Cassini MAPS highlights: Moon-magnetosphere interactions

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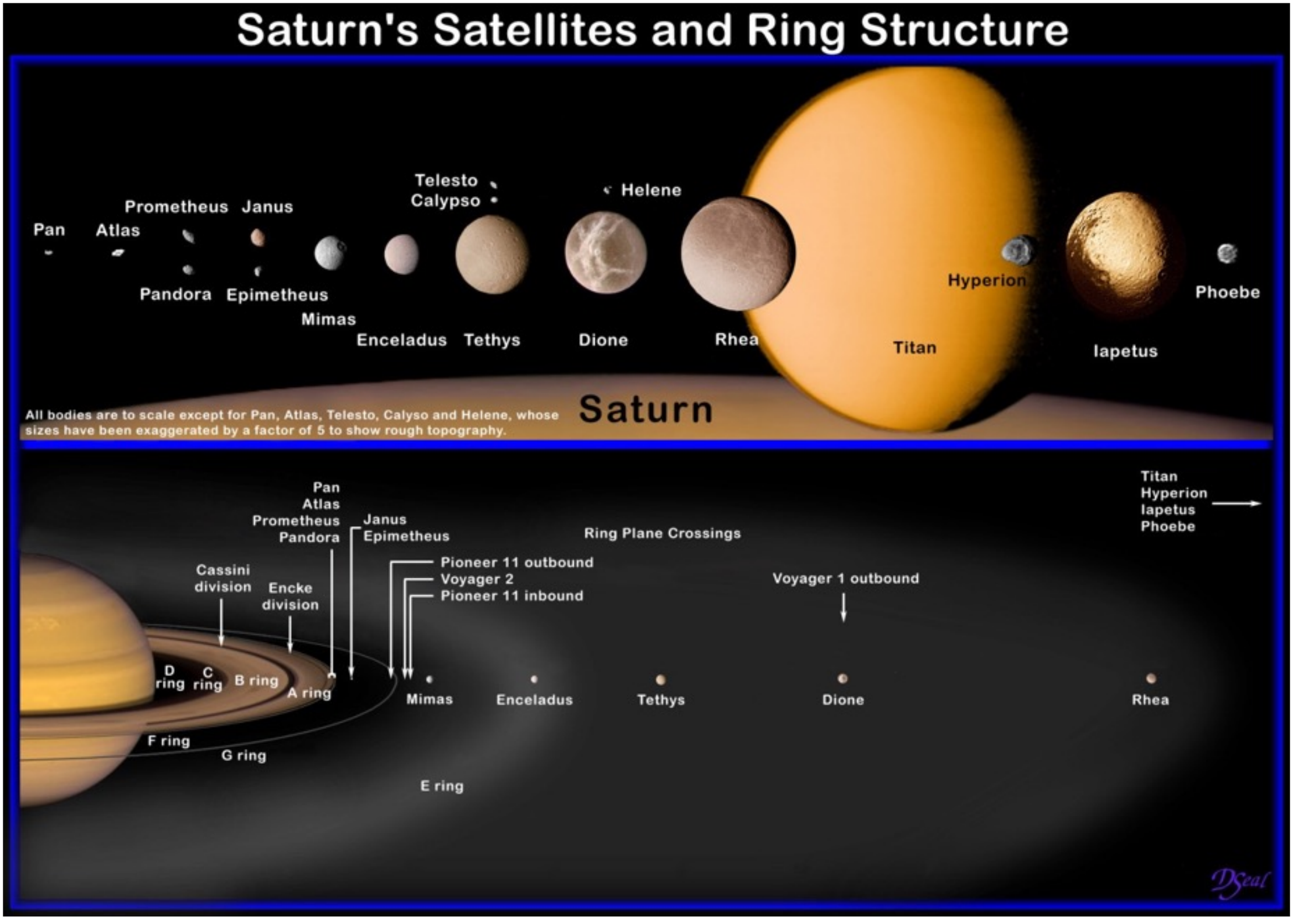
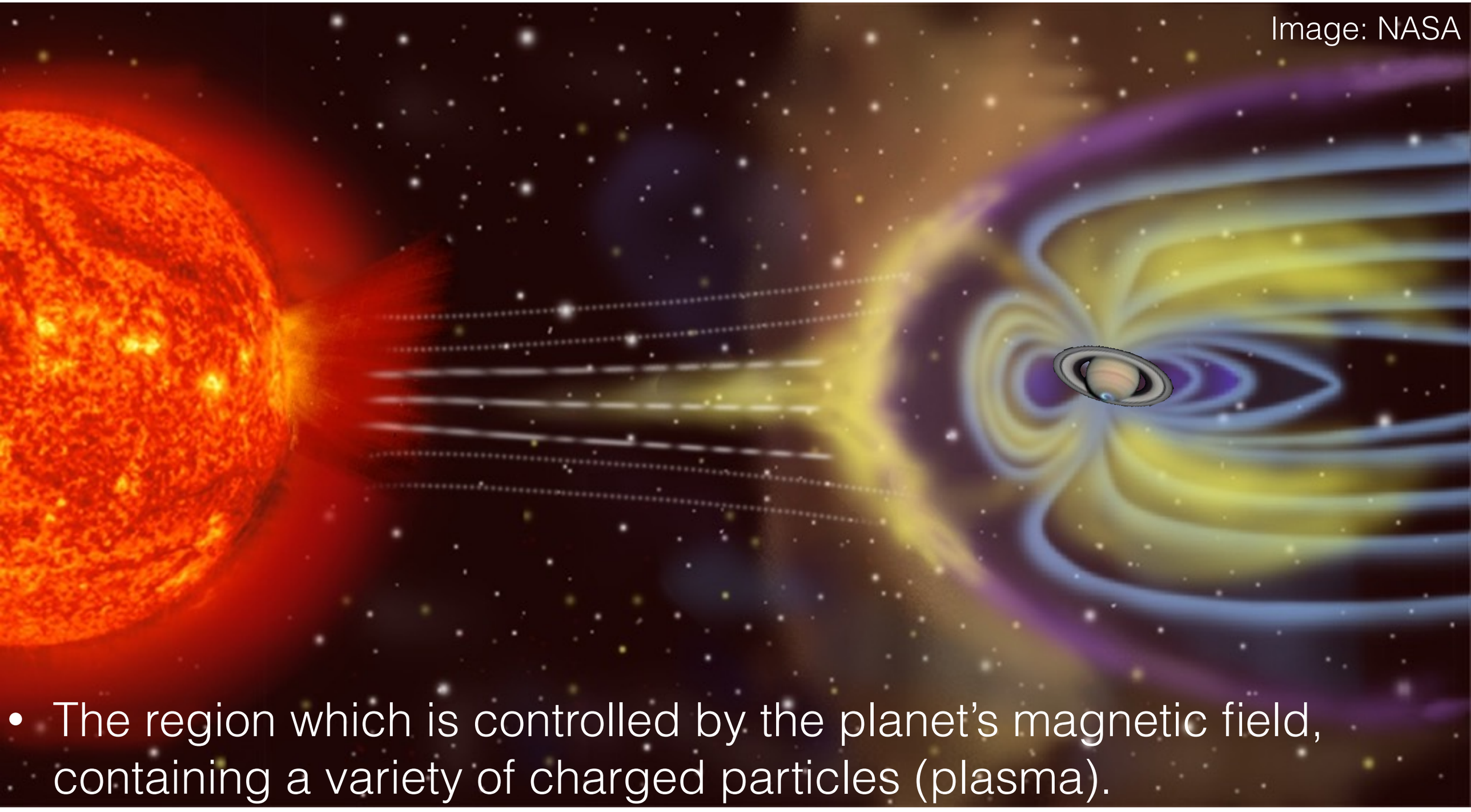
Thanks to Geraint Jones (MSSL/UCL, UK), Andrew Coates (MSSL/UCL, UK), Tamas Gombosi (U. Michigan, USA), Norbert Krupp (MPS, Germany)

28 July 2015

Saturn's Satellites and Ring Structure

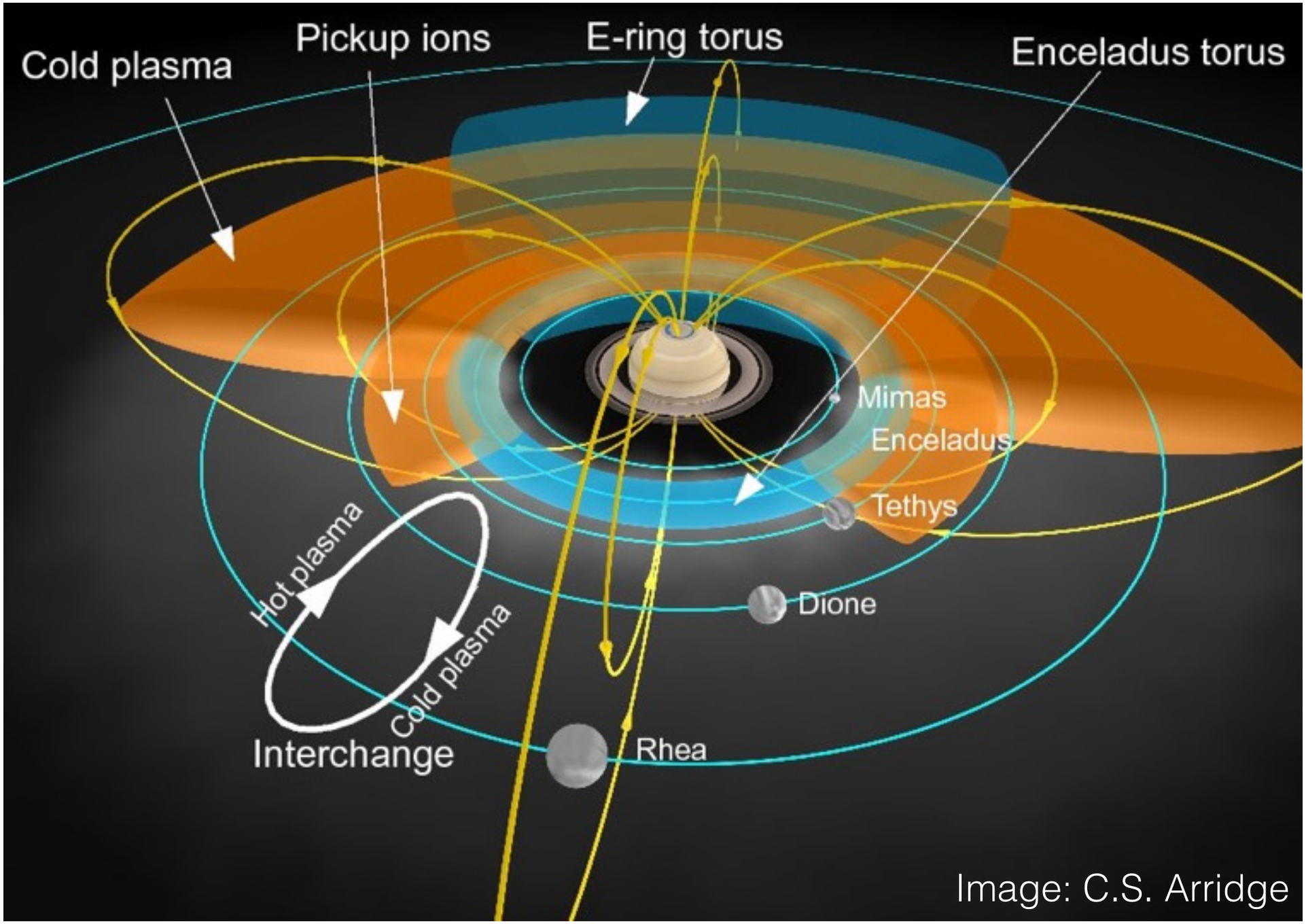


Magnetosphere



- The region which is controlled by the planet's magnetic field, containing a variety of charged particles (plasma).

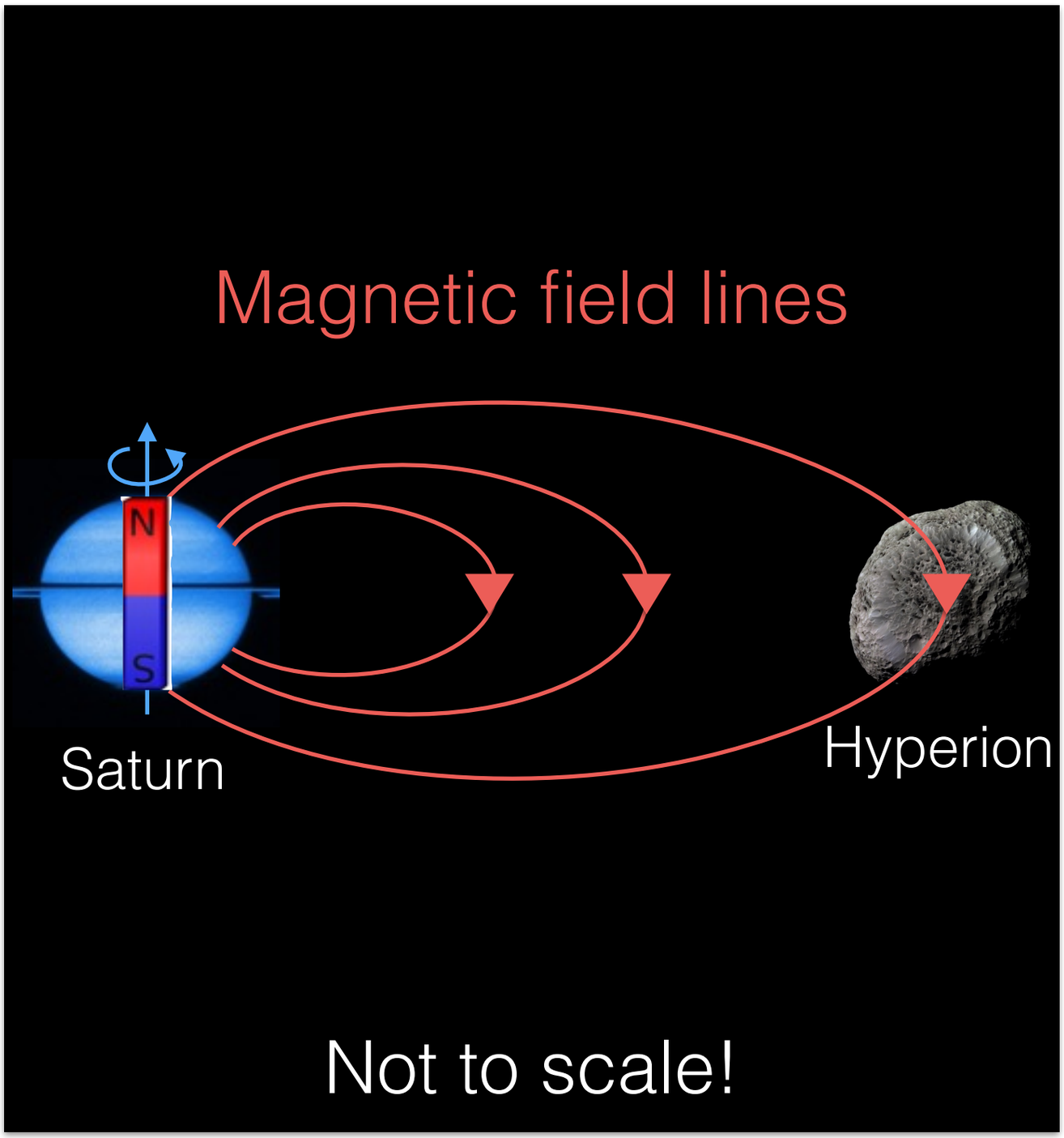
Moons interact with the magnetic field and plasma



Hyperion

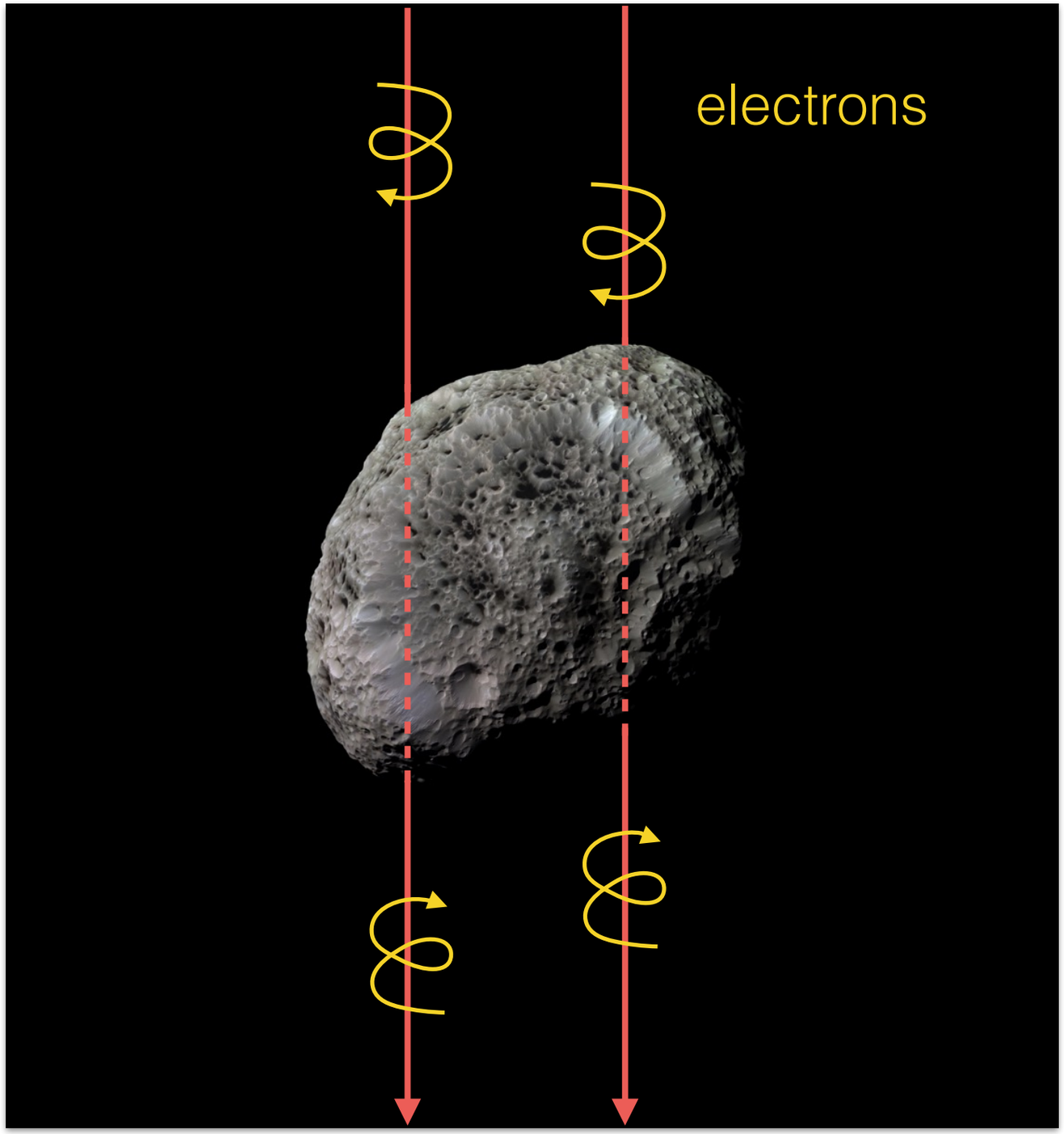
- Vital statistics:
- size 180 x 133 x 103 km
- low density - mainly water ice?
- orbits at ~25 R_S (1 R_S = Saturn radius = 60268 km)

Hyperion in Saturn's magnetic field



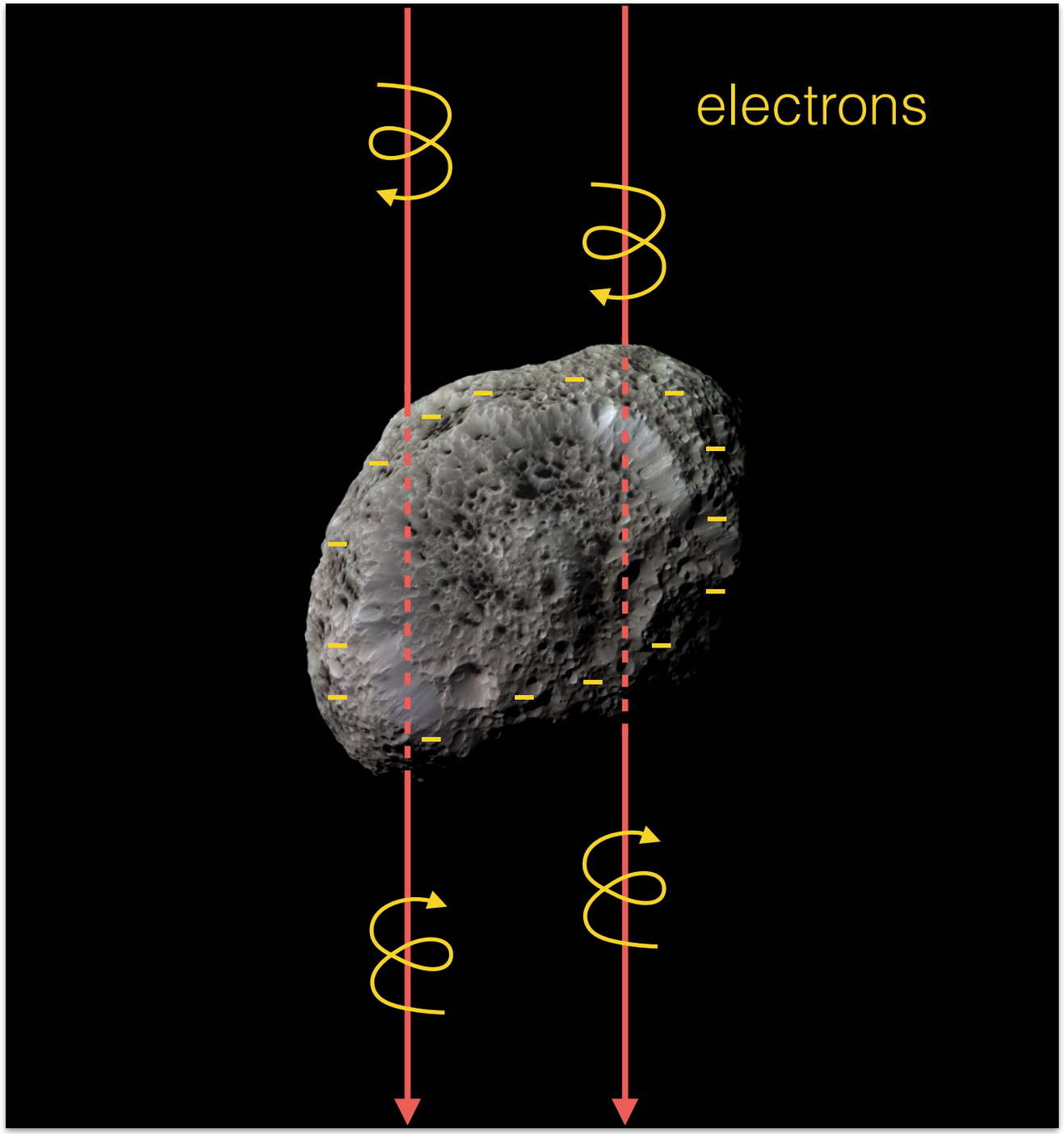
- Saturn's magnetic field rotates over Hyperion with a rotation period of ~11 h

Electron absorption



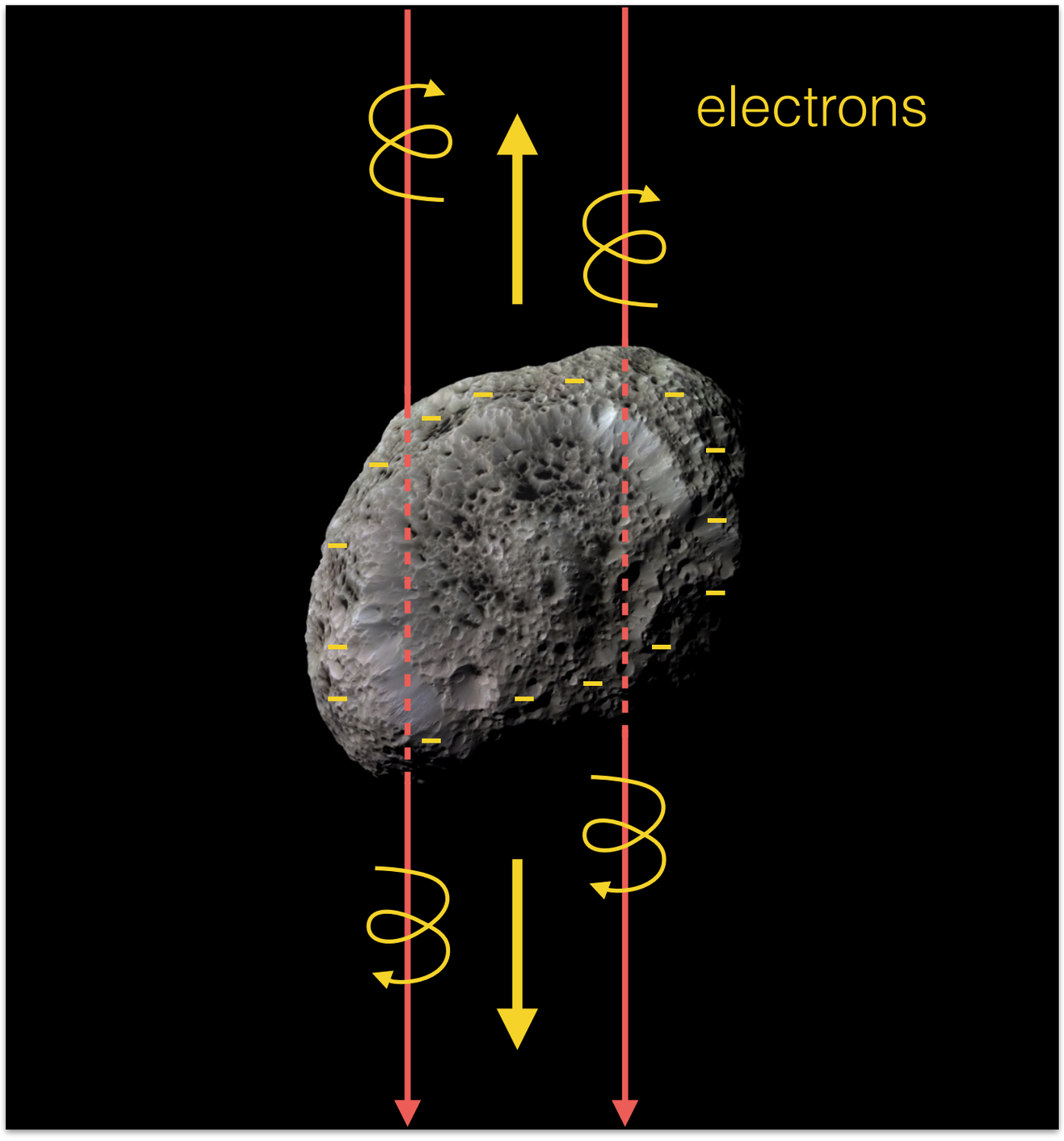
- Saturn's magnetic field lines move past Hyperion
- Electrons travelling along the magnetic field lines are absorbed by the moon

Surface charging



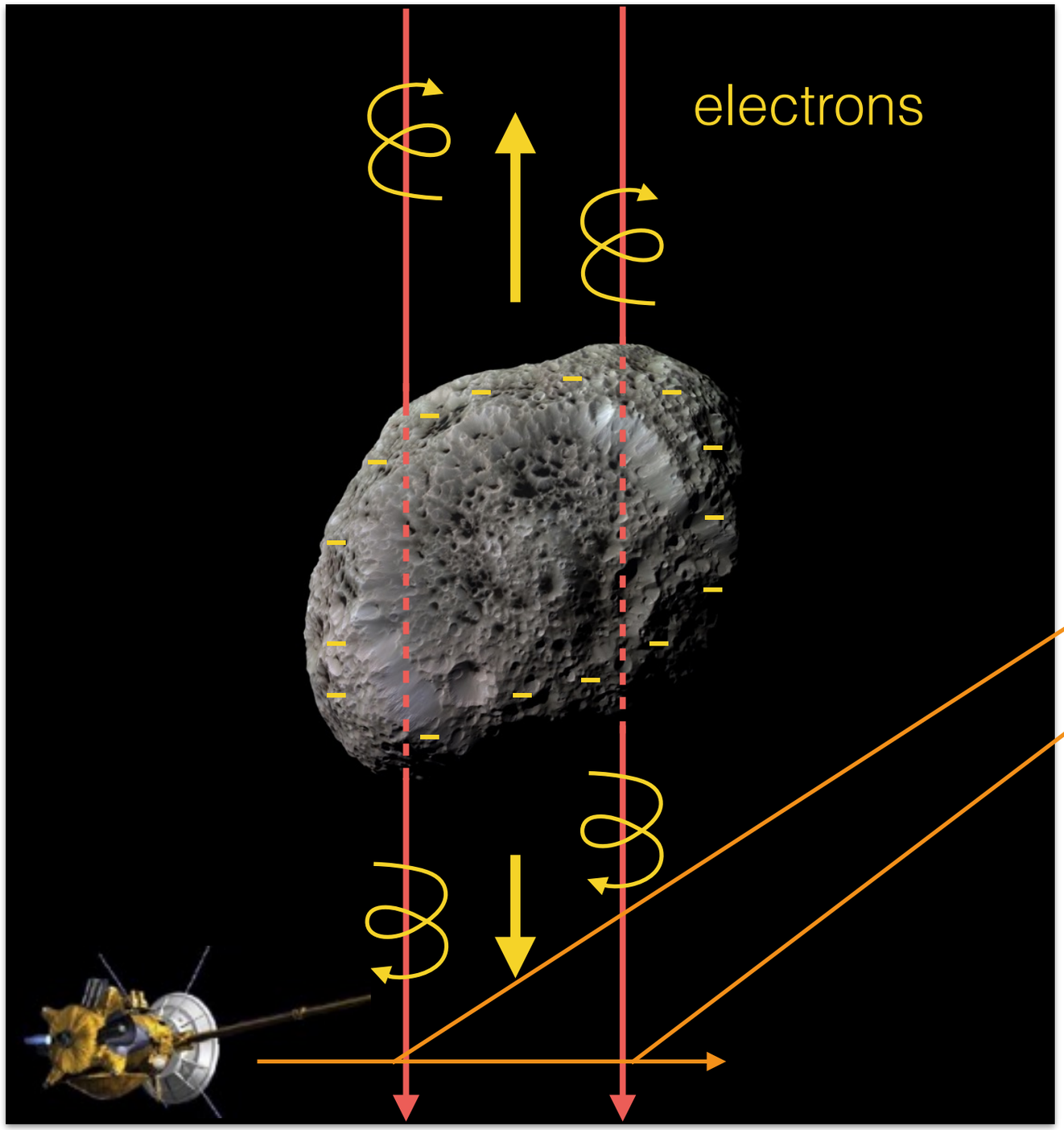
- Magnetic field lines move past Hyperion
- Electrons travelling along the magnetic field lines are absorbed by the moon
- The electrons make the moon surface negatively charged

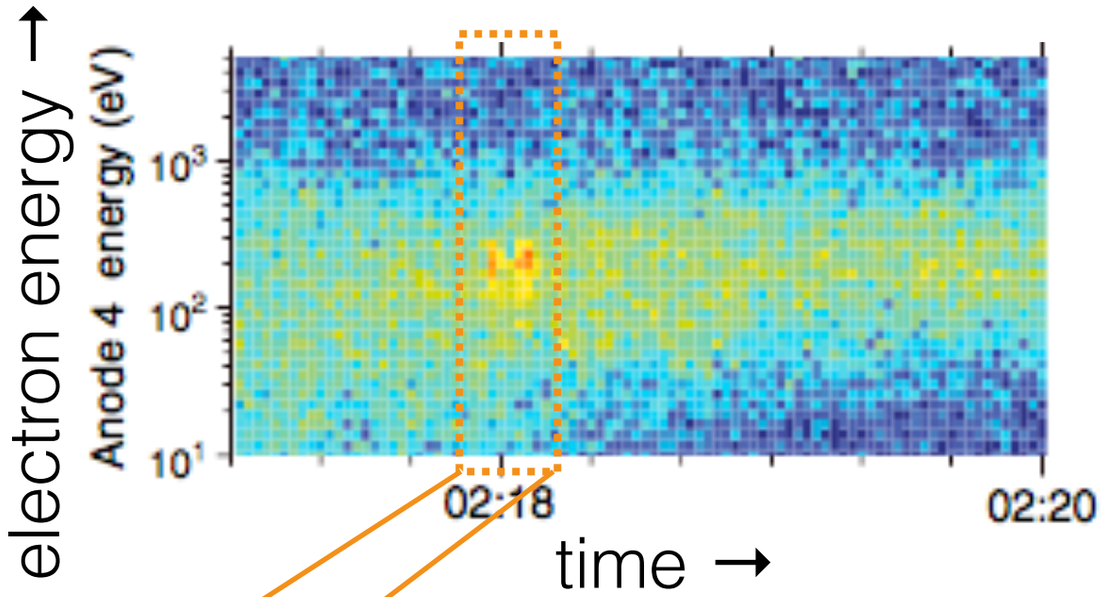
Electrons repelled



- Magnetic field lines move past Hyperion
- Electrons travelling along the magnetic field lines are absorbed by the moon
- The electrons make the moon surface negatively charged
- The negatively charged surface repels other electrons, accelerating them away from the moon

Cassini measurements

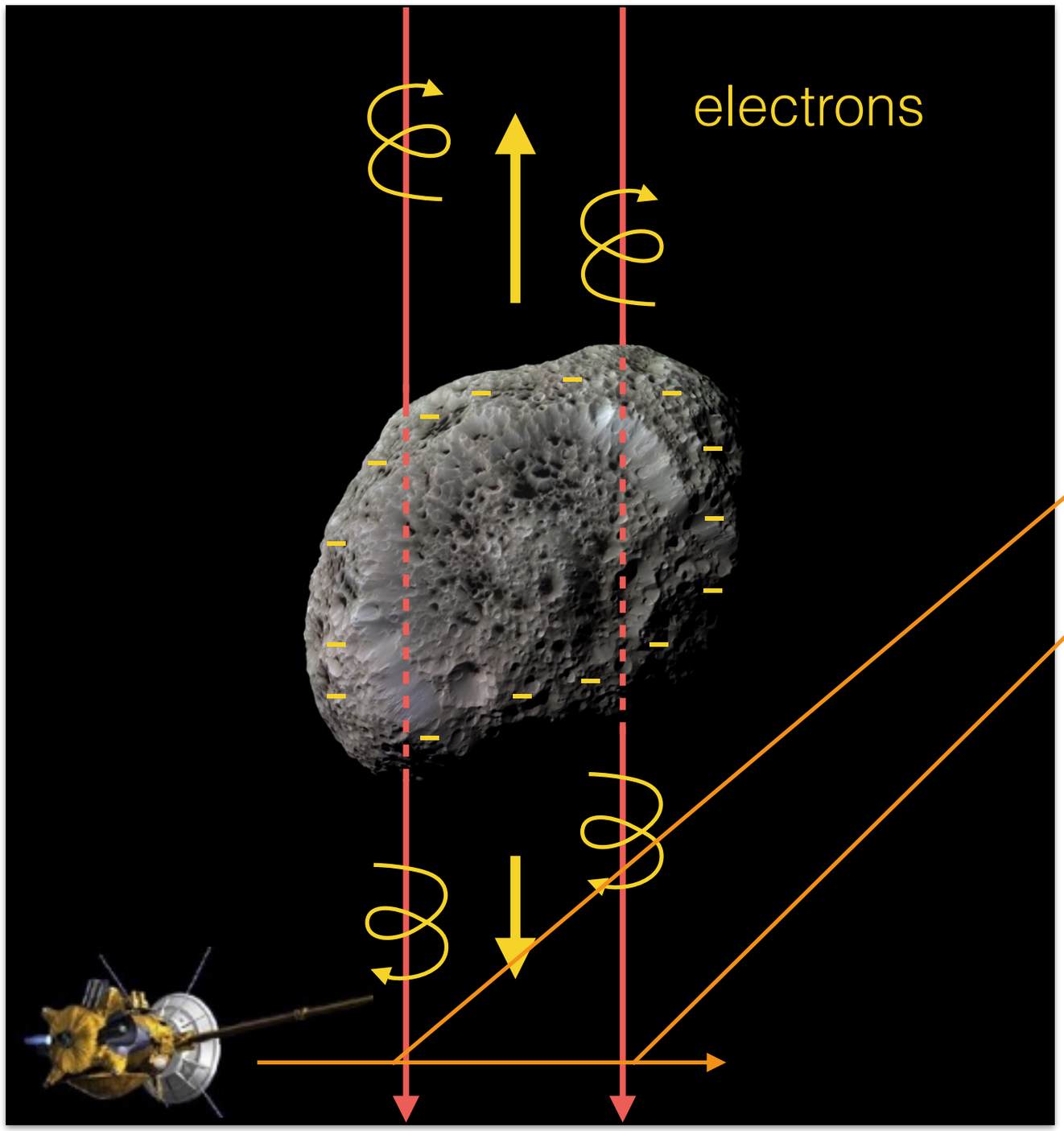


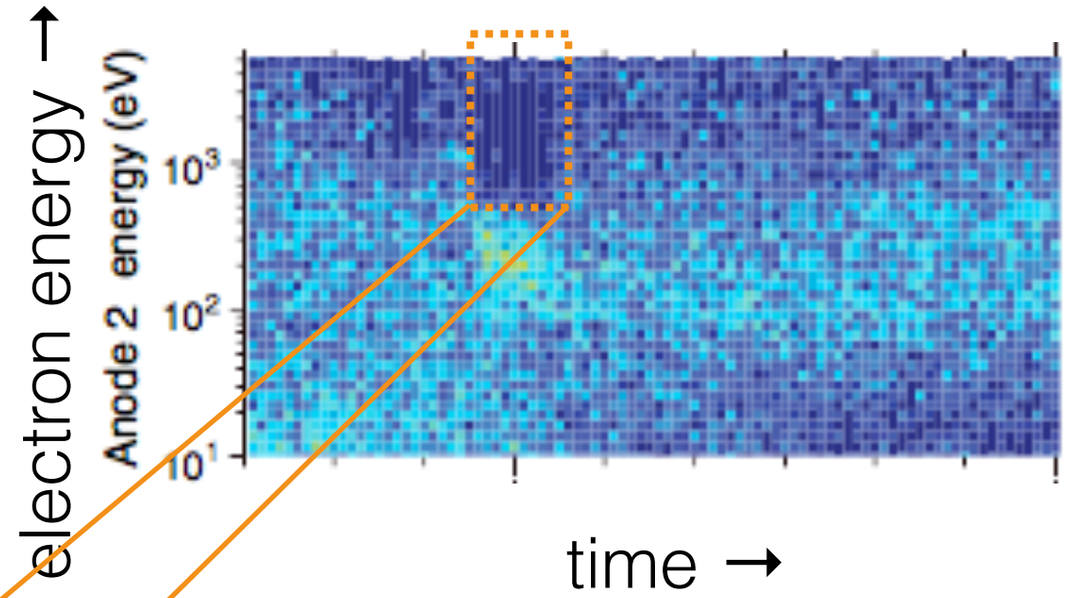


Nordheim et al., GRL, 2014.

- When Cassini flew through the magnetic field lines connected to Hyperion it measured the repelled electrons

Cassini measurements

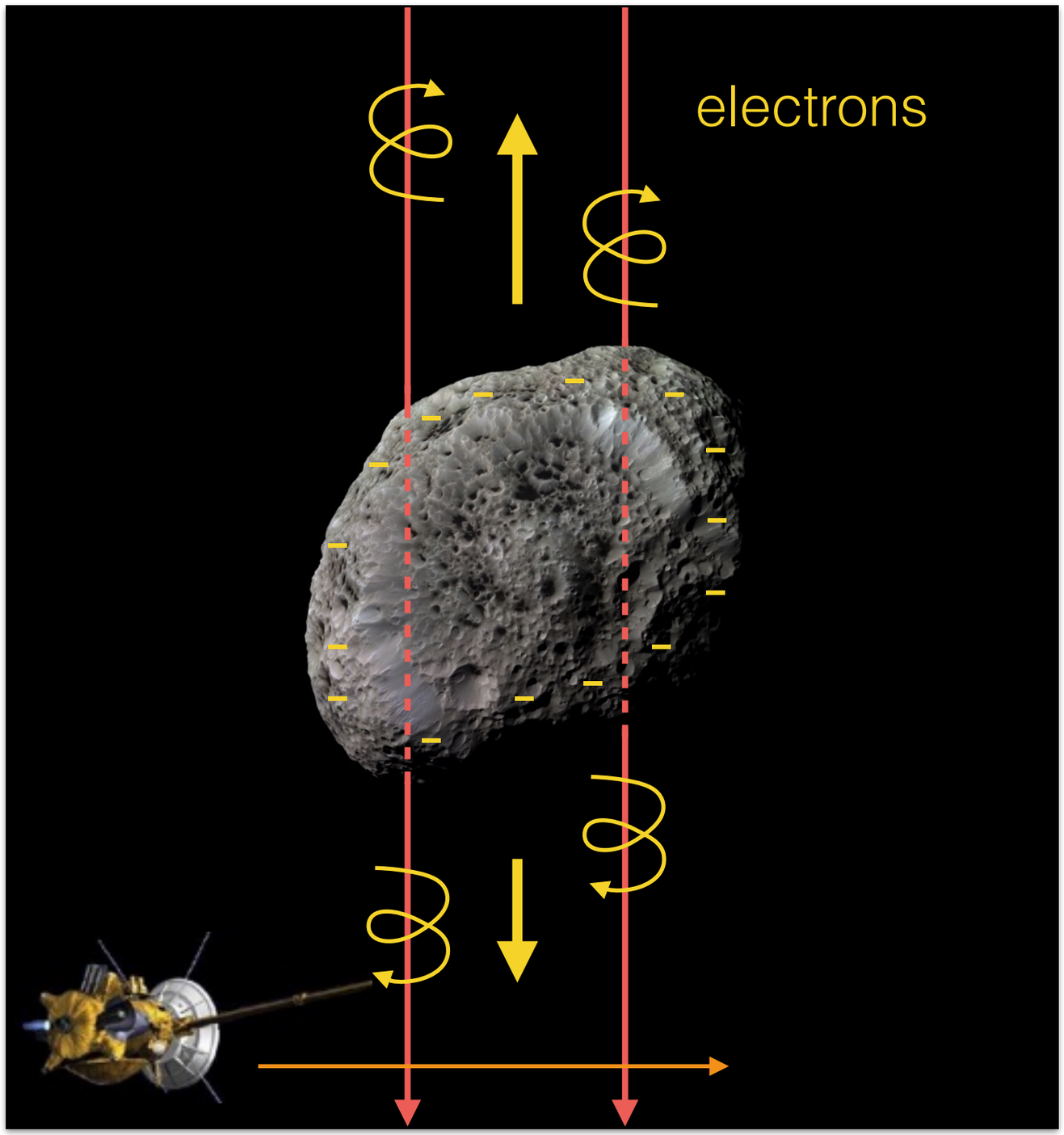




Nordheim et al., GRL, 2014.

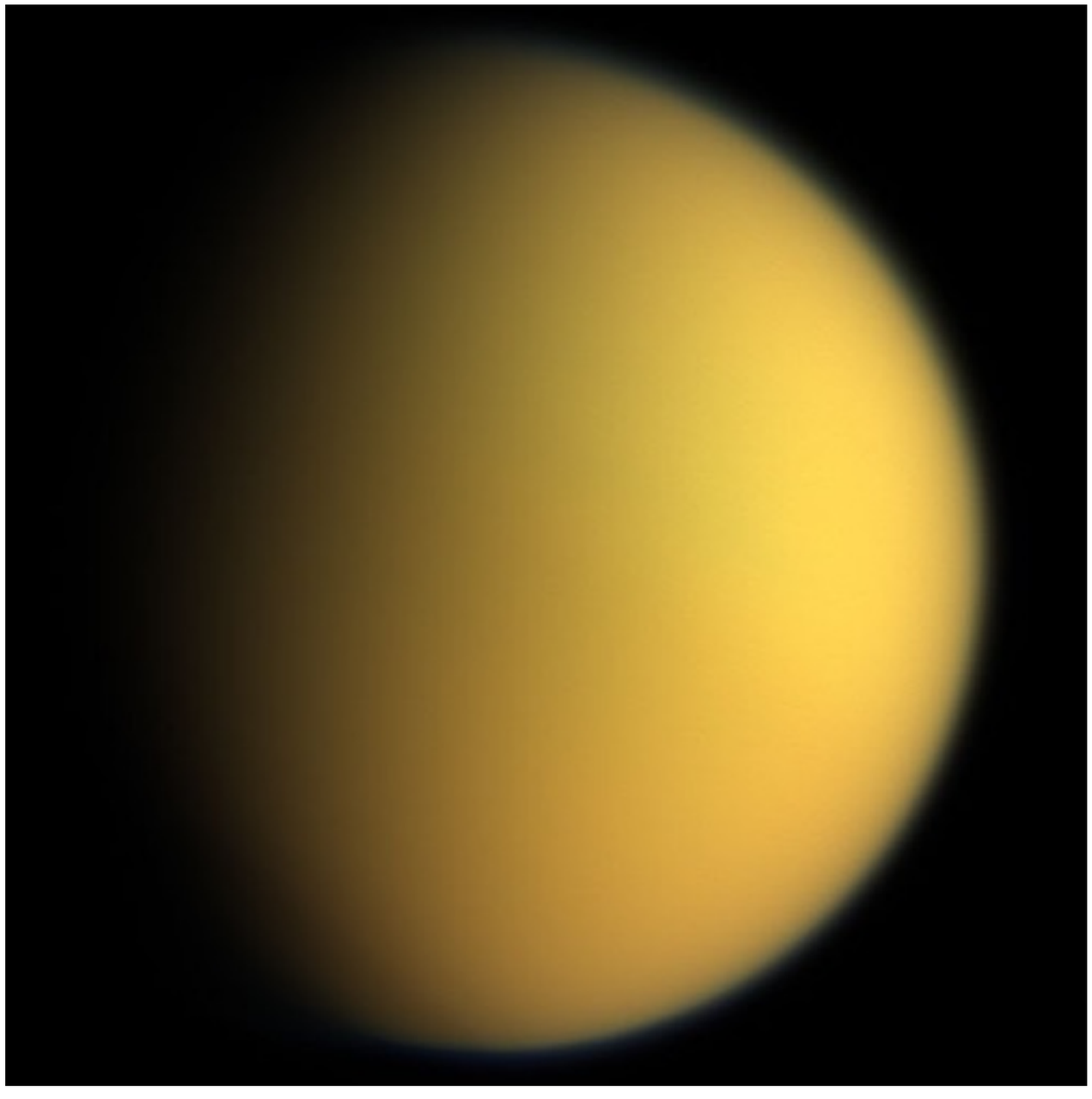
- Cassini also detected a drop-out in the higher energy electrons which had been absorbed by the moon

Hyperion: an electron accelerator



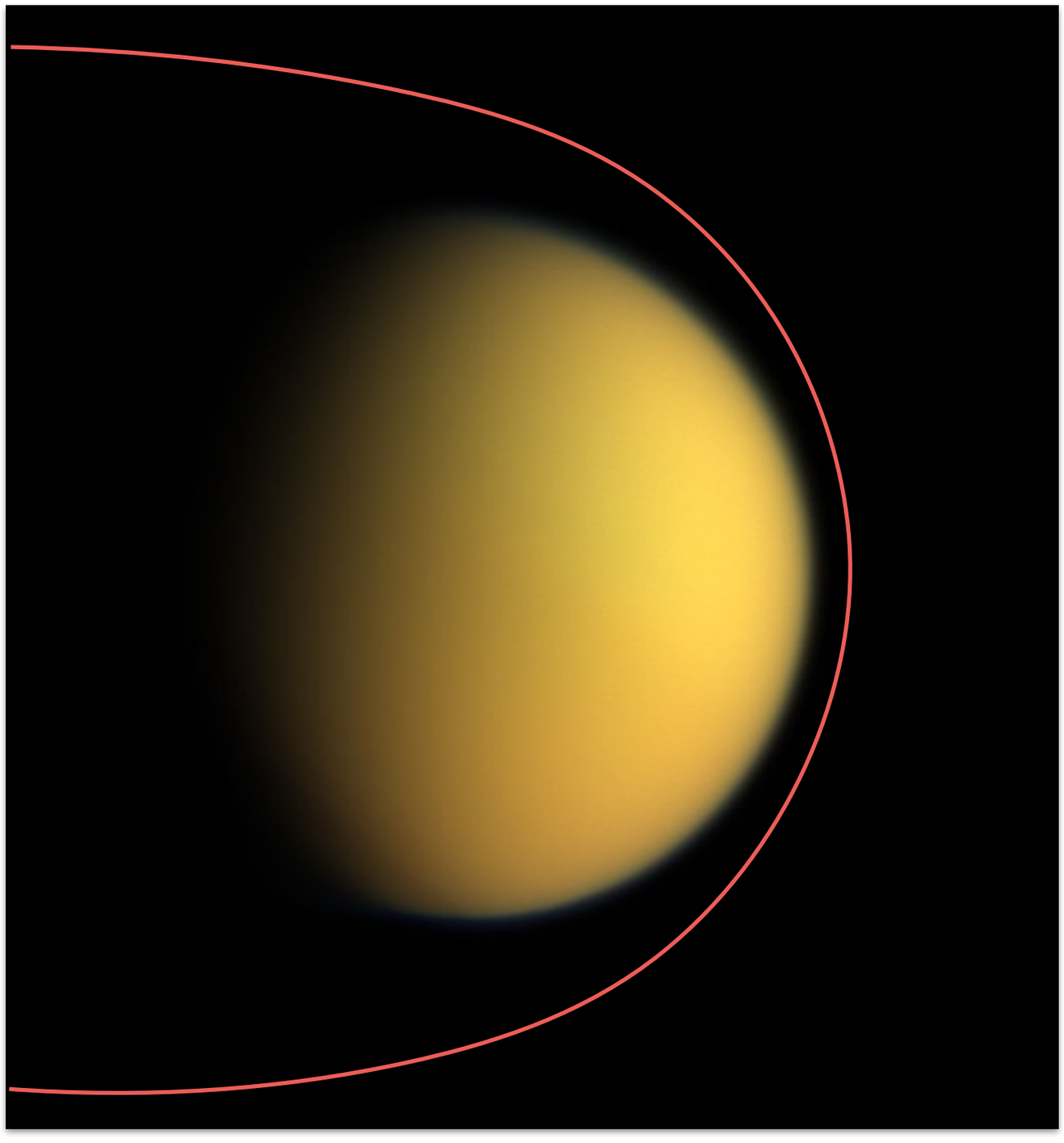
- Hyperion's surface was electrically charged to around -200 volts by plasma from Saturn's magnetosphere striking it.
- Low energy electrons were accelerated up to the spacecraft by the large potential difference. Cassini can remotely detect charging conditions on moons.
- Surface charging of a natural body has previously only been observed at the Earth's Moon - first published detection in the Outer Solar System.
- Nordheim et al., GRL, 2014.

Titan



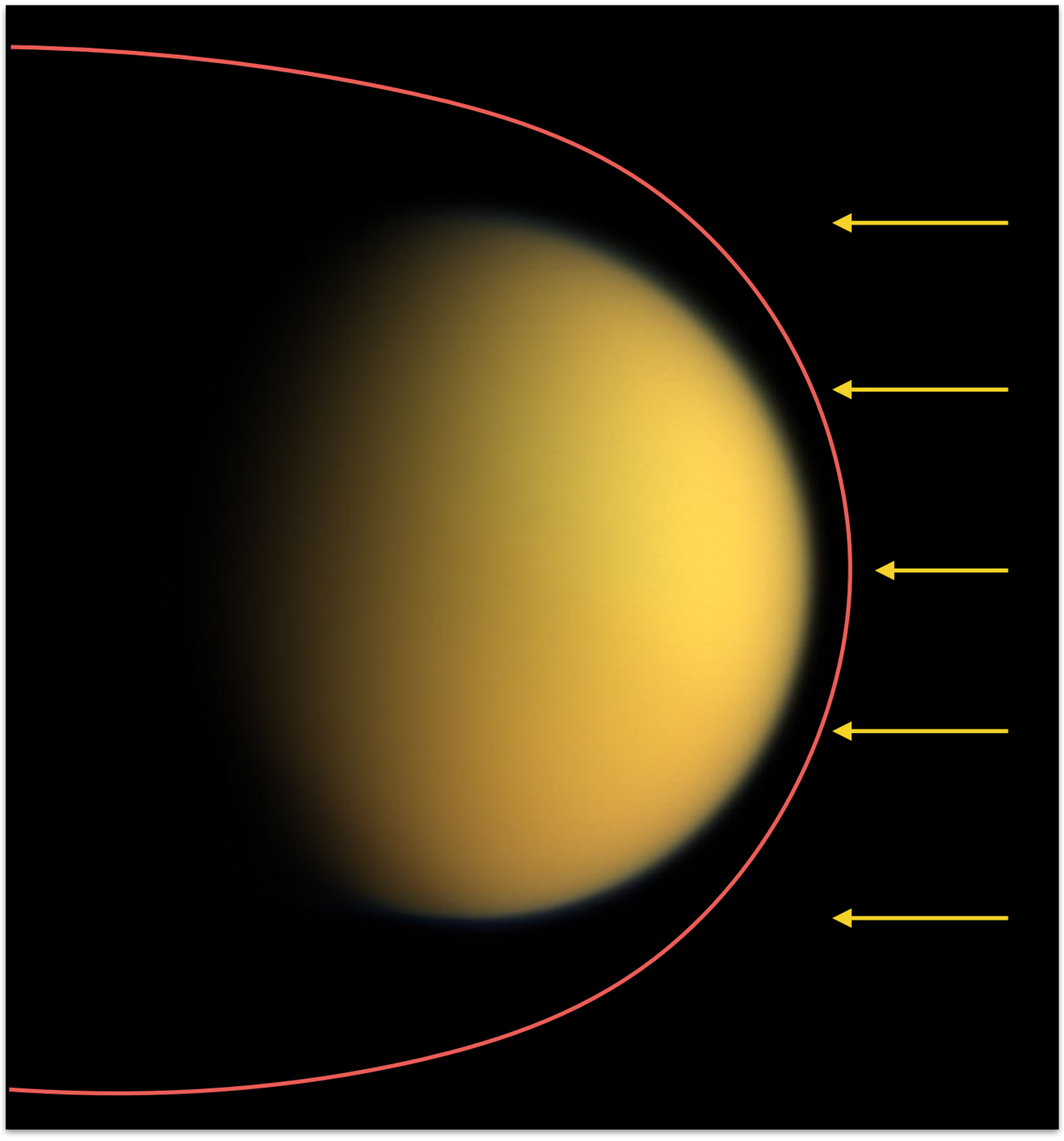
- Vital statistics
- diameter ~5000 km
- thick nitrogen atmosphere
- orbits at ~20 R_S (1 R_S = Saturn radius = 60268 km)

Magnetic field draping



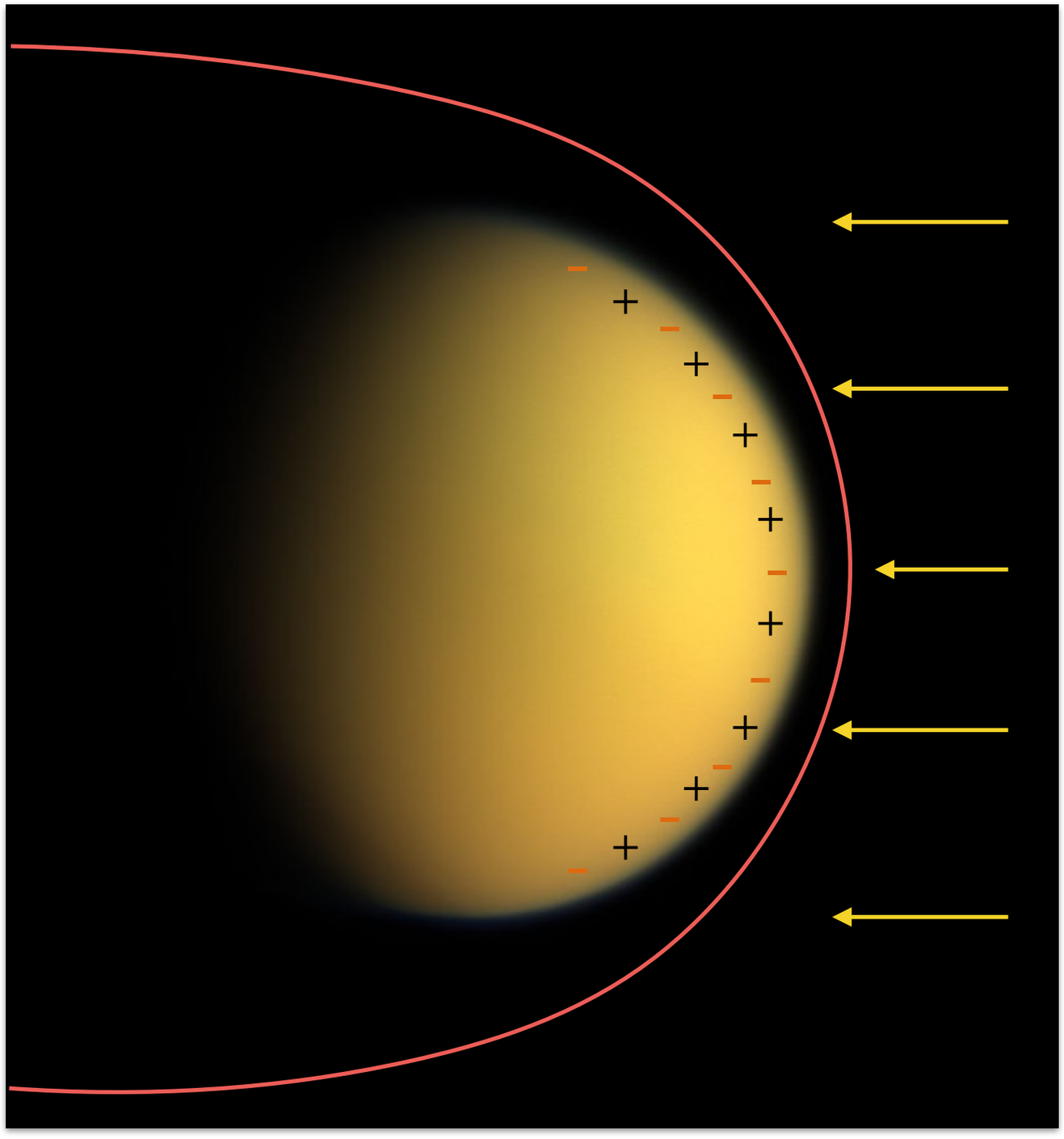
- Saturn’s magnetic field drapes around Titan’s thick atmosphere

Effect of sunlight



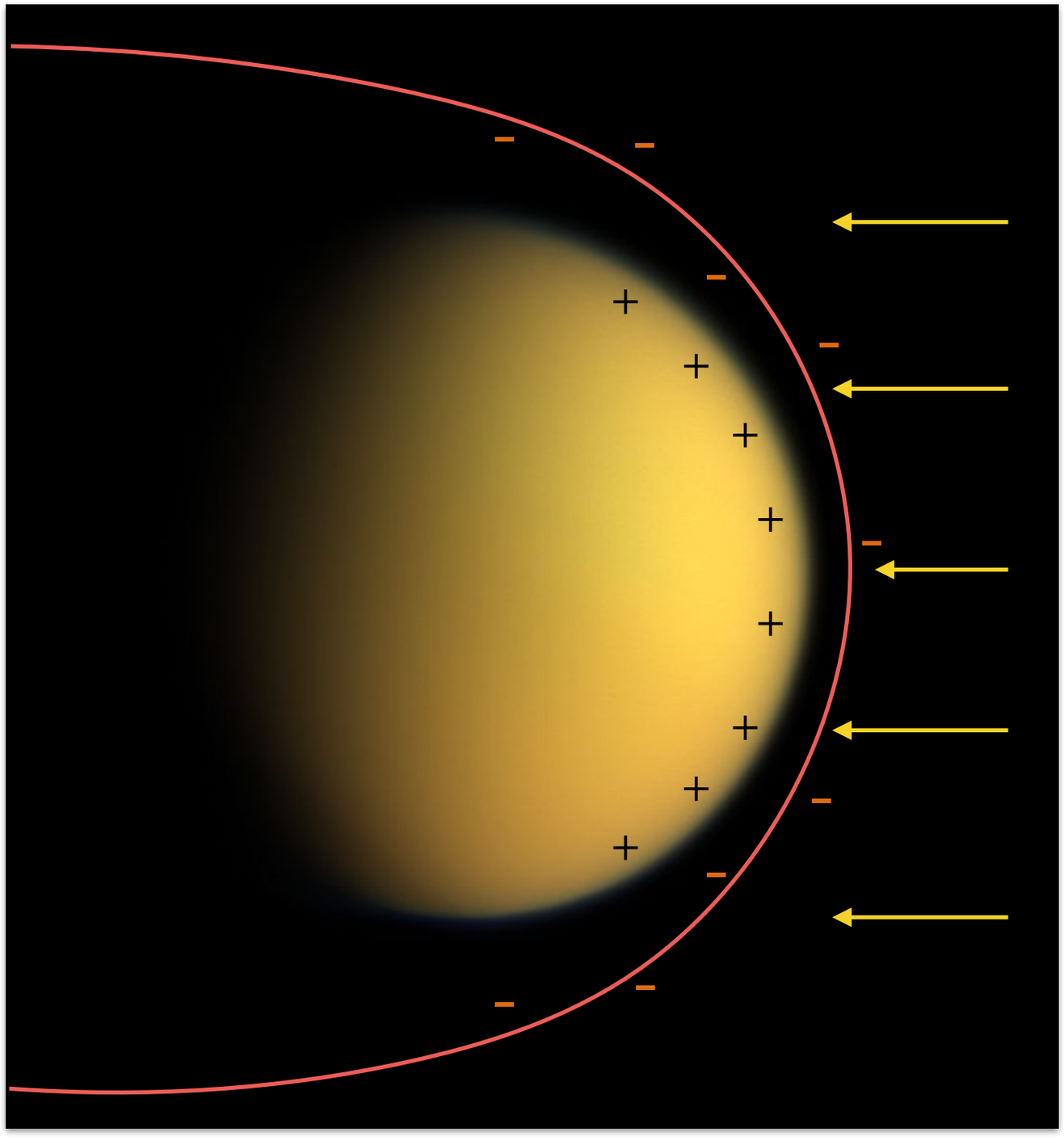
- Sunlight ionises Titan's atmosphere ("photoionisation")

Effect of sunlight



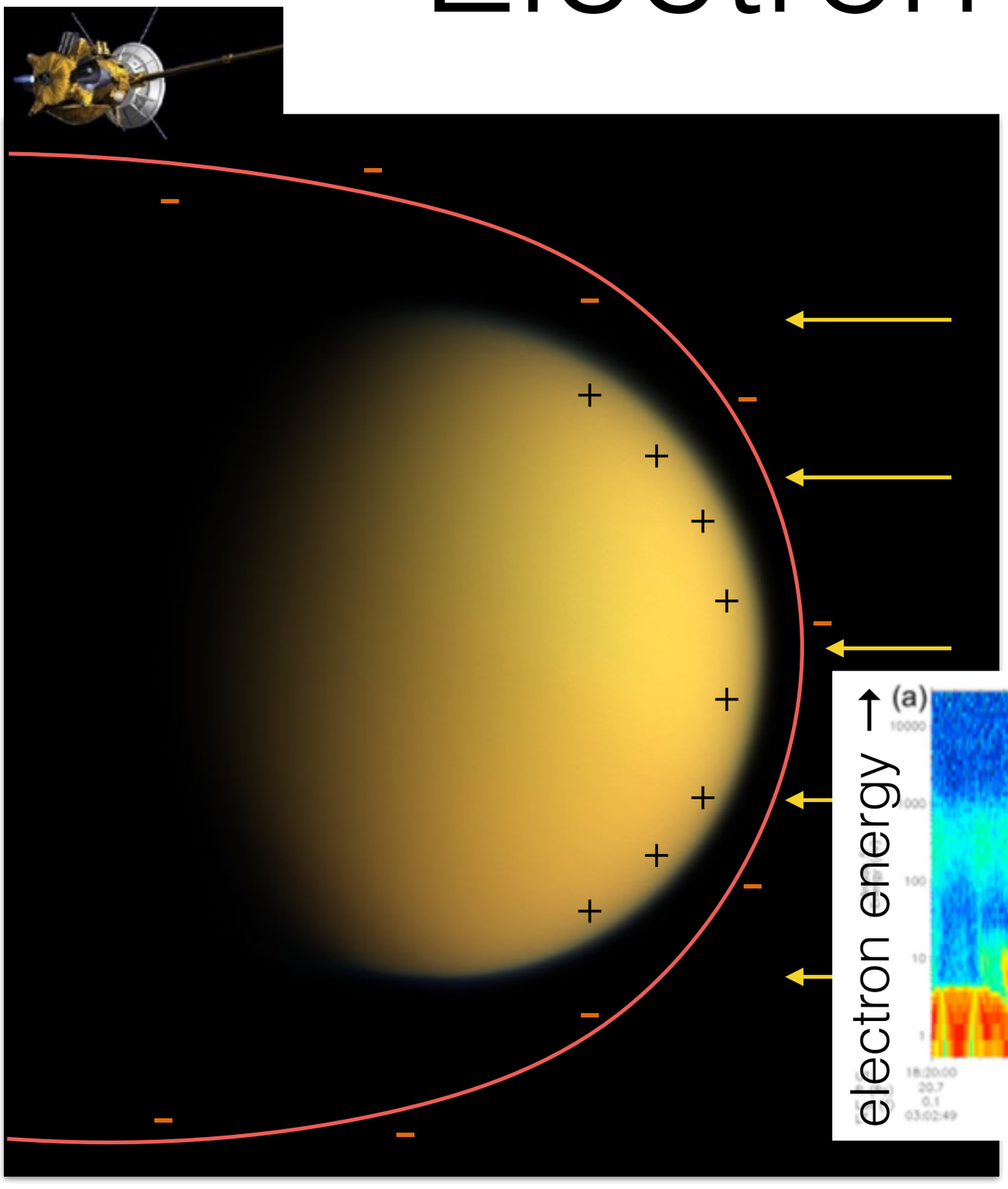
- Sunlight ionises Titan's atmosphere ("photoionisation")
- Electrons (-) separate from ions (+) in the upper atmosphere

Charge separation

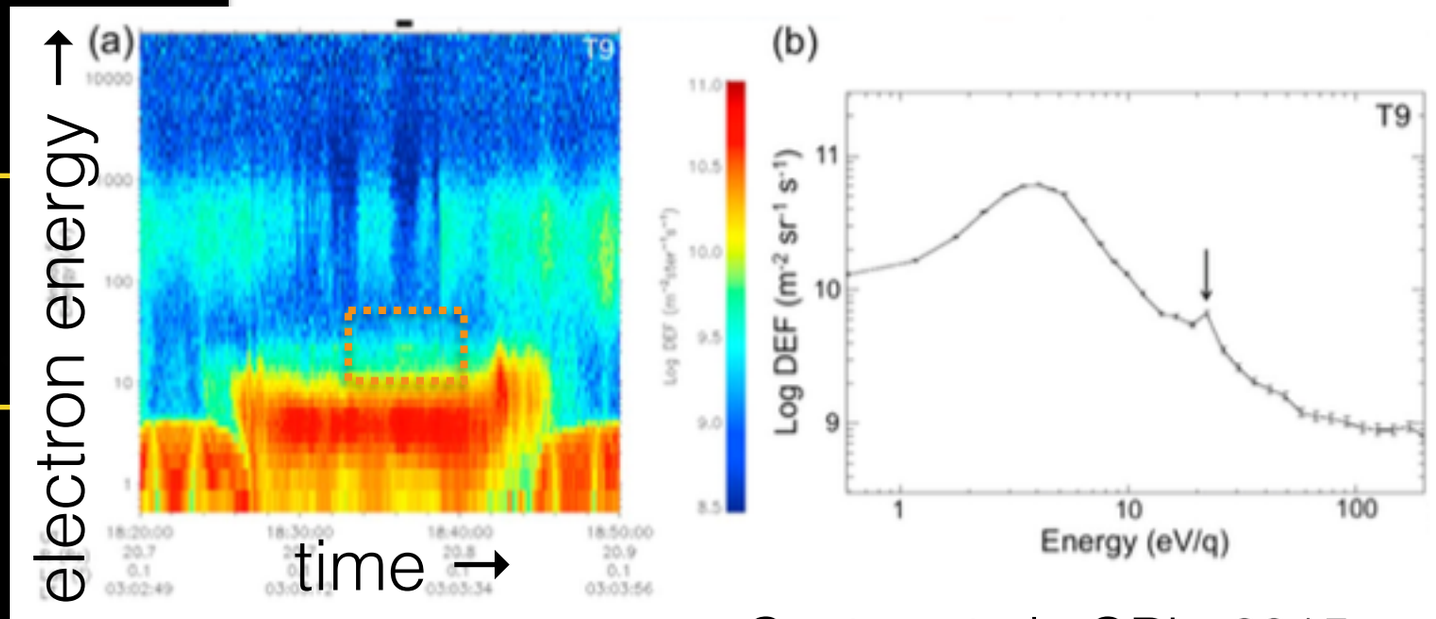


- Sunlight ionises Titan's atmosphere ("photoionisation")
- Electrons (-) separate from ions (+) in the upper atmosphere
- The electrons are more energetic than the ions and can move along the magnetic field lines

Electron energy

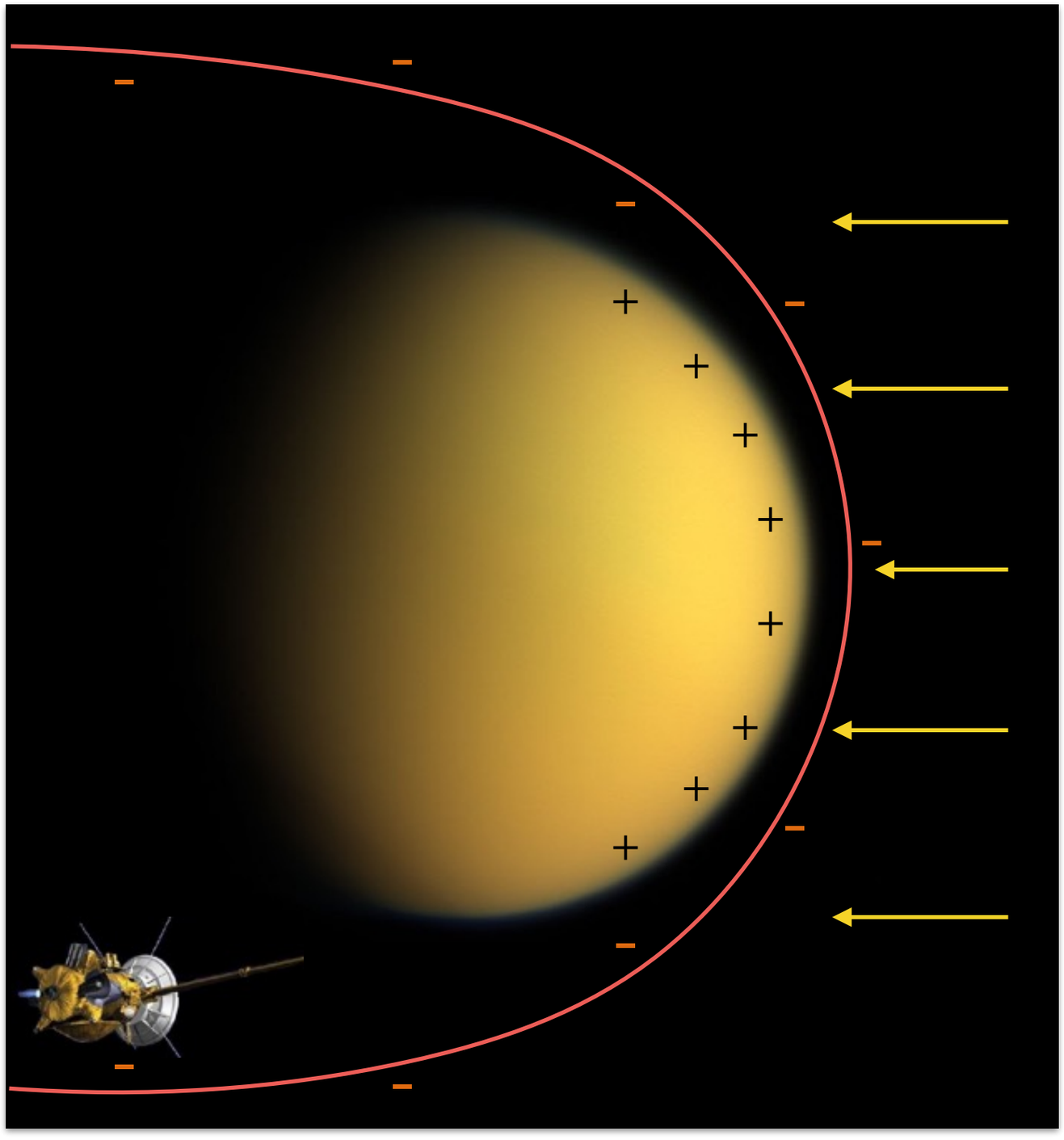


- The electron energy is characteristic of the nitrogen atmosphere
- Cassini detects the electrons (photoelectrons) far away from where they are produced

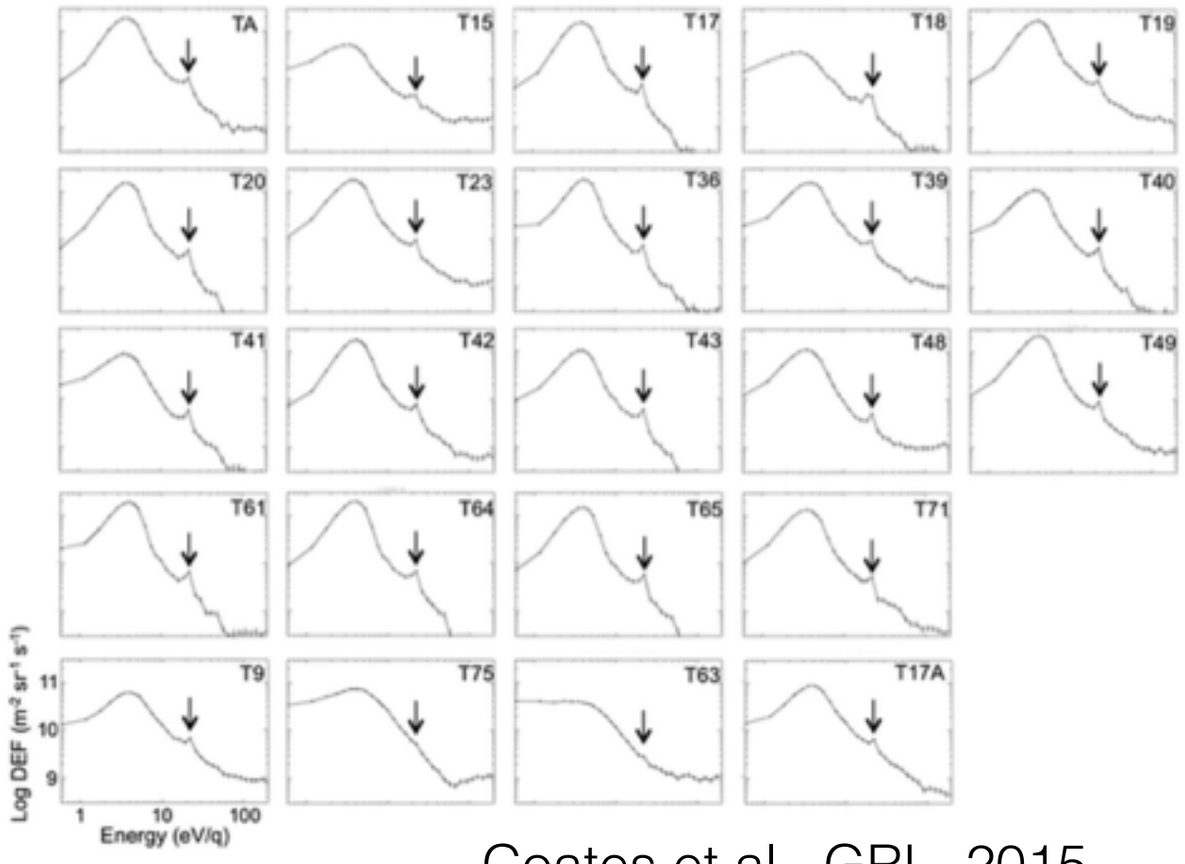


Coates et al., GRL, 2015.

Dayside and tail

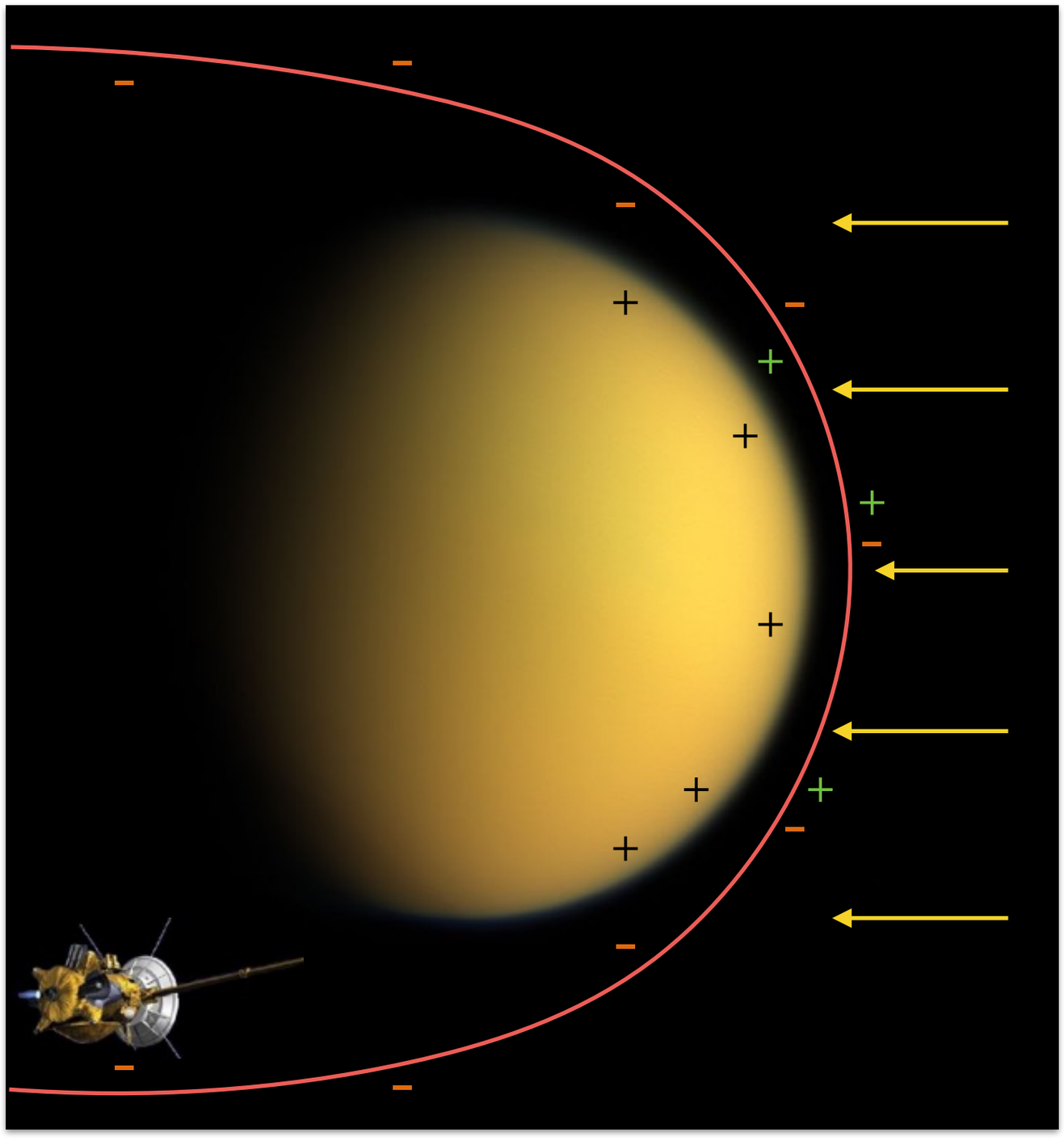


- Cassini detects the electrons from the atmosphere on many Titan flybys, both on through the sunlit region and in the distant tail:



Coates et al., GRL, 2015.

Titan's 'polar wind'



- The separation of the electrons (-) and ions (+) sets up an electric field, which pulls the ions (+) out of the atmosphere

- The voltage between the sunlit atmosphere and the tail is ~3 V

- Cassini measurements show Titan is gradually losing its atmosphere to the surrounding space at a rate of ~7 tonnes every 24 h

Coates et al., GRL, 2012; 2015.

Summary

- Saturn's moons interact with the planet even though they don't have their own magnetic fields

- The irregular satellite Hyperion has a charged surface, which accelerates electrons away from it

- Titan's atmosphere is ionised by sunlight, leading to loss of mass along Saturn's magnetic field lines draped through its atmosphere

Coming up

- Cassini will soon move into the last phase of its mission: the Grand Finale

- The last close flyby of Hyperion by Cassini took place on 31st May 2015

- There will be several more close Titan flybys until mid-2017 so we can study the moon's interaction over different seasons

References

- Nordheim, T. A., G. H. Jones, E. Roussos, J. S. Leisner, A. J. Coates, W. S. Kurth, K. K. Khurana, N. Krupp, M. K. Dougherty, and J. H. Waite (2014), Detection of a strongly negative surface potential at Saturn's moon Hyperion, Geophys. Res. Lett., 41, 7011–7018, doi:10.1002/ 2014GL061127.

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