ASTR170

Earth: Spaceship

Four Stages of Planetary Development

- Stage 1: differentiation, when material separates according to density. Densest materials are core.
- Stage 2: cratering, solid surface formed and bombarded. 'Heavy bombardment period'
- Stage 3: basin flooding, radioactive decay heats interior melting rock in upper mantle, molten rock gets to crust flooding impact craters. (Enviro cooled + rainfall + flooded basins = oceans)
- Stage 4: slow surface evolution, contains progress of at least 3.5 billion years. Almost all surfaces = 1 billion years old.

Earth's Interior

- Explored through seismic waves that travel through the earth from core to crust
  - ⇒ Pressure waves (P): travel by compressions and decompression. Particles vibrate backwards and forth and can only be supported by liquids
  - ⇒ Shear wave (S): a displacement of particles = distort material but not compressed by particles vibrating up and down. This wave is supported by both liquids and solids
- Core+ 55% of Earths radius, 500k, 14g/cm^3 dense and made of iron and nickle

Earth's Magnetic Field

- Produced by cores conductive –iron-nickle convection this, conducting liquid generates Earth's magnetic field, known as dynamo effect
- Deflects solar wind, however, some high-energy particles follow the magnetic field line exciting the particles as they leak in the magnetosphere causing the aurora lights

Earth's Crust

- Low-density rock that floats on mantle. Shifting and changing from tectonic places
- Plates + erosion = why earth isn't heavily cratered

The Atmosphere

- Created through outgassing leading to a rich nitrogen (80%) and oxygen (20%) atmosphere as well as carbon dioxide
- Oceans formed by bombardment by icy comets that sucked the carbon dioxide out of the atmosphere = lime stones. Allows planets to rapidly emit oxygen into the atmosphere without it being destroyed
- Ozone layer exists through oxygen whilst protecting earth from harmful UV radiation
- Human effects on the atmosphere
  1. Global warming: rapid amounts of greenhouse gases trapped in the atmosphere through emission of CO^2 and deforestation = heating planet
  2. Destruction of ozone: Through emission of Chlorofluorocarbons (CFC"s) in air con etc. Solved through the government band of CFC's worldwide = ozone hole over Antarctica shrinking

Earth's Composition

- Nitrogen and oxygen particles create natural air. High pressure lower to the ground = less particles as you go higher due to less pressure from less freq. Collisions in particles

Earth's Movement

- 100,000km/hr orbit around Sun
- Solar system orbiting milky way 800,000km/hr
- Milky way moves on gravity and dark matter so the solar system travels 320 km/sec

- The Suns energy. 49% deflected through atmosphere, 51% absorbed by land and oceans

ASTR170

Comparing the Moon and Mercury

The Moon from Earth's View

- Two kinds of Terrain
    1. Lunar highlands; overlapping mountains caused by bombardment. Craters 4 to 4.5 billion years' old
    2. Maria; 'sea' (lowlands) resembles a water mass. Ancient lava flows cover craters solidifying them. Craters 2-4 billion years' old/
- Craters form in heavy bombardment (debris from planet building), presence today indicate no surface evolution
- Rocks from the Apollo mission all igneous- solidified lava (no sedimentary rock)
    - ⇒ Highlands = low density. Calcium, aluminium. 4 -4.5 billion years
    - ⇒ Maria = dark and dense. Iron, manganese and titanium. 2-4 billion years
- Simas Rilles = remains of ancient lava flow, lava tubes have collapsed during bombardment
- Ejecta is the visible impact from bright rays of young craters

History of the Moon

- 1970's hypothesis is it was formed by a collision with proto-earth causing matter and debris to orbit the earth until it compressed to form the moon
- Surface solidified 4.6-4.1 billion years ago from its molten state.
- Size means it cooled rapidly with no escape velocity, magnetic field or atmosphere = unprotected by meteorites

Mercury

- Rotation period is 59 days; revolution period is 88 days. A day on Mercury is 2 years' long
- Temperature at night = -173C and day = 330C
- Similarities to the moon = lowlands (intercrater plains) flooded by lava, heavily cratered and no atmosphere

Mercury's Interior

- 60% denser than moon due to denser core with a huge iron core
- Magnetic field 1.1% as strong as Earth's, its size indicates it should be cooled by now yet it may retain a molten outer core

History of Mercury

- Formed in inner most solar nebula, its cratering would've occurred same time as the moons
- Planet shrinking caused the lava channels to be squeezed off the surface

ASTR170

Venus and mars

Venus' Rotation
- Rotates clockwise once every 143 days. Reasons proposed:
    1. Struck off centre by a large planetismal
    2. Models suggest its position to the sun with a molten core and dense atmosphere reversed rotation through tidal waves

Venus' Atmosphere
- Atmosphere composed of 96% carbon dioxide, 3.5% nitrogen, 0.5% water vapour, sulfuric acid, hydrochloric acid and hydrofluoric acid. Thick clouds composed of sulfuric acid droplets and microscopic sulfuric crystals
- Atmospheric circulation, caused by slow rotation not breaking up wind. Circulates gas to dark side of planet and poles produces 300km/hr jet streams in upper atmosphere – east to west
- Extremely dry however, ratio of deuterium and heavy isotopes of hydrogen in atmosphere indicate once had significant amounts of water
    - ⇒ Water destroyed by lack of ozone layer to absorb UV that breaks down water molecules
- 100 times denser than Earth, temp 400C and drier than Earth, 4 thick cloud layers visible from earth

Craters on Venus
- Surface estimated to be 100 million years old, 1000 surface craters
- No surface water – no erosion, sharp and fresh
- Surface action evident with the presence of lava flows

Volcanos on Venus
- Shield volcano's produced from hotspots, grow large due to lack of tectonic/ horizontal crust movement
- Sapas mons volcano 400m (base) and 1.5 km high
- 2 lava channels, overlapping. Largest system being 6800km

History of Venus
- Low density crust and crust being temp halfway to boiling point means to stiff to form tectonic plates
- Internal heat lost through convection currents of hot magma that rises beneath crust to core.
    - ⇒ *Coronae's:* circular bludge on surface
- Carbon Dioxide (CO^2) produced during the planets outgassing into the atmosphere
- Highland regions: Ishtar Terra and Aphrodite Terra

Canals on Mars
- Giovanni Schiparelli thought he saw canals on Mars which produced conspiracies of life on Mars
- Was an optical illusion, put to rest when Marine 4 flew by in 1965

Mar's Interior
- No magnetic field, yet traces of frozen magnetism in old crust meaning had a liquid core that once generated a magnetic field
- Is differentiated, seen through Doppler shift measurement. Has dense core, less dense mantle and low density crust

Mar's Atmosphere
- Composed of 95% Co^2, 1.6% argon, 3.4% nitrogen. 1% as dense as Earth's atmosphere
- Reddish soil caused oxygen oxides (rust) located in chemical compounds in soil
- Atmosphere formed by outgassing (possibly). Due to it molecule velocity being greater than escape velocity so it lost all the lighter gasses
    - ⇒ Holds onto H20 (frozen), NH^3, CH^4m N^2, O^2 and CO^2
- Polar caps vaporise in spring, Co^2 returns in Atmosphere

ASTR170

Mar's Surface

- 2 parts; Southern highlands is heavily cratered and northern highlands smooth valleys, resurfaced about a billion years ago
- Olympus Mons = largest volcano in solar system. Hasn't sunk meaning Mars has a thicker crust than Earth. Found within the volcanic bludge Tharsis Rise which can modify climate and seasons

Water on Mars

- Suggestions that Mars used to have surface water
  - ⇒ Outflow channels: cut by flooding
  - ⇒ Valley networks: valles marineris
  - ⇒ Gullies: recently eroded (no craters)
- Mineral Hematite (found by Opportunity + Spirit) and sedimentary rock (found by curiosity) on surface, require water to form

Moons of Mars

- Phobos and Deimos are tidally locked to Mars, too small to be made spherical by gravity, with densities of 2g/cm^3 and 0.07 Albedos and very cold and cratered with a layer of dust
- Caught from outer asteroid belt – hypothesised Jupiter's

History of Mars

- Noachian Period (4.3-4.7 billion years ago)
  - ⇒ Heavy bombardment
  - ⇒ Crust formation
  - ⇒ Liquid surface (?) present and flooding of plains by great lava flows
- Hesperian Period (3.7 – 3 billion years ago)
  - ⇒ Loss of atmosphere
  - ⇒ Froze or lost water crust
  - ⇒ Outflow channels formed
  - ⇒ Part of surface covered by lava flows as Tharsis Rise formed
- Amazonian Period (3 billion years to present)
  - ⇒ Loss of internal heat
  - ⇒ Thick crust = lack of geological activity
  - ⇒ Slow erosion from wind

ASTR170

The Jovian Worlds

Mass of Jupiter
- Diameter 1.4 x 10^6km and Mass 1.9 x 10^27 kg with an average density of 1.3g/km^3 meaning there isn't much rock
- Mass inferred through the tracking of inner most moons orbital patterns

Jupiter's Interior
- Consists of mostly (metallic or liquid) hydrogen and helium
- Centre of core 5 or 6 x hotter than sun's surface. Doesn't explore due to pressure
- Jupiter's oblateness caused by its rapid rotation. Indicates liquid interior

Jupiter's Magnetic Field
- Produces synchrotron radiation *(radio energy produced by fast electrons)* hence 14 times stronger than Earths
  - ⇒ Produced through highly conductive liquid metallic hydrogen core
- Holds and traps high radiation and energized particles
- Galilean moons orbit inside magnetosphere and heavier ion in the radiation belt – comes from volcanic Io
  - ⇒ Orbit period 1.8 days, Jupiter's magnetic field rotates every 10hrs = magnetic field sweeps up stray particles accelerating their orbit as they are ionised

Jupiter's Atmosphere
- Below clouds = ocean with no surface or waves
- Strong belt-zone circulation, are divided in two categories, low-pressure bands where the gas is sinking and high-pressure bands where gas is rising; they are unchanging since first observed
- Hydrogen rich and clouds confined to a shallow layer

History of Jupiter
- Formed from colder gases in the outer solar nebula, ices and water could dense hence Jupiter rapidly to capture helium and hydrogen gases
- Hydrogen core = liquid metallic = very strong magnetic field
- Rapid rotation causes heat flowing upwards from interest to have currents, cool gas in dark belts and hot gas in bright belts

Calisto: An Ancient Surface
- Avg. density 1.89 g/km^3. Made of ice and rock mixture
- Tidally locked to Jupiter (same face)
- Never fully differentiated, yet is heated by radioactive decay
- Appears dark due to solar UV and wind particles
- 10km layer of liquid water 100km below surface

Ganymede: A puzzling past
- Largest moon in solar system. Density 1.9 g/cm^3. Differentiated rock and metal core with an ice rich mantle
- 1/3 crust old, dark + cratered. 2/3 bright, possibly flood (?)
- Has own magnetosphere, magnetic field 10% as strong as Earths
  - ⇒ Liquid core not hot enough for a molten metallic core
- Layer of water 120 km below surface

Europa: Hidden Ocean
- Density 3.0g/cm^3 – mostly rock and metal with ice crust
- Active crust. Reflects 67% of sunlight that hits it
- No magnetic field = no molten core
- Water revealed 15km under surface, likely to have rich dissolved minerals = good conductor when interacting with Jupiter's magnetic field

Io: Roaring Volcanos
- 150 active volcanos visible on surface, burying any newly formed craters
- Atmosphere – sulphur + oxygen. Leak into space due to low escape velocity

- Heated by tidal interactions with Jupiter
  - ⇒ Tidal interactions so powerful Io is kept in place by Ganymede and Europe being locked in orbital resonance, gravitational interaction maintains orbit
- Avg. density. 3.55g/cm^3 – interior rock

Jupiter's Rings

- Particle very dark and reddish, some rock particles microscopic
- Forward Scattering - scattering light forward when particles have same diameter as wavelength of light – majority of particles are as thin as smoke
- Debris fallen into the roche limit –distance from planet and moon- that eventually falls into planet, Io contributes to building

Mass of Saturn

- 1/3 of Jupiter. Density 0.03g/cm^3 (floats)

Saturn's Interior and Magnetic Field

- No heavy elemental core rather liquid hydrogen. Planets squished from rotation
- Heated through liquid helium droplets falling towards centre
- Radiates 1.8 as much energy as receives from Sun = heat flows out of its interior
- Magnetic field not inclined to axis of rotation, Perfect alignment of axis of rotation + magnetic axis

Saturn's Atmosphere

- Belt-zone circulation, light coloured zone = rising gas, darker zones = sinking gas
  - ⇒ Not as distinct as Jupiter
- Strong winds = wind blows around equator at 500m/s
- Composition; hydrogen (96%), helium (3%), h20 (0.0004%), methane (0.4%) + ammonia (0.01%)
- Colder than Jupiter and the clouds form lower so its dimmer

Saturn's Rings

- Discovered by Galileo, thought Saturn was a 3 body planet – later realised as a disk
- Gaps in rings caused by resonances with inner moons. Solid rings unstable = separate particles
- Made of of billions of ice particles each on solo orbit around the planet
  - ⇒ Range from microscopic specks to chucks larger than a house
- Gravitational effects of small moons = shepherd satellites confine rings to narrow strands
- Ring composition differentiation
  - ⇒ Cassini Division contains particles richer in rock

Saturn's Moons

- Titan, largest moon
  - ⇒ Thick atmosphere; mostly nitrogen, 1.6% methane
  - ⇒ Surface temp 94K and pressure 50% greater than Earth
  - ⇒ Core rocky. Mantle + Crust = large amounts of ice
  - ⇒ Hypothesis of rivers, lakes and oceans of methane
  - ⇒ Geological activity = few craters.
- Smaller moons; Hyperion, Dione, Rhea
- Saturn is not warm enough to have its moons be formed with it like Jupiter
  - ⇒ Hypothesis reg moons formed with Saturn while irregular were captured

History of Saturn

- Formed in outer solar nebula = icy particles stable allowing it to grow rapidly to capture hydrogen and helium from nebula
- Rings made from collision with comet from Kuiper belt with a moon (hypothesis)
- Outward flow of heat from core drives convection current in the mantle and rapid rotations = magnetic field

Discovery of Uranus
- Discovered by William Herschel as an extended object, originally called the Georgian Star

Motion of Uranus
- Inclined axis of 98 degrees' perpendicular to orbit = sun moves pole to pole
  - ⇒ Cause by possible large impact during planetesimal formation or Saturn's tidal interaction altered

Uranus's Atmosphere
- No surface = transition from gas phase to fluid interior
- Composition hydrogen (26%), helium (mass), methane, ammonia and water vapour
  - ⇒ All blend into fluid interior
- Cloud layers of methane ice particles, others formed from ammonia, ammonium hydrosulphide and water. Forming not distinct belt zone circulation
- Methane in atmosphere absorbs longer wavelength protons = blue appearance

Uranus' Interior
- Average density = 1.3g/cm^3
- 3 Layers
  1. Atmosphere = rich in hydrogen and helium
  2. Mantle = large amounts of water, methane + ammonia in solid or slushy state mixed with hydrogen and silicate
  3. Core = small heavy element core (unknown)
- Magnetic field 75% stronger than Earth. Rotation inclined 30 degrees
- Radiates less than 10% heat than receives from sun.

Uranus's Moons
- Main moons: Titania, Umbriel, Ariel and Miranda = spectra show they contain frozen water and dark surface suggests mixture of ice and dust
- Main moons tidally locked with large rock cores, ice mantle
- Inner moons: dark as coal with ice surface. Darkened by orbiting radiation belt
- Albedo. 0.10

Uranus's Rings
- Dark and faint, confined by shepherd satellites. Discovered because Uranus crossed in front of a star
- Composed of thin layer of dark boulder particles = 0.015 albedo
- Particles collide, each other/pushed away by radiation pressure = resupplied by moon debris

History of Uranus
- Evidence suggest it and Neptune formed closer to where Jupiter is now in the solar nebula, yet were moved back gravitational forces of other Jovian planets

Discovery of Neptune
- Discovered based on discrepancies in Uranus' orbital motion

Neptune's Atmosphere and Interior
- Marked by belt-zone circulation parallel to equator. Dark cyclonic disturbance's caused by gas rising from planets interior
  - ⇒ Retrograde high speed winds
- Model suggest small heavy element core surrounded by mantle of slushy/solid water mixed with a heavier element
- Tipped 47 degree on its axis of rationed. Magnetic field generated through dynamo effect conducted by fluid mantle
  - ⇒ Retains heat from radioactive decay of materials
- Composition of atmosphere = predominantly hydrogen with methane

Neptune's Moons
- Triton, only large retrograde moon in the solar system and was most likely capture
  - ⇒ Ice surface with thin nitrogen atmosphere

- ⇒ Presence of flooded areas + lack of craters = possible geo activity
- ⇒ Surface composed of ice, nitrogen, methane, carbon monoxide, carbon dioxide
- ⇒ Dark smudged on surface from rising methane from below surface
- ⇒ Frozen nitrogen in polar cap, causes crustal smudged

Neptune's Rings

- Rings regularly resupplied by dust from meteorite impacts on moons
- Forward scattering light with smaller dust particles than Uranus

History of Neptune

- Highly elliptical orbit with Tritons retrograde orbit suggest that Neptune's orbit was disturbed by the capture of the moon
- Hazy atmosphere due to changing wind patterns, hides mantle that is believed to generate an off-centre magnetic field

ASTR170