Triton Plasma Interactions

Mats Holmstrom, Martin Wieser, Lucas Liuzzo*, Stas Barabash
Swedish Institute of Space Physics
*Space Sciences Laboratory, UC Berkeley

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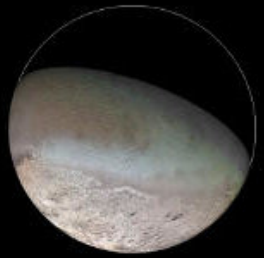
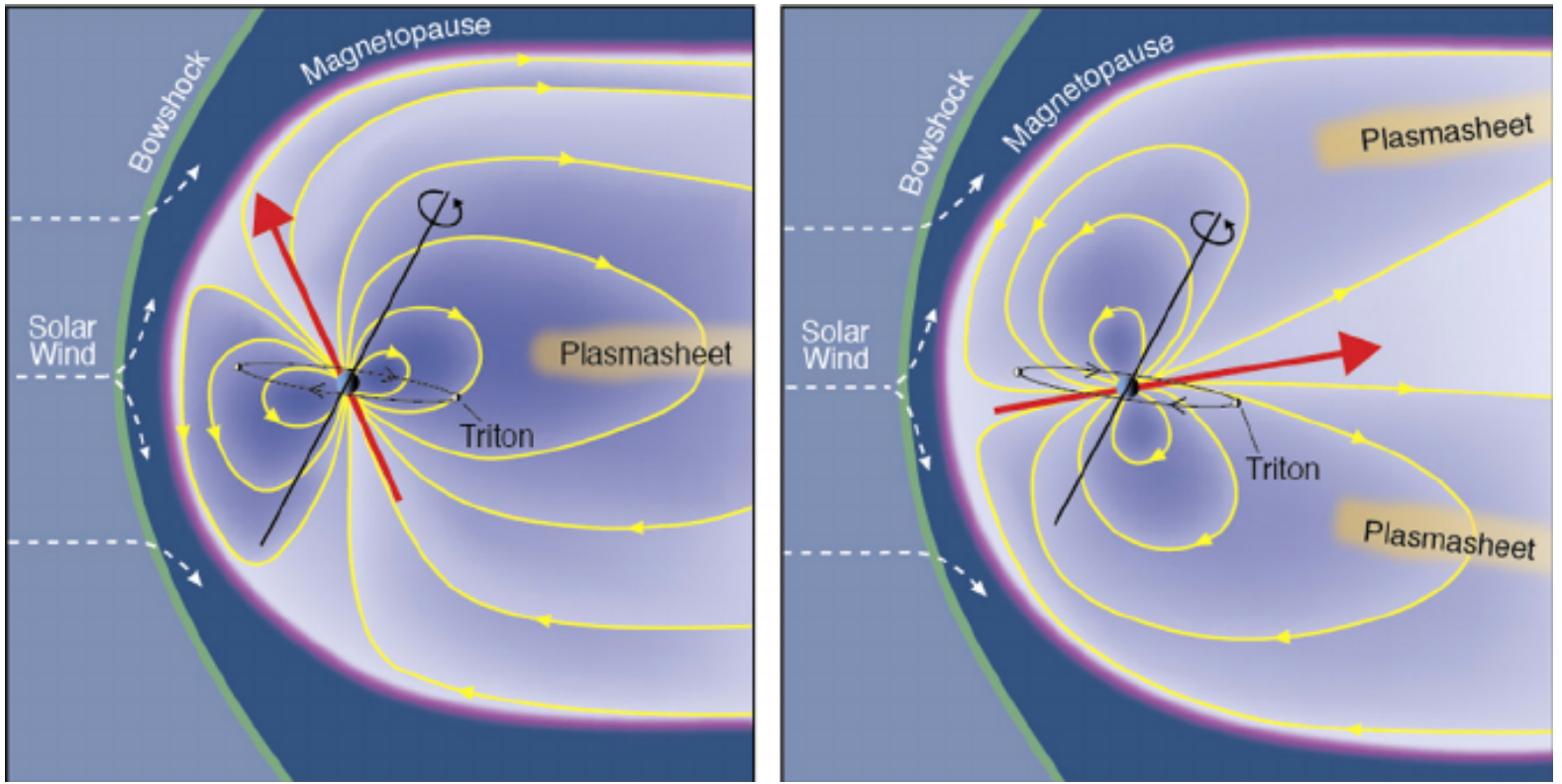


Overview

- Triton's plasma environment
- Atmosphere and ionosphere
- Plasma interactions
  - Hybrid model results

Triton in Neptune’s magnetosphere

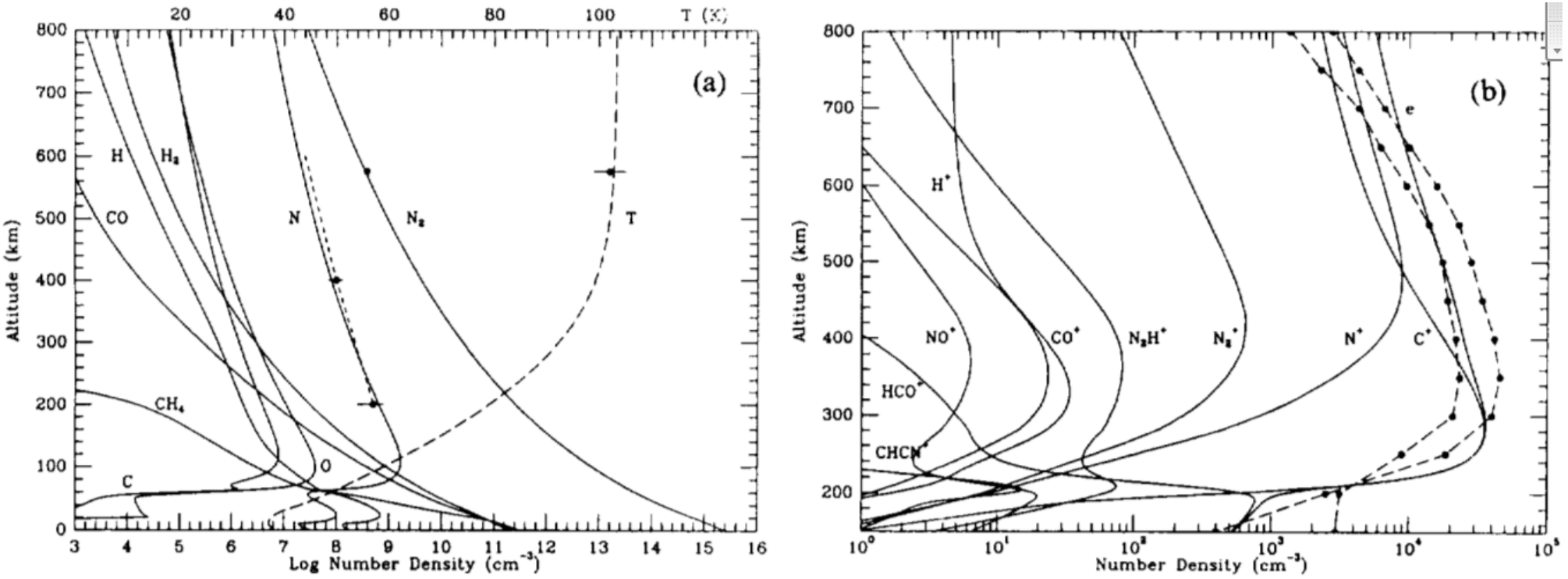


[Steve Bartlett and Fran Bagenal]

Atmosphere and Ionosphere

- Triton radius is 1353 km
- N2 and CH4 sublime from ice at 38 K
- Haze, clouds and plumes
- N 1e8 /cc at 400 km, 100 K, escape: 1e25
- Above 200 km: Energy from EUV and precipitating electrons (1e8 W)
- 200-500 km: N2 -> N, N2+, N+
- Above 500 km: C+ and N+ dominate
- Escape velocity: 1.46 km/s
- Peak e- density: 3e4 /cc at 340 km alttitude = 1.25RT (At 50 km for Callisto)

Atmosphere and Ionosphere



(Krasnopolsky, 1995)

Plasma interaction

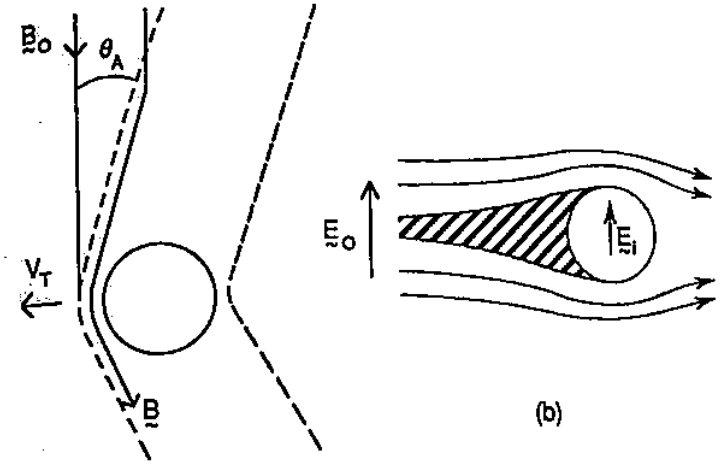


Fig. 2. (a) View of Triton, facing Neptune, where v_T is velocity of Triton relative to plasma and B_0 is ambient field. Alfven characteristics are dotted, typical field line is solid. Sub-Alfvenic interaction. (b) View of Triton from north along B_0, showing plasma flow streamlines. Convective electric field is E_0 far upstream but is reduced to E_i in ionosphere. Plasma in shaded region flows into ionosphere.

(Strobel, 1990)

- Large, almost infinitely conducting ionosphere (small B, large e- density)
- Excludes the field and plasma

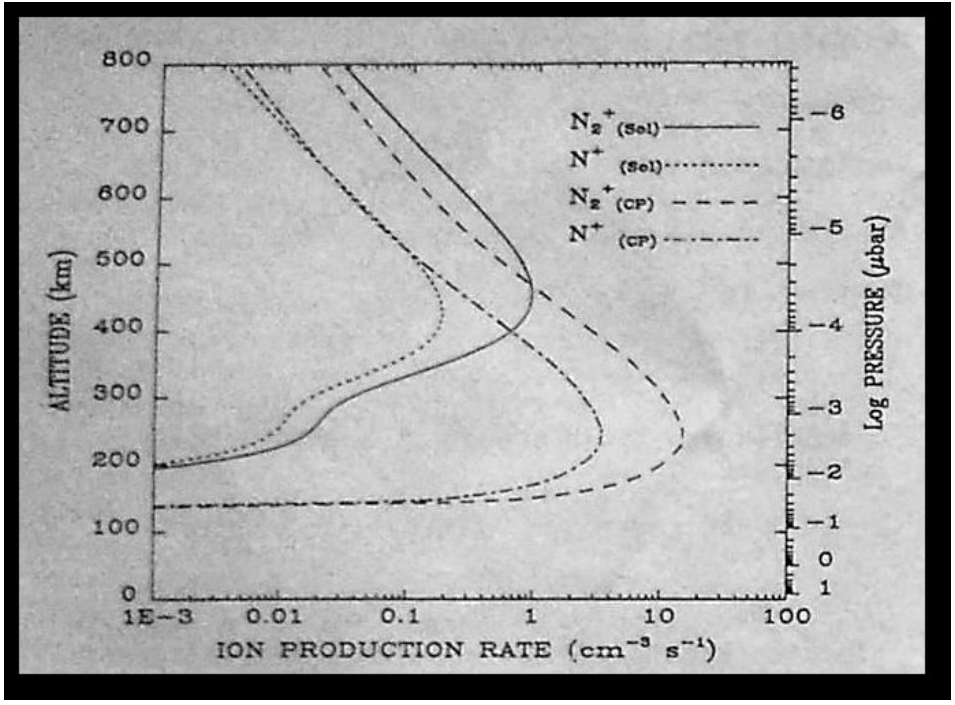
Magnetospheric Plasma

- Relative velocity = 43 km/s => planet transit in 1 minute
- At plasma sheath (magnetospheric equator):
  - H+ 0.07 /cc, 7 eV = 81 000 K ~37 km/s
  - N+ 0.04 /cc, 65 eV = 754 000 K ~30 km/s. Rg=544 km=0.4 R (not MHD!)
- With Te = 30 eV = 348 000 K. Sound speed is 44 km/s
- 8 nT field => Alfven speed 220 km/s, Plasma beta 0.016
  - => Ms = 1, Ma = 0.2. Transsonic, sub-Alfvenic
- e- gyroradius is 58 km at 20 keV
- Electron precipitating power is between 0 and 1e9 W

Hybrid Model

- Hybrid = ions as particles and electrons as a mass-less fluid
- Resistive obstacle below 600 km altitude
  - Subsurface and ionosphere conductivity represented by a magnetic dipole at the center of the moon

    Here m = (-0.82, 1.24, -1.46) e16 [T m^3]
- Production of ions above obstacle by analytical profile (depending on e- and EUV influx)
- e- fluxes could be computed by test particles
- Ion inertial length ~ planet radius
  => time step ~ dx^2

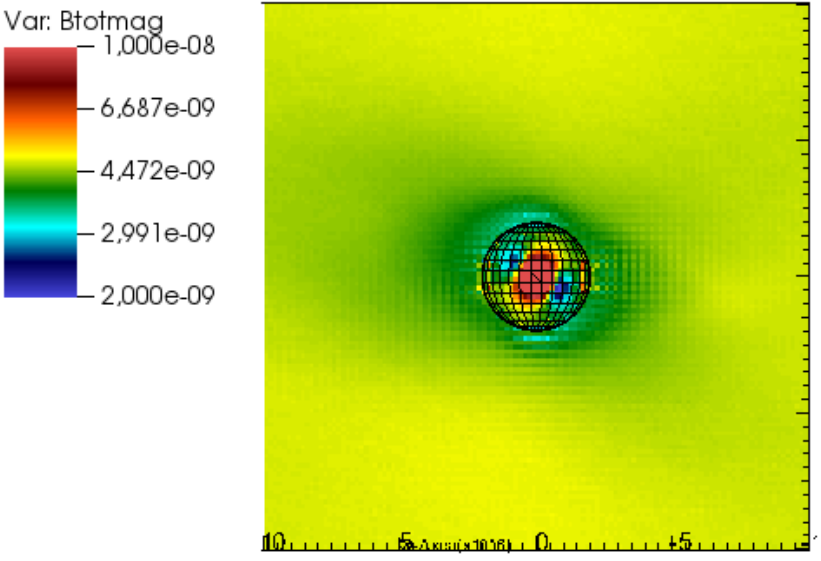


(Strobel, 1990)

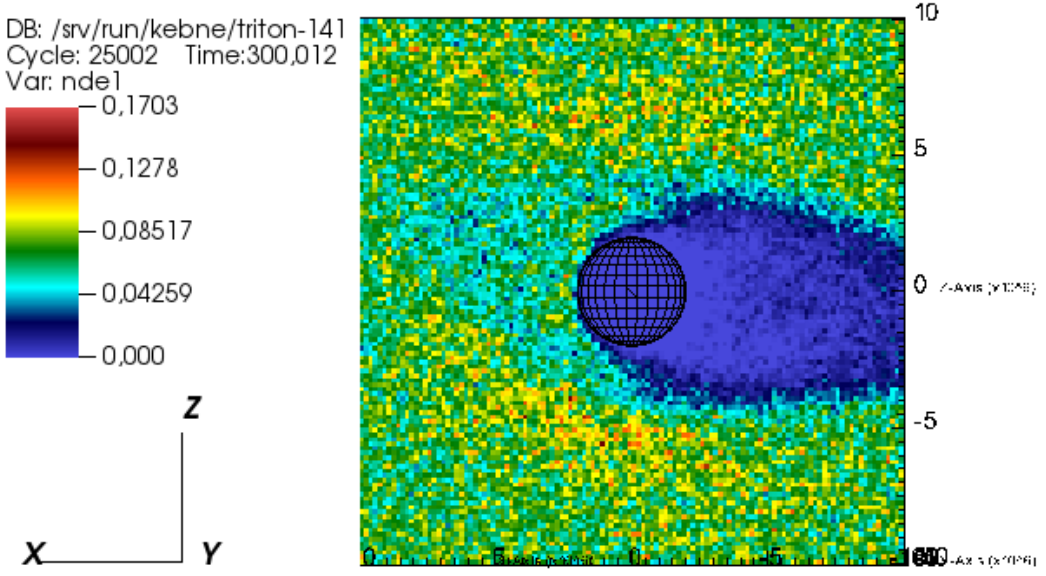
Triton hybrid model runs

- External plasma: H+ and N+ flows along -X
  Ionospheric plasma: N+
- photoionization (along -X) and spherical symmetric e- impact ionization

Plasma interaction

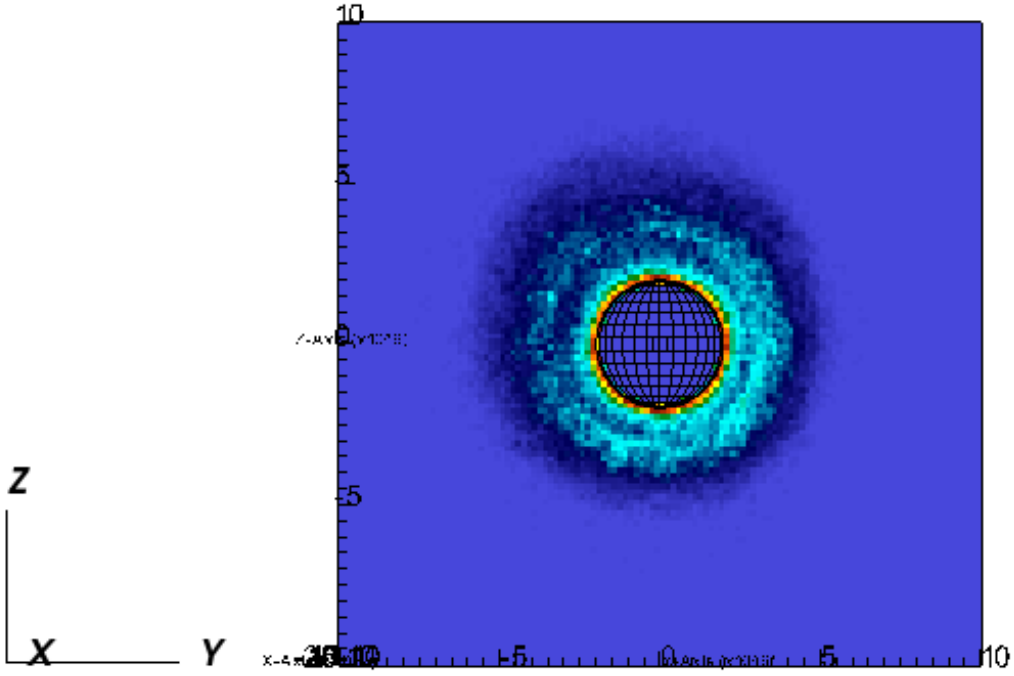


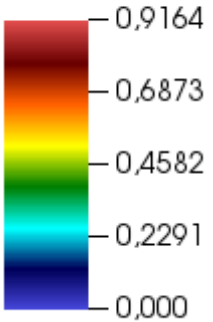
Magnetic field magnitude [T]

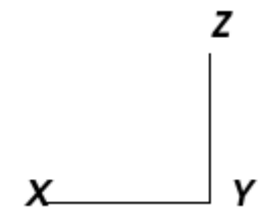


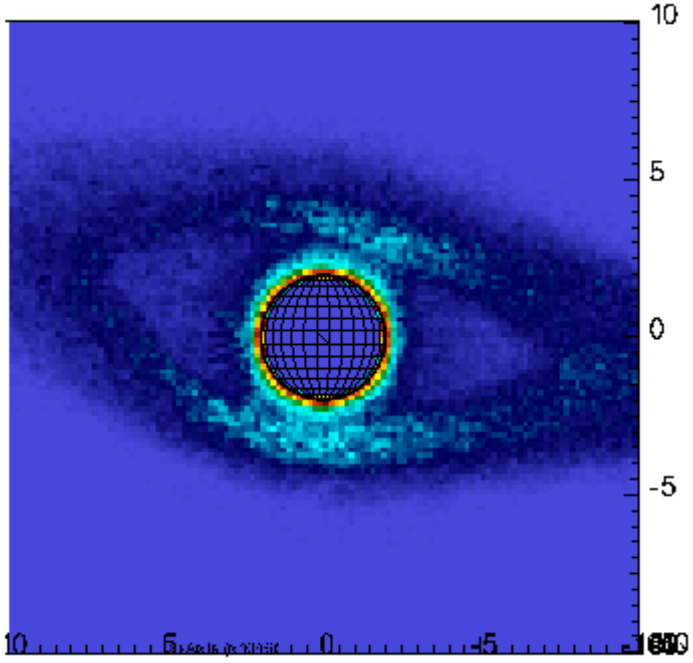
N+ number density [cm-3]

Ionospheric plasma





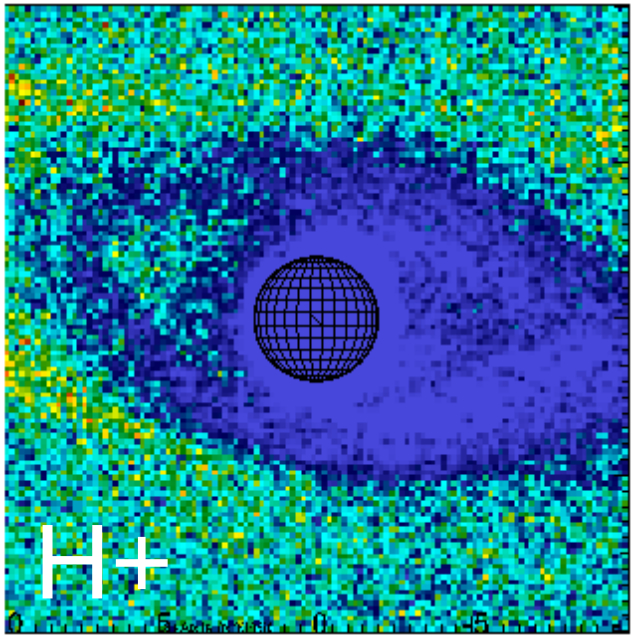


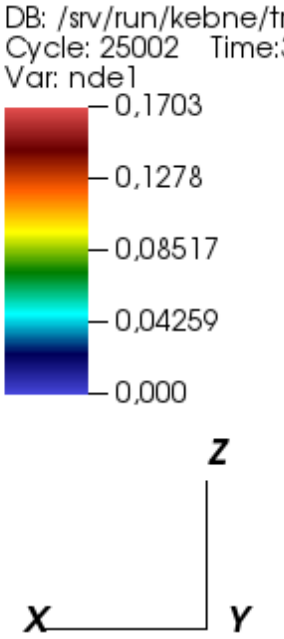


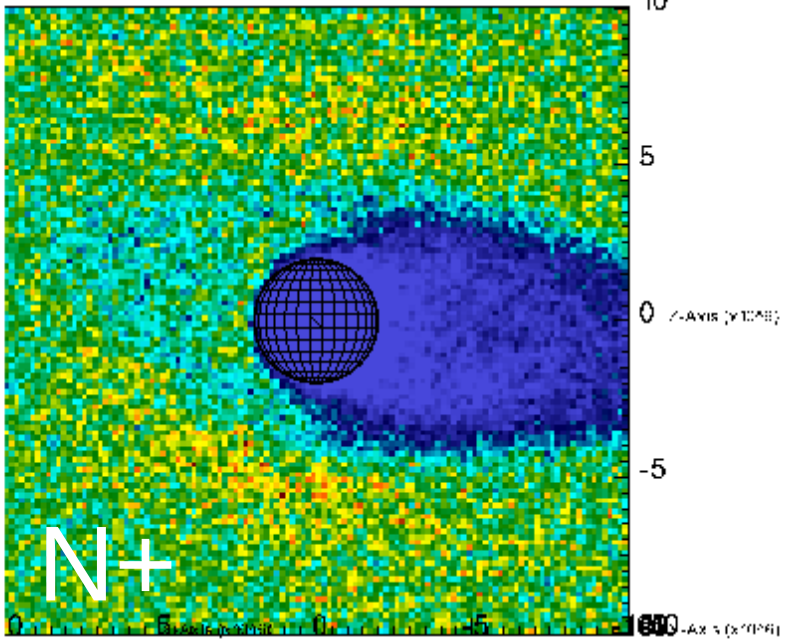
N+ Number density [cm-3]

Ionospheric plasma propagating along magnetic field, upstream and downstream

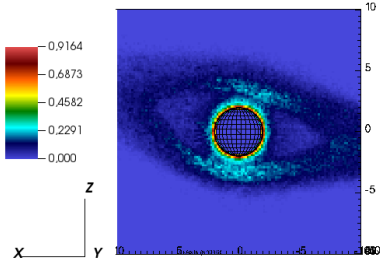
H+ and N+ separation. Number density





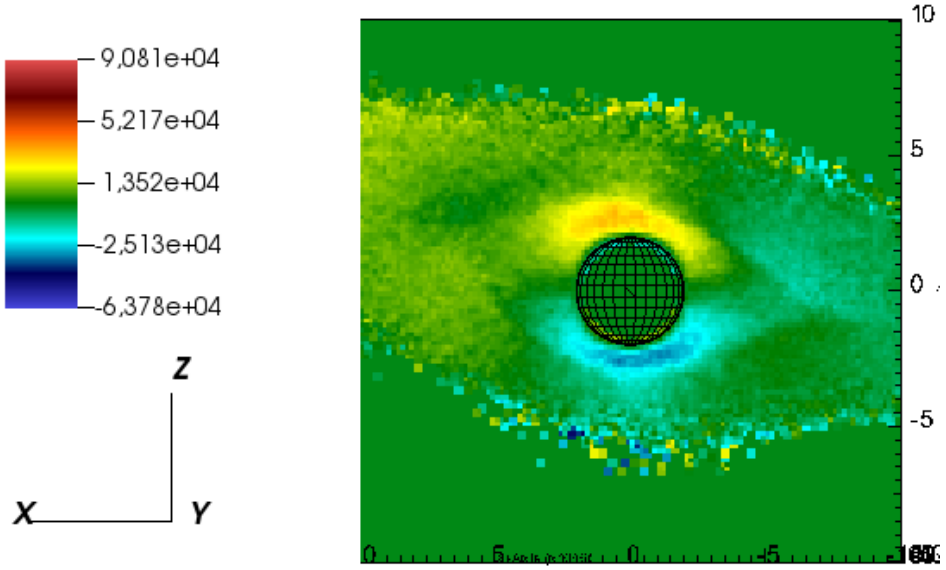


Ionospheric N+:

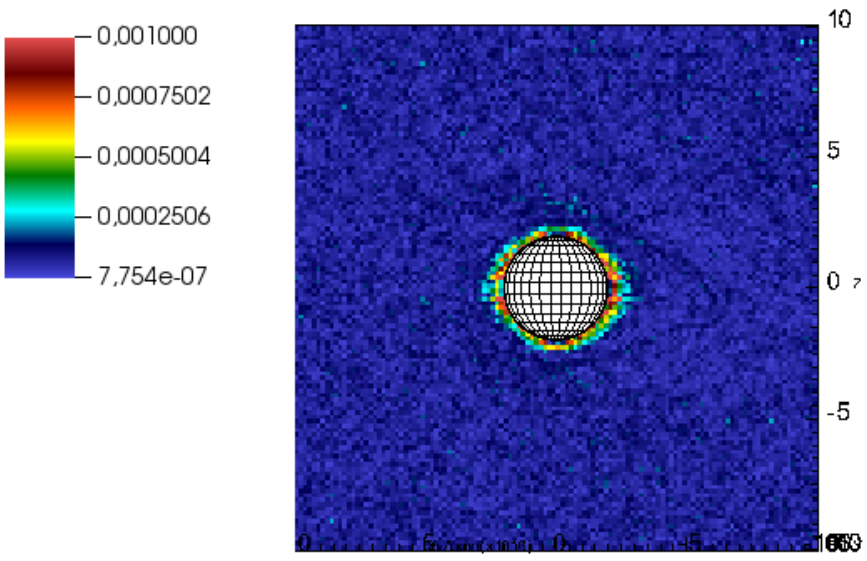


N+ not Magnetized

Acceleration of ionospheric N+ by E-fields

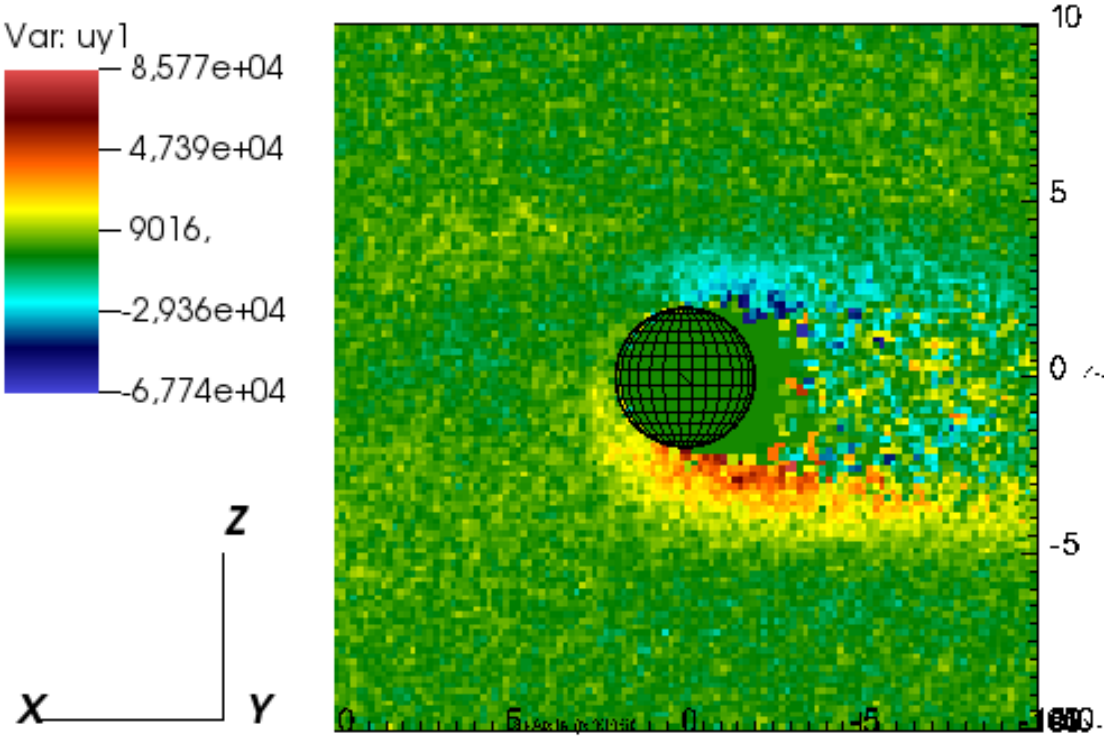


Ionospheric N+ z-velocity [m/s]



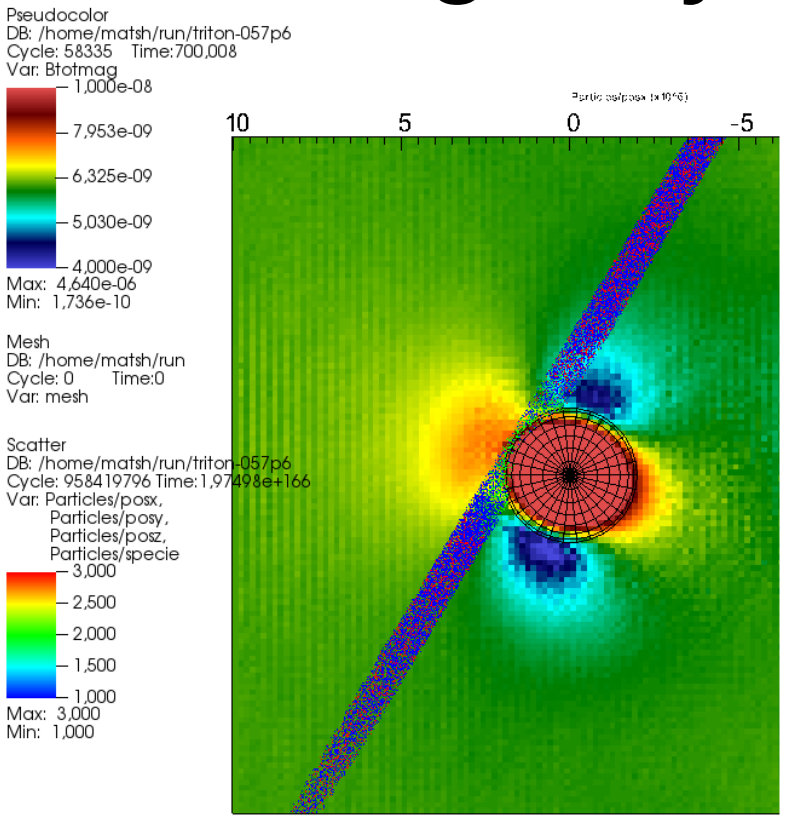
Electric field [V/m]

N+ circulate around the wake



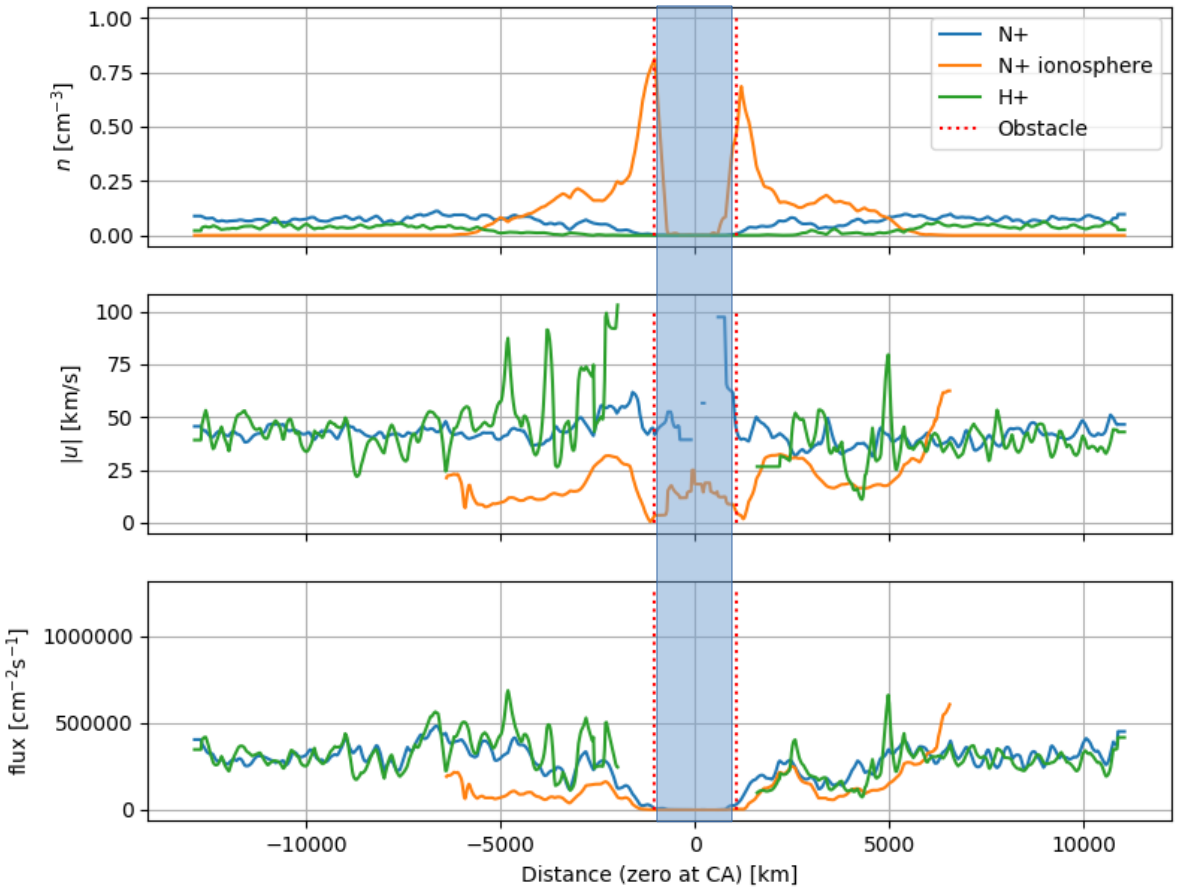
y-velocity (out of page) [m/s]

Particles along a flyby trajectory

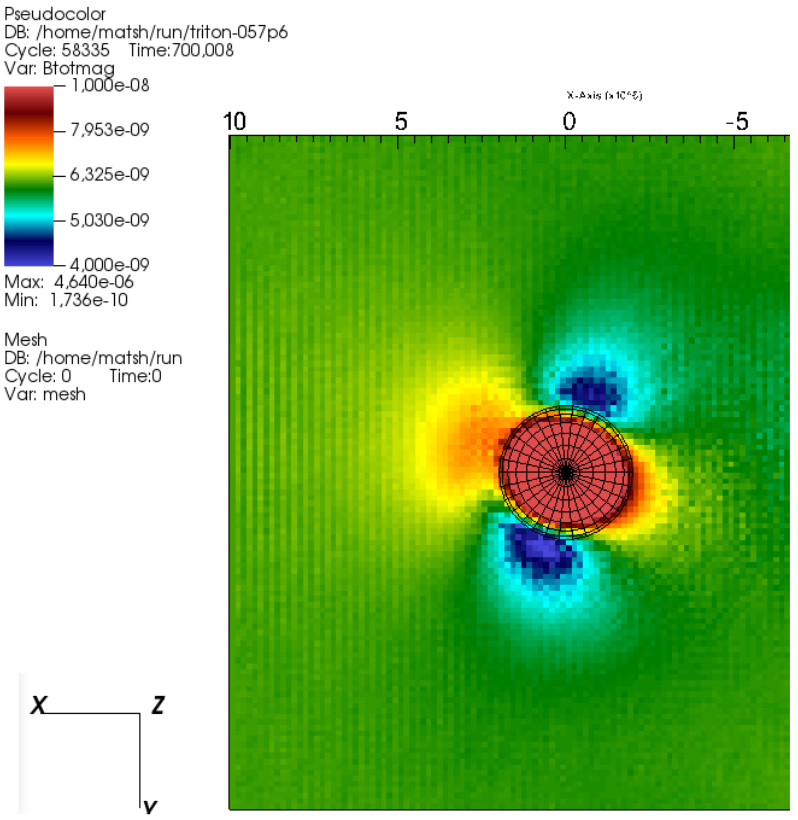


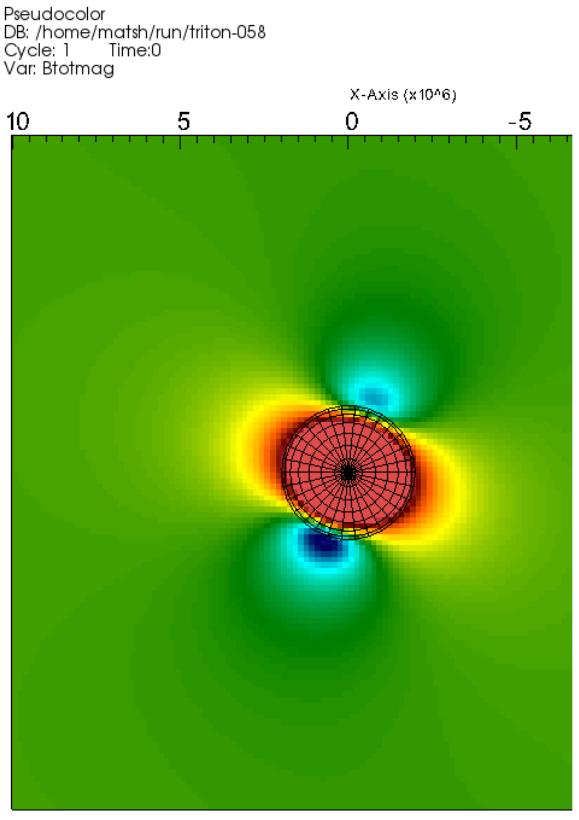
Blue: External N+, Red: External H+, Green: Ionospheric N+

Plasma parameters along a trajectory



Plasma effects, |**B**|

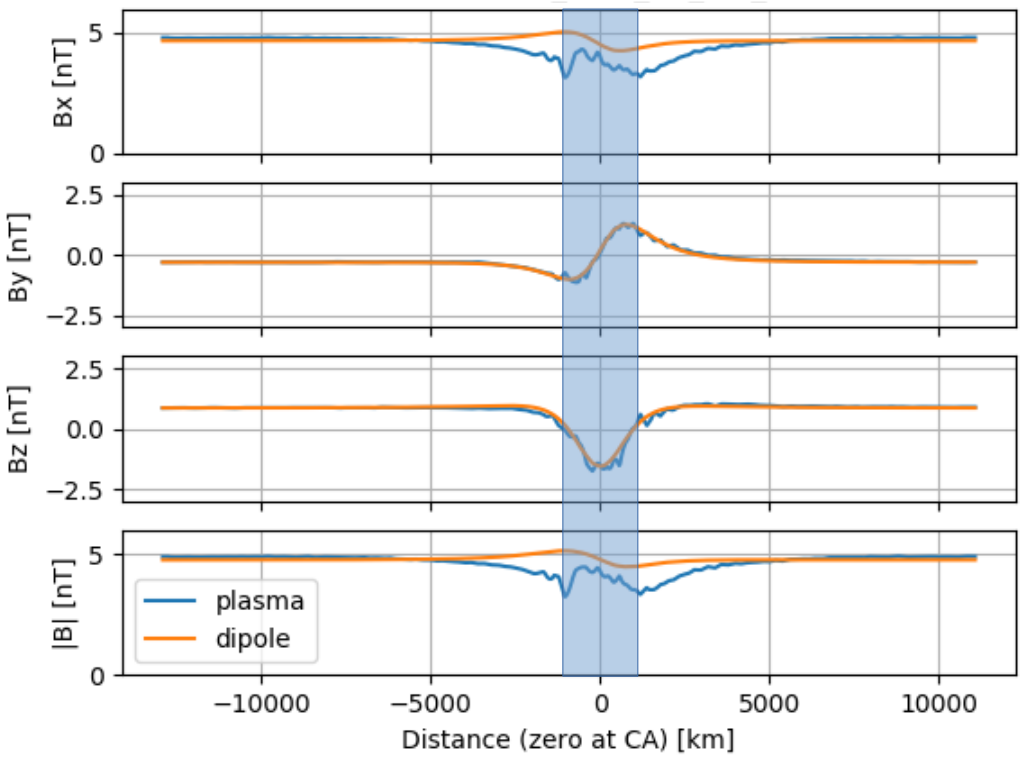




Hybrid run

Only induced dipole

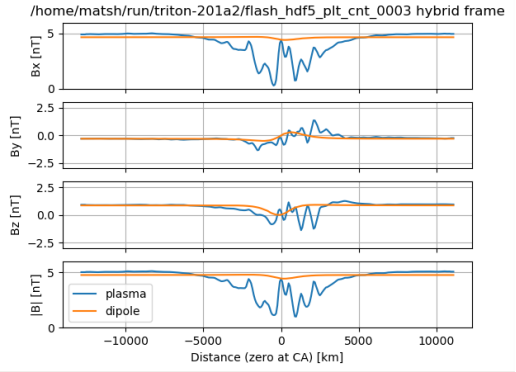
Plasma effects



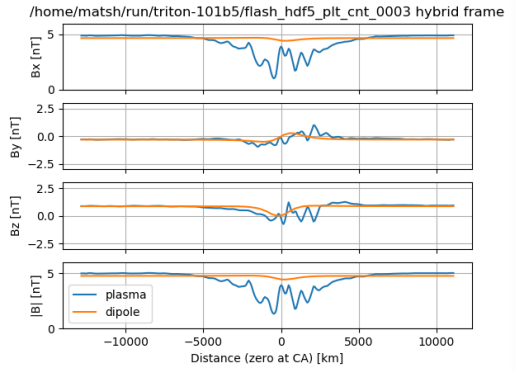
Plasma effects are in Bx.
-X is the flow direction and the external magnetic field is 11 degrees away.
Ionospheric plasma outflow along +-X

Density

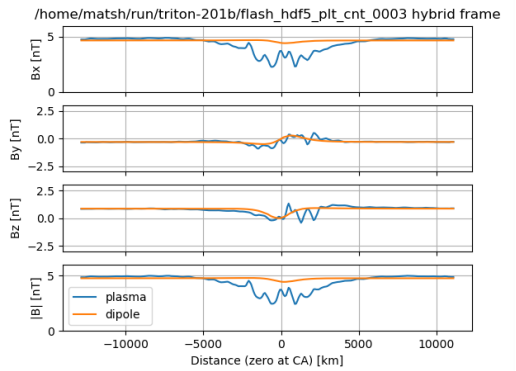
0.055 /cc



0.11 /cc



0.22 /cc



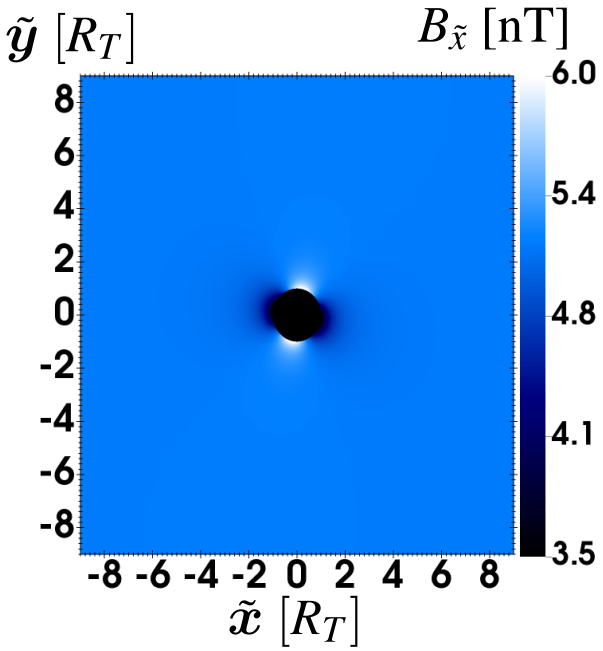
Plasma effects decrease with increasing external density

Opposite to expected...

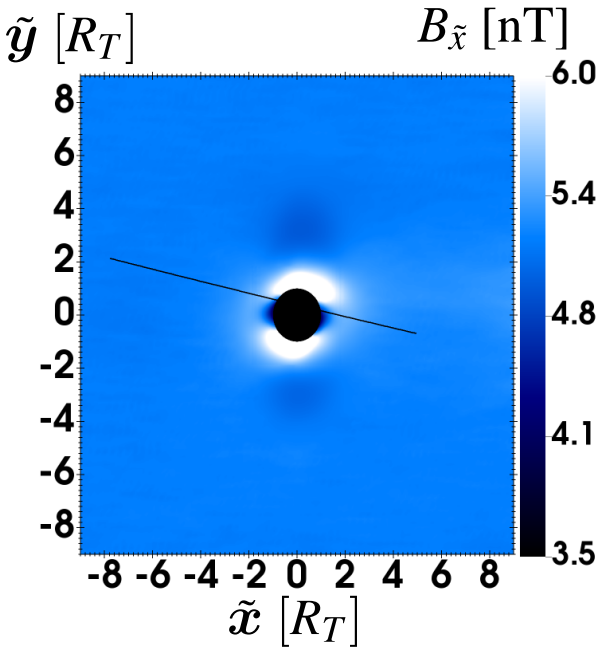
Approximately 0.5 change in plasma effect for a change of 1.0 in density

Triton's Plasma Interaction: AIKEF

- Unobscured induced field visible for H^+ upstream
  - Weak plasma interaction
- Stronger interaction for N^+ plasma
  - Induced field partially obscured, but still visible near the moon
- Plasma composition near Triton is likely a *mixture* of H^+ and N^+



100% H^+ upstream plasma



100% N^+ upstream plasma

Summary

- Triton presents a unique plasma interaction
  - Dense, expanding, ionosphere
  - Changing external conditions. Configurations possible with plasma flow along external magnetic field
  - Separation of external H+, N+, and ionospheric N+
  - Kinetic effects important
  - Numerically challenging due to high Alfven velocities and large ion inertial length
- Outstanding questions
  - How does the plasma interaction depend on external conditions?
    (Triton location in Neptune's magnetosphere)
  - Dependence on external density?
    - Stronger plasma interaction for higher mass specie external plasma (N+ instead of H+)
    - Weaker plasma interaction for increasing charge density (?)
  - Physics of the plasma interaction
    - Acceleration of ionospheric ions
    - Morphology and dynamics of Triton's magnetosphere tail