Cassini MAPS highlights: Moon-magnetosphere interactions

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Saturn's Satellites and Ring Structure

All bodies are to scale except for Pan, Atlas, Telesto, Calypso and Helene, whose sizes have been exaggerated by a factor of 5 to show rough topography.
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 Rs (1 Rs = 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**

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- 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

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

Nordheim et al., GRL, 2014.
• Cassini also detected a drop-out in the higher energy electrons which had been absorbed by the moon.

Nordheim et al., GRL, 2014.
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 Rs (1 Rs = 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")
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- Electrons (-) separate from ions (+) in the upper atmosphere
Charge separation

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- 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

