

Summary Notes - Topic 12: Formation of Planetary Systems

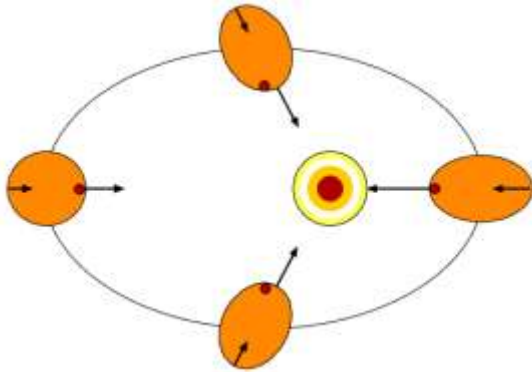


12.1 Gravitational and Other Forces in the Solar System

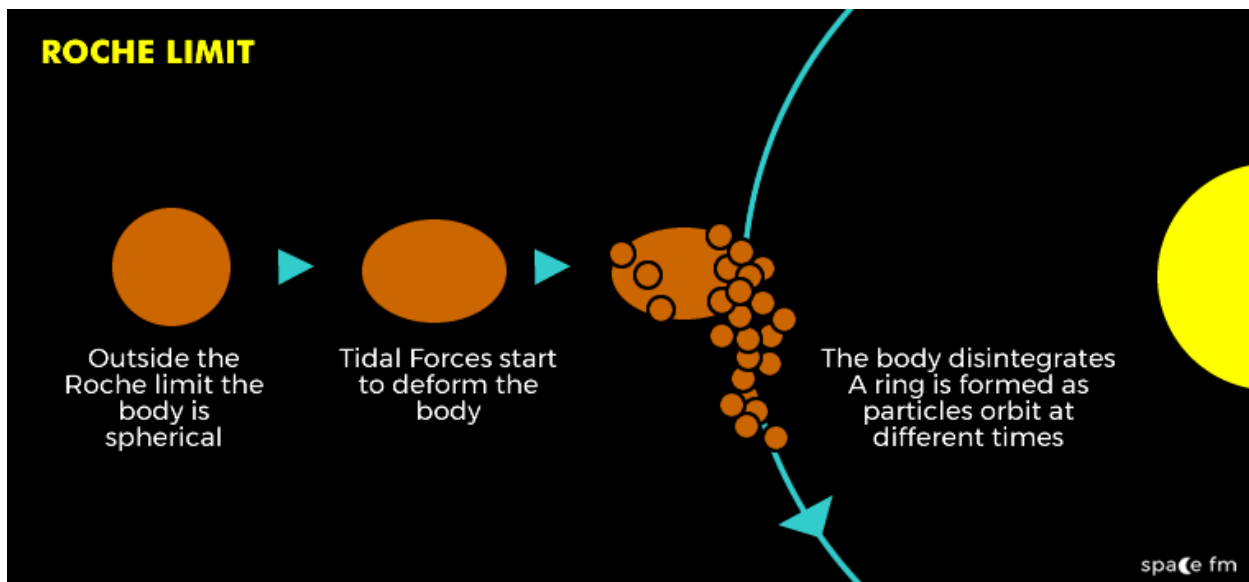
a) Gravitational Attraction Producing Regular Motion

- Gravity keeps **planets in orbit** around the Sun and **moons in orbit** around planets.
- The **balance between gravity and inertia** results in stable orbits.
- The centre of gravity is called the '**barycentre**'. The barycentre of planet-moon systems is within the body of the planet. Pluto-Charon have a centre outside of Pluto.

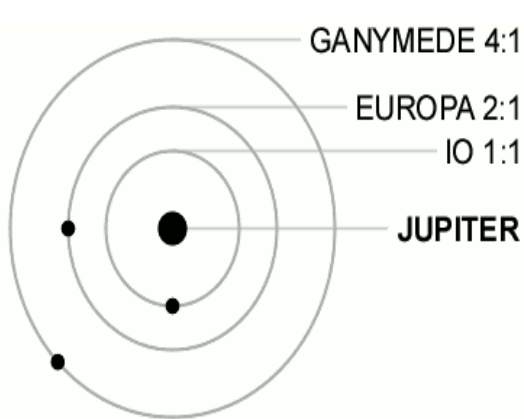
b) Tidal Gravitational Forces and Their Effects



- **Roche Limit** - If a body such as a small moon approaches too near a larger planet it will be broken apart by tidal forces. This distance is called the Roche limit and is typically 2 or 3 orbital radius of the planet and probably less for comets.
- **Ring Systems:** Moons within the **Roche Limit** are pulled apart by tidal forces, forming rings (e.g., Saturn's rings).
- **Asteroid Belts:** Jupiter's gravity prevents asteroids from forming a planet.
- **Internal Heating:** Tidal forces stretch and heat moons (e.g., Io's volcanic activity).



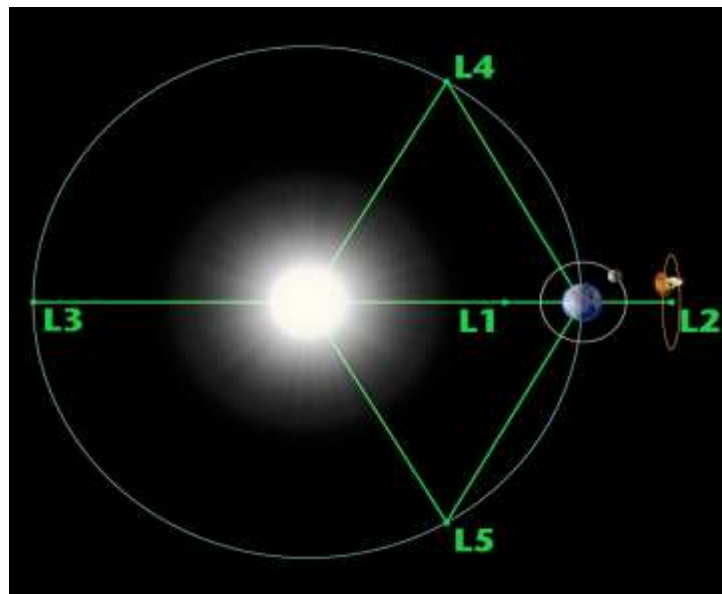
c) Gravitational Interactions of Multiple Bodies



- **Orbital Resonances:** Moons or planets can lock into patterns, e.g., Ganymede, Europa, and Io orbit Jupiter in a **1:2:4 resonance**.

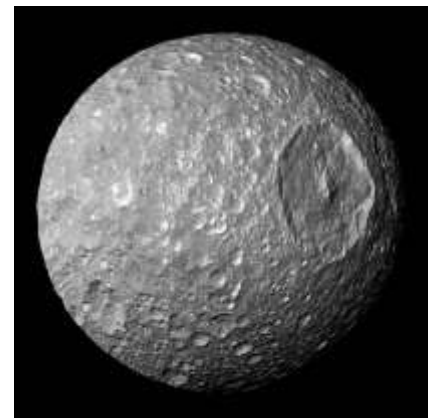
- **Chaotic Motion:** Small gravitational changes over time can **disrupt orbits** (e.g., asteroid belt objects).

- **Lagrangian Points:** Stable positions where gravity balances, allowing objects to stay put (e.g., James Webb Space Telescope at L2).



d) Accidental Collisions and Their Effects

- **Impact Craters:** Large bodies colliding with planets/moons leave craters (e.g., Chicxulub crater from the dinosaur-killing asteroid).
- **Orbital Changes:** A collision can **alter an object's orbit** (e.g., some asteroids were pushed into the Kuiper Belt).
- **Axial Tilt Changes:** Giant impacts can tilt planets (e.g., Uranus is tilted **98°** due to a past collision).



e) Effects of Solar Wind

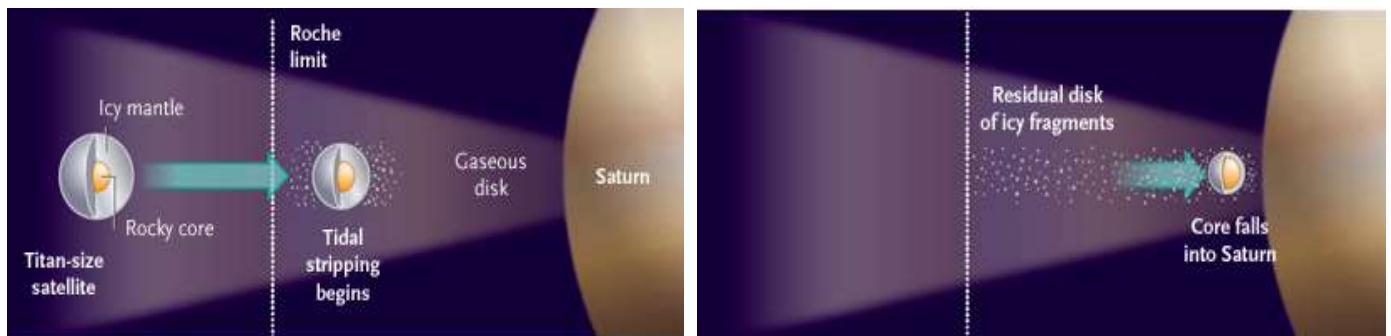
- The solar wind is a constant flow of charged protons and electrons flowing outward from the Sun. They can reach a velocity of 400 km per second
- The Sun also produces intense solar flares, or 'coronal mass ejection' - CME, on occasion. These are violent outbursts of particles that blast away from the sun in any direction.
- Aurorae - The Earth creates a field called the Magnetosphere. This extends in the direction of the Sun but much further in the opposite direction, even further than the distance to the Moon. It deflects the damaging effects of the solar wind. Aurorae are also seen on Jupiter and Saturn.
- **Comets:** The solar wind **pushes a comet's ion tail** away from the Sun.
- **Planetary Atmospheres:** The solar wind **stripped away Mars' atmosphere** over time.
- **Heliosphere:** The solar wind creates a **bubble** in space that protects the Solar System from interstellar particles.



12.2 Forces in Planet and Moon Formation

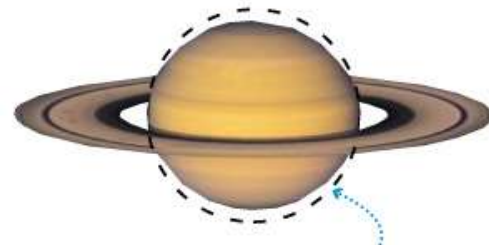
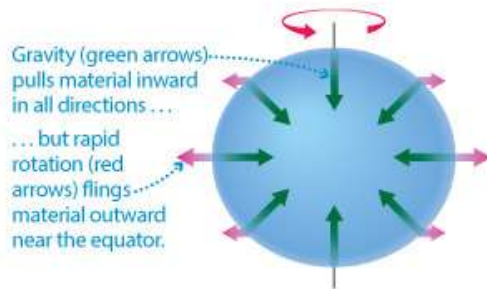
a) Roche Limit and Tidal Breakup

- A moon within the **Roche Limit** experiences **tidal forces stronger than its gravity**, causing it to break apart.
- This process **creates ring systems** (e.g., Saturn's rings).



b) Spherical vs. Irregular Shapes

- **Smaller bodies** (asteroids, small moons) remain **irregular** due to weak gravity.
- **Larger bodies** (planets, big moons) become **spherical** because gravity pulls material into a rounded shape.



c) Gravity and Atmospheres

- A planet's **gravity** determines whether it can hold an atmosphere.
- **Larger planets** (e.g., Earth, Jupiter) **retain thick atmospheres**.
- **Smaller planets/moons** (e.g., Mercury, the Moon) **lose their atmospheres** over time.

12.3 Formation of Gas Giants

Two main theories explain gas giant formation:

1. **Core Accretion Model** – A rocky/icy core forms first, then attracts gas.
2. **Disk Instability Model** – The gas disk fragments directly into a planet.

12.4 Methods for Discovering Exoplanets

a) Transit Method

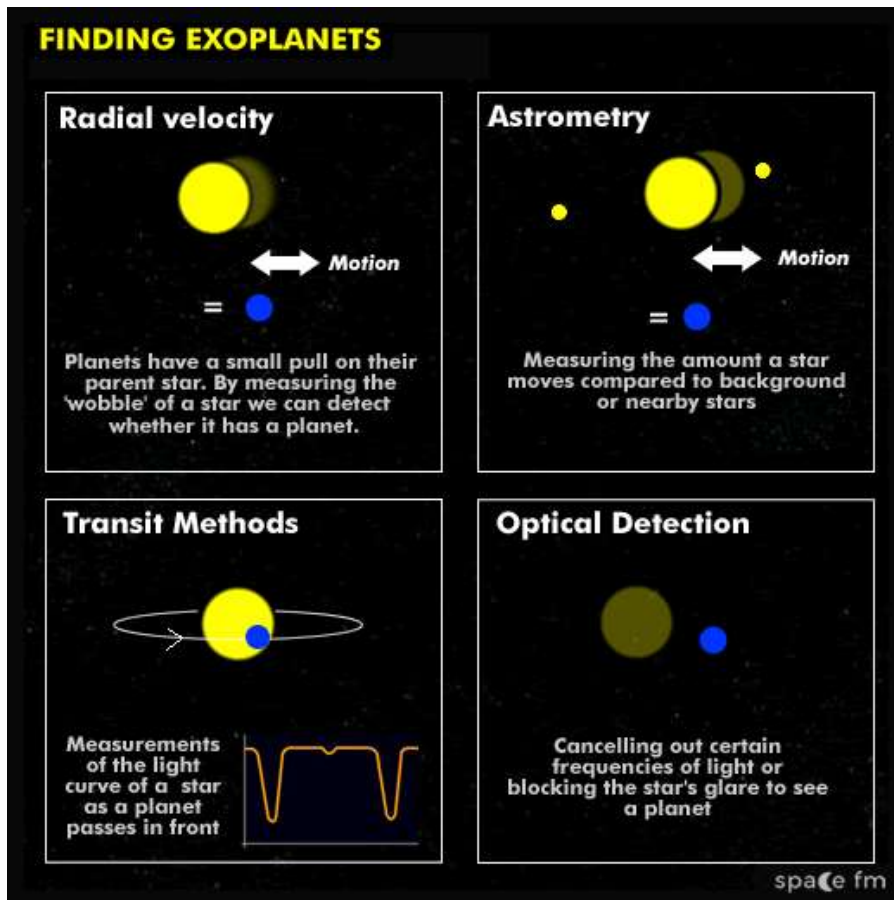
- A planet passing in front of a star **blocks some light**, causing a small dip in brightness.
- Used by telescopes like **TESS** and **Kepler**.

b) Radial Velocity (Doppler Shift) Method

- A planet's gravity makes a star **wobble**, shifting its light spectrum.
- Works best for **large planets close to stars**.

c) Astrometry

- Measures tiny **side-to-side movements** of a star caused by orbiting planets.



12.5 Possibility of Life in the Solar System

Scientists agree that if life (past or present) is to be found elsewhere in the Solar System that it will likely be carbon based and have required water to form and survive. Scientists are interested in water in any form throughout the Solar System.

It is unlikely that life exists in the human or animal forms that we're familiar with, due to a lack of breathable oxygen or an appropriate position in the Solar System. Instead scientists think life could be microscopic or algae.

a) Titan (Saturn's moon)

- Thick atmosphere with **methane lakes**.
- Some scientists think **life could exist in its liquid methane**.

b) Europa (Jupiter's moon)

- **Subsurface ocean** beneath an icy crust.
- May have hydrothermal vents like Earth's deep oceans.

c) Enceladus (Saturn's moon)

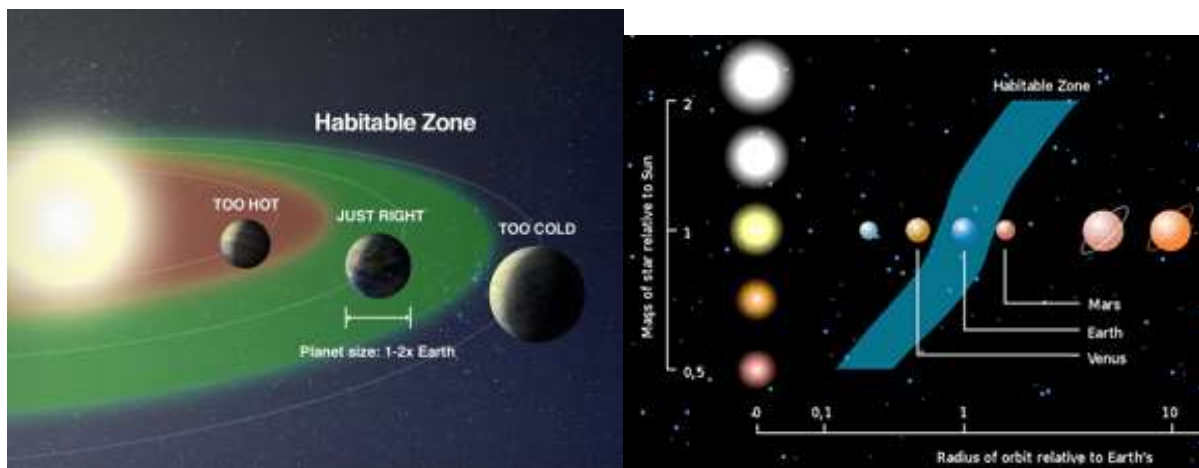
- **Water geysers** detected—suggests an **underground ocean**.

d) Life Outside the Solar System

- **Exoplanets in the habitable zone** may have liquid water.

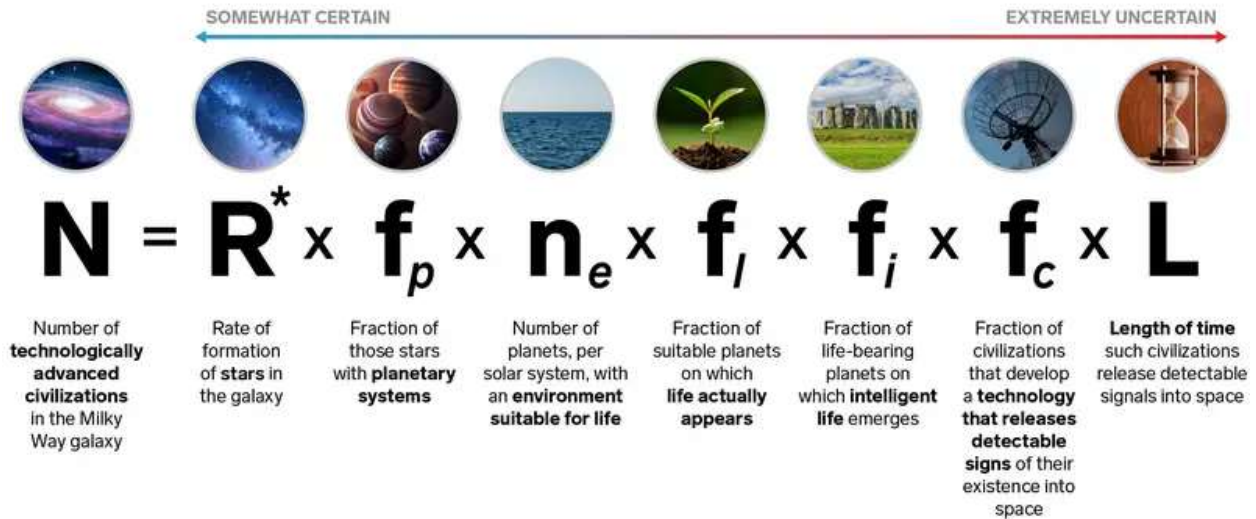
12.6 The Goldilocks (Habitable) Zone

- The region where **liquid water** can exist on a planet's surface.
- Earth is inside, but **Mars is on the edge**—hence, its water is mostly frozen.



12.7 The Drake Equation

- Estimates the number of **communicating civilizations** in the galaxy.
- Factors include:
 - Number of **habitable planets**
 - Probability of **life forming**
 - Likelihood of **intelligent life developing**



12.8 The Search for Extraterrestrial Intelligence (SETI)

- **SETI uses radio telescopes** to search for alien signals.
- Some scientists worry about the **risks of contacting aliens** (e.g., Stephen Hawking's concerns).
- Knowing that we are not alone will have a profound effect on our philosophy and outlook as a species. It is useful to compare benefits and dangers of the effects of contacting another intelligent civilisation. Consider the following statements:

Alien forms of life could lead to cures for existing illnesses	vs	They could also create new bacteria capable of killing all life
Intelligent life may share knowledge about science that we have yet to discover.	vs	Depending on an unknown alien force for knowledge prevents us from advancing as humans
Intelligent life may share advances in technology such as travel and communication.	vs	Intelligent life may be aggressive and set out to invade or hurt Earth life forms including humans