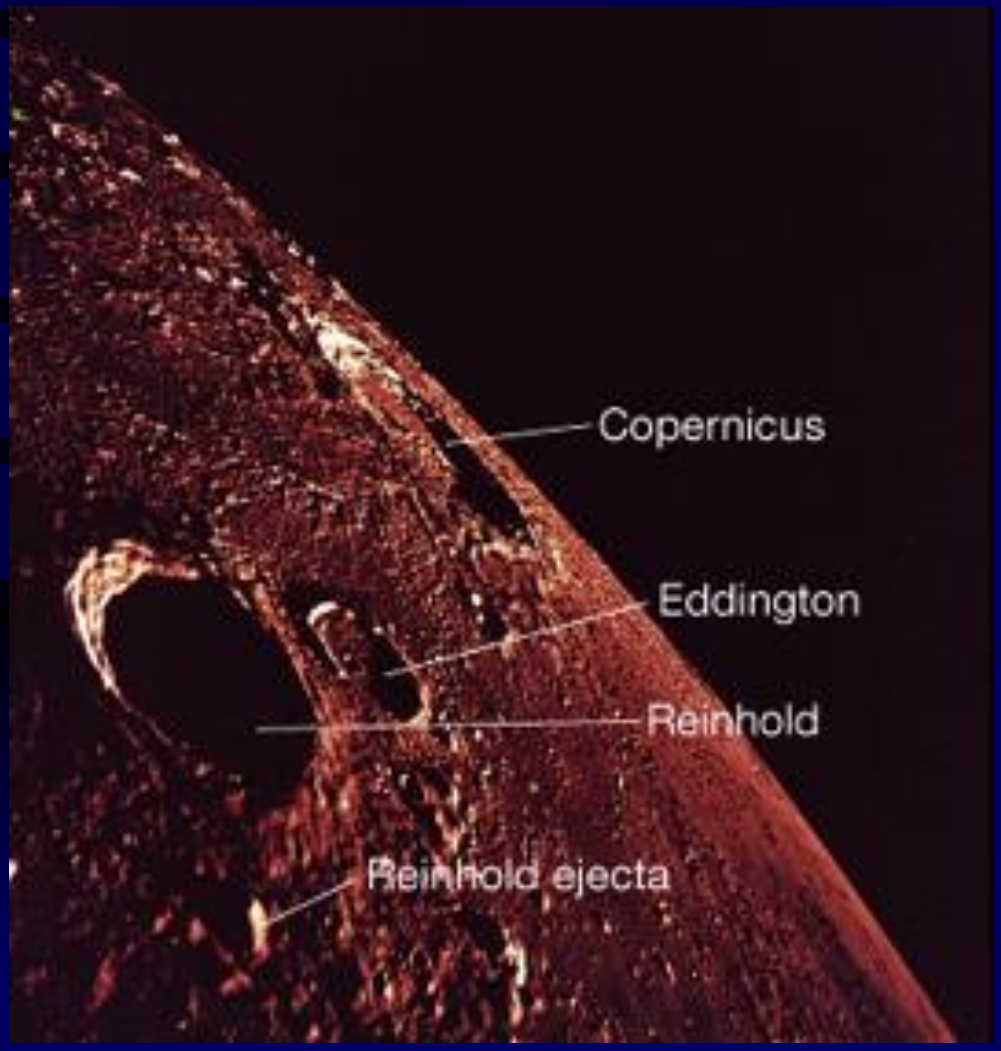
- Especially well visible near the **terminator** – the borderline between light and shadow

Tides

- Daily fluctuations in the ocean levels
- Two high and two low tides per day
- A result of the difference in gravitational pull from one side of the Earth to the other
  - $F = G M m / R^2$

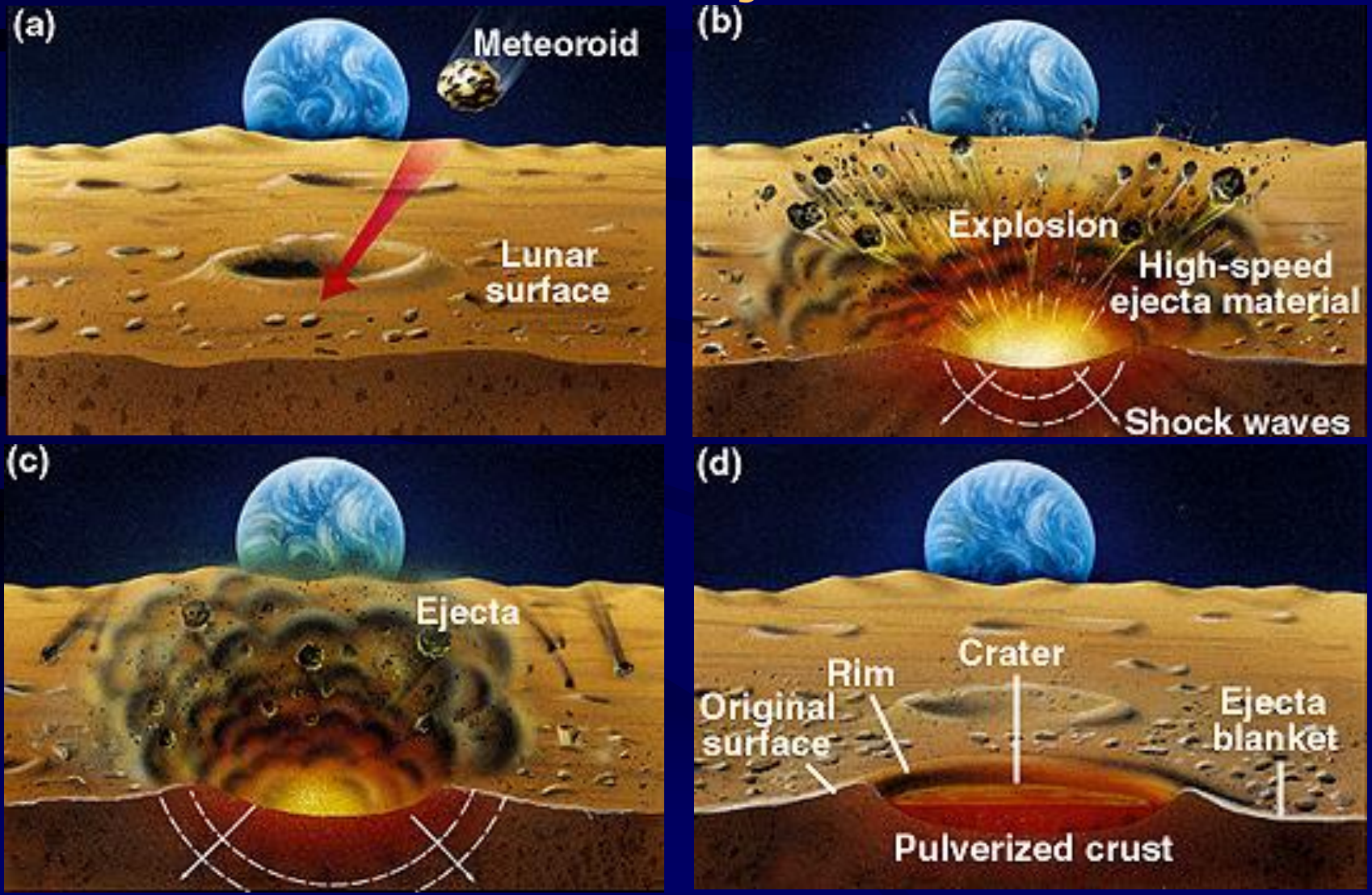


Lunar Craters



- Old scars from meteoroid impacts
- Lots of them; all sizes
  - Copernicus ~ 90 km across
  - Reinhold ~ 40 km across
  - Also craters as small as 0.01 mm!

How They Form



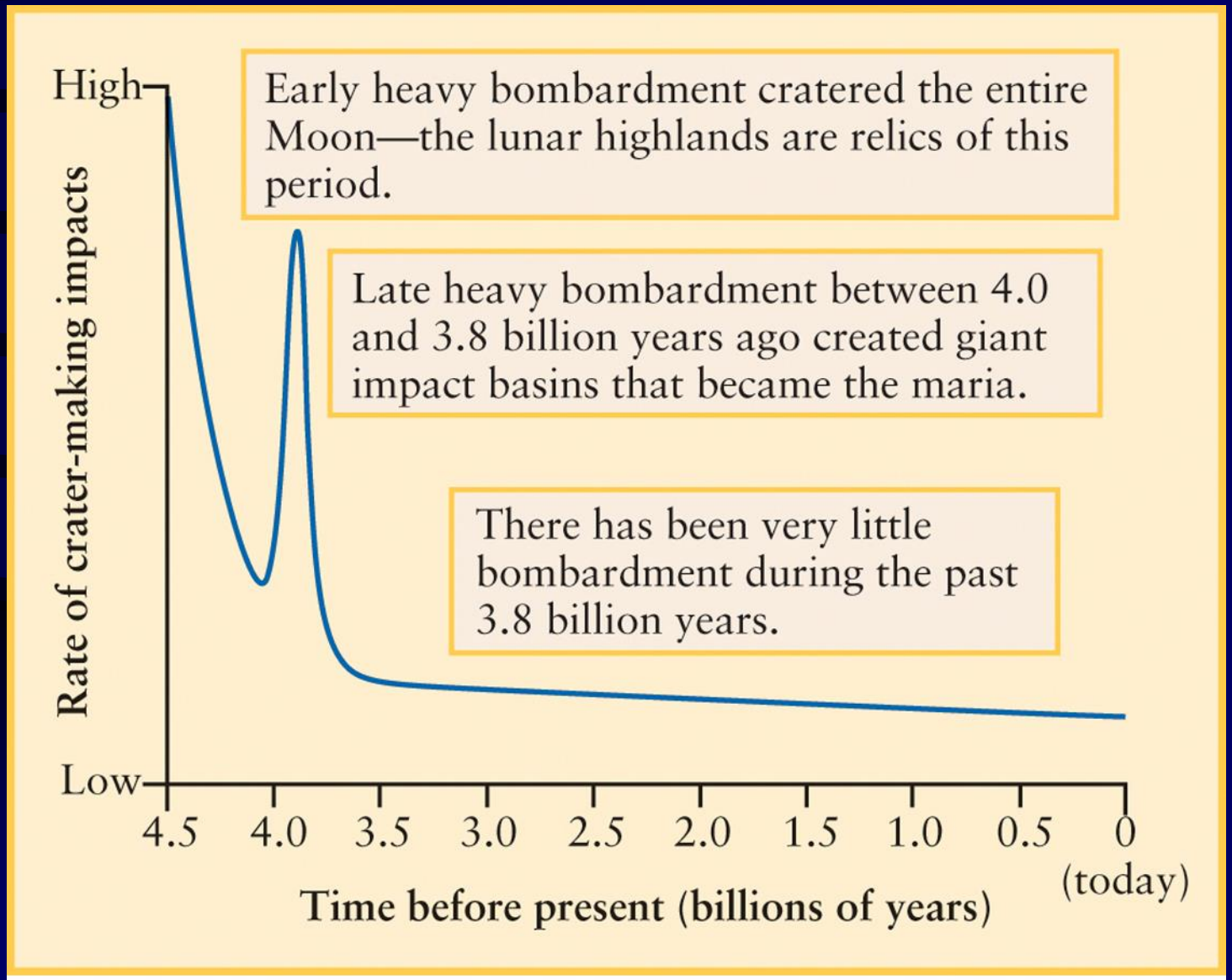
Moon's Changing Surface

(a) 4 billion years ago

(b) 3 billion years ago

(c) Today

Timeline of Bombardment of the moon



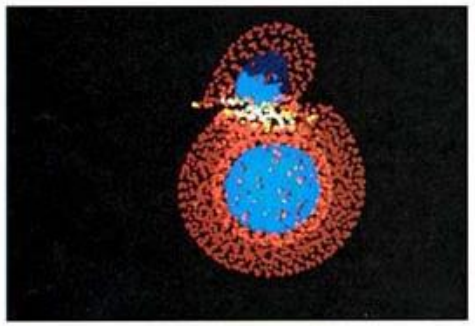
Adapted from T. Grotzinger, T. H. Jordan, F. Press, and R. Siever, Understanding Earth, 5th ed., W. H. Freeman, 2007

Ages of the Earth and Moon

- Determined by radioactive dating
  - Compare amount of radioactive material with amount of decay product
  - Useful isotopes:
    - Uranium-238 (half-life 4.5 billion years)
    - Uranium-235 (half-life 0.7 billion years)
    - For shorter time scales, Carbon-14 (5730 years)
- Oldest surface rocks on Earth (Greenland, Labrador) about 3.9 billion years old
  - When rocks solidified
- Lunar highlands: 4.1–4.4 billion years old
  - Rocks from lunar maria slightly younger, more recently melted
- Meteorites: 4.5 billion years old
  - Date to origin of solar system

Formation of the Earth-Moon System: Impact Theory

1



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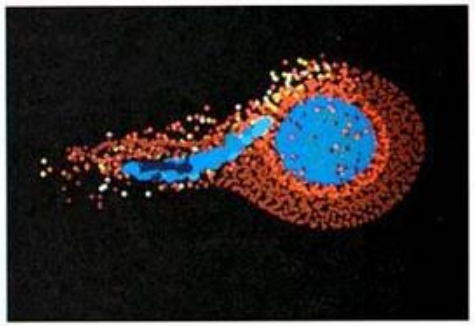

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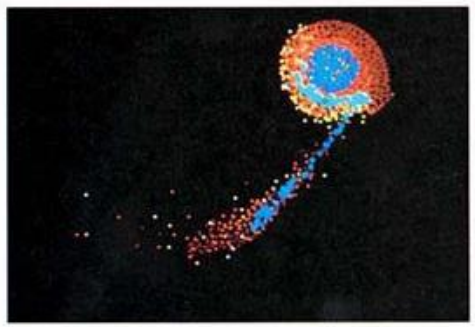

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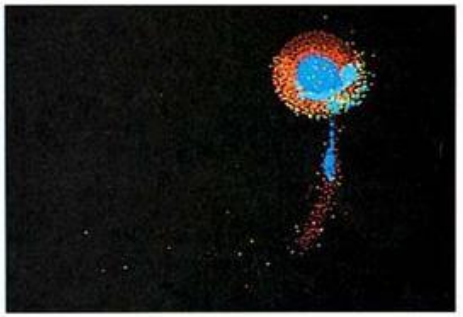

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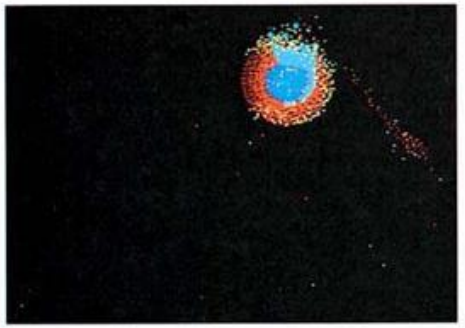

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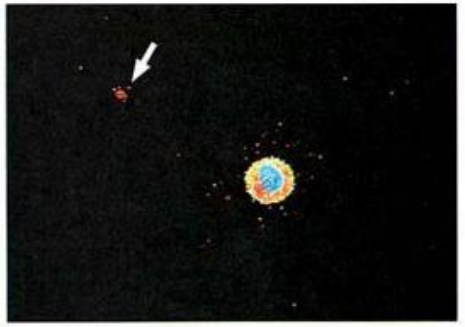
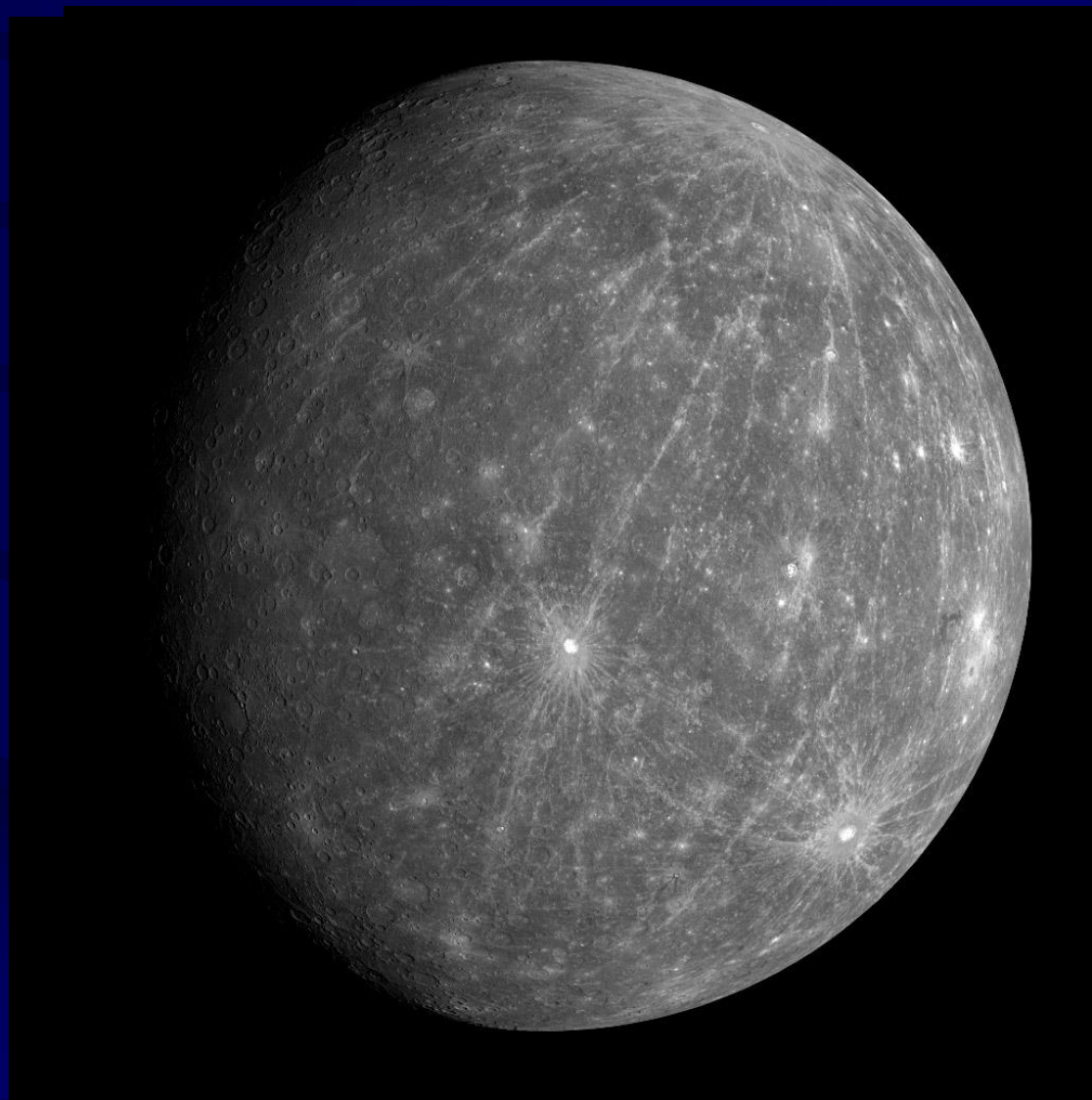


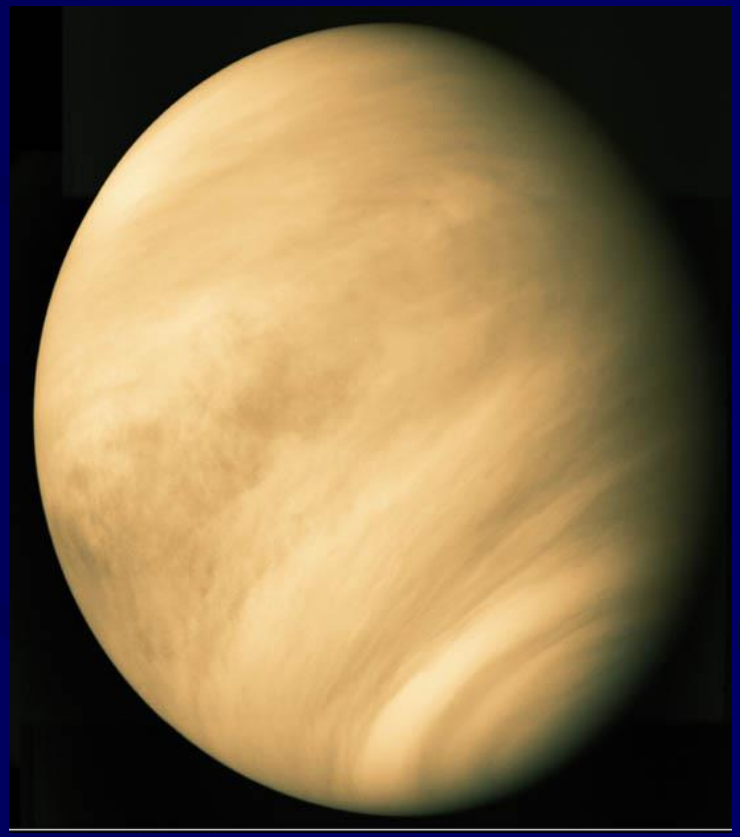
Mercury

- Small, bright but hard to see
- About the same size as the moon
- Density about that of Earth
- Day ~ 59 Earth days
- Year ~ 88 Earth days



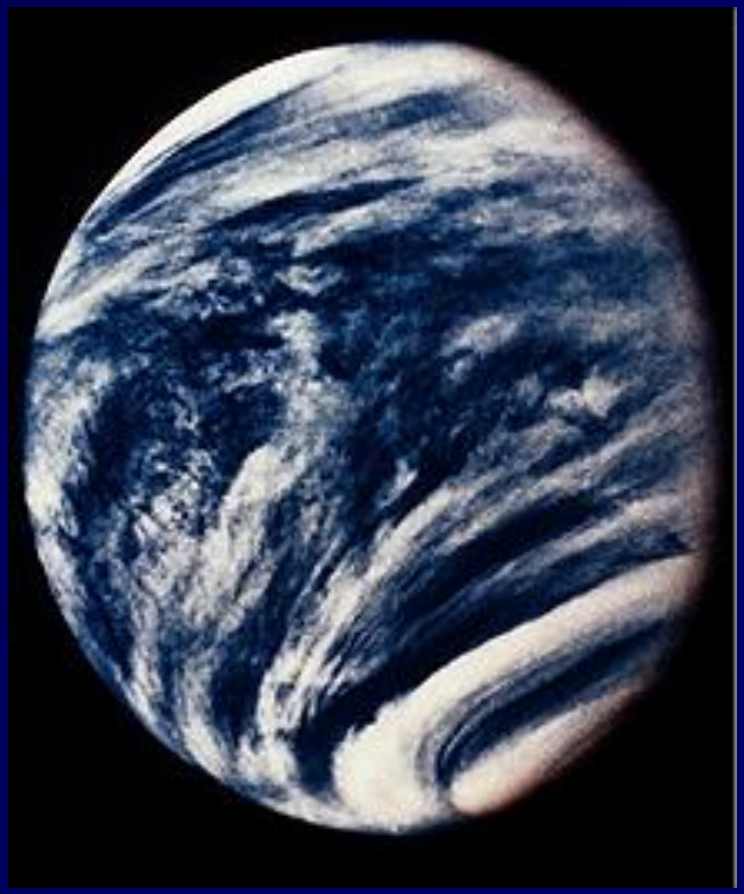
Venus

- Bright, never very far from the sun
  - "Morning/Evening star"
- Similar to Earth in size and density
- Day ~ –243 Earth days (retrograde!)
- Year ~ 225 Earth days



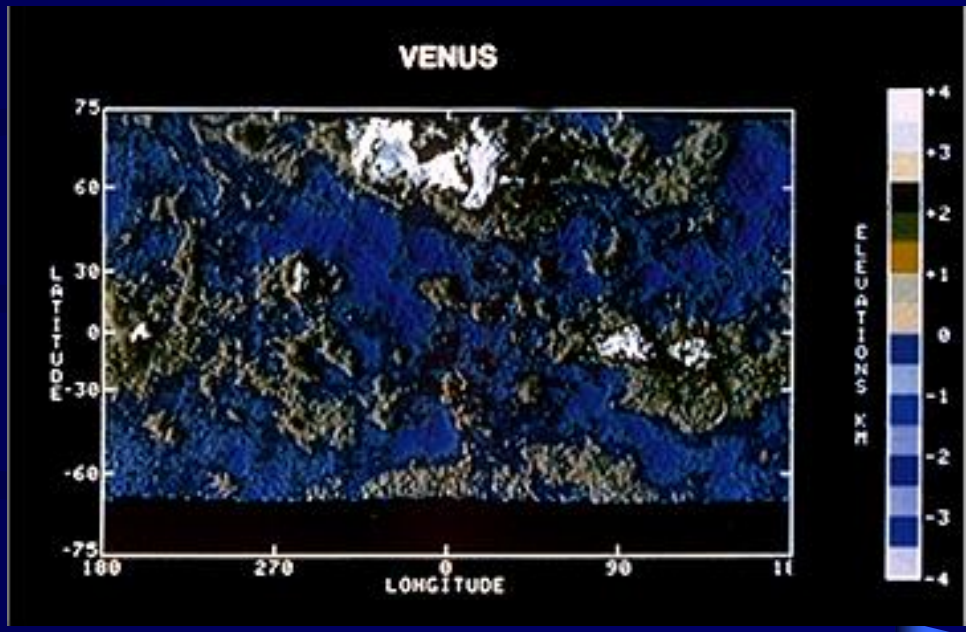
Venus

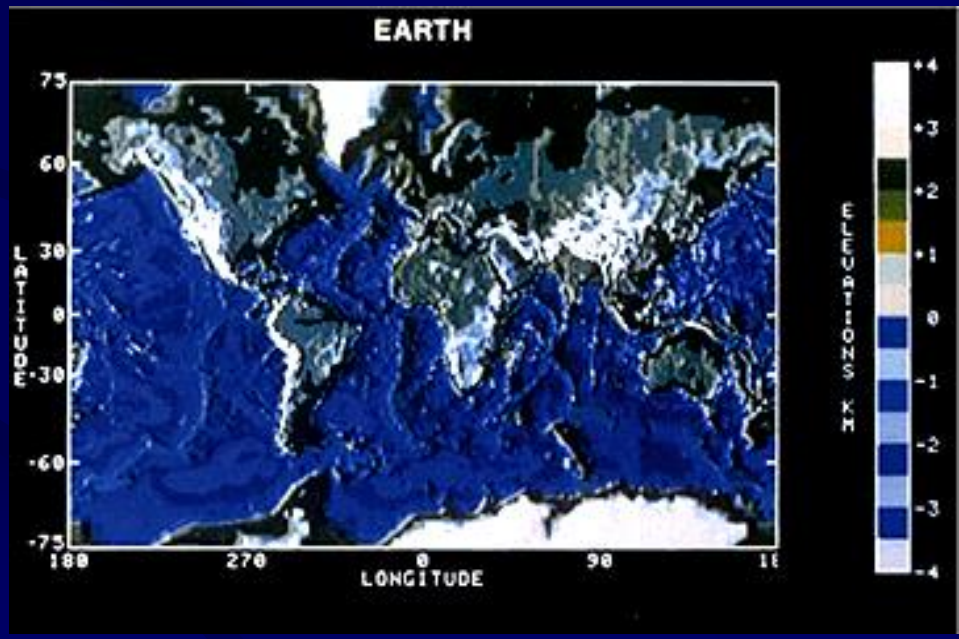
- Very thick atmosphere, mostly CO_2
- Heavy cloud cover (sulfuric acid!)
  - About 90 times the pressure of Earth's atmosphere
  - Very strong greenhouse effect, surface temperature about 750 K
- No magnetic field



Surface Features

- Two large "continents"
  - Aphrodite Terra and Ishtar Terra
  - About 8% of the surface
- Highest peaks on Aphrodite Terra rise about 14 km above the deepest surface depression
  - Comparable to Earth's mountains

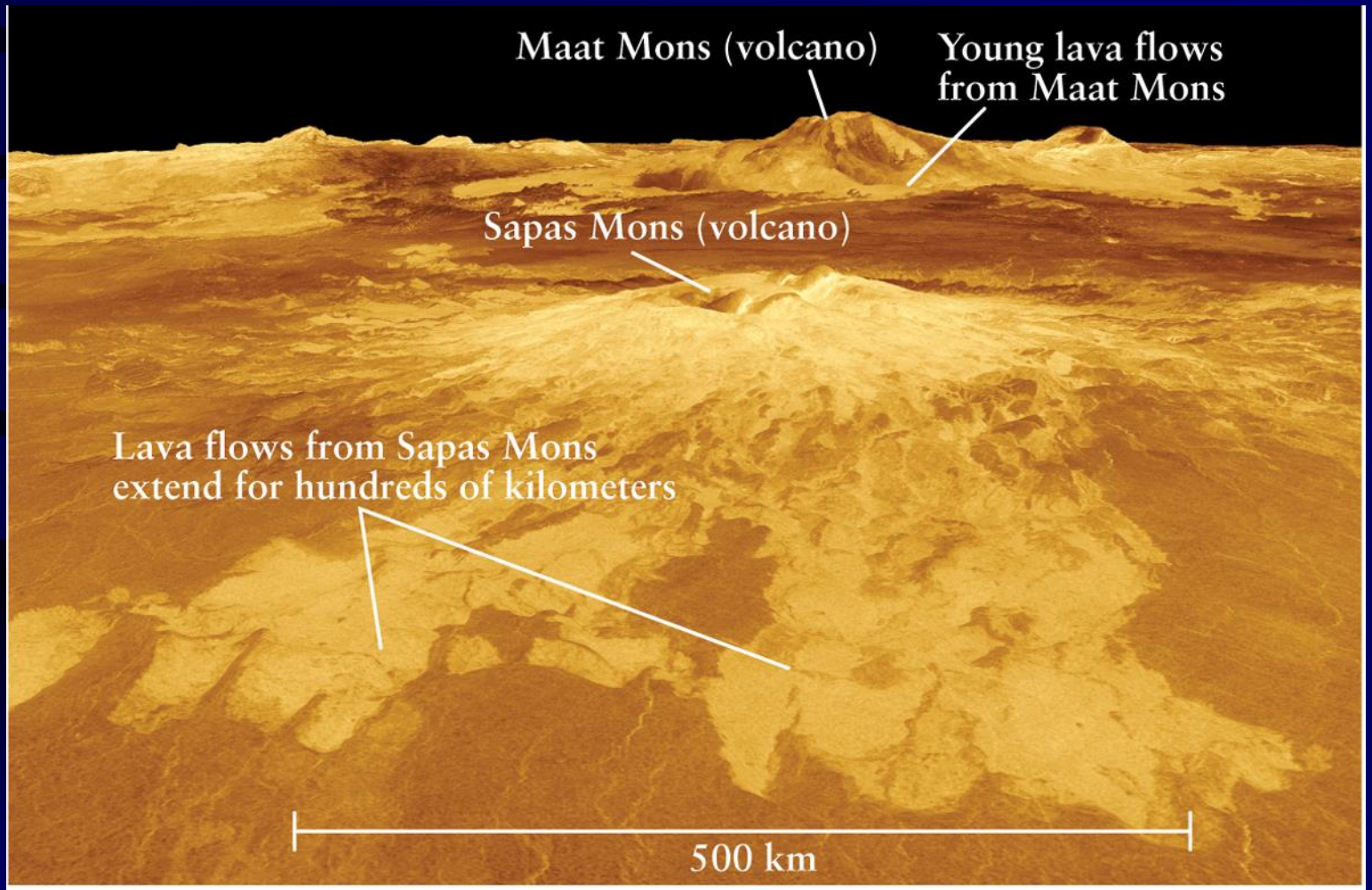




Venus - Touchdown

View from Russian probe Venera 14 (1975)

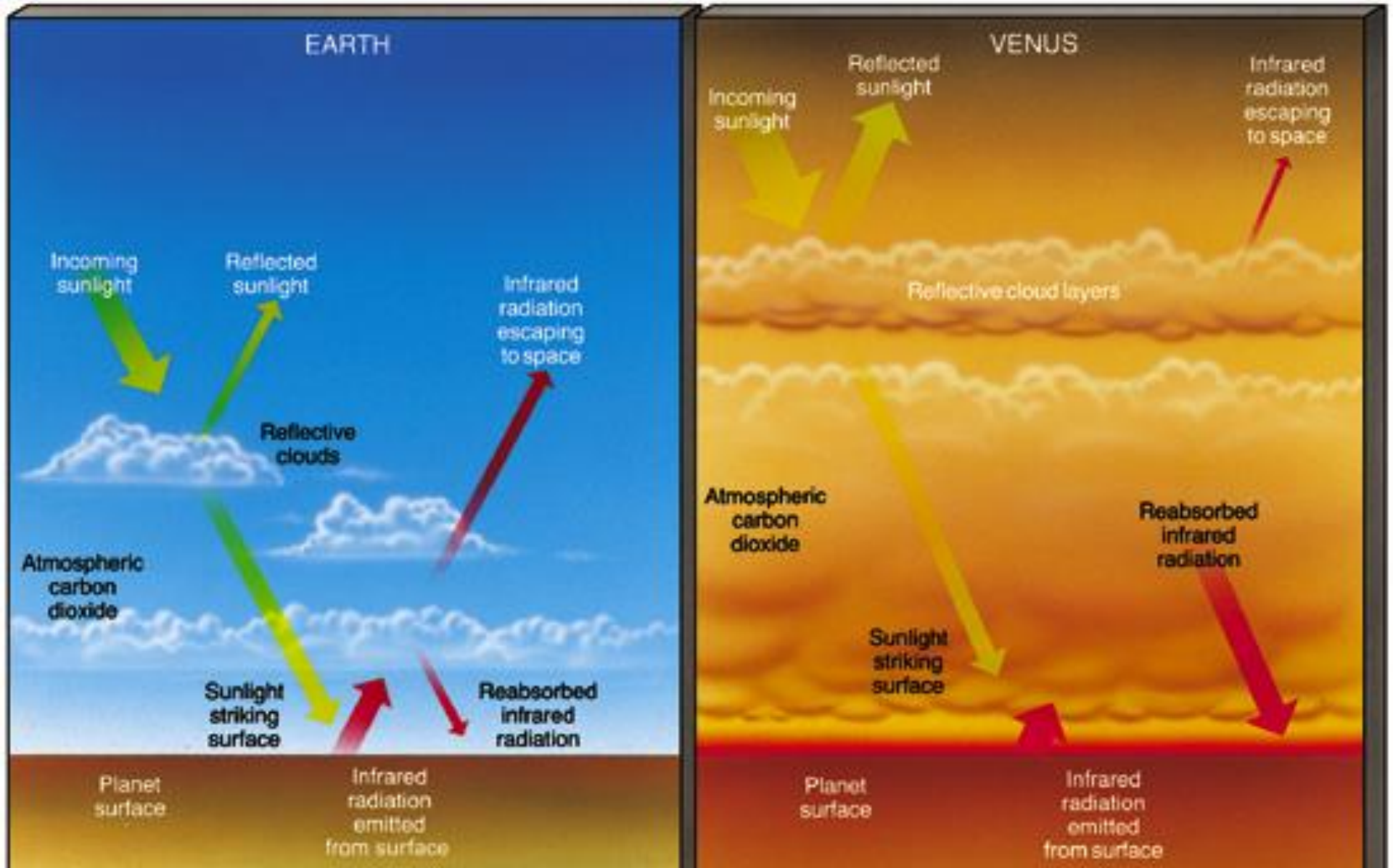
Venus is being constantly resurfaced



(a) Volcanoes and lava flows on Venus

NASA, JPL Multimission Image Processing Laboratory

Hothouse Venus: 850 °F

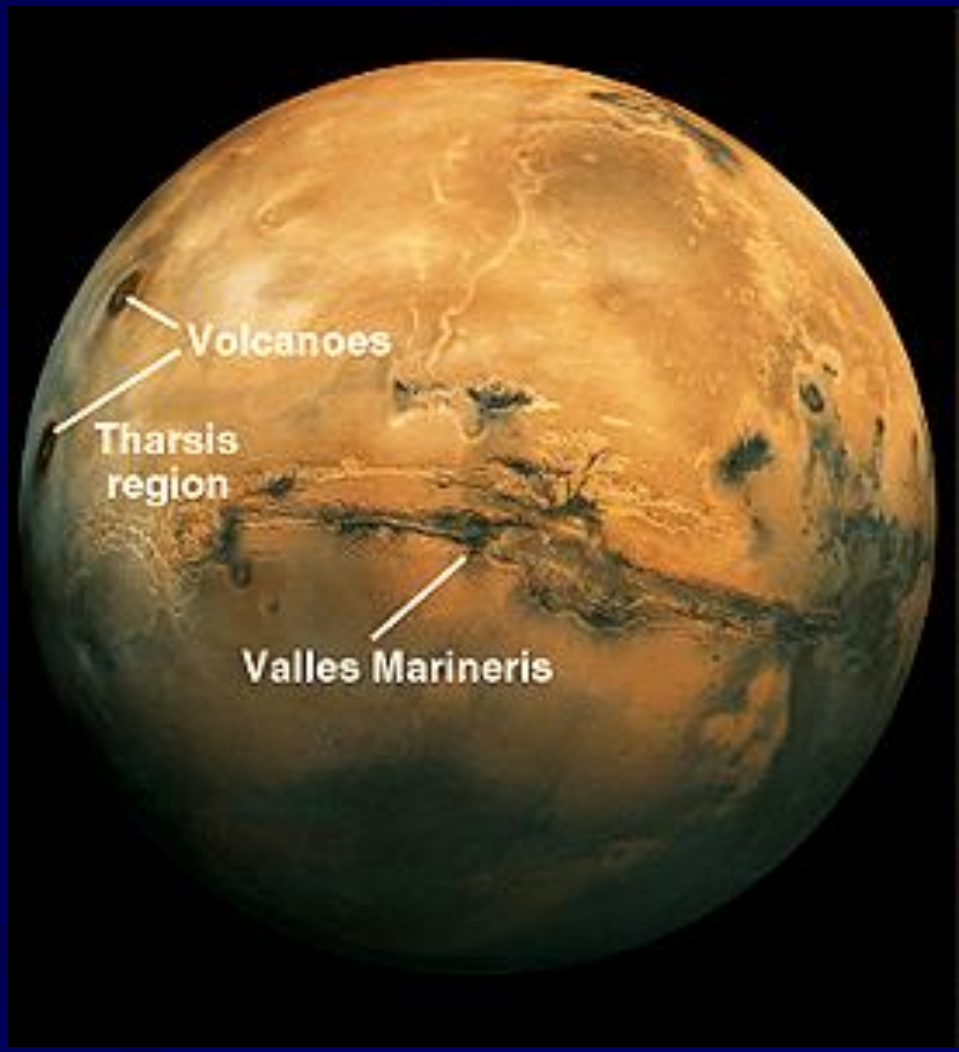


Mars

- Fairly bright, generally not too hard to see
- Smaller than Earth
- Density similar to that of the moon
- Surface temperature 150–250 K
- Day ~ 24.6 hours
- Year ~ 2 Earth years
- Thin atmosphere, mostly carbon dioxide
  - 1/150 the pressure of Earth's atmosphere
- Tiny magnetic field, no magnetosphere

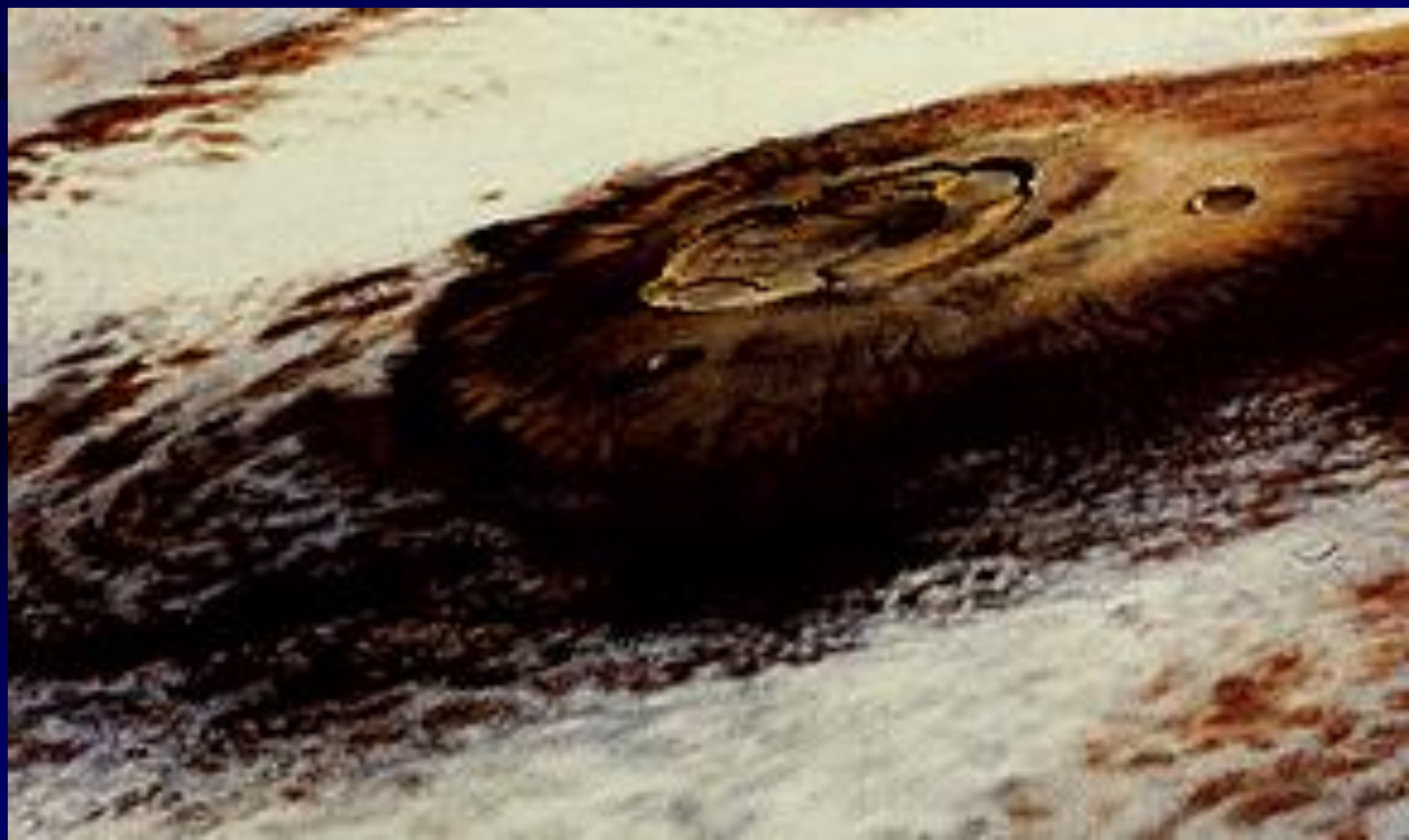
Mars

- Northern Hemisphere basically huge volcanic plains
  - Similar to lunar maria
- Valles Marineris – Martian "Grand Canyon"
  - 4000 km long, up to 120 km across and 7 km deep
  - So large that it can be seen from Earth

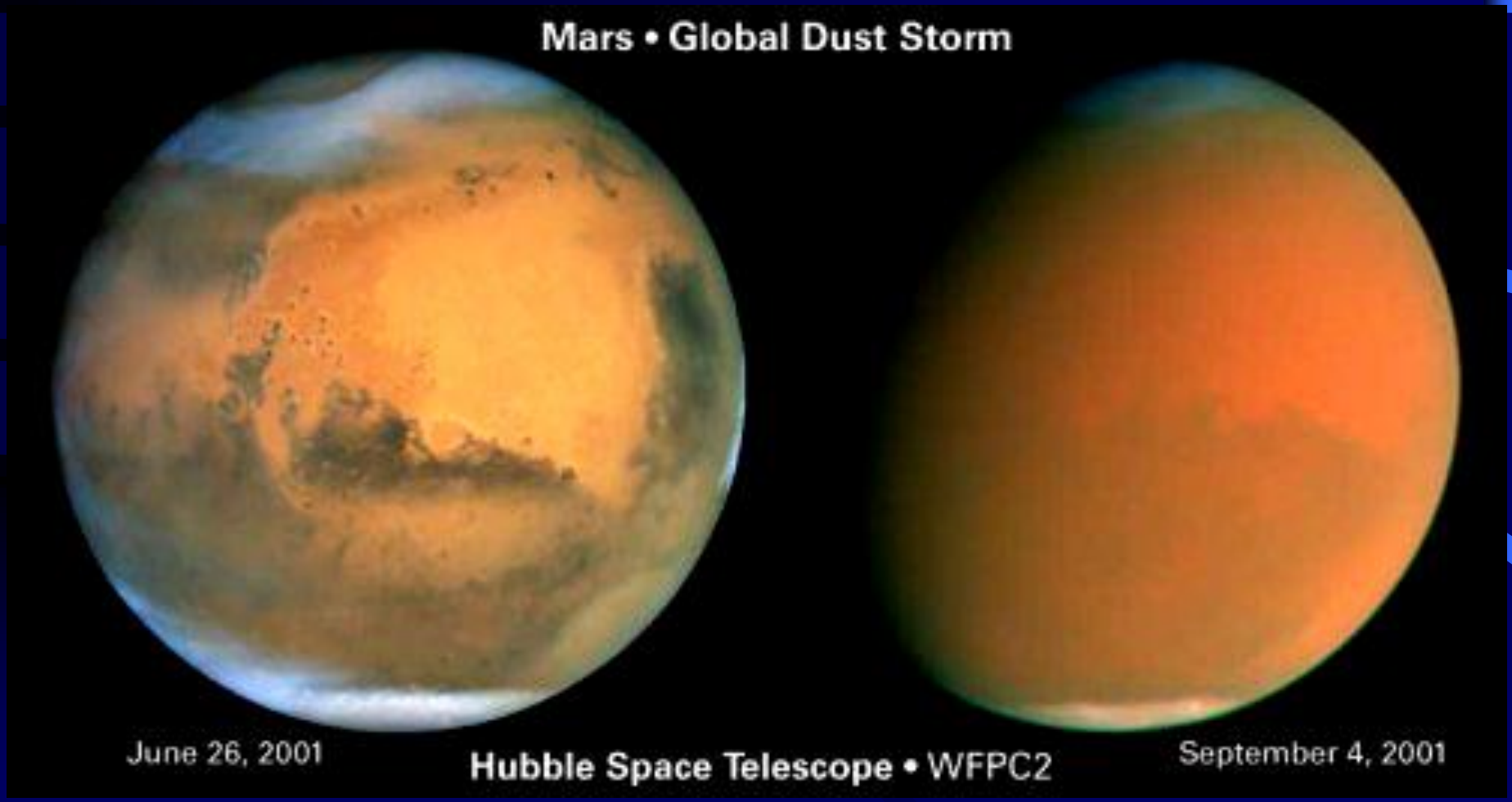


Martian Volcanoes

- Olympus Mons
  - Largest known volcano in the solar system
  - 700 km across at base
  - Peak ~25 km high (almost 3 times as tall as Mt. Everest!)



Martian Seasons: Icecaps & Dust Storms



Martian Surface

Iron gives the characteristic Mars color: **rusty red**!

View of Viking 1

1 m rock

Sojourner

Martian Panorama

Note: the sky is not black as on the moon,

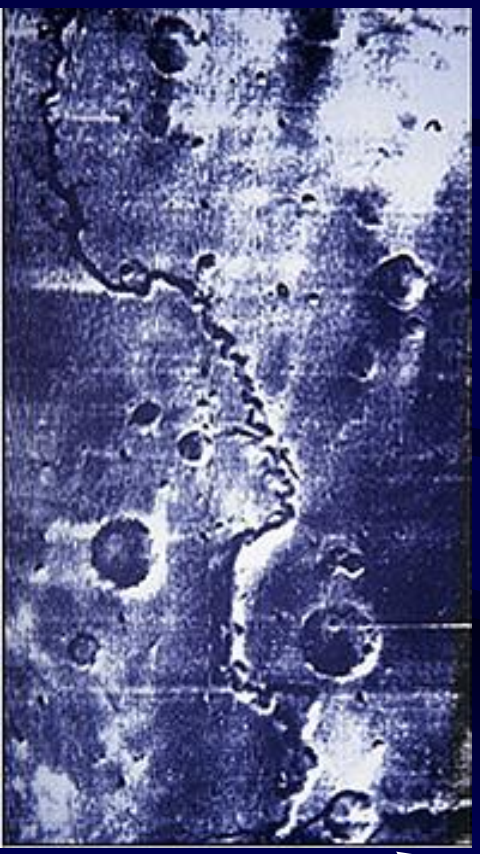
but pale pink of the dust in the **atmosphere**!

Video: Curiosity Landing

"Twin Peaks" – about 1-2 km away

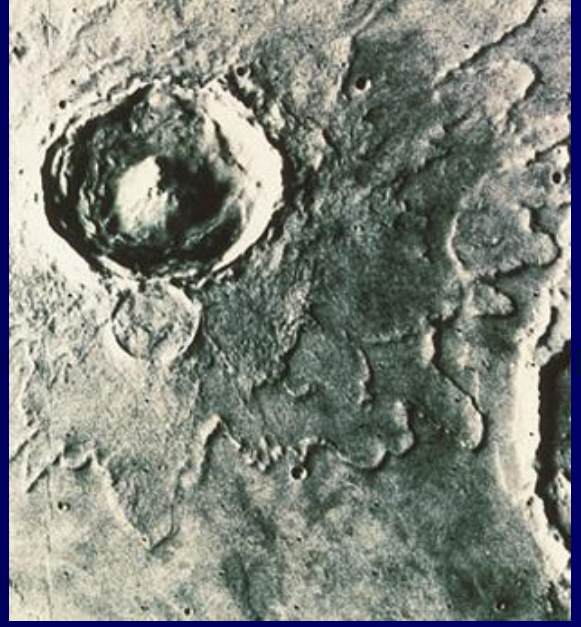
Water on Mars?

Mars



Louisiana

Runoff channels

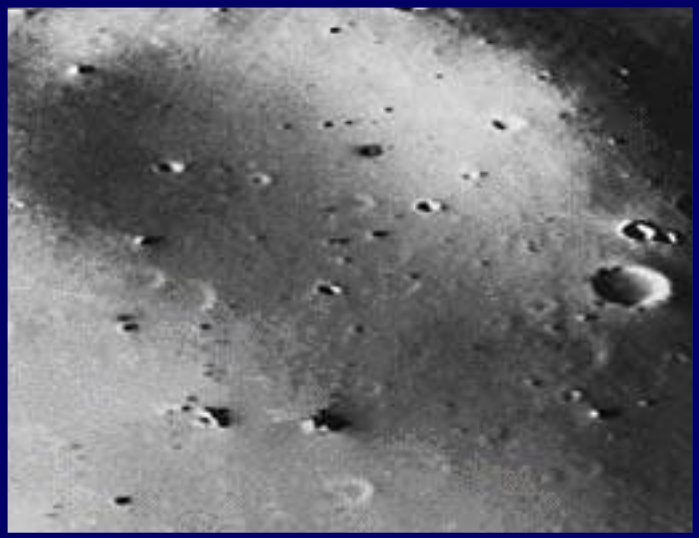


Outflow Channels

Mars' Moons – Big Flying Rocks

- **Phobos** (Fear)
  (28 x 20 km)

- **Deimos** (Panic)
  (16 x 10 km)



Life on Mars?

- Giovanni Schiaparelli (1877) – observed "*canali*" (channels) on Martian surface
- Interpreted by Percival Lowell (and others) as irrigation canals – a sign of intelligent life
- Lowell built a large observatory near Flagstaff, AZ

(Incidentally, this enabled C. Tombaugh to find **Pluto** in 1930)

- Speculation became more and more fanciful
  - A desert world with a planet-wide irrigation system to carry water from the polar ice caps?
  - Lots of sci-fi, including H.G. Wells, Bradbury, …
- **All an illusion!** There are no canals…

Viking Lander Experiments (1976)

- Search for bacteria-like forms of life
- Results inconclusive at best