

# Titan's photoelectrons: Studying the plasma environment of Saturn's Earth-like moon

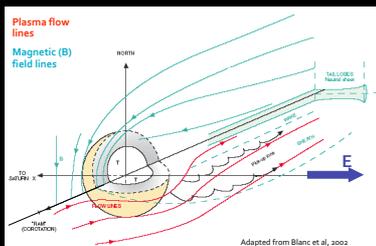
Anne Wellbrock aw2@mssl.ucl.ac.uk  
Supervisors: A.J. Coates, A.D. Aylward

## 1. INTRODUCTION

- The giant moon Titan orbits Saturn at a distance of 20 Saturn radii
- Titan is hence exposed to a hot plasma that surrounds Saturn (Saturn's magnetospheric plasma)
- This plasma flows past Titan, interacting with its dense nitrogen and methane based atmosphere

*In this study we investigate the use of ionospheric photoelectrons as tracers of magnetic field lines in order to learn more about this complex plasma environment*

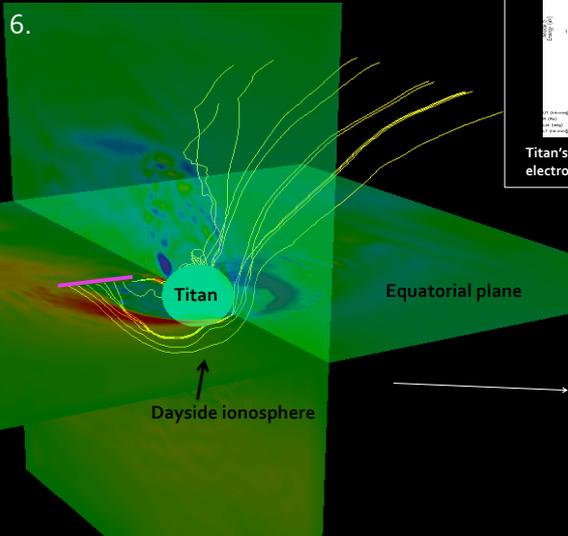
## 2. MAGNETIC FIELD LINE DRAPING AROUND TITAN



Titan has no intrinsic magnetic field of its own. Magnetic field lines of the magnetospheric plasma drape around Titan due to

- Mass loading. Atmospheric molecules are ionised and picked up by incoming magnetospheric plasma, which therefore slows down at these mass loading sites. However plasma flow continues elsewhere, causing the field lines to drape.
- Ionospheric pressure forces. Saturn's magnetic field tries to penetrate Titan's conducting ionosphere. Currents are set up to try to exclude the field lines.

Pink line: Flyby trajectory of spacecraft when photoelectrons were observed  
Yellow Lines: Magnetic field lines that are connected to the photoelectron region (pink line)



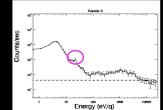
## 7. CONCLUSIONS

- Discrete photoelectron peaks in ELS spectra are generally observed in Titan's dayside ionosphere due to solar radiation ionising neutral N<sub>2</sub>
- Observations of photoelectrons at larger distances from Titan where they are unlikely to have originated (due to low neutral densities at these distances) are reported for the first time in this study (Wellbrock et al, 2008, Coates et al, 2007)
- The most likely explanation for observations at such large distances is that these photoelectrons originated in the dayside ionosphere but then travelled to the observation sites via magnetic field lines
- Results from the HYB model (Sillanpaa, 2008) strongly support this idea
- Therefore observations of ionospheric photoelectrons at large distances from Titan can be used as tracers of magnetic field lines providing a new approach to understanding Titan's complex magnetic environment and its atmospheric escape processes

## 3. IONOSPHERIC PHOTOELECTRONS

Photoelectrons are electrons that are produced when an atom or molecule is ionised due to electromagnetic radiation. In planetary ionospheres (the upper, ionised part of the atmosphere) photoelectrons can be produced when a certain type of solar radiation, called Helium (II) line at 30.4nm, ionises neutral molecules in the upper atmosphere. These can be observed in electron energy spectra as peaks at certain energies, e.g. at Mars, Venus and Earth (Frahm et al, 2008, Coates et al, 2008, Tsang et al, 2008).

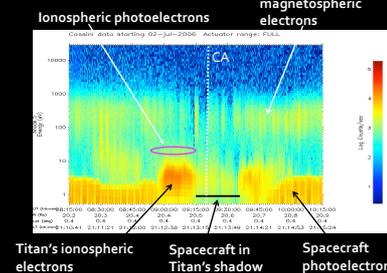
At Titan, discrete peaks in the electron energy spectrum at ~24eV can be observed in the ionosphere due to the ionisation of N<sub>2</sub> (Coates et al, 2007, Galand et al, 2008), such as the encircled peak shown here observed by Cassini's CAPS electron spectrometer (ELS)



## 4. WHY STUDY PHOTOELECTRONS AT TITAN?

- Photoelectron peaks are generally observed in the dayside ionosphere (i.e. the part of the ionosphere that is exposed to solar radiation) because neutral N<sub>2</sub> densities are high enough there and can be ionised by solar radiation
- In this study we investigate observations of photoelectrons at large distances from Titan where neutral N<sub>2</sub> densities are low therefore local production is unlikely
- We suggest that photoelectrons may have travelled to these large distance observation sites from the dayside ionosphere via magnetic field lines
- Photoelectron observations at large distances can therefore provide information about Titan's magnetic environment and atmospheric escape processes by using them as tracers of field lines

## 5. CASSINI CAPS ELS ELECTRON SPECTROGRAM OF T15



T15 = Cassini's 15<sup>th</sup> Titan flyby  
2 July 2006 from 08:15UT to 10:15UT

Horizontal axis: Energy (eV)  
Vertical axis: UT time  
Colour bar: Log counts/sec  
Closest approach (CA) altitude was 1900km

Photoelectron peaks can be observed on the pink region indicated, at altitudes up to 5760km (2.2R<sub>T</sub>).  
These peaks are also clearly visible in the electron spectra (a time slice through this spectrogram)

## 6. COMPARISON WITH T15 HYBRID MODELLING RESULTS

Results from the HYB model (Sillanpaa, 2008) indicate magnetic connections (yellow lines) between Titan's dayside ionosphere near the south pole and the photoelectron observation sites (pink line)

This strongly supports the idea that photoelectrons produced in the dayside ionosphere can travel to larger distances from Titan via magnetic connections

**Background image:**  
Cassini image of Titan behind Saturn's A and F rings and moon Epimetheus. Titan's surface is not visible because of the dense, orange haze layer (NASA).

**Acknowledgements:** Thanks to J. Sillanpaa, G. R. Lewis, G. H. Jones and C. S. Arridge for their contributions to this study.

**References**

- Coates, A. J., F. J. Cray, D. T. Young, K. Szeged, C. S. Arridge, Z. Bebess, E. C. Sittler Jr., R. E. Hartle, and T. W. Hill (2007), Ionospheric electrons in Titan's tail: Plasma structure during the Cassini T9 encounter, *Geophys. Res. Lett.*, 34, L24505, doi:10.1029/2007GL030949.
- Coates et al. (2008), Ionospheric photoelectrons at Venus: Initial observations by ASPERA-ELS, *Planetary and Space Science* 56 (2008) 804-806.
- Frahm et al. (2008), Carbon dioxide photoelectron energy peaks at Mars, *Icarus*, Volume 192, issue 2, p. 371-382, 2008.
- Young, D.T., et al., Cassini Plasma Spectrometer Investigation, *Space Science Review*.
- Galand, M., R. V. Yelle, A. J. Coates, H. Backes, and J. E. Wahlund (2006), Electron temperature of Titan's sunlit ionosphere, *Geophys. Res. Lett.*, 33, L21202, doi:10.1029/2006GL027188.
- Tsang et al. (2008), Photoelectrons at Venus in the ionosphere and the Tail, *American Geophysical Union, Fall Meeting 2008*, abstract #P13B-1312.
- Sillanpaa et al. (2008), Cassini's CAPS and MAG measurements during Titan flyby T15 compared to HYB model results, *American Geophysical Union, Fall Meeting 2008*, abstract #P21A-1338.
- Wellbrock et al. (2008), Observations of photoelectrons with CAPS ELS at Titan, *American Geophysical Union, Fall Meeting 2008*, abstract #P21A-1332.