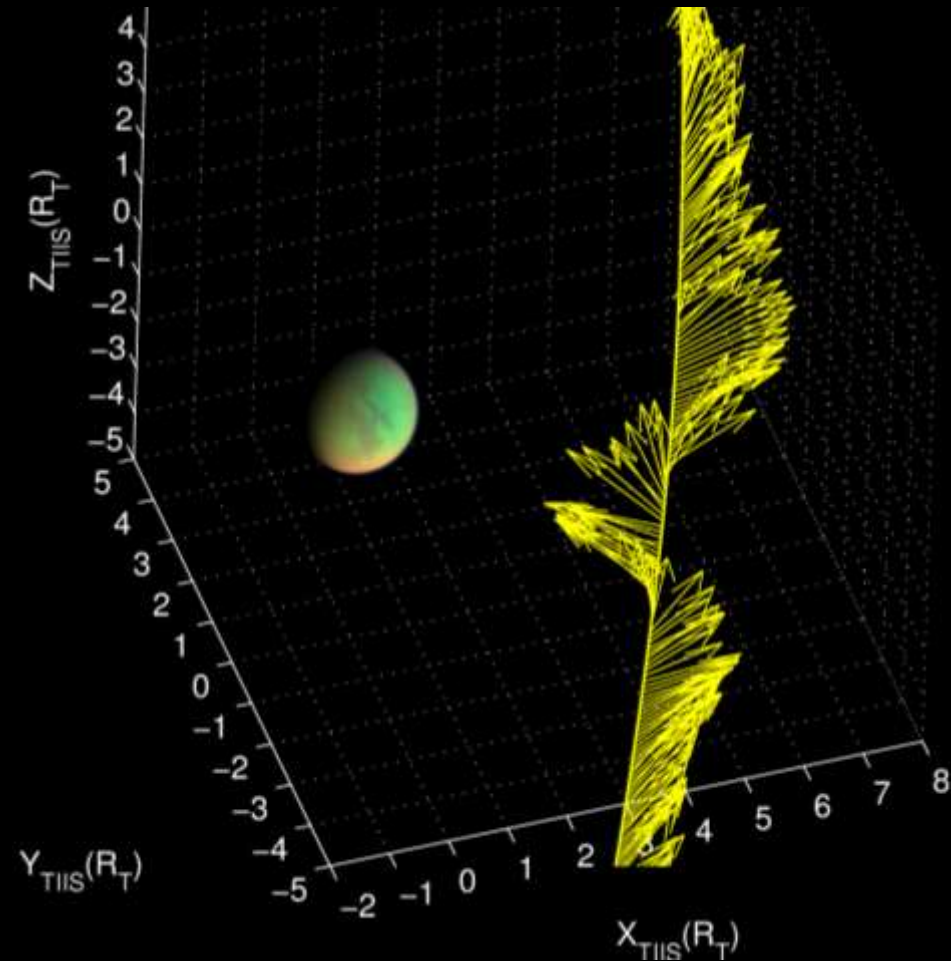


Titan's Plasma Environment and Interaction

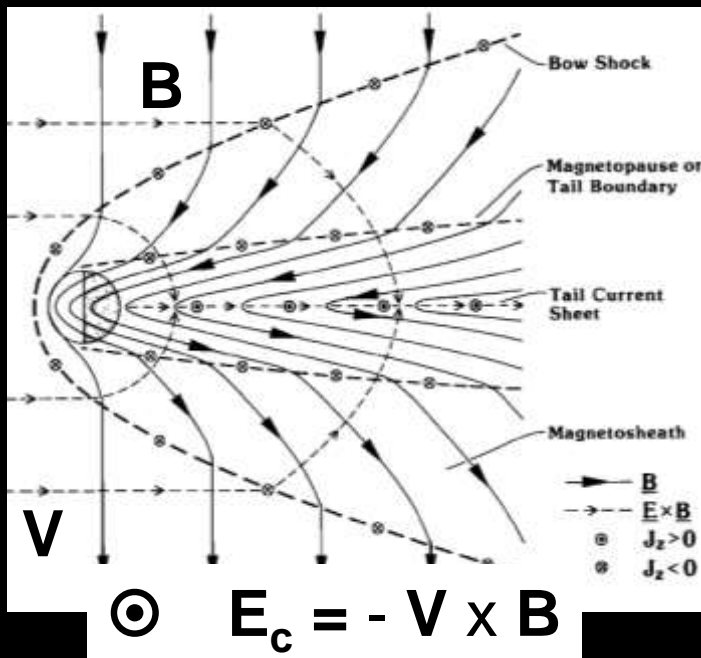
Presented by Nick Achilleos
(APL/UCL)

César Bertucci
Cassini MAG Team
Instituto de Astronomía y Física del Espacio
Buenos Aires



The Induced magnetosphere (IM)

After Saunders and Russell, 1986



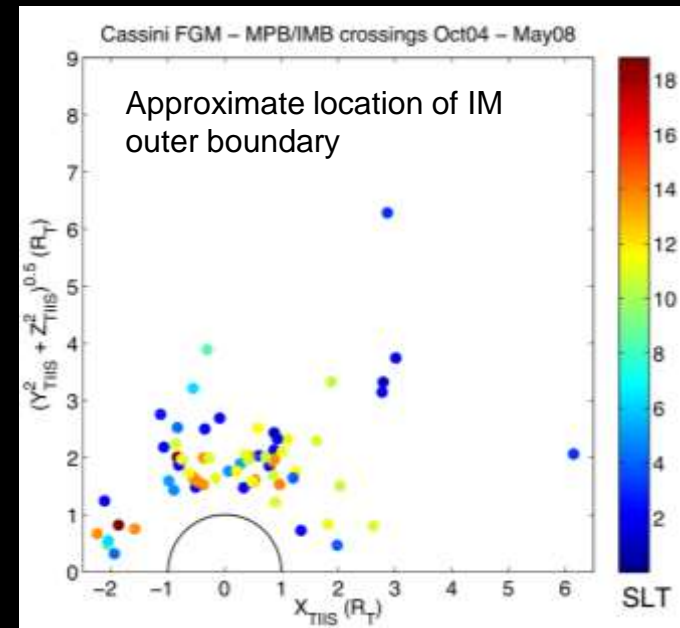
- No intrinsic field (Wei et al., 2010)
- Formed by ‘accreted’ frozen-in fields (Alfven, 1957) pileup and draping.
- Lobes along V (away lobe) and $-V$ (toward lobe)
- Current sheet plane defined by $V \times B$ and V .
- This picture applies for steady conditions.

Titan's interaction : timescales

Voyager 1 - Saturn's Magnetosphere

$\langle B \rangle$	5 nT
V	80-150 km/s
n_p	0.1 cm^{-3}
n_{N^+}	0.2 cm^{-3}
T_e	200 eV
T_p	210 eV
T_{N^+}	2.9 keV
V_{Alfven}	64 km/s
V_{Sound}	210 km/s

from Hartle et al. (1982) and Neubauer et al. (1984)

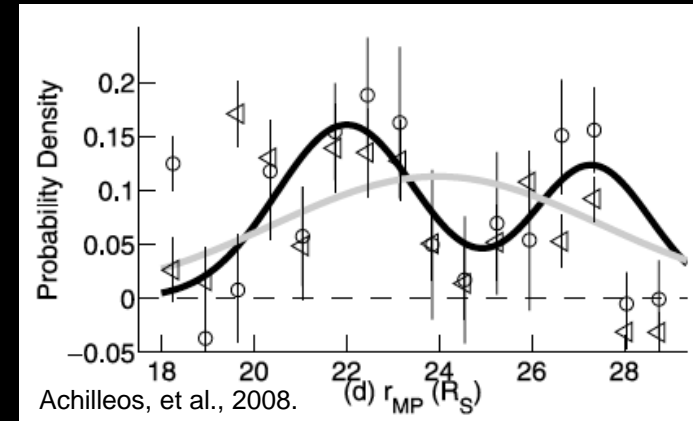


- Outside the IM
 - Flow time of transit across $4 R_T$: at least 1.1 min.
 - For Alfvén waves (V_A): ~ 3 min.
- Inside the IM: IM is replenished with new field lines in 20 min - 3 hours (Bertucci et al., 2008).

Plasma environment: structure

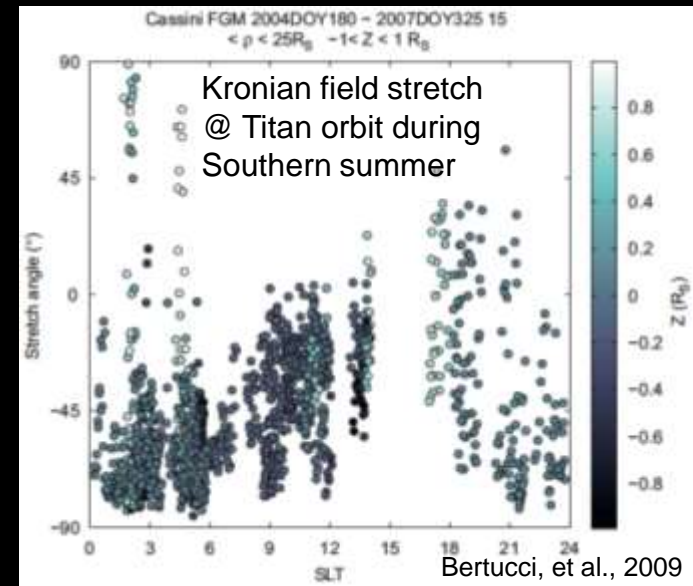
- Proximity to magnetopause

- Average standoff distance: 22 and 27 R_S (Achilleos et al., 2008). Titan's noon orbit in solar wind for $P_{SW} > 0.0345$ nPa, that is approximately more than two times the average (Bertucci et al., 2008)
- Magnetopause waves on dawn sector (Masters et al., 2009)



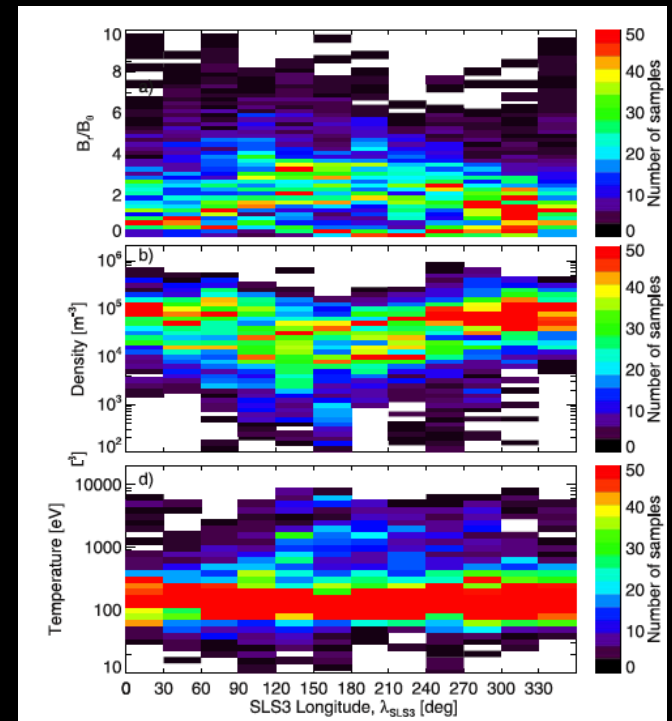
- Proximity to Saturn's magnetodisk. Average structure defined by stress balance (e.g., Arridge et al., 2007; 2008; Khurana et al., 2009; Achilleos et al., 2010).

- **Lobe**: Low density (mainly $H^+ \sim 0.01$ cc $^{-1}$), strong (~ 10 nT), stretched fields.
- **Current sheet**: higher densities (notably, $W^+ \sim 0.1$ cc $^{-1}$) and pressure, low (< 5 nT), north-south fields, noon/midnight asymmetry (Sergis et al., 2009) .



Plasma environment - variability

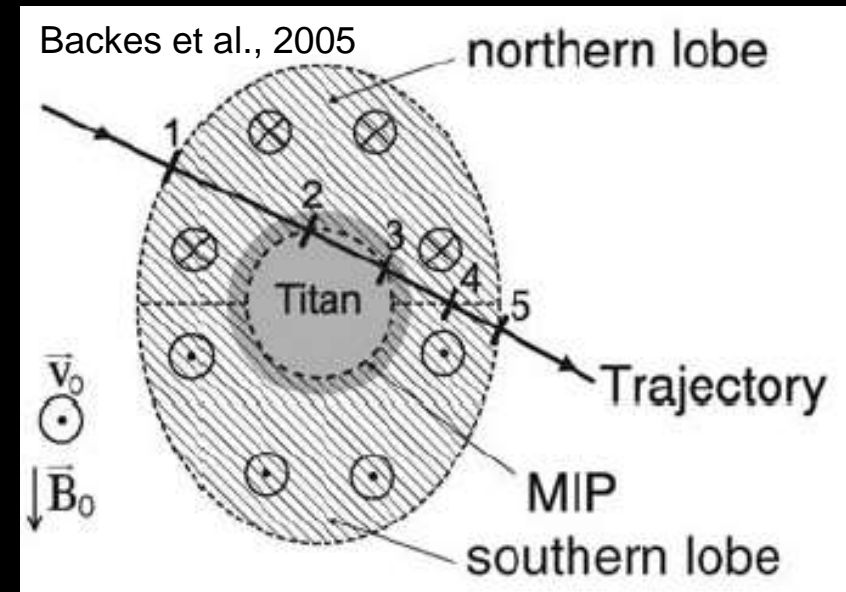
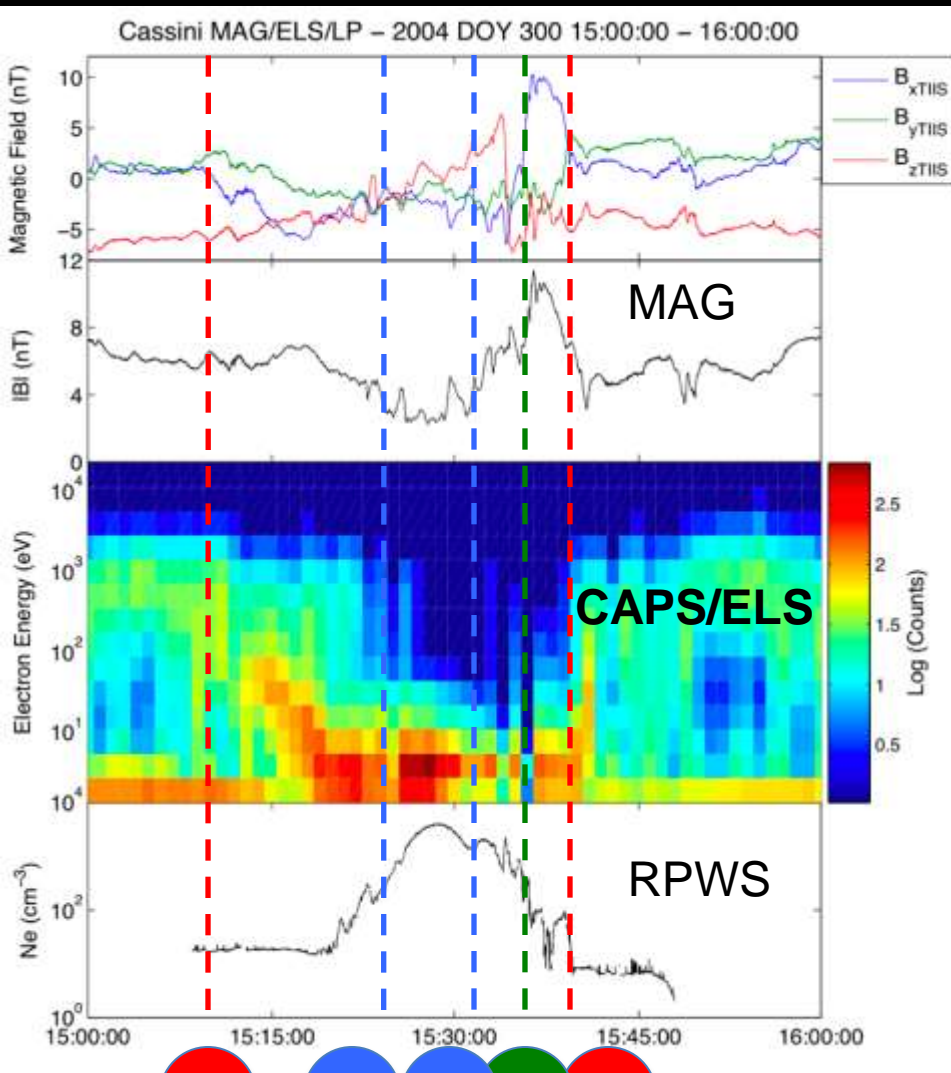
- “Short” timescales (\sim fossil fields)
 - Solar wind pressure induced magnetopause motion, disk flapping (Bertucci et al., 2008).
 - Kronian magnetospheric periodicities: before equinox, Titan tends to be in lobes around $\lambda_{\text{SLS3}} = 170^\circ$ (Arridge et al., 2008; Bertucci et al., 2009).
- “Long” timescales (days, years)
 - Orbital period: SLT (Wolf and Neubauer, 1986)
 - Kronian seasons: Titan more likely to be in lobes around solstices, and in current sheet around equinoxes (Arridge et al, 2008; Khurana et al., 2010).



Flyby classification

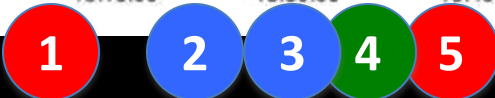
- Flybys are classified according to the inbound/outbound plasma and field properties (Sittler et al., 2009; Rymer et al., 2009; Simon et al., 2010 a,b; Nemeth et al., 2011). Upstream categories including most flybys are:
 - Lobe (Magnetospheric)
 - Sheet (Magnetospheric)
 - Mixed (Magnetospheric)
 - Magnetosheath
- Examples described here
 - TA: 11 SLT, Sheet
 - T32: 13.6, Magnetosheath

IM Overall configuration - TA

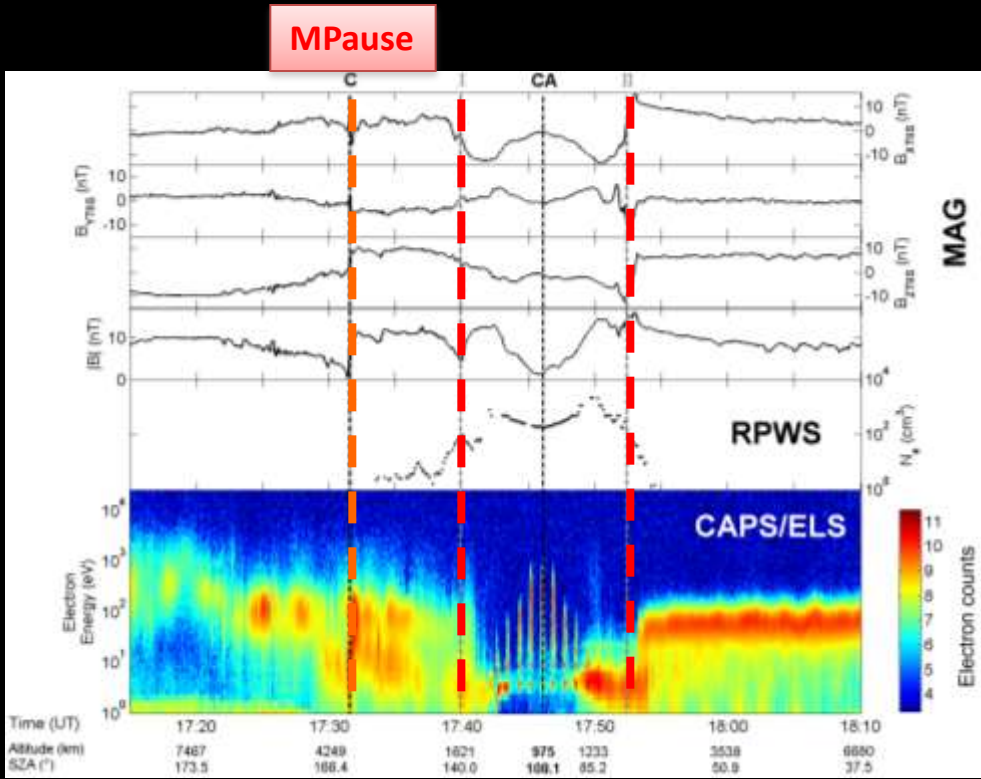


Upstream V and B organize geometry

- 1,5: IMB displaying cooling of plasma.
- 2,3: 'Magnetic ionopause' indicating diamagnetic effect of ionosphere.
- 4: polarity reversal layer with no clear signs of plasma energization.



T32 - IM response to extreme variability



MPause

Kronian M'sphere

Sheath

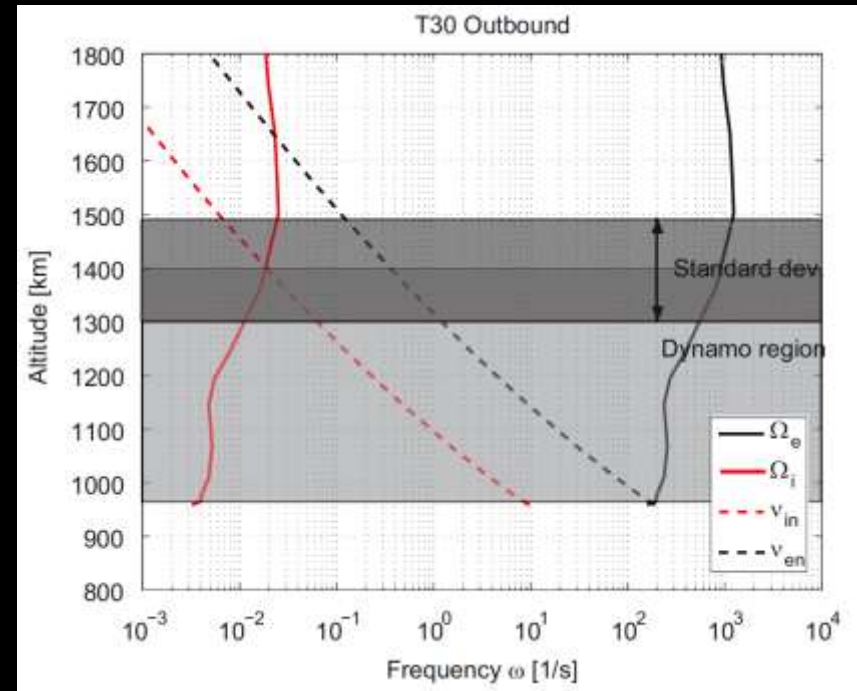
Induced magnetosphere with Kronian fossil fields

Sheath

- The fields above Titan's collisional ionosphere during T32 are incompatible with draped IMF lines
- They coincide with Kronian draped fields to which Titan was exposed 20 minutes before CA.
- IMF / Kronian fossil fields boundary coincides with IMB for other flybys implying a strong increase in the massloading there.
- A comparison of the times spent inside / outside the Kronian magnetosphere leads to a fossil field lifetime up to 3 hours.

Magnetic convection/diffusion within the ionosphere

- Titan's ionosphere is also a complex electromagnetic system where transport dominates in the upper layers and diffusion a lower altitudes.
- Rosenqvist et al., (2009): Dynamo region where gyro frequencies \sim neutral collision freq. (1400-900 km).
- Cravens et al., (2010): Neutral dynamics dominates transport below 1500 km, and diffusion dominates below 1000 km.
- Agren et al., (2011) 10 to 100 nA m⁻² currents in the ionosphere. Currents below the exobase (\sim 1400 km) are principally field parallel and Hall.



Gyro and neutral collision frequencies vs altitude for T30 (Rosenqvist et al., 2009).

Summary

- Titan's interaction with its plasma environment is of atmospheric type.
- This interaction is however, subject to extremely variable conditions leading to very limited sets of observations during which upstream conditions are steady.
- TA and T32 teach us respectively how the IM general configuration is and how the IM reacts to abrupt changes in upstream conditions.
- Fossil fields diffuse within the collisional ionosphere as conductivities decrease with increasing neutral density. The knowledge of the electric properties of the ionosphere is essential to understand the temporal evolution of the external fields and the capacity of induced field generation.