

# 1 Mercury and Venus

- Read chapter 8&9 in the textbook
- Exercises: Do all “Review and Discussion” and all “Conceptual Self-Test”

## 2 Mercury

- similar in size to the moon
- average density  $5.4 \text{ gm/cm}^3$  – much denser than the moon
- no appreciable atmosphere – not large enough to hold one so close to the sun
- orbit about 0.4 AU – eccentric (0.206)
- orbital period – 88 earth days
- greatest elongation, only  $28^\circ$
- stay close to the sun – hard to see
- peak temperature 700K and below 100K in night
- temperature dependent on the latitude – Mercury has negligible axis tilt
- best optical resolution – similar to the moon with the unaided eye
- almost all information about Mercury – Mariner 10 and now MESSENGER
- surface cratered like the moon, but different as well – few lava flow regions
- Mercury’s craters are less densely packed compared to the moon
- crater walls not as high, ejecta material closer to crater – high gravity
- perhaps older craters filled by volcanic activity
- much too be learned – intercrater plains different than the moon – absence of rilles, volcanic activity different than the moon
- scarps – not on moon, but on Mercury – occurred after bombardment
- uplift result of cooling – 4 billion years ago
- no evidence of plate tectonics
- last great geological event – huge crater Caloris Basin
- seismic waves cause weird terrain on the opposite side

- similar to the Orientale Basin on the moon – floor different
- orbital dynamics of Mercury very interesting – resonance
- early astronomers thought Mercury would be tidally locked like the earth-moon system
- 1965, radar observations indicated (Doppler shift) that Mercury rotates once every 59 days – exactly two-third of a Mercury year
- “fine-tuning” – dynamics at work
- orbit is eccentric – tidal locking force diminishes rapidly with distance
- locking shared between aphelion and perihelion
- rotation nearly synchronous at perihelion – same face every other time
- one of many examples of resonances that we will see in the solar system later
- Mercury has a weak magnetic field – could be the result of a small dynamo like the earth
- lack of active surface geology suggests Mercury is solid to a great depth, like the moon – dynamo must be small, if present
- Magnetic field could also be the result of an extinct dynamo
- Mercury’s magnetic field and large average density suggests the planet is differentiated
- Mercury’s core, much bigger relative to the earth (uncompressed density)

### 3 Venus

- inner planet as well 0.7 AU – very little eccentricity
- orbital period 245 earth days
- mass and size similar to earth – 0.82 earth masses, density  $5.2\text{gm/cm}^3$
- greatest elongation  $47^\circ$
- brightest object in the sky next to the sun and the moon – can cast a weak shadow
- Venus, highly reflective 70% of sunlight reflected – reason for brightness
- cannot see surface in telescope – just clouds
- hard to determine rotation rate – radar Doppler shift, 243 earth days, retrograde
- south pole upside down, axis tilt  $177.4^\circ$

- earth's sister planet in size – thought perhaps has similar geology and atmosphere
- early spectroscopic studies indicated mostly CO<sub>2</sub> in the upper atmosphere – hoped that lower regions would contain water vapour – upper atmospheric temperature similar to earth's 240K
- radio observations in 1950s showed that the surface had a blackbody spectrum at 730K – not at all like Earth
- radar probing and satellite observation have mapped Venus to high precision (Venera, Pioneer Venus, Magellan)
- cloud structures revealed in the UV (sulphuric acid)
- large scale topography – different from earth's continental land masses (8%)
- two main continental areas: Ishtar Terra and Aphrodite Terra
- highest peaks 14km above lowest depression
- Maxwell Montes, and Lakshmi Planum indicate geological activity
- no plate tectonics, no spreading like the Mid-Atlantic ridge
- surface is “new”, less than a billion years old – cratering with larger craters much less than the moon
- evidence of lava flows, deep cracks from new crust collapsing
- evidence of buckled a fractured surface
- large scale surface recycling not present, but much evidence for volcanism
- most volcanoes – shield volcanoes )like Hawaii – not from plat boundaries
- formation of caldera (crater) on the summit as dome collapses from lava withdrawal
- formation of large lava domes along with large coronae – suggests convective motion under the crust (similar to Earth, but without tectonics)
- not plate tectonics – energy release catastrophic, reshapes surface
- evidence for ongoing volcanic activity
- surface does possess craters, but even less than earth – thick atmosphere prevents meteors from reaching the surface
- Soviet Venera landers took pictures from the surface
- chemical composition: basaltic and material similar to granite

- Venus's atmosphere very different from Earth
- atmosphere 90 times more massive than Earth
- 90% of the Earth's atmosphere, below 10 km, 50 km on Venus
- temperature drops more quickly with altitude than on Earth
- troposphere extends to 100 km on Venus – reflective clouds at 50 km to 70 km
- below the clouds, layer of sulphuric acid haze
- above the clouds, high speed jet stream (400 km/h) along with sulphuric acid
- wind speeds on the surface 2 m/s
- CO<sub>2</sub> is the main atmospheric gas, 96.5% by volume, 3.5% N<sub>2</sub>, trace amounts of other gases
- example of a run-a-way greenhouse effect
- secondary atmosphere on earth result of outgassing – Nitrogen released from interactions with sunlight, water vapour condensed, carbon dioxide and sulphur compounds dissolved and locked up in surface rocks
- cooler conditions on earth results in carbon dioxide becoming locked up
- on Venus, too warm for oceans to condense, carbon dioxide never locked up, water vapour stays in atmosphere, feeding the greenhouse effect, water reacts with sunlight, eventually breaking it apart – no water vapour in Venus's atmosphere today
- Venus has no magnetic field, no dynamo (slow rotation)
- Venus's surface seems like an immature earth – perhaps high surface temperatures have played a role

## 4 Mars

- eccentric orbit (ave: 1.52 AU) – Mercury only more eccentric
- orbital parameters – changes sunlight received by 45%
- axis tilt similar to earth , 23.98°
- sidereal day 24h 37min
- orbital parameters, axis tilt southern summer near perihelion – complicated by large eccentricity

- closest Earth-Mars separation about 0.38 AU
- largest angular size 25" (100km across)
- physical properties: 3.9gm/cm<sup>3</sup>, mean surface temp, 210K, mass, 0.11 Earth 6.42 × 10<sup>23</sup>kg, 0.53 Earth radii (3394km) 2 moons, atmosphere mostly CO<sub>2</sub> (tin)
- Mars reflects only 15% of light reflected – much dimmer than Venus
- many satellite, and lander observations: Mariner missions, Viking missions, Mars surveyor, Pathfinder, Mars Exploration Rover mission
- surface mapped in detail: accuracy down to few metre level
- striking feature: northern hemisphere different from southern hemisphere
- Tharsis bulge: newest feature – upward building geology
- northern hemisphere lower than southern hemisphere, also less cratered – northern hemisphere younger
- Hellas Basin – deepest structure, probably impact in origin
- no evidence of plate tectonics – upward building process similar to Venus, but smaller mass yields different results – no recurring catastrophic resurfacing
- Tharsis bulge – massive canyon (tectonic fracture): Valles Marineris
- Valles Marineris: 4000km long, 7km deep, 120km wide at widest (Grand Canyon on Earth 20km wide 2 km deep)
- Mars – large volcanoes, upward building features not impeded as much by gravity
- Olympus Mons near Tharsis: 700km in diameter, 25km high above surrounding plains – shield volcano, not associated with plate tectonics
- other large shield volcanoes – low surface gravity
- perhaps limited, intermittent activity
- thin atmosphere offers little resistance to meteors – erosion from Martian winds
- massive dust storms can envelop the planet – erosion rate still 100 times slower than on Earth – Mars crater deficit under 5km
- cratering rate gives surface age – southern highlands, 4 billion years, volcano areas, few hundred million years, northern hemisphere 2-3 billion years
- water on Mars: near miss for life?

- compelling evidence for past and present water on Mars
- geological structures similar to water erosion features on Earth
- runoff channels in southern highlands – similar to river systems
- runoff channels, approximately 4 billion years old
- outflow channels – relics of catastrophic flooding – found in equatorial regions (not interconnected like the runoff channels)
- perhaps evidence of of planetwide water cycle
- also evidence of fan shaped river deltas – perhaps shallow seas once existed in low land areas (Hellas basin)
- possible evidence for beaches – but lacking in certain carbonate rock that should accompany large bodies of water – debate continues
- evidence of sub-surface permafrost – some ejecta blankets have a liquid, fluidized appearance
- gullies give the appearance of ongoing melting and runoff!
- Mars has polar ice caps composed mostly of dry ice (frozen carbon dioxide)
- two parts – seasonal and residual caps
- maximum size, southern seasonal cap: 4000 km across; northern cap 3000km across
- caps different in size – eccentric orbit
- southern winter longer, colder than northern cap
- seasonal caps composed entirely of carbon dioxide
- residual caps smaller, brighter in appearance, greater north-south asymmetry
- southern residual cap 350km across, mostly CO<sub>2</sub>, but some water ice
- northern cap, warmer, and much larger, 1000km across, perhaps made mostly of water ice – spectroscopic observations show increase in water vapour above the north pole in northern summer
- warmer temperature probably connected to planet wide dust storms that originate in the southern summer – dust deposited in the north polar cap, absorbs sunlight
- aside from gullies, no evidence of liquid water – small amount water vapour in the atmosphere

- water locked up in permafrost – present level in the atmosphere maximum possible under Martian conditions
- lander have found compelling evidence for water in Martian past
- Martian atmosphere – thin 1/150 of Earth pressure, 95% CO<sub>2</sub>, small amounts nitrogen, argon, oxygen
- little day-to-day variation, 50 K colder than Earth – massive dust storms occur periodically in the southern hemisphere with high winds
- Mars – atmospheric evolution, greenhouse effect fails to form
- carbon cycle – worked in the “wrong” direction
- lower level of volcanism, cooler surface temperatures (Mars-Sun distance), CO<sub>2</sub> depleted by absorption in surface rocks – not returned by geological activity
- lower surface temperature, carbon remains locked, increased carbon locking, lower surface temperature,...
- lower surface gravity, cannot hold a thick atmosphere like Earth
- result: thin atmosphere of CO<sub>2</sub>, with minor greenhouse effect
- Martian interior: weak magnetic field 1/800 of Earth’s, no seismic studies carried out thus far
- rapid rotation, and low density suggests lack of a magnetic field results from non-metallic, and/or non-liquid core (perhaps partially molten) – iron-sulfide
- Mars, smaller size, more efficient cooling, plate tectonics never gets started – crust becomes thicker faster than Earth or Venus
- Mars, two moon: Phobos (9400km from center), Deimos (23,500km from center)
- both orbit in a prograde fashion – both tidally locked
- Phobos 7h 39min
- Deimos 30h 18min
- unlikely that the moons formed with Mars – captured asteroids – perhaps once one object
- Phobos low orbit interacts with atmosphere – will crash into the planet in a few tens of millions of years