Poster n°4

Simulation of the plasma environment of Titan in the magnetosheath flow of Saturn

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Introduction

It is assumed that Titan has no intrinsic magnetic field able to isolate its ionosphere and exosphere from the external plasma, i.e. the magnetospheric plasma of Saturn most of the time, or the solar wind. Neutral atoms are ionized by solar photons, electronic impacts, and charge exchanges with ions of the ambient plasma. The newborn ions are then accelerated by the motional electric field. Hence the interaction between the flowing plasma and Titan's neutral exosphere contributes to the escape of atmospheric components.

We investigate the case where Titan moves across Saturn's magnetosheath by means of three-dimensional, multi-species, hybrid simulations. Ions are treated as macroparticles while electrons are modeled by a massless neutralizing fluid. This approach allows a full and self-consistent kinetic treatment of the ions, including finite Larmor radii effects which are mandatory for the physics of pickup ions.

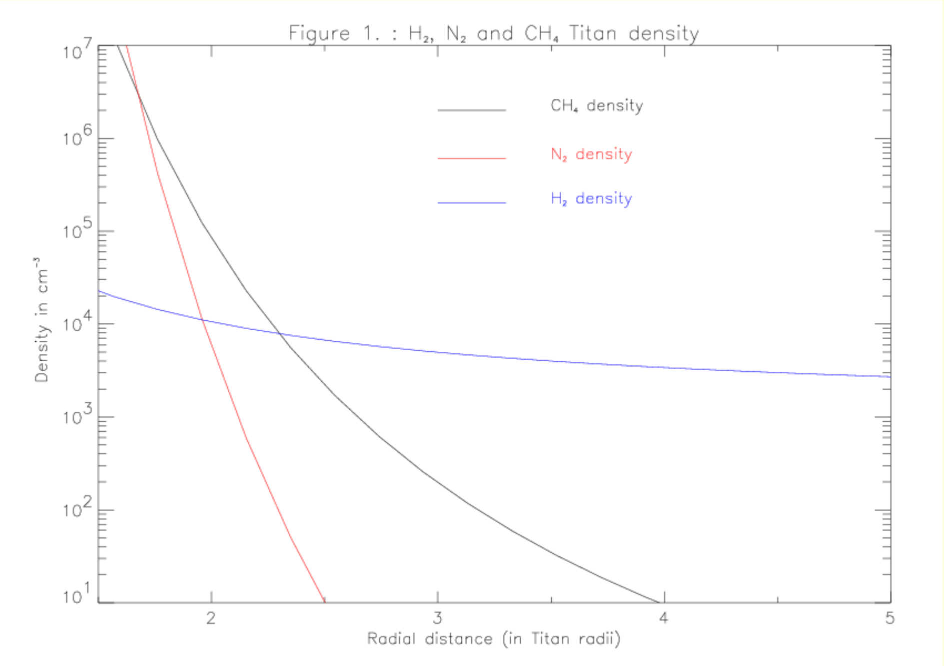
The various ionisation processes are separately and self-consistently implemented in our model thus allowing to investigate the contribution from each process to the formation and dynamics of the plasma environment of Titan.

Titan neutral environment

In the present model, the neutral exosphere of Titan is made of molecular hydrogen, nitrogen and methane. Spherical symetry is assumed, and radial profiles of density are given by a simplified Chamberlain's model, i.e. an isothermal pressure equilibrium in the gravity field of the satellite. Profiles are governed by density and temperature at the exobase with parameter values given by:

Keller et al. [JGR 97, A8, 1992] or

Amsif et al. [JGR 102, A10, 1997].



Our hybrid model does not describe correctly the collisional region below the exobase, we therefore limit the neutral density to its value at the exobase. Figure 1 shows the radial profiles of the neutrals components: the unit of the radial distance to the centre of Titan is the radius of Titan.

Description of the solar wind plasma

The simulated solar wind plasma is collisionless and made of 95% protons and 5% alpha particles (number densities : $n_{H+} = 0.2\ cm^{-3}$ and $n_{He++} = 0.01\ cm^{-3}$). He^{++} nuclei convey 20% of solar wind momentum and kinetic energy.

Our model is adapted to the super-Alfvenic and supersonic flow of the solar wind around Titan in the magnetosheath of Saturn. In this simulation the external magnetic field is the interplanetary magnetic field (IMF) convected by the solar wind.

Solar wind conditions are those encountered by Voyager 1 during its outbound traversal of the Saturn's magnetosheath, very likely behind a quasi-parallel bow shock (1980, day 321, from 02:00 to 04:00 UT): referred by Bavassano Cattaneo et al. [JGR 105, A10 , 2000] .

Measured parameters:	$B_{IMF} \approx 1.5$ nT	$\beta_{H+} \approx 1.$	$V_{SW} \approx 370$ km. s^{-1}
Assumed parameters :	$\beta_{He++} \approx 0.2$	$\beta_e \approx 1.$	
Derived parameters :	$V_{alfvèn} \approx 67$ km.s^{-1}	$M_A \approx 5.5$	$M_s \approx 5.1$

Coupling neutral and charged species

Neutral species are ionized by photons and by electronic impacts; the two processes are simulated consistently and independently through the specification of ionization frequencies and cross sections. Charge exchange reactions of protons with hydrogen, nitrogen and methane molecule are taken into account with their specific cross-sections. Ionospheric escape is not taken into account.

Bow shock and pile-up of the magnetic field

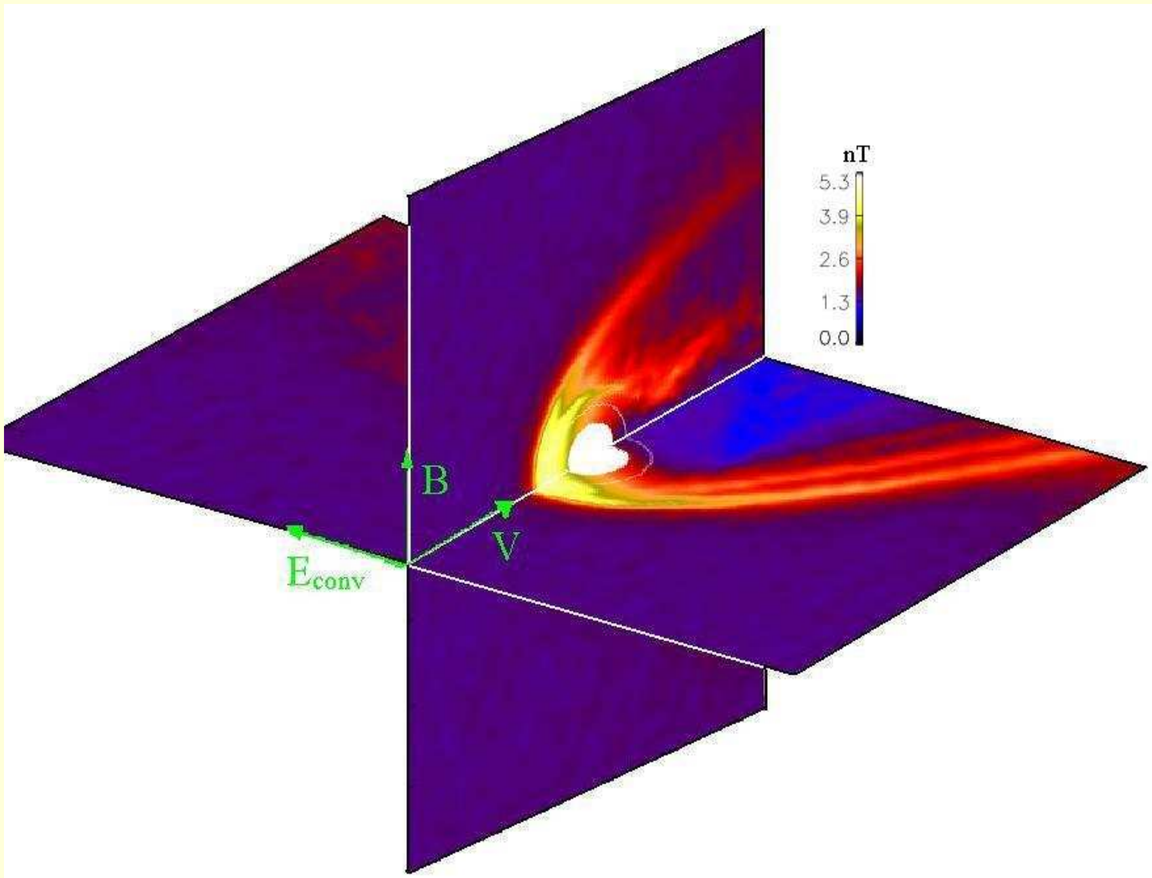


Figure 2. : Intensity of the magnetic field around Titan

⇒ The supersonic and super-Alfvenic flow forms a bow shock around Titan.

⇒ Magnetic field piles-up on the dayside and drapes around Titan, forming a magnetotail with two lobes on the nightside.

Planetary ions: density (log. scale), energy/nucleon (N_2^+ is computed, but is not shown here)

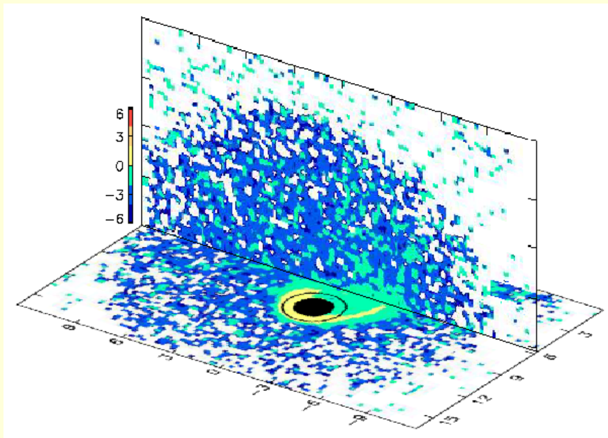


Figure 3-a : H_2^+ density number

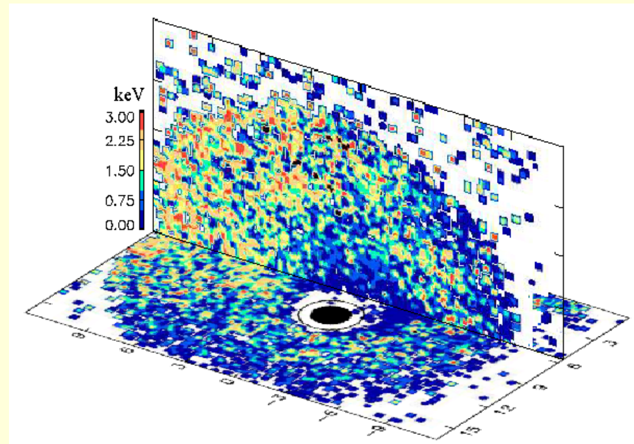


Figure 3-b : H_2^+ energy/nucleon (up to 3keV)

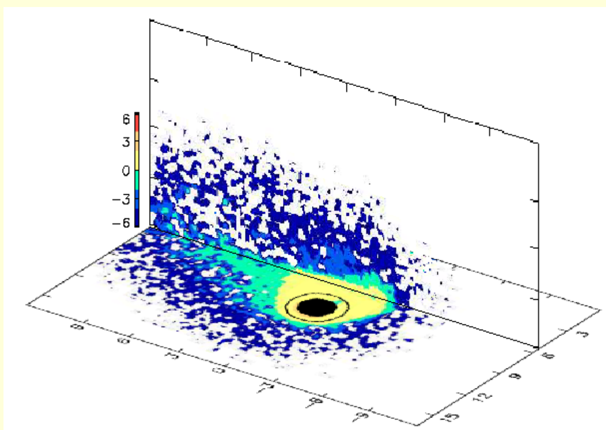


Figure 3-c : CH_4^+ density number

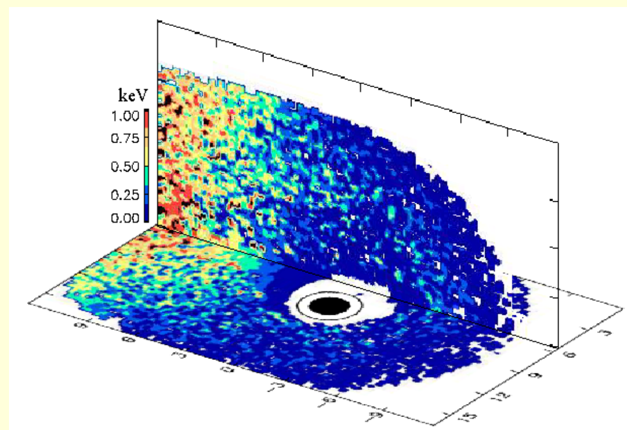


Figure 3-d : CH_4^+ energy/nucleon (up to 1 keV)

Solar wind protons: acceleration in the wake, post shock and massloading decceleration

⇒Density (log. scale) and energy maps, in the plane containing the solar wind flow and the motional electric field, clearly show the asymetry due to the motional electric field.

⇒A proton cavity is formed on the nightside of the moon. This region is filled by planetary ions. Slowed down solar wind protons are seen upstream of the bow shock due to the mass loading of the solar wind.

Right panel shows evidence for reacceleration of solar wind protons in the wake.

Figure 4-a
Density

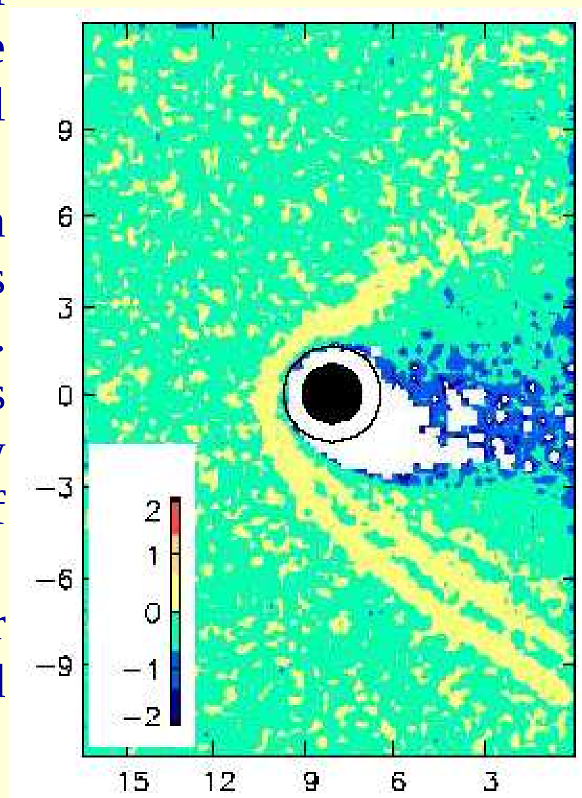
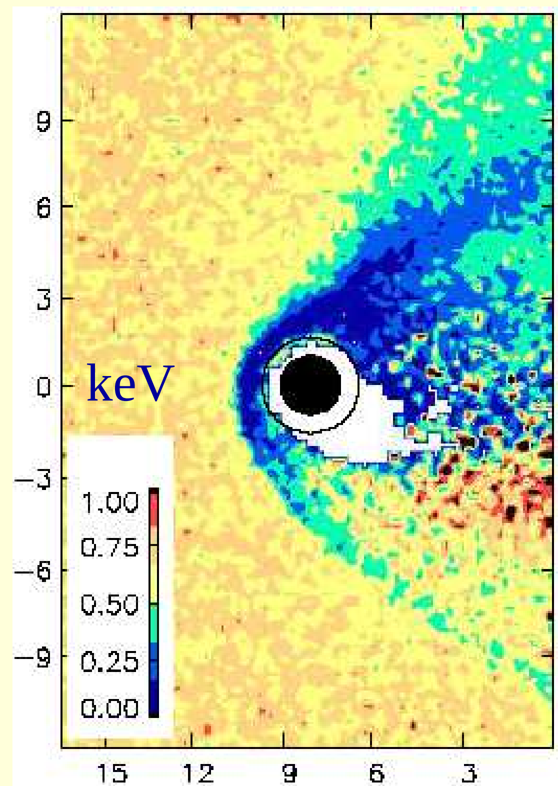


Figure 4-b
Energy/nucleon



Conclusions

We have investigated the case of Titan in the magnetosheath of Saturn for supersonic and super-Alfvenic flow conditions like those encountered by Voyager 1 on day 321 1980.

1. A bow shock is formed and the IMF is draped around the satellite: the magnetic field is piled-up on the dayside and a magnetic tail with two lobes is formed on the nightside.

2. Solar wind protons are decelerated downstream of the bow shock, but also upstream due to massloading by planetary ions. Solar wind protons are reaccelerated in the plasma wake of the satellite

3. Planetary ions are accelerated by the motional electric field of the solar wind:
   - light ions (H_2^+) gain energy closer to the moon due to their smaller gyroperiod
   - heavy ions (CH_4^+, N_2^+) are confined close to the equatorial plane defined by the velocity of the incoming solar wind and the IMF.

The present code will be adapted to the subsonic conditions prevailing most of the time in the environment of Titan and to the interaction with the corotating magnetospheric plasma.

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