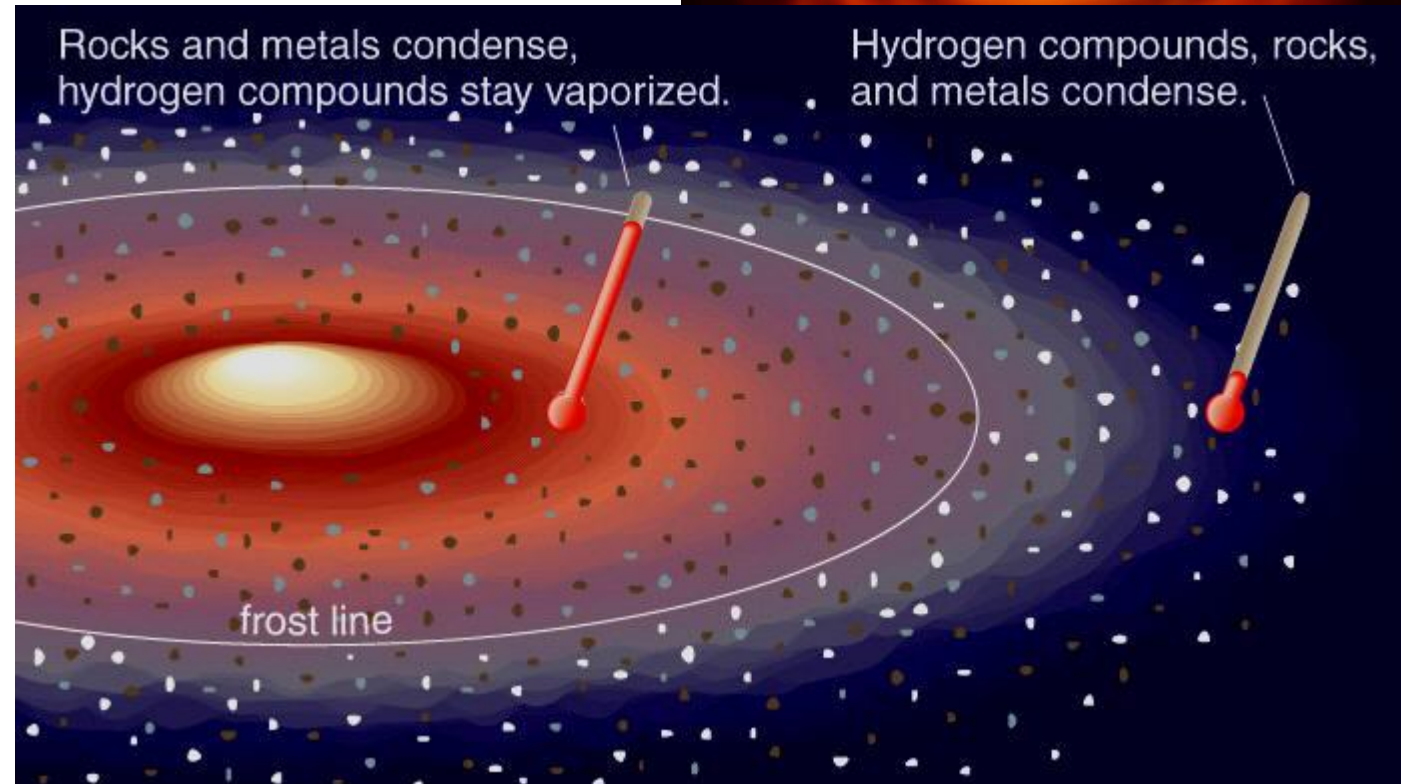
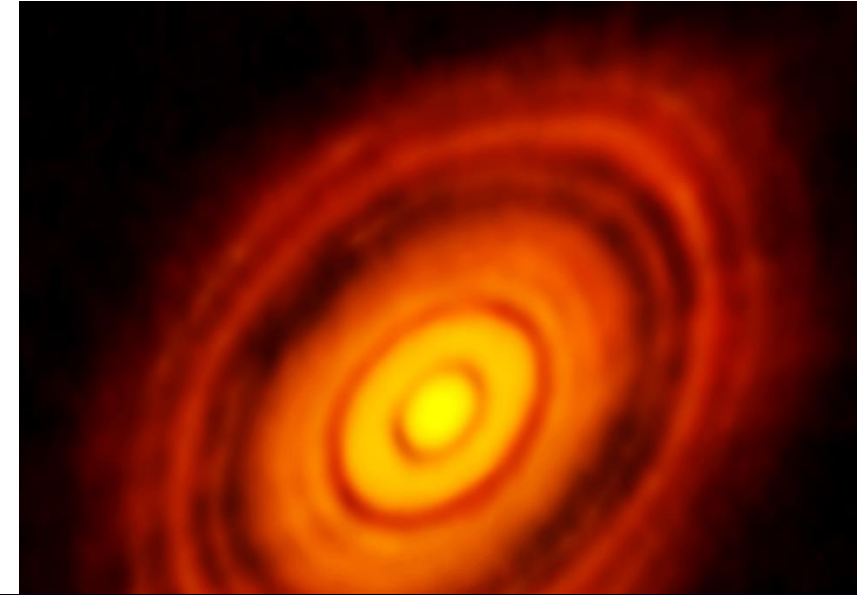


Topic 12: Formation of Planetary Systems



The Solar System: Planets and Moons

- 4.6 billion years ago the nascent Sun was surrounded by a **protoplanetary** disc made from 75% H, 23% He, and O, Si, C, Fe % Ni.
- At 5 AU the **frost line** marks a boundary where beyond it, volatiles could freeze. Within it metals and rocks could condense.
- H and He remained gaseous and large amounts were blown to the outer Solar System.



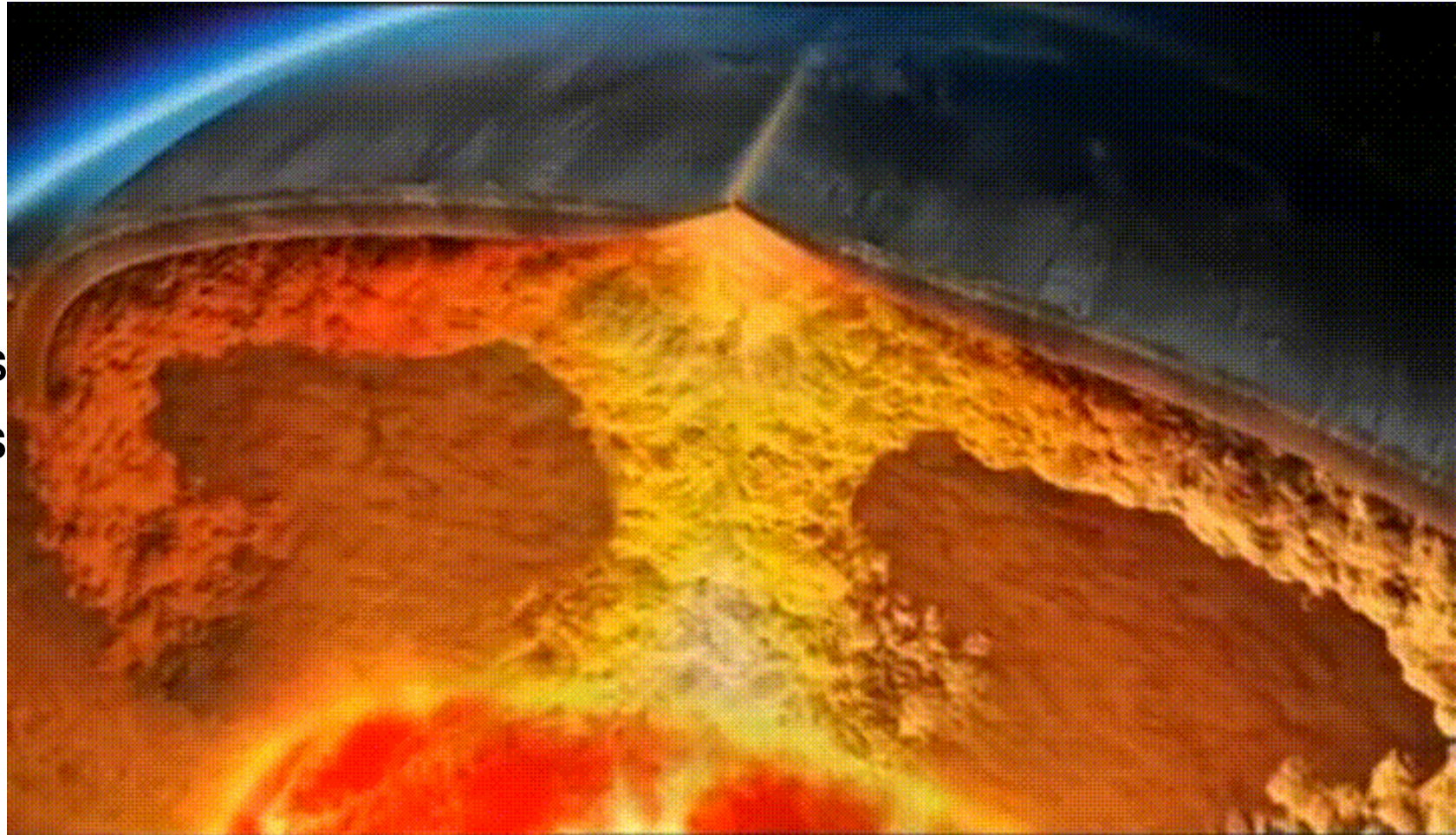
The Solar System: Planets and Moons

- Planets form by **accretion**.
- small grains of solid material collide and stick to form larger flakes.
- Eventually after ~100 million years the cores of planets are formed.
- Due to more ice beyond the frost line the outer planets grew larger cores leading to larger gravity therefore attracting a large amount of gas.



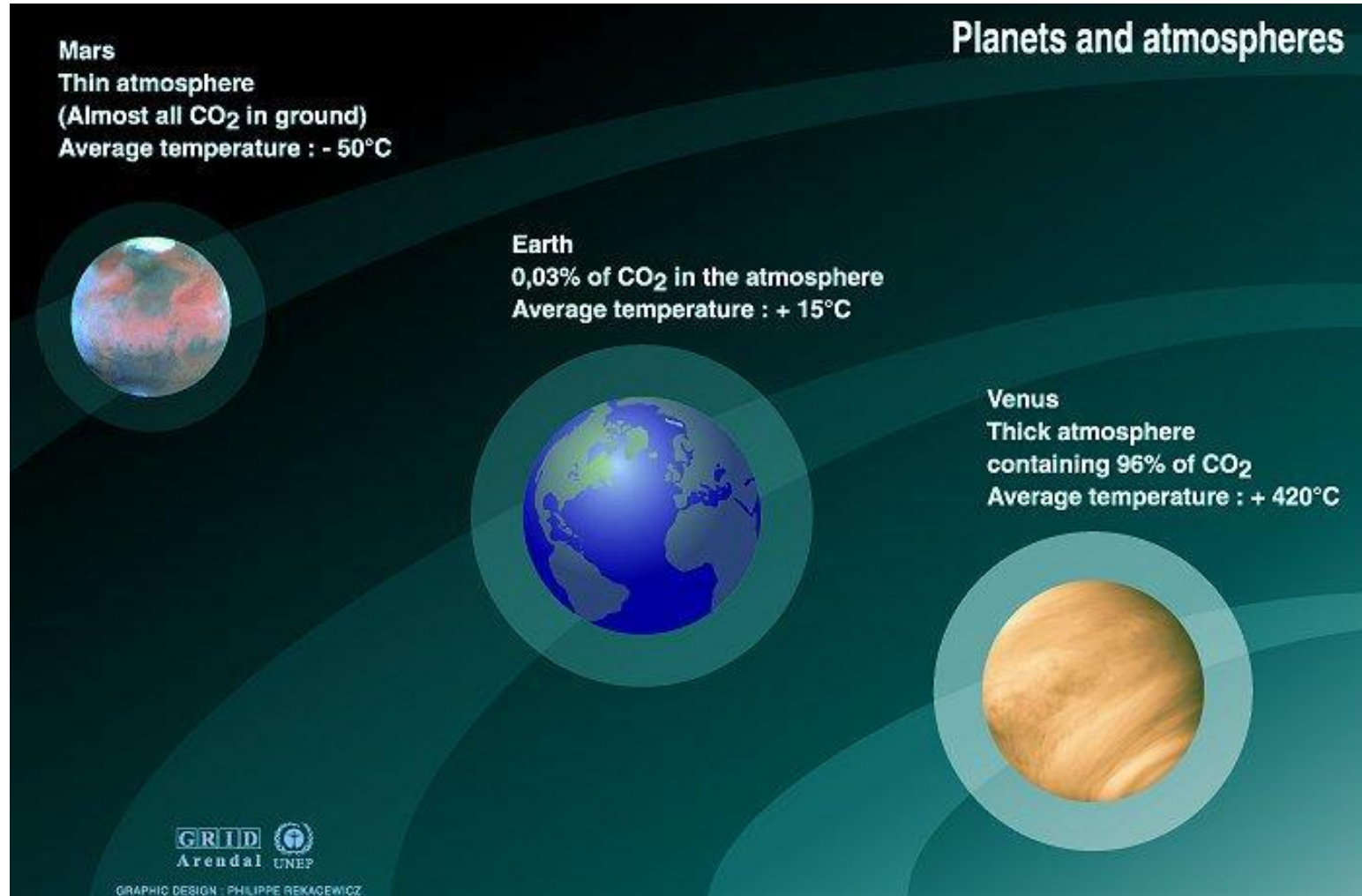
The Solar System: Planets and Moons

- **Internal radioactive** heating caused the cores to melt, less dense material rose.
- On terrestrial planets semi molten mantles and solid crusts formed.
- On gas giants slushy mantles formed.



The Solar System: Planets and Moons

- Some bodies retained enough gas to form an atmosphere. This was determined by its:
 - **Mass** – a larger mass means more gravity
 - **Temperature** – a lower temperature means particles move slower and less likely to escape.



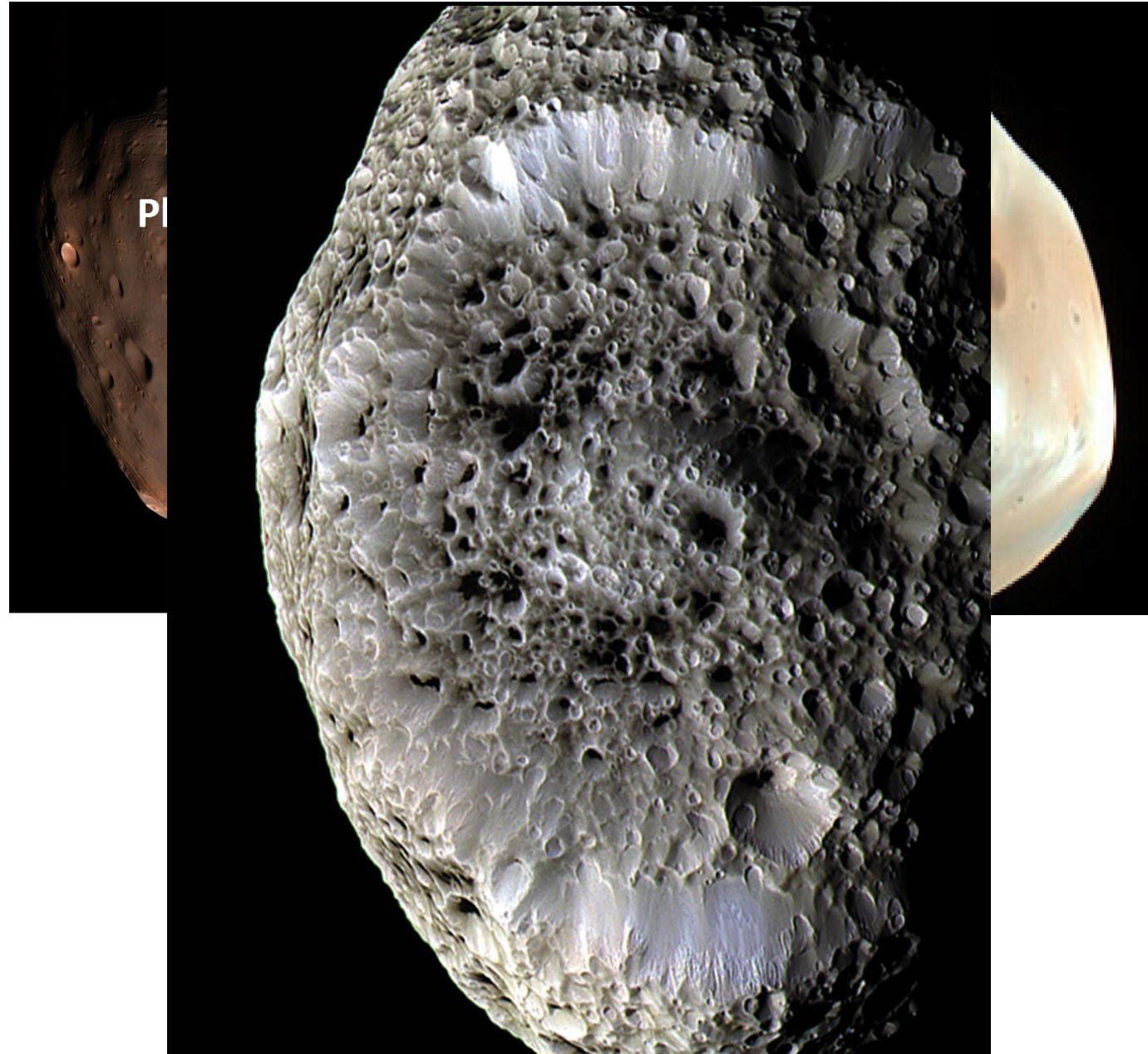
The Solar System: Planets and Moons

- There were originally over 50 bodies in the early Solar System. Due to collisions they broke apart and reformed to make the 8 planets.
- Evidence:
 - Mercury's core is **over 60%** its volume (Earth's is <20%) due to collisions removing outer layers.
 - The **backwards spin** of Venus and **sideways spin** of Uranus could be due to significant collisions.
 - Numerous **impact craters** on bodies.



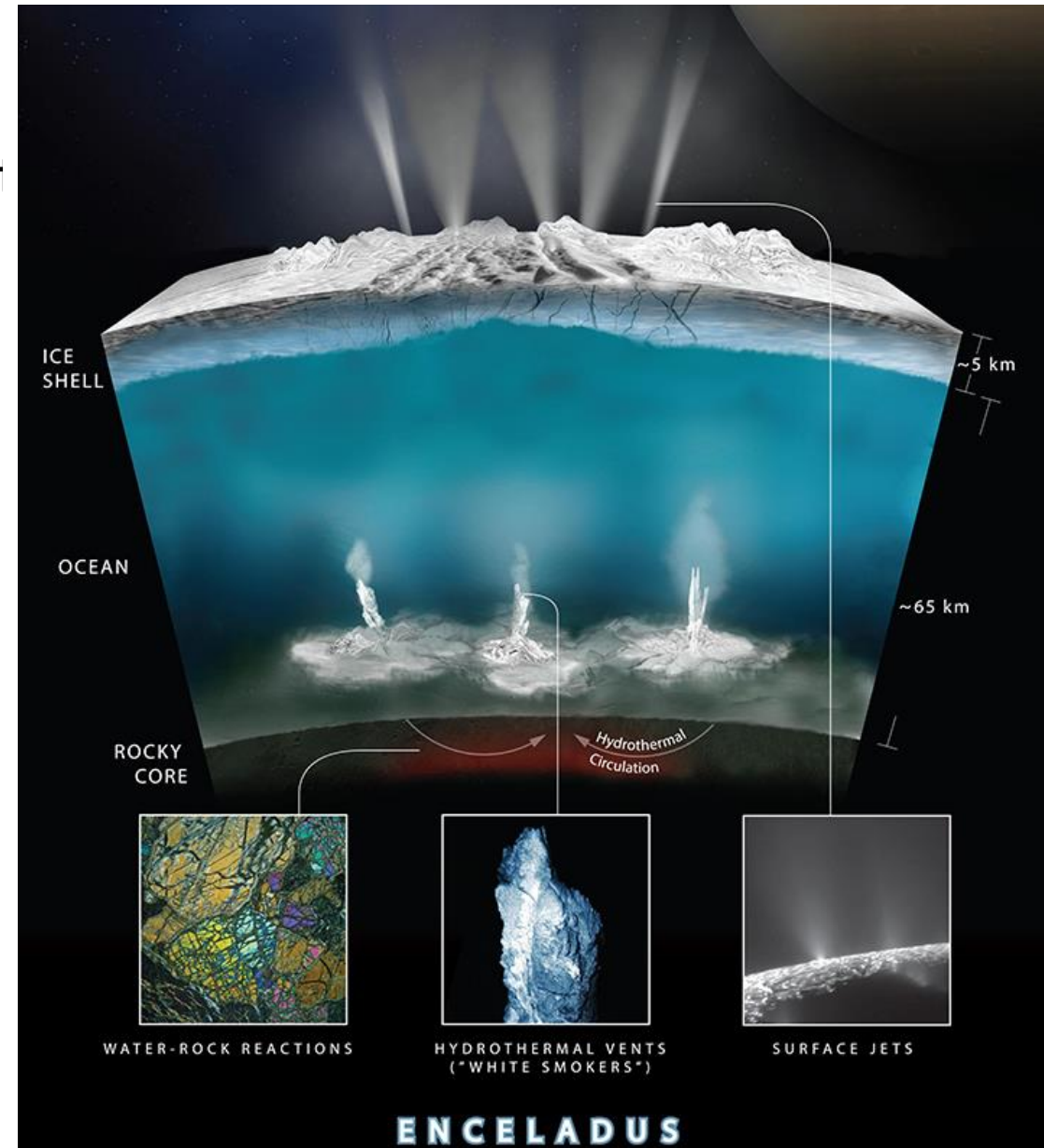
The Solar System: Planets and Moons

- All planets are spherical but not all moons are.
- **Icy** moons less than **400 km** are unable to form a sphere.
- Likewise, **rocky** moons are unable under **600 km**.
- Some moons were formed in situ around planets – they therefore orbit in the **same plane and spin**.
- Some moons were captured from the **Asteroid** and **Kuiper belt**.



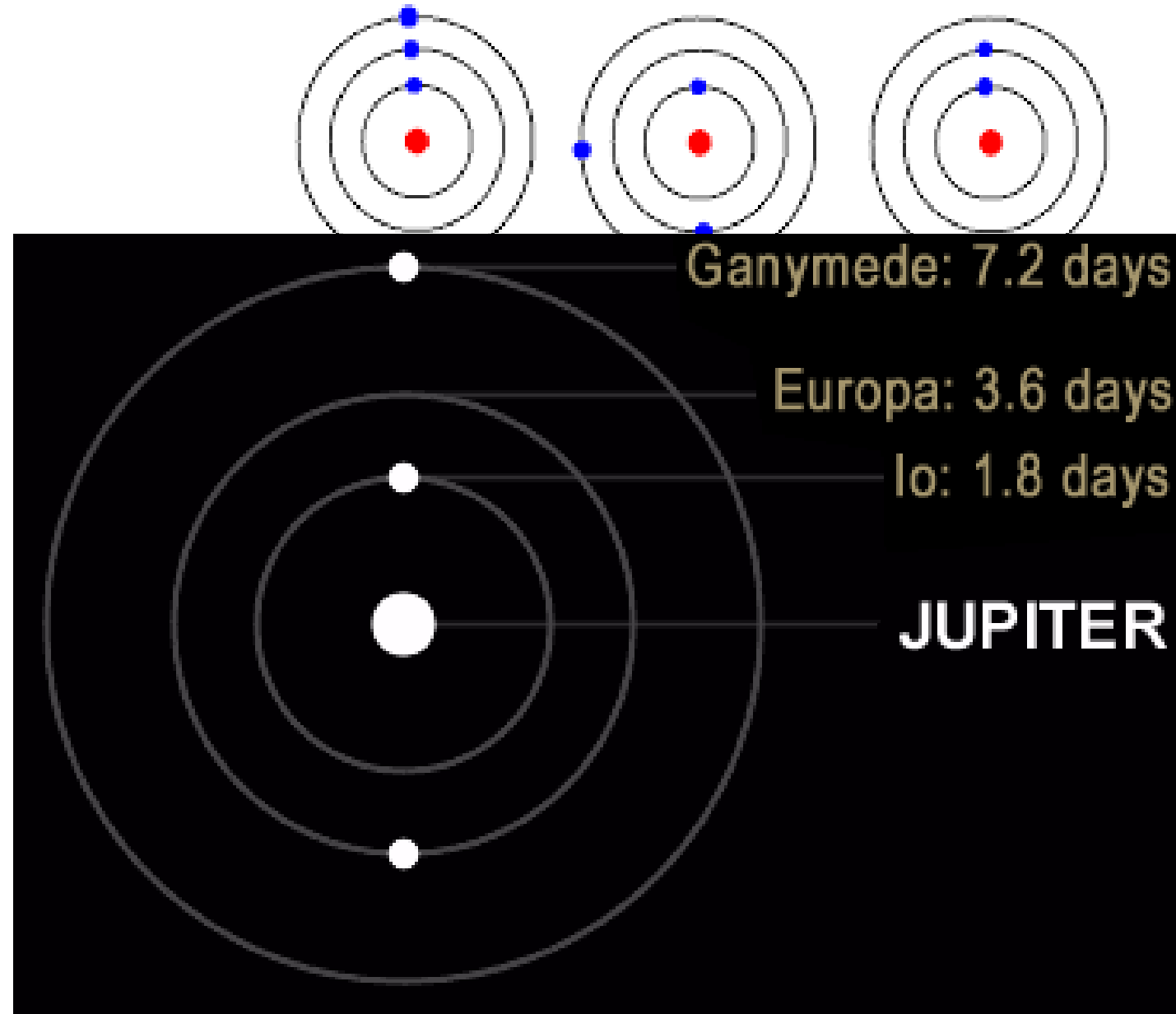
The Solar System: Planets and Moons

- Neptune's moon **Triton** has a **highly inclined**, unstable orbit that is taking it closer to Neptune; it will be broken apart from **tidal forces**.
- **Tidal heating** is caused by the internal frictions from this.
- Rotational kinetic energy is converted into thermal energy.
- This causes the moon's spin to slow and fall into a **synchronous rotation** – rotation and orbit time are the same.
- It also ejects nitrogen from geysers (**cryovolcanism**) due to this.



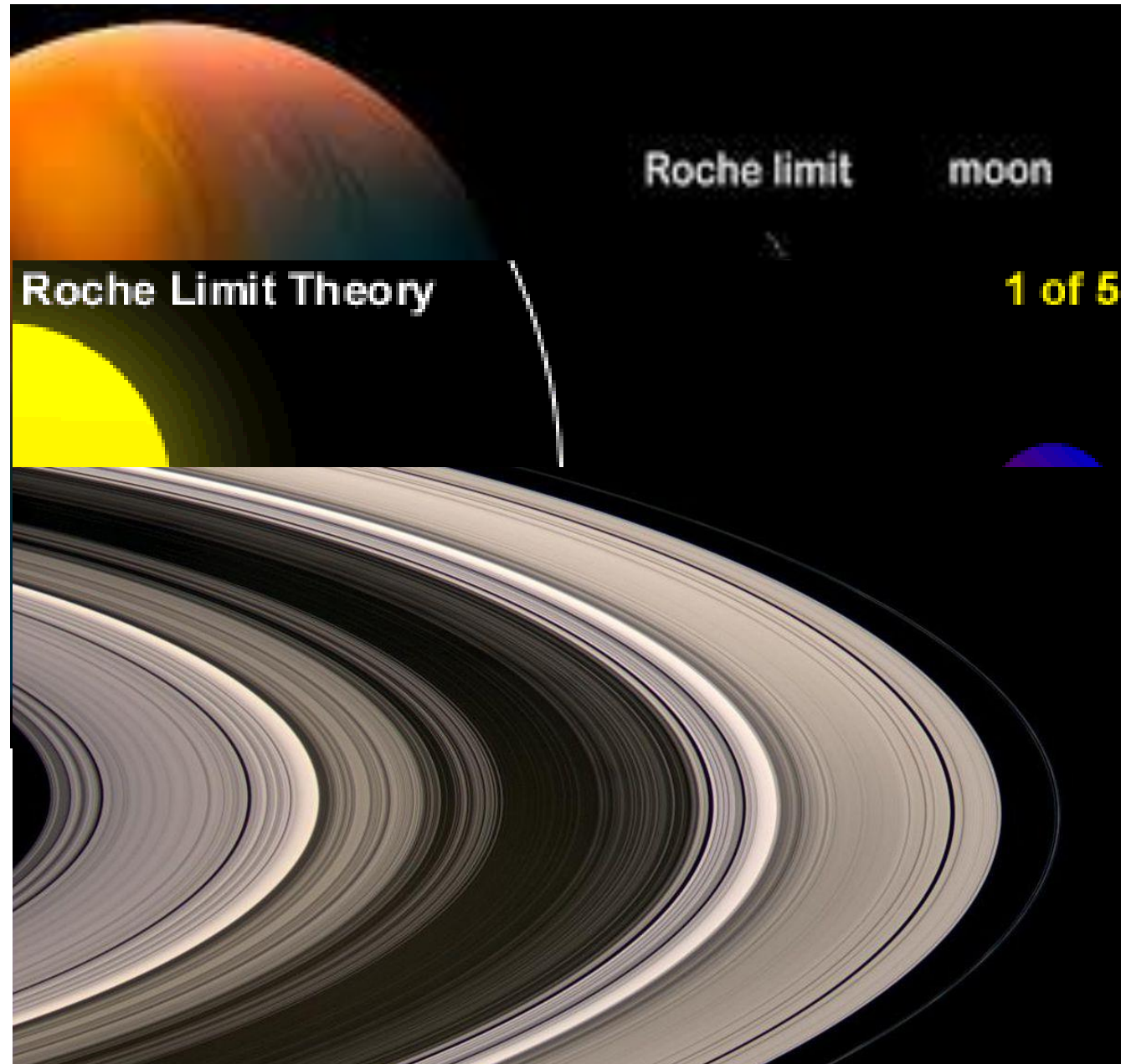
The Solar System: Planets and Moons

- Multiple moons around one planet can cause **orbital resonance**.
- The Moons of Jupiter – Ganymede, Europa and Io – orbital periods are in the exact ratio of **4:2:1**.
- Regular gravitational tugs cause **tidal heating**.



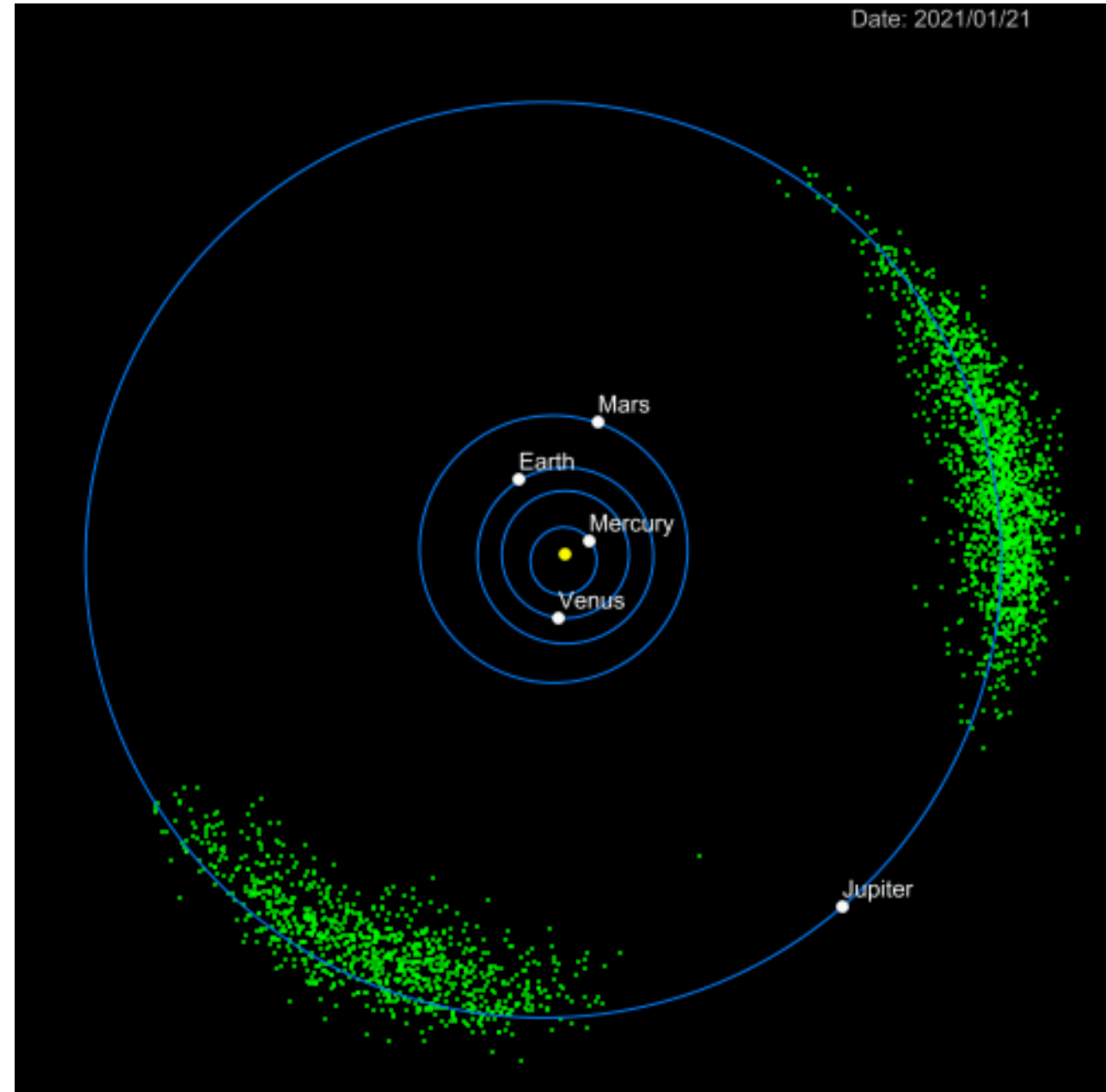
The Solar System: Planets and Moons

- If a body's internal elastic forces which resist the deformation are not strong enough, the tidal force will break it apart (or prevent it from forming).
- The minimum distance to orbit a parent body without breaking apart is the **Roche Limit**.
- It is approximately **2.5 x** the radius of the parent body.
- This is a likely explanation for ring systems



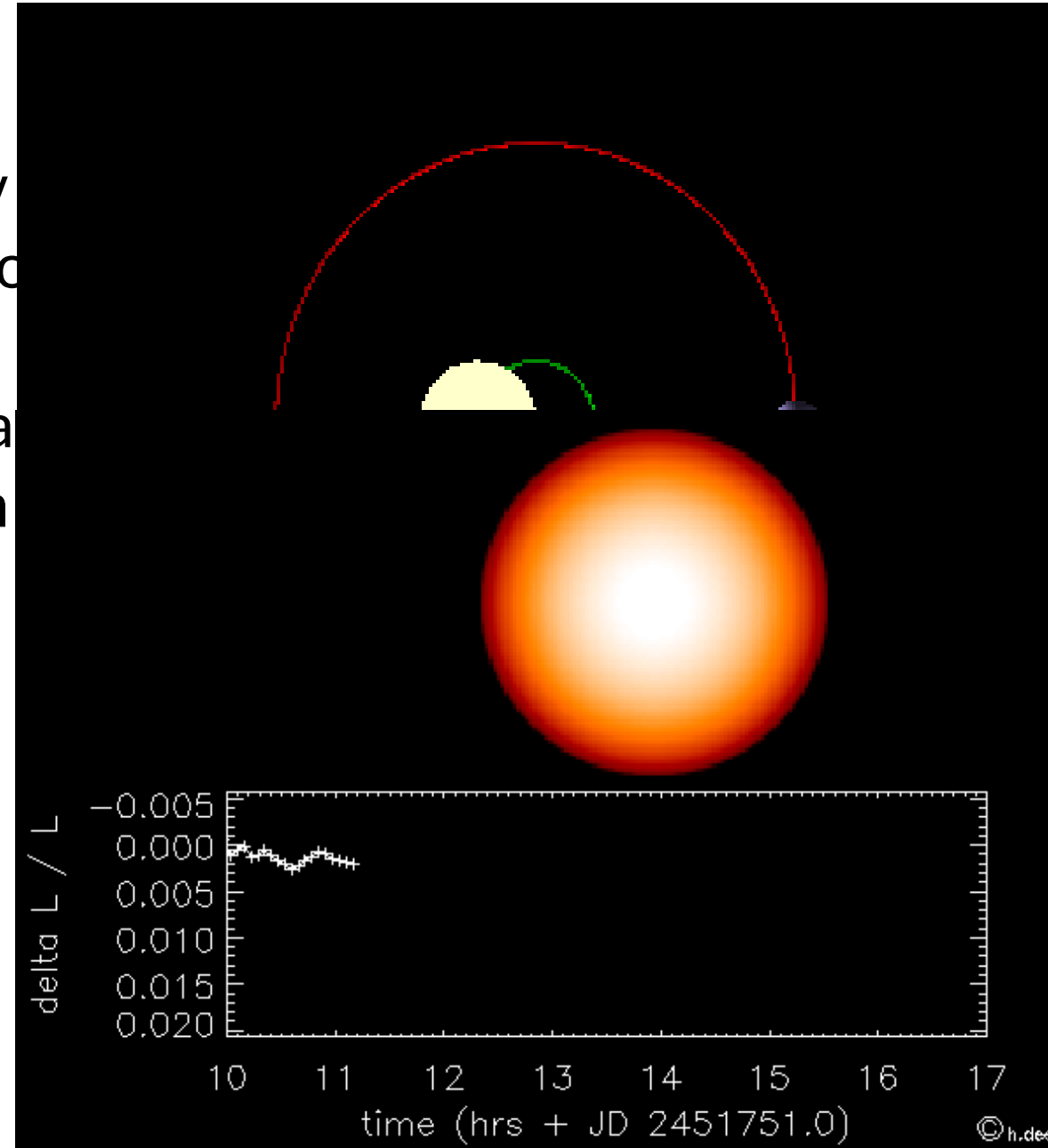
The Solar System: Planets and Moons

- **Lagrangian Points** are points at which the combined gravitational force due to 2 massive bodies are equal to the centripetal force needed for an orbit.
- At points L1-3 the orbits are unstable.
- Points L4 and 5 are **stable** and an object placed there will remain in a stable orbit.
- In Jupiter's there are several Trojan asteroids.



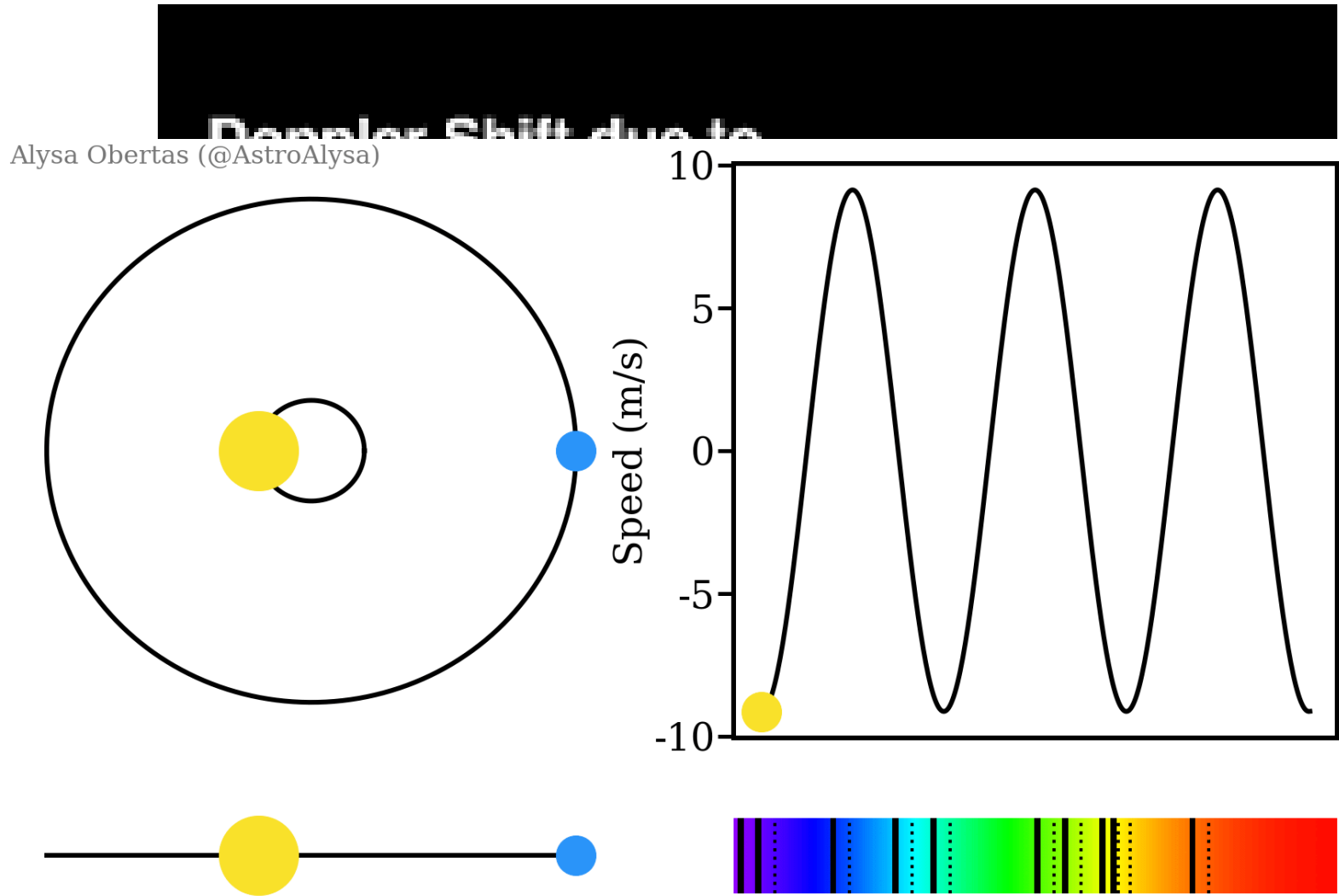
Exoplanets

- The first system of **exoplanets** was discovered in 1995. Since then many more have been found using 3 indirect methods:
 1. **Astrometry** – a massive exoplanet can cause a star to ‘wobble’ as they both orbit around a common centre of gravity.
 2. **Transit method** – when an exoplanet moves across the disc of the star its brightness drops (by 1%) - this is known as a wink.



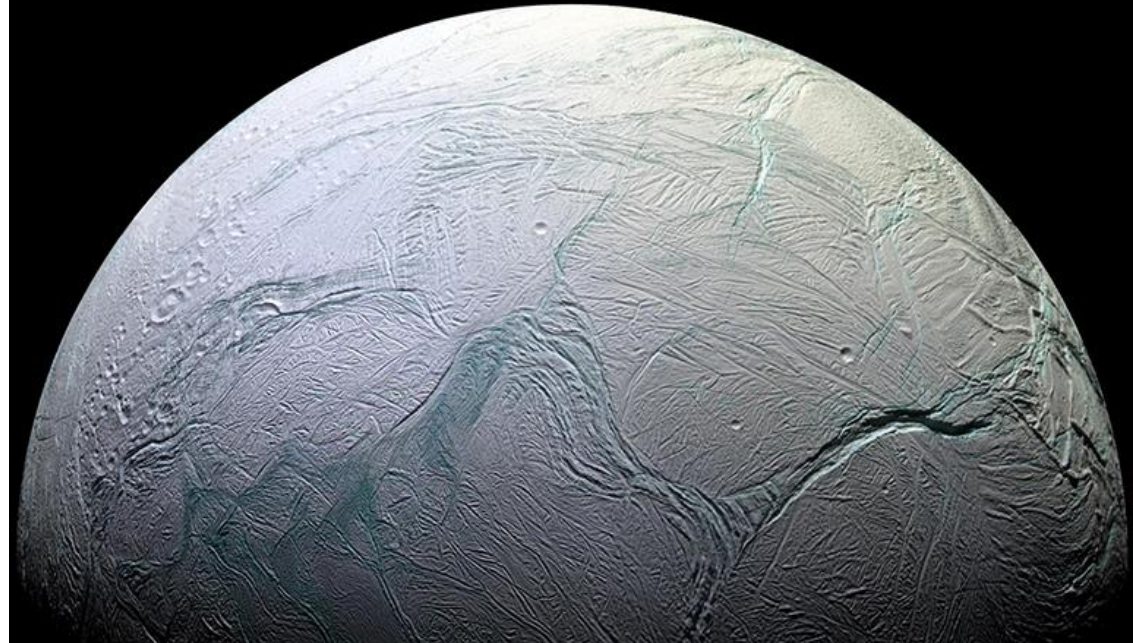
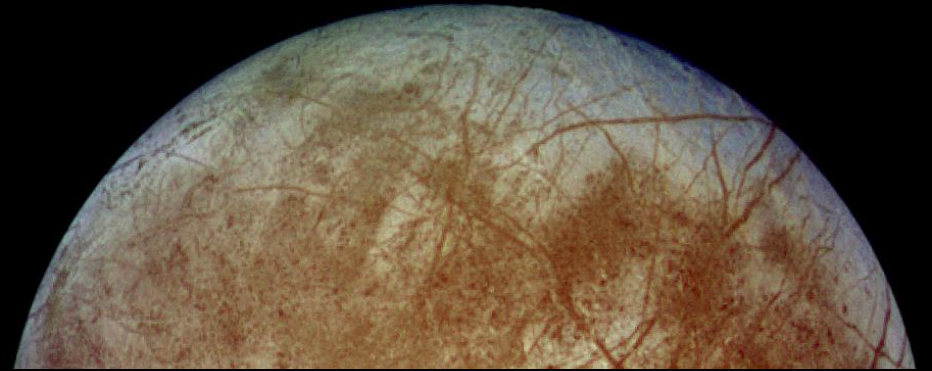
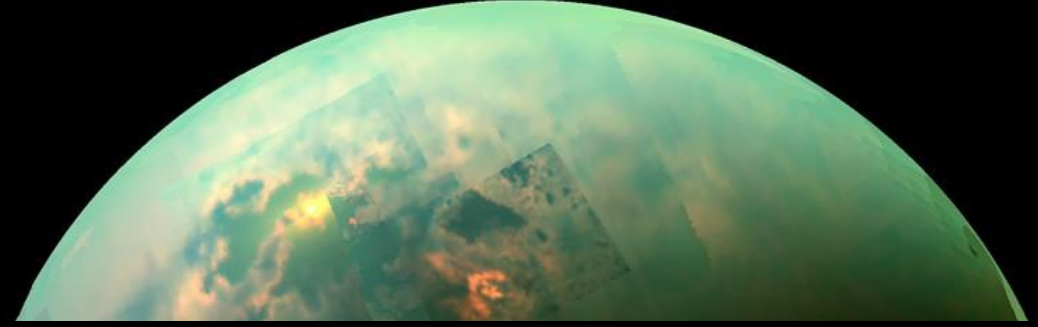
12.2 Exoplanets

3. **Radial velocity method** – the light from an object changes depending on its motion (Doppler effect). As a star ‘wobbles’, spectroscopy can be used to observe its spectral lines change.



Extra-Terrestrial life

- In addition to energy, carbon and water are needed for life.
- Carbon – makes **complex molecules** such as amino acids – the building blocks for organic life.
- Water – an excellent **solvent** to **transport nutrients**.
- There are 3 possible candidates for life in our Solar System:
 1. Titan
 2. Europa
 3. Enceladus



Extra-Terrestrial life

- For planets to support life outside of our Solar System is must be within a star's **Habitable Zone**.
- The **Drake Equation** estimates a figure for the number of civilisations in our galaxy that might have the technology to communicate with us.

