Chapter 06: The Terrestrial Planets

Notes and Sketches

6.1: Orbital and Physical Properties

- All terrestrial planets are naked-eye objects
- Only Sun and Moon are brighter than Venus in our sky
- Density: Mercury, Venus, Earth all about the same (Mars less dense)
- Temperature: Closer = hotter

6.2: Rotation Rates

Mercury's Curious Spin

- Small object orbiting close to primary: Look at gravity very carefully
- Not exactly synchronous (like Moon): eccentricity
- Took until 1965 for radar/Doppler data to determine rotation rate
- One full rotation (59 Earth days) takes (2/3) of a revolution (88 Earth days)
- One solar rotation = 2 full revolutions

Venus and Mars

- Determine Venus' rotation rate using Doppler method (also took until 1960s to determine)
- One complete rotation = 243 Earth days
- Rotation is retrograde
- One revolution takes 225 Earth days

Mars

- Rotation rate = 24.6 hours (compare to 24h on Earth, but this is a coincidence)
- Revolution = 687 Earth days
- Tilt: axis tilted 24° (compare to Earth = 23.5°, but this is a coincidence)
- Axis tilt results in seasons

6.3: Atmospheres

Mercury

- None
- Can trap solar particles temporarily
- Surface temps extreme: 100K (not in the sun) to 700K (solar noon at the equator)

Venus

- Atmospheric pressure = 90 atm (Earth = 1 atm)
- 96.5% CO_2: Runaway greenhouse effect
- Surface temperature crazy hot (over 700 K)
- Thick cloud deck almost impenetrable to visible light: Use IR and UV observing
- Clouds are not H_2O: Sulfuric acid (H_2SO_4)

Mars

- Extremely thin atmosphere: pressure only 0.007 atm
- 95% CO_2, but no greenhouse effect (not enough molecules)
- Small planet, low gravity: Probable that atmosphere was thicker, but escaped into space
- Seasons, but overall much colder than Earth (larger distance from Sun)

6.4: The Surface of Mercury

Craters

- Covered with impact craters
- Caloris Basin: HUGE impact crater

Scarps

- Cliff-like feature seems to be result of crust cooling and shrinking
- No evidence of volcanic or tectonic activity

6.5: The Surface of Venus

Large Scale Topography

- Cannot map this visually; use radar wavelengths
- Somewhat similar to Earth: Elevated "continents"

Volcanism and Cratering

- Much evidence of volcanic activity: shield volcanoes
- Tectonic activity: No evidence for plate tectonics; coronae
- Impact craters
- Probable ongoing volcanism: Sulfur dioxide fluctuations in atmosphere, radio bursts similar to volcanic activity on Earth

6.6: The Surface of Mars

The View From Earth

- The view from Mars itself is better: Mariner (4, 6, 7, and 9), Viking (1 and 2), Mars Global Surveyor, Pathfinder/Sojourner, Mars Explorations Rovers (Spirit/Opportunity), Mars Reconnaissance Orbiter, Phoenix, Odyssey
- Those are only the successful NASA probes (Europeans, Russians, Japanese also launched successful probes)
- Mars has no canals. Sorry, Percival.

Large Scale Topography

- N hemisphere and S hemisphere very different
- N: Smooth-looking plains, not much topography, less impact cratering
- S: Rough terrain, bigger differences in elevation, more impact cratering
- Cratering indicates N hemisphere is younger surface than S

Martian Grand Canyon

- Valles Marineris
- Not carved by flowing water like Earth's Grand Canyon
- Probably a split/crack in crust

Martian Volcanism

- Olympus Mons = biggest volcano in the solar system
- Volcanic mountains 10-25km tall (Everest ≈ 9km)
- Exceptionally high volcanoes: Low gravity, do not collapse under their own weight
- Evidence suggests activity about 100 million years ago

Evidence for Past Water on Mars

- Mars has geologic features that are virtually indistinguishable from features on Earth
- The features on Earth are know to derive from the presence of liquid water
- Mars has no liquid water now, but it seems very likely that it had in the past
- Other geologic observations argue against abundant liquid water
- We just don't know

Where is the Water Today?

- Arctic permafrost: Locked into the soil near the poles
- Polar ice caps: Grow and recede with seasonal changes
- NASA released photos in 2006 indicating that there may still be liquid groundwater, and it may occasionally break through and flow on the surface

Exploration By Martian Landers

- We have landed on Mars, or orbited, or flown by with literally 24 separate spacecraft
- That does not count the failures
- There are ten more unmanned missions planned for the next decade (Russia, China, India, USA, ESA)

Notes and Sketches

Life on Mars

- Viking Landers performed three separate experiments with inconclusive results
- ALH84001: Meteorite of Martian origin examined for fossil evidence of bacteria
- No direct evidence of past or currently existing life

6.7: Internal Structure and Geological History

Mercury

- Mercury has a magnetic field: About 1/100 field strength of Earth
- Magnetic axis is offset from rotation axis, N pole much stronger than S pole
- Cannot be generated in the same way as Earth's field
- Proportionally larger Fe/Ni core: solid core = refrigerator magnet? No definitive answer yet.
- Structure = core + crust (no mantle to speak of)

Venus

- No magnetic field: Partially molten core, but slow spin
- Core, mantle, crust structure probable
- No plate tectonics: slow cooling? Soft crust?

Mars

- Magnetic field: About 1/800 field strength of Earth
- Low density = small core, less iron
- Smaller core still partially molten, though
- Smaller planet, faster cooling: thicker crust, no plates
- No geologic activity for about 2 billion years

6.8: Atmospheric Evolution on Earth, Venus, and Mars

The Runaway Greenhouse Effect on Venus

Secondary Atmospheres

- Terrestrials did not accrete atmospheres while forming
- Volcanic outgassing: atmospheric gases released from interior of planet during eruptions
- Mostly H_2O, CO_2, SO_2, and nitrogen compounds

On Earth

- Cool enough to condense H_2O and form huge oceans
- CO_2, SO_2 dissolve in oceans, solar UV breaks nitrogen bonds, gradually atmosphere becomes predominantly N_2
- High % O_2 direct result of life (biological processes)

On Venus

- Too warm for oceans: Leaves a lot of CO_2 in atmosphere
- Volcanism adds more CO_2 to atmosphere
- More CO_2, more trapped heat, temperature increases
- If there *was* any liquid H_2O, it evaporates as temp increases
- H_2O vapor is also extremely effective at trapping heat
- Repeat until no liquid H_2O, and temp is over 700 K

Evolution of the Martian Atmosphere

- Atmosphere today is not what it used to be
- Atmosphere used to be dense enough to keep liquid H_2O on the surface
- Liquid H_2O dissolves CO_2 out of atmosphere: cooling
- Rapid internal cooling: Less volcanism means less CO_2 outgassed to replenish atmosphere
- Greenhouse is not working here!
- Low gravity: Atmosphere gradually leaks into space

Notes and Sketches