Venus, the Morning/Evening Star

What We Will Learn Today

- What are planet Venus' features?
- What is a planetary atmosphere?
- How do atmospheres gain or lose gases?
- How does greenhouse effect work?
- How is Venus unique in the solar system?

Planet Venus Details

Property	Value
Semi-major axis	0.7 AU
Size (radius)	0.95 R_{Earth}
Mass	0.82 M_{Earth}
Average density	5.24 g/cc
Composition	Rocks, metals
Average surface temperature	740 K
Moons	None
Orbital period	225 days
Rotation period (sidereal)	243 days
Axis tilt	177.3^{o}
Orbital inclination	3.4^{o}
Orbital eccentricity	0.007

Earth's "twin"

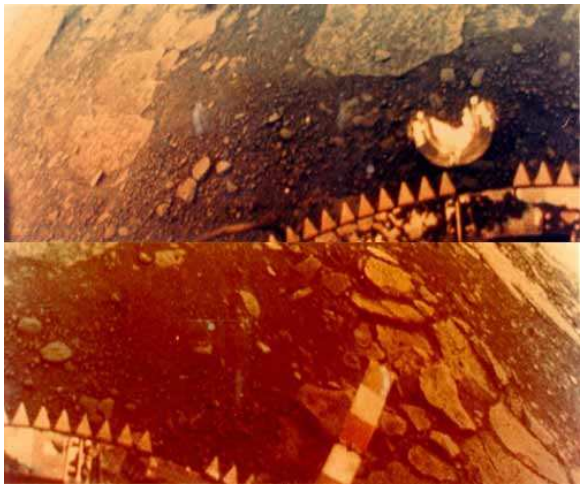
Hottest planet

Slowest rotator, by far!

Retrograde

Enshrouded in a Perpetual Cloud

- Remember Mog?
- So how do we learn about its surface?
- Orbit the planet: Magellan spacecraft
  - Orbited Venus and mapped surface 1990 – 1993
  - Produced very detailed maps (100 m resolution)
- Peer through the clouds: Radar mapping
  - Bounce radio waves off surface to create a 3-D image
  - Distance = ½ * speed of **light** * time delay from signal launch to echo recorded
    - Note: radio waves are light, not sound!
- Land on the surface: Venera spacecraft
  - Series of crafts orbited and landed on Venus
  - Took pictures
  - Melted in a few minutes!



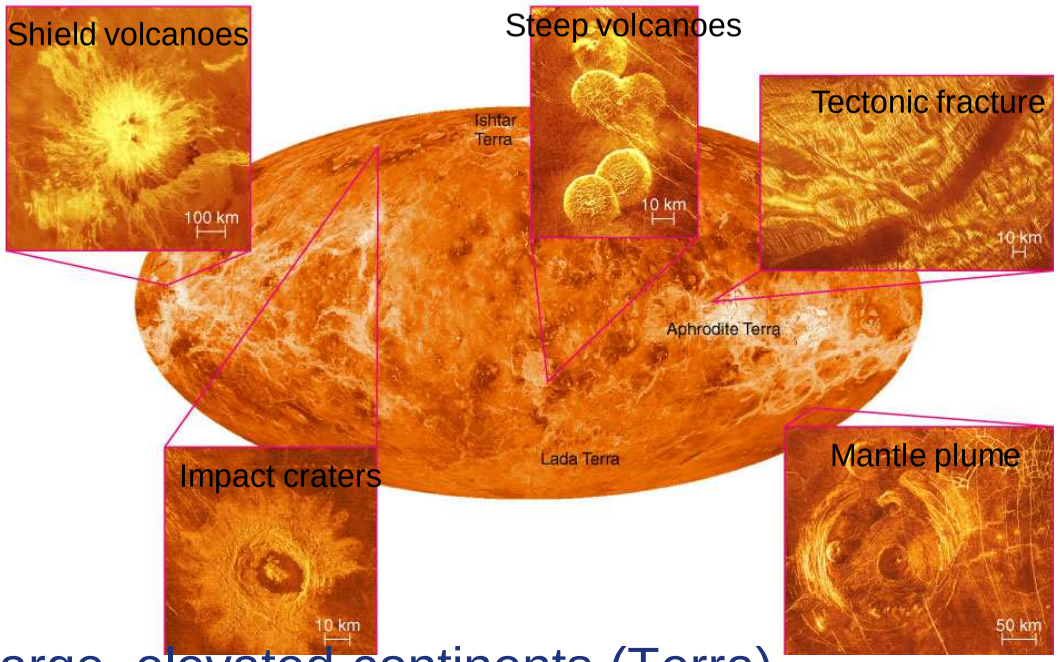
Visiting Venus Would Not Be Fun!

- Searing heat (740 K = 470 ^{o}C = 880 ^{o}F)
  - Melts spacecrafts in a few minutes
- Very high pressures (90x Earth)
  - Like being ½ mile under water
- Mostly carbon dioxide, no oxygen to breathe
- Sulfuric acid in atmosphere will your burn skin
  - Acid rains high in atmosphere evaporate before reaching the ground
- Dull always, dull everywhere!
  - Not much change in temperature from day or night, equator to pole
  - No seasons

Earth's twin?

- Similar radius, mass, gravity
- Similar density
- Similar internal structure

Surface Features of Venus



Highest peak = 40,000 ft

Fig 9.33

- Three large, elevated continents (Terra)
- Few, large impact craters, uniformly distributed
  - No small craters: Small meteoroids burn up in thick atmosphere
  - 750 million year old surface everywhere: Global repaving at that time!
- Volcanic mountains, lava plains
  - Active volcanically, thin lithosphere
- No erosion
  - Slow rotation: No wind, no change in temperature
- No plate tectonics (perhaps was present in the past)

Interior very similar to Earth

Venus' Thick Atmosphere

- Carbon dioxide (96%), Nitrogen (3.5%)
- 90x pressure as on Earth
  - 90 bars (from barometer)
  - 1 bar = 14.7 pounds/square-inch
- Relatively large size caused hotter interiors
- Mantle convection limited lithosphere thickness
- Volcanic activity enriched atmosphere
- Large amount of CO_2 in atmosphere led to runaway greenhouse effect
- Thick atmosphere is efficient in moving heat across planet: Pole & Equator equally hot
- Highly reflective (*albedo*) molecules in upper atmosphere make planet bright

Fig 10.1

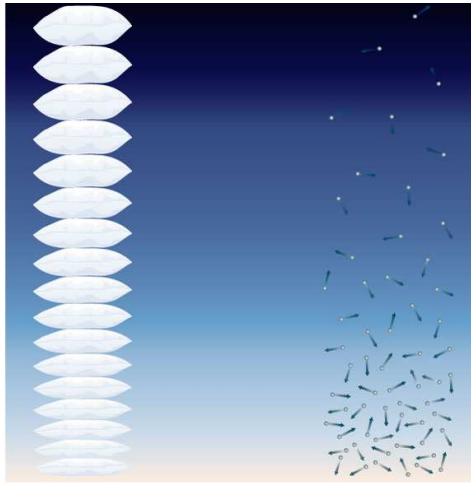


Fig 10.4

How Atmospheres Gain Gasses

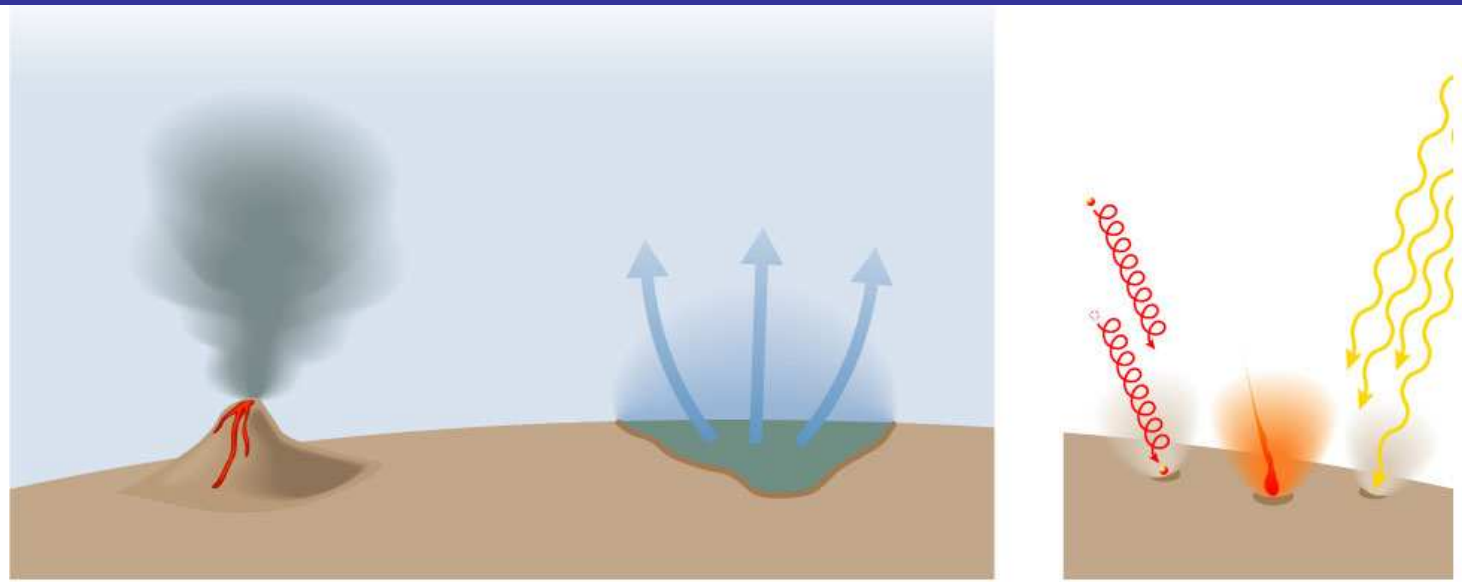


Fig 10.20

- Terrestrial worlds were born without an atmosphere
  - Gravity too weak to capture substantial Hydrogen & Helium
- Gained atmosphere in three (yes, 3 again!) ways
  - Volcanic *outgassing* is the primary source
    - H_2O, CO_2, N_2, sulfur gases (H_2S, SO_2)
  - Evaporation or sublimation of surface liquids or solids
  - Surface ejection by micrometeorites
    - Relevant only for “airless” places like Mercury & Moon
- Venus is still volcanically active

How Atmospheres Lose Gasses

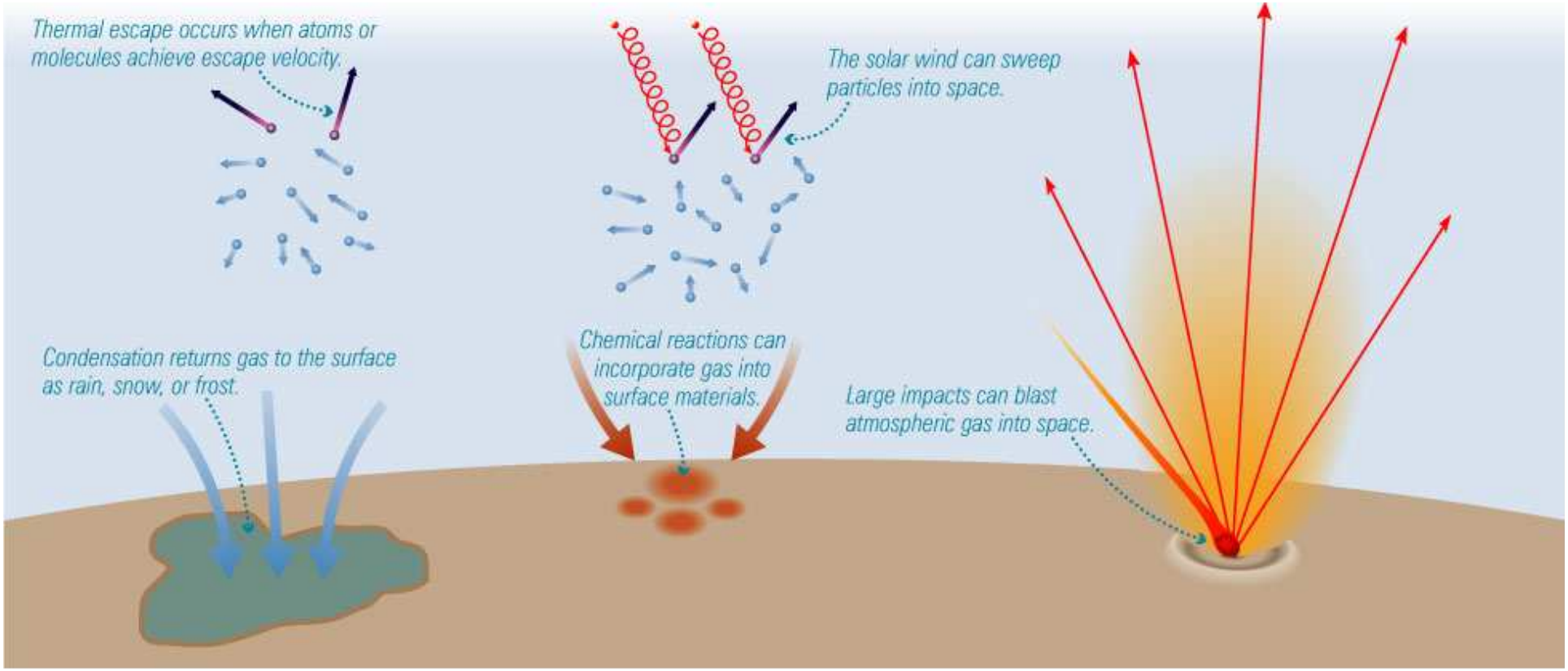


Fig 10.21

Evolution of Venus' Atmosphere

- Outgassing put lots of CO_2 and H_2O into the atmosphere
- Both of these are greenhouse gases
  - Responsible for the high temperatures
  - Runaway greenhouse effect
    - More water in atmosphere = higher temperature = evaporation of any surface water…
  - UV light from Sun breaks apart the water molecules
    - Hydrogen escapes, preventing reformation of water
    - Higher Deuterium in Venus' atmosphere gives credence to theory
    - Over billions of years, oceans' worth of water is lost
    - Oxygen trapped in other molecules and blown away by solar wind
      - Lack of magnetic field leaves atmosphere vulnerable

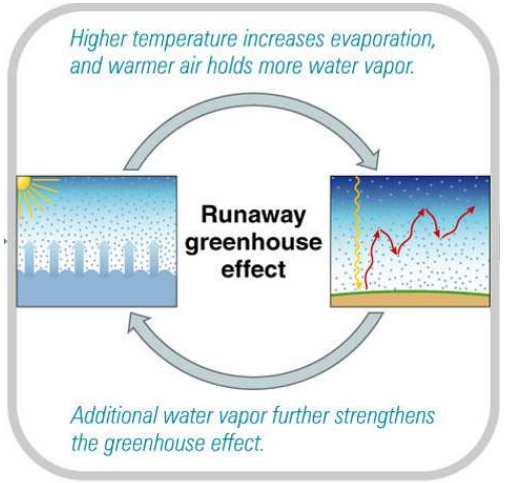


Fig 10.31

Greenhouse Effect

- Visible light from the Sun
  - Some absorbed, some reflected
- Absorbed light is remitted
  - Bulk of this is in infrared (Wien's law)
- Some gases in atmosphere absorb infrared radiation
  - H_2O, CO_2, CH_4, CFC particularly good
  - Molecular rotation and vibration excitation
- Blanketing effect increases the temperature

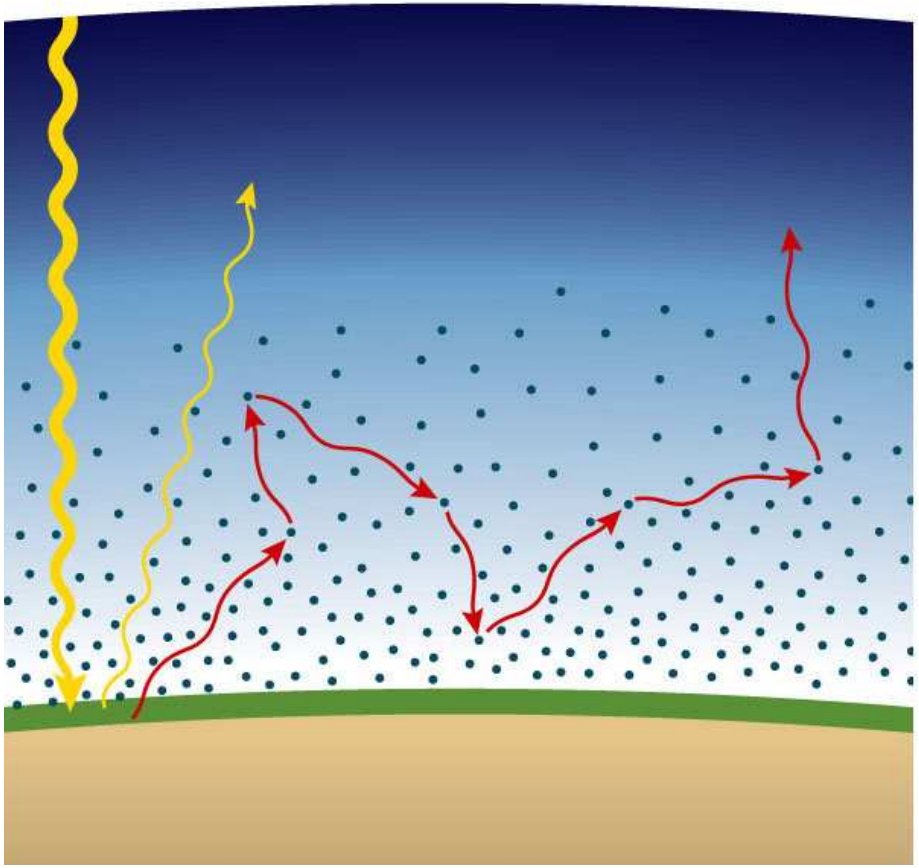


Fig 10.6

The Effect of Greenhouse

- In the absence of greenhouse, a planet's temperature is determined only by
  - Planet's distance from the Sun
  - Reflectivity of the planet's surface
- Why is Venus' "no greenhouse" temperature lower that Earth's?

Table 10.2 The Greenhouse Effect on the Terrestrial Worlds

World	*Average Distance from Sun (AU)*	*Reflectivity*	*"No Greenhouse" Average Surface Temperature**	*Actual Average Surface Temperature*	*Greenhouse Warming (actual temperature minus "no greenhouse" temperature)*
Mercury	0.387	12%	163°C	425°C (day), −175°C (night)	—
Venus	0.723	75%	−40°C	470°C	510°C
Earth	1.00	29%	−16°C	15°C	31°C
Moon	1.00	12%	−2°C	125°C (day), −175°C (night)	—
Mars	1.524	16%	−56°C	−50°C	6°C

Unique Features of Venus

- Brightest “dot” in our sky
  - Only Sun & Moon are brighter
- Closest planet to Earth
- Hottest planet in the solar system
  - Runaway greenhouse effect
- Thickest atmosphere among terrestrial planets
- Most reflective planet (highest albedo)
- Slowest rotator
- Spins backwards
  - Sun will rise in the West and move to East, slowly, if you could see it!