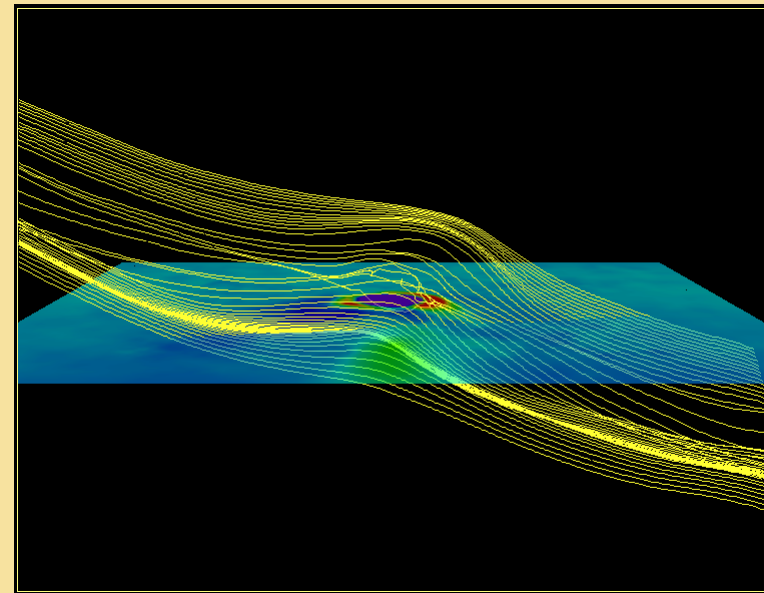
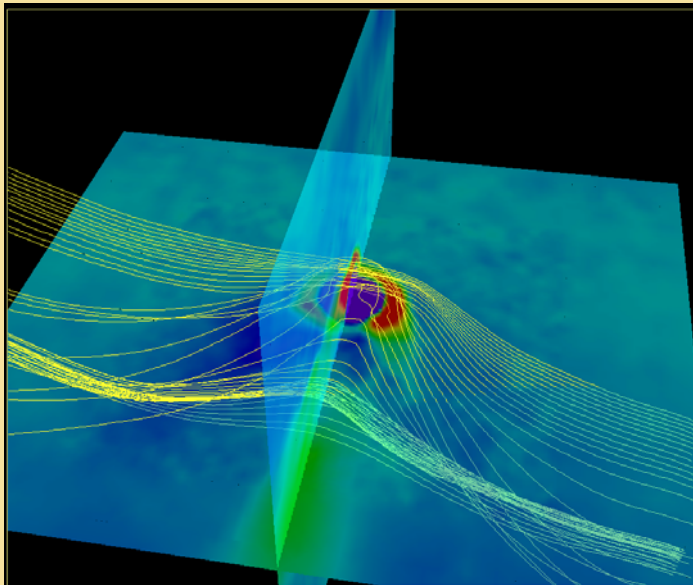


Improved Hybrid Simulation on the Plasma Interaction of Titan

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Finnish Meteorological Institute



1. Titan's unique plasma interaction

Titan's atmospheric interaction with Saturn's magnetospheric plasma is interesting

- Magnetospheric plasma flow is very hot ions.
- Flow is subsonic and shockless though varying

Cassini mission includes over

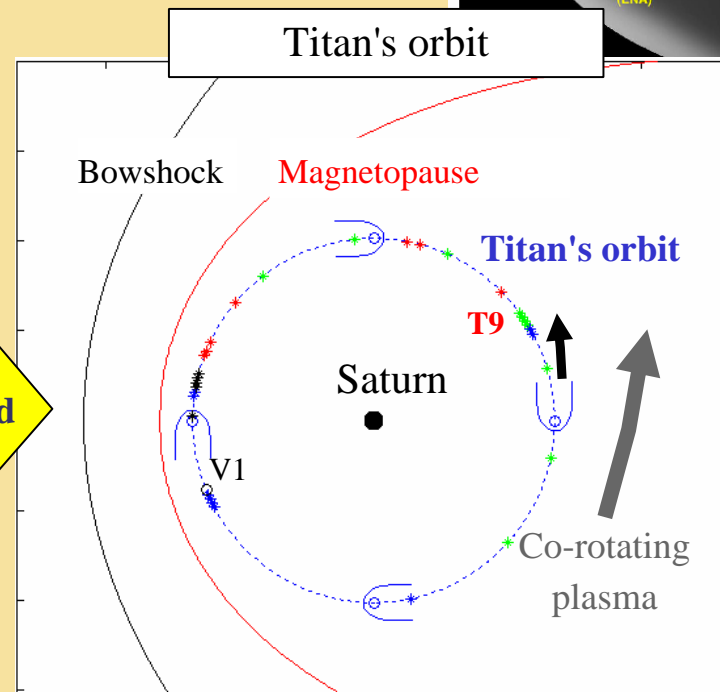
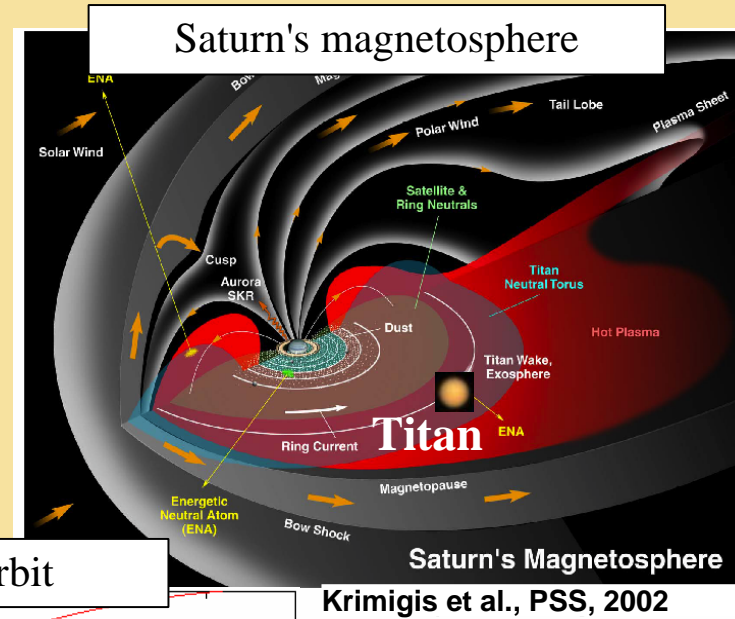
40 close Titan flybys

Flyby **T9** was particular –

Cassini passed through
the middle of the wake

at $5 R_T$ (Titan's radius $R_T = 2575$ km)

Solar Wind



Titan flybys

- * years 2004 and 2005
- * year 2006
- * year 2007
- * year 2008
- V1 Voyager 1 pass

2. Our quasi-neutral hybrid model

Hybrid: macro-particles for ions (four species: H^+ , O^+ , N_2^+ , CH_4^+)

whereas electrons treated as fluid

Quasi-neutral: $\sum n_{ions} = n_e$

Ions experience Lorentzian force

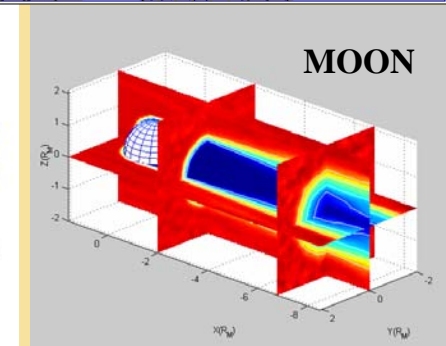
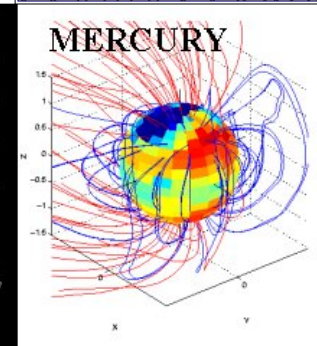
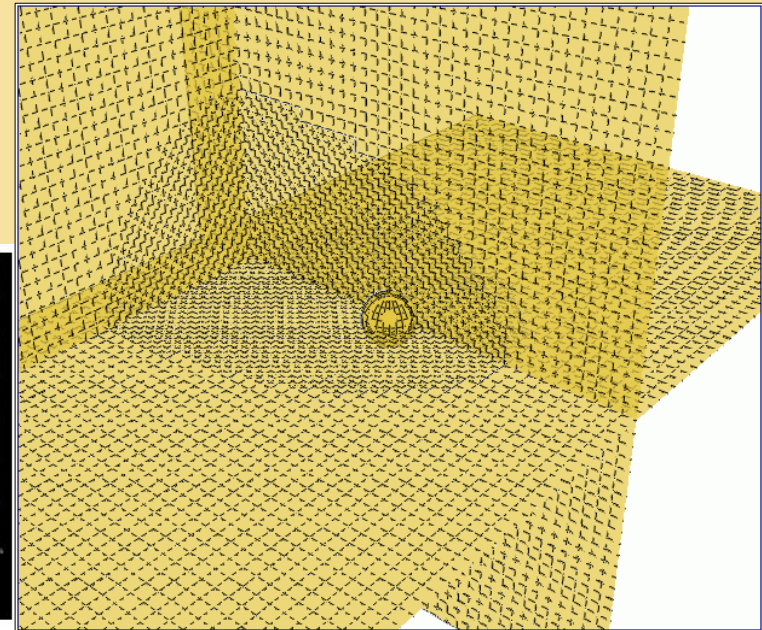
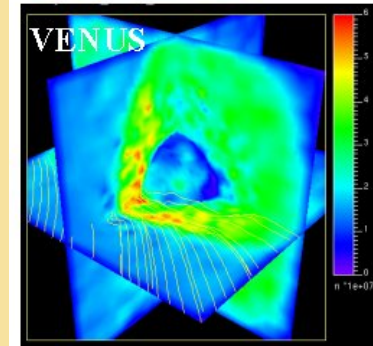
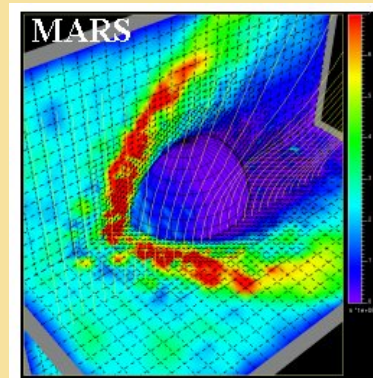
\Rightarrow drifts, gyroeffects

Self-consistent propagation of particle motion and fields

Our code:

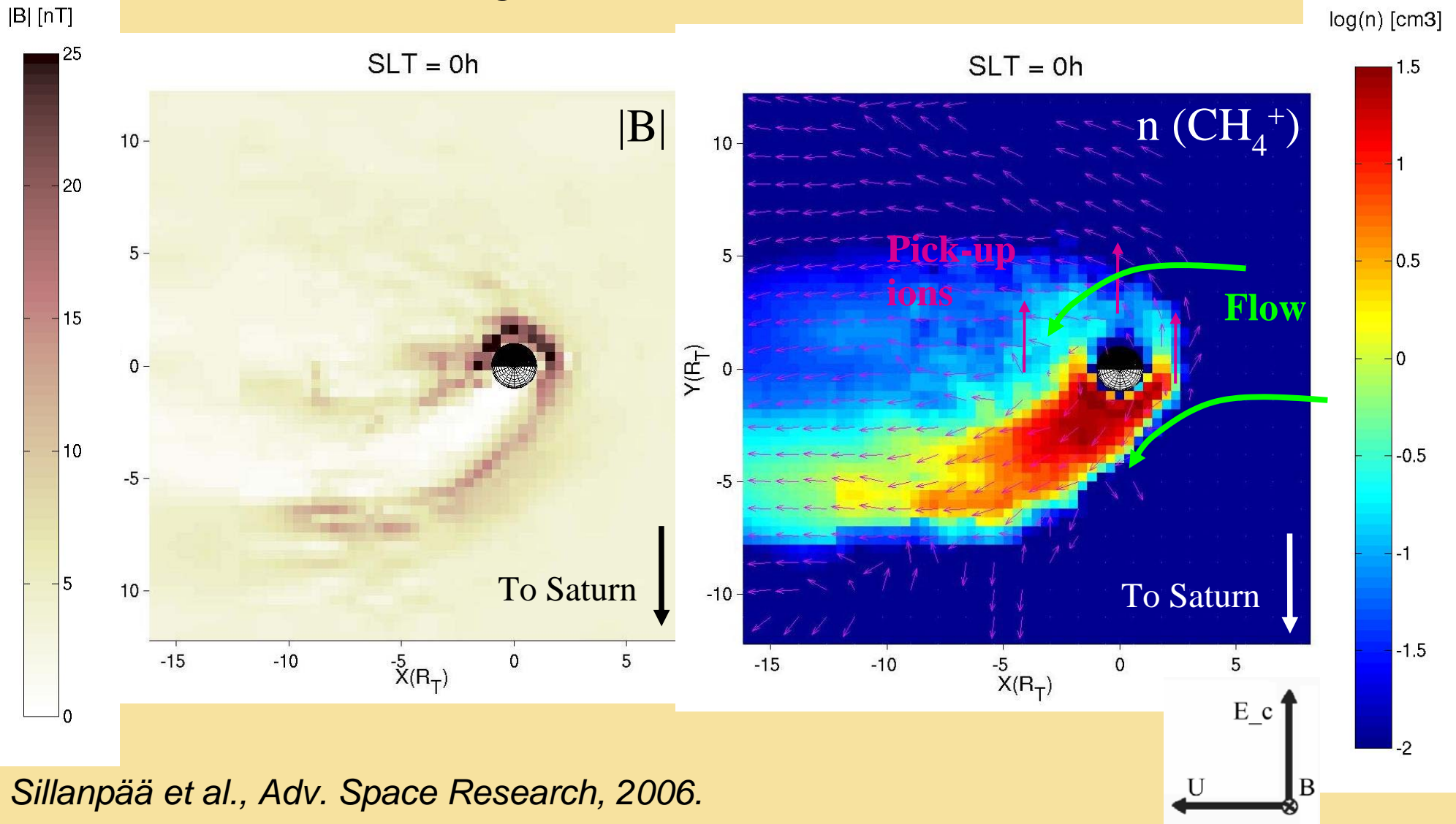
hierarchically enhanced grid-density structure uses splitting and joining

Family of models incl. models for Mars, Venus, Mercury and the Moon



3. Turning of the tail

Induced magnetic field and ionotail



Sillanpää et al., Adv. Space Research, 2006.

4. *Simulation parameters for the nominal case*

The understanding of the Titan interaction should start from the nominal case:

magnetospheric magnetic field is southward and $\perp U_{\text{bulk}}$

\Rightarrow induced electric field E_C points to the anti-Saturn direction.

$B = 5\text{nT}$, $U_{\text{bulk}} = 120\text{ km/s}$, $v_{\text{th}} = 141\text{ km/s}$

coordinates: X is in direction of $-U$, Y as E_C , and Z 'northward'

grid cell size is $0.2 R_T = 500\text{ km}$

number of macro ions per cell = 50 (splitting and joining)

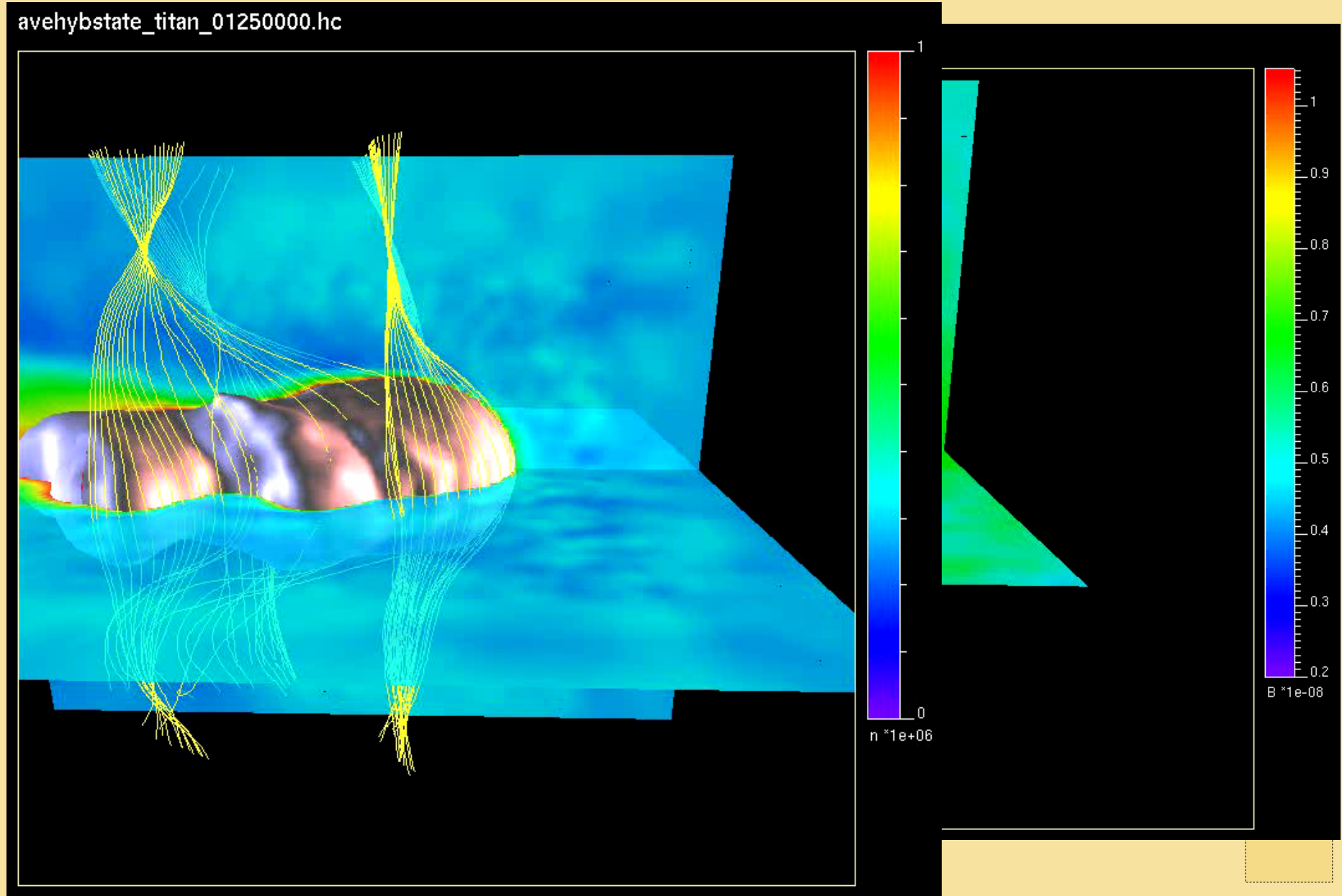
four ion species:

incident flow: \mathbf{H}^+ , \mathbf{O}^+ with density ratio 1 : 2 , $n(\mathbf{H}^+) = 0.1\text{ cm}^{-3}$

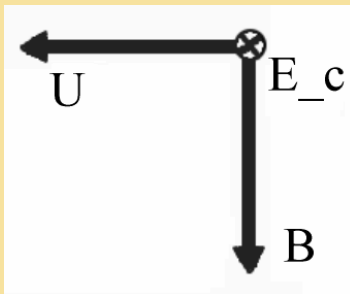
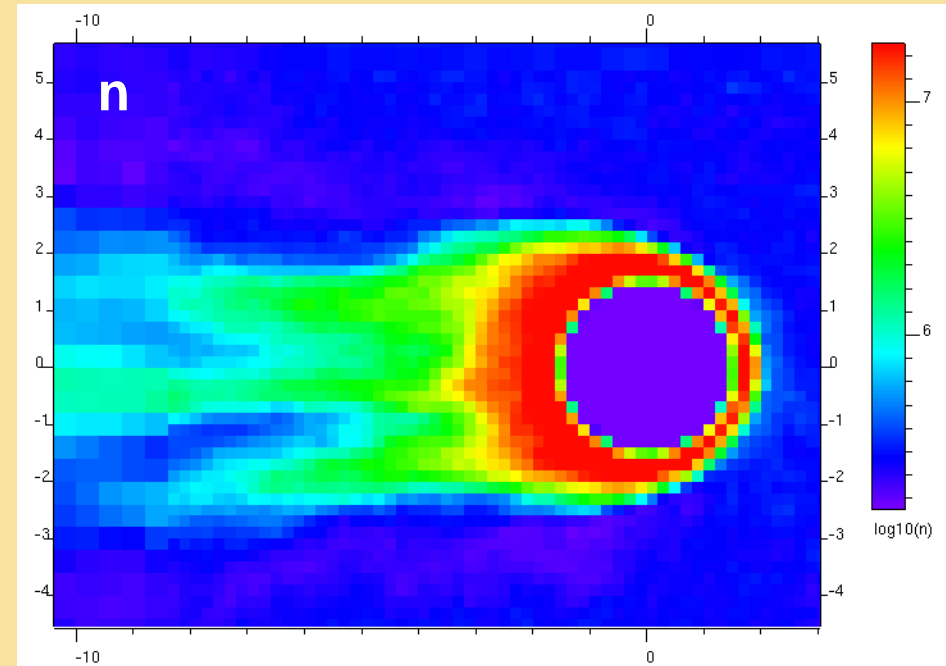
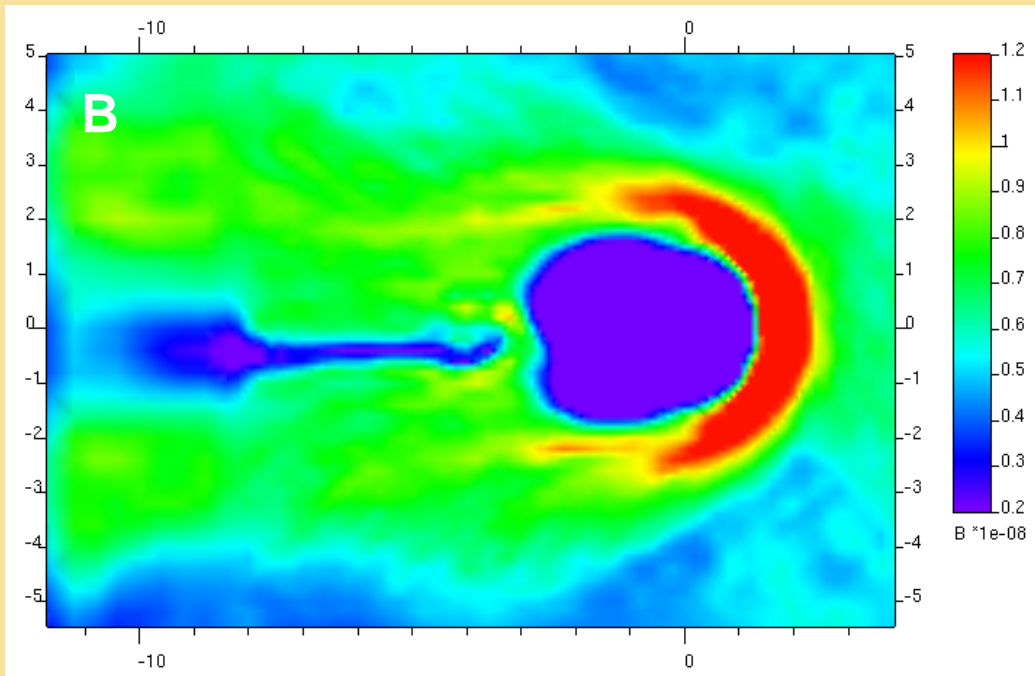
\mathbf{CH}_4^+ emitted using Chamberlain profile with SLT = 10 h ($2\text{e}25\text{ ions/s}$)

\mathbf{N}_2^+ emission is uniform from the obstacle boundary ($1.6 R_T$) ($1.6\text{e}25\text{ ions/s}$)

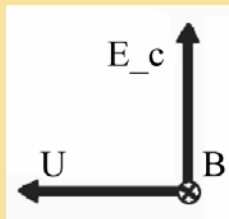
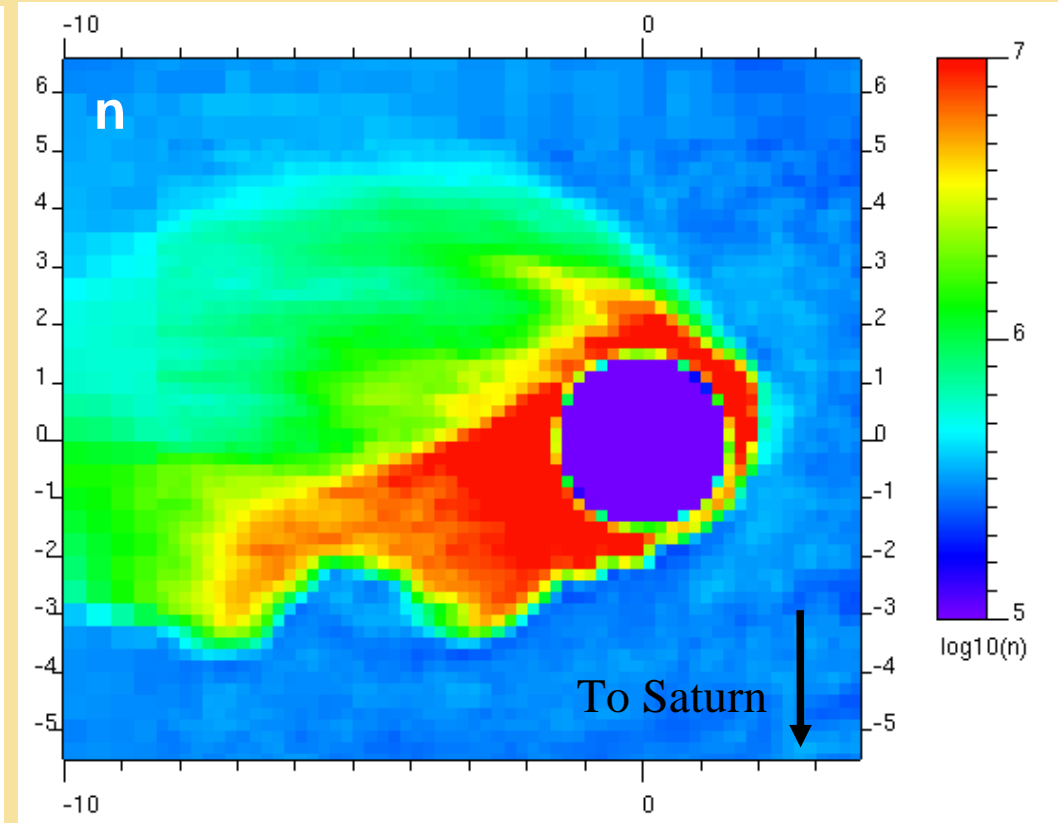
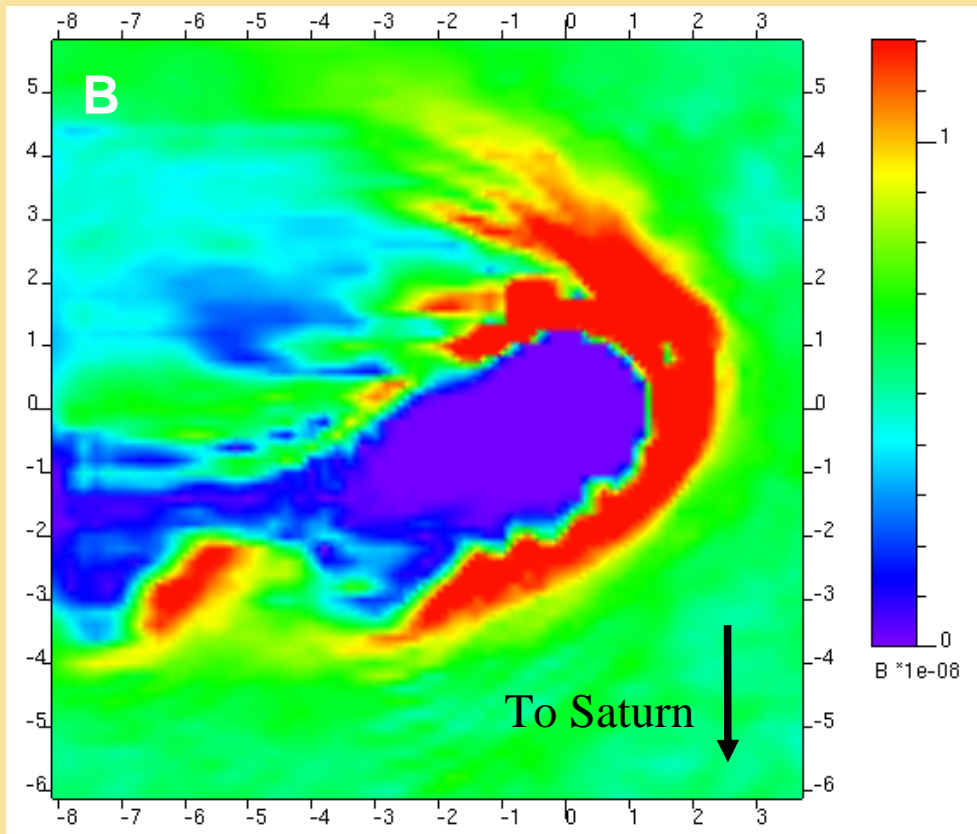
5. Nominal Case Results – animations



5. Nominal Case Results – *B and n on Y=0 plane*

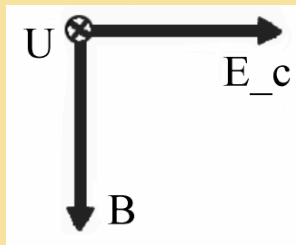


5. Nominal Case Results – *B and n on Z=0 plane*

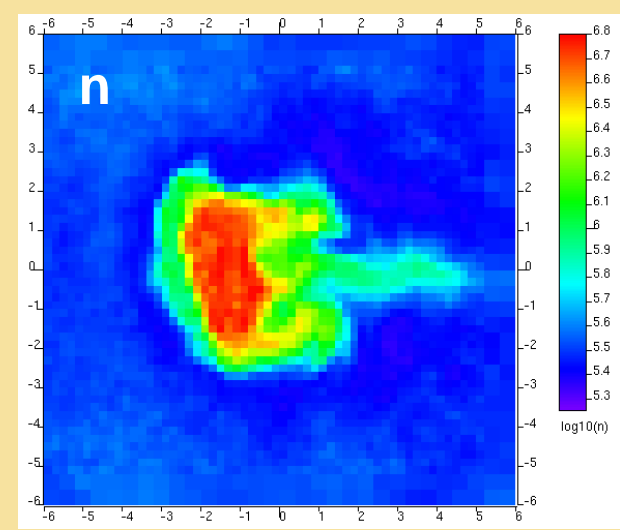
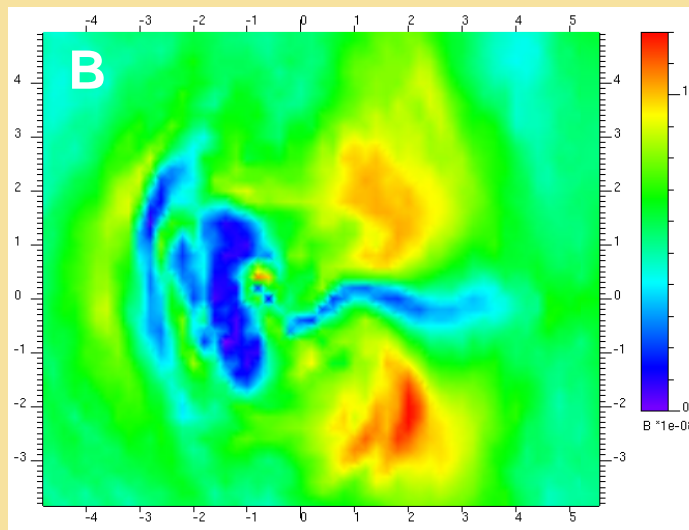
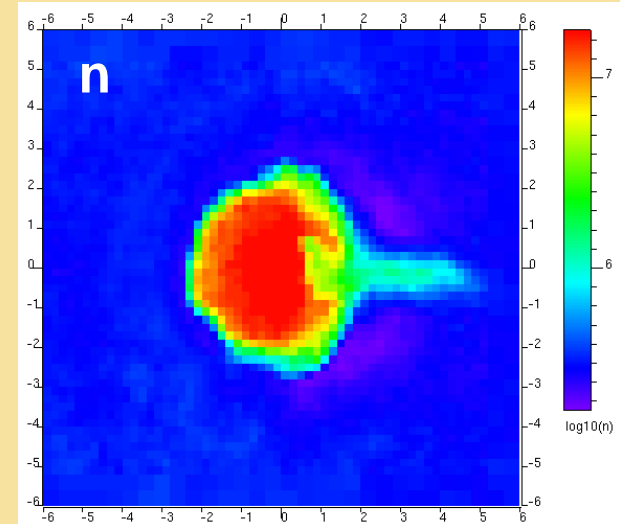
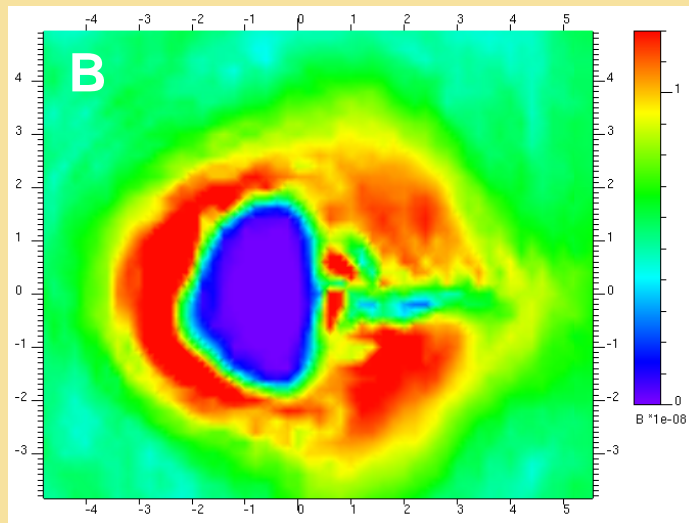


5. Nominal Case Results – ion extension in the E_C direction

$X = -2 R_T$ plane



$X = -5 R_T$ plane



6. Conclusion

Our hybrid simulation model:

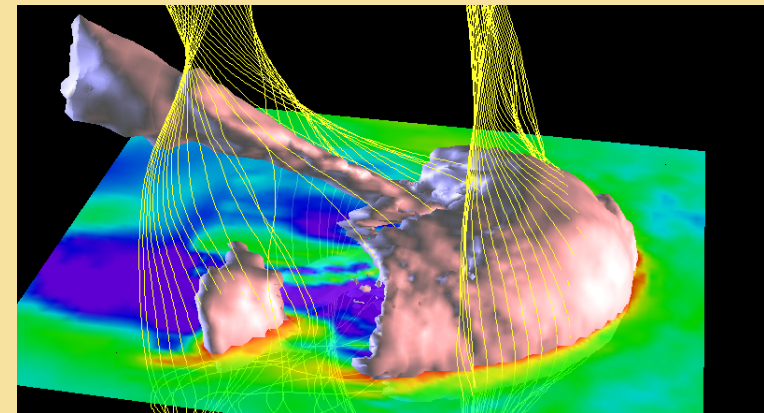
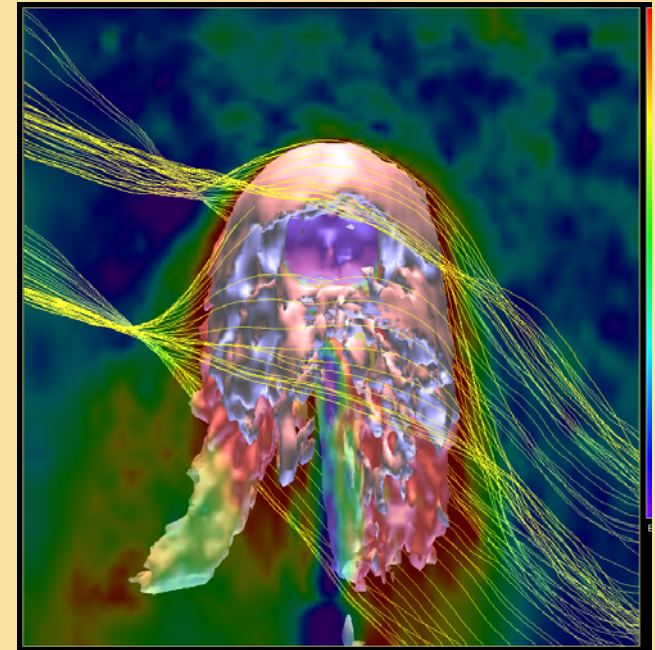
- visualization of Titan's plasma interaction
- field and **particle** propagation self-consistent
- same advanced code for all our objects
(one line of development
– all functions available for all objects)

Further work in progress:

- we are continuing with comparisons with CAPS and MAG data sets, especially T9
- primary research objectives include
- determining limits for ion emissions
 - constructing a picture on the effects of variable flow conditions

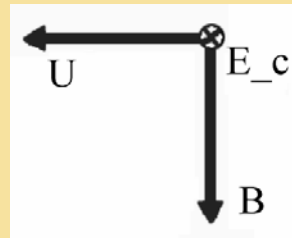
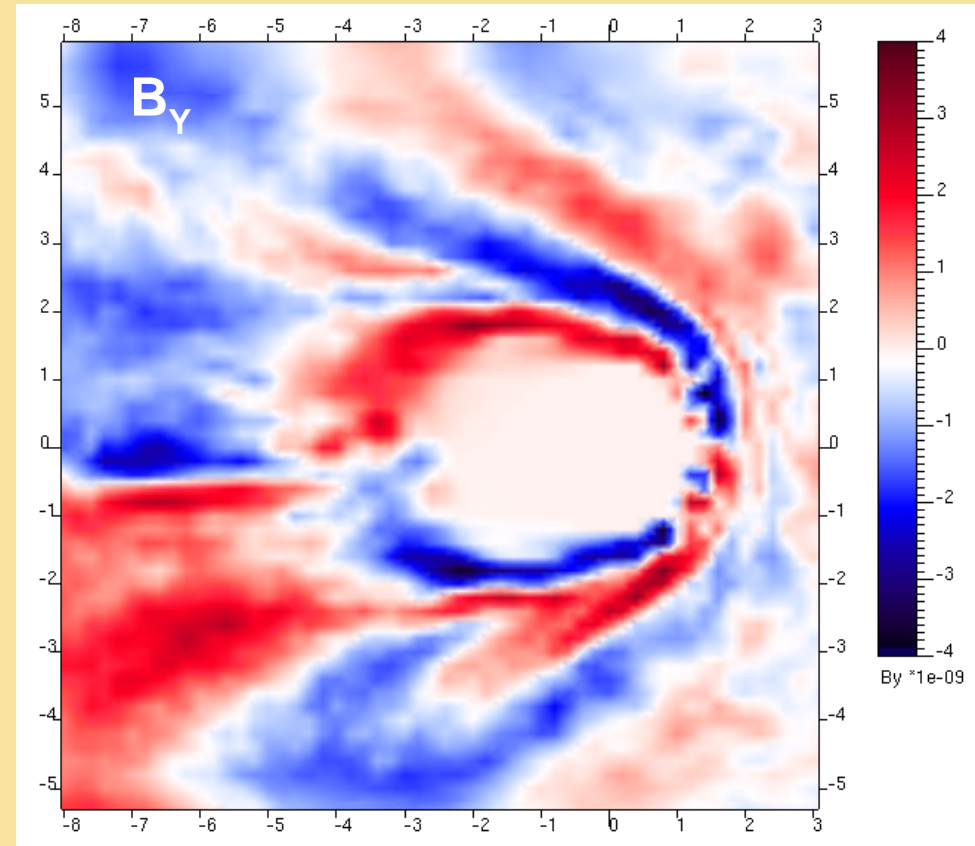
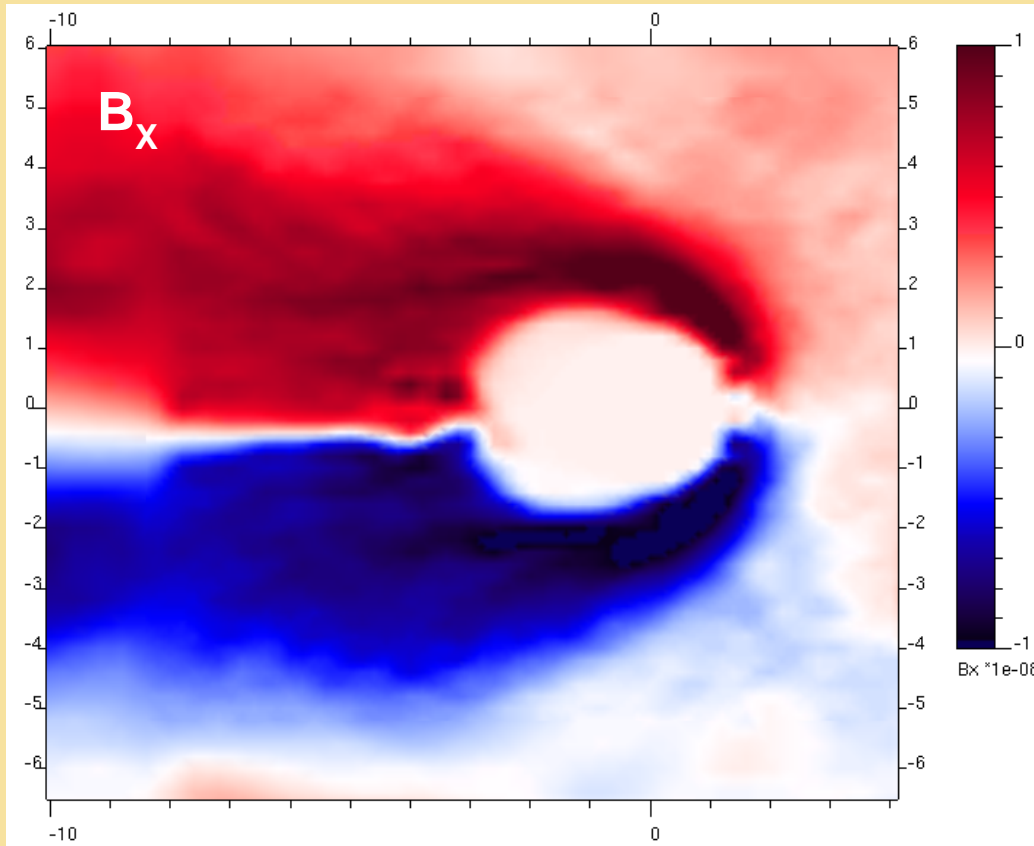
Understanding Titan's plasma interaction:

All in all, Cassini's many flybys are providing the needed measurements – and simulations the tools to interpret them.



- End of presentation
- Forward to Appendix slides

Appendix – B_X and B_Y on $Y=0$ plane

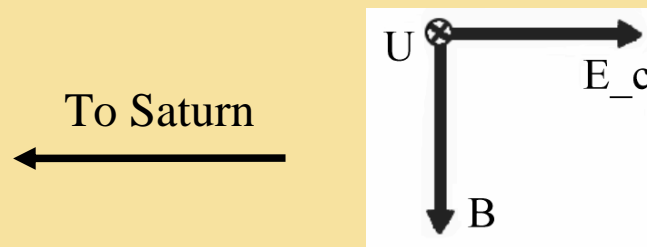
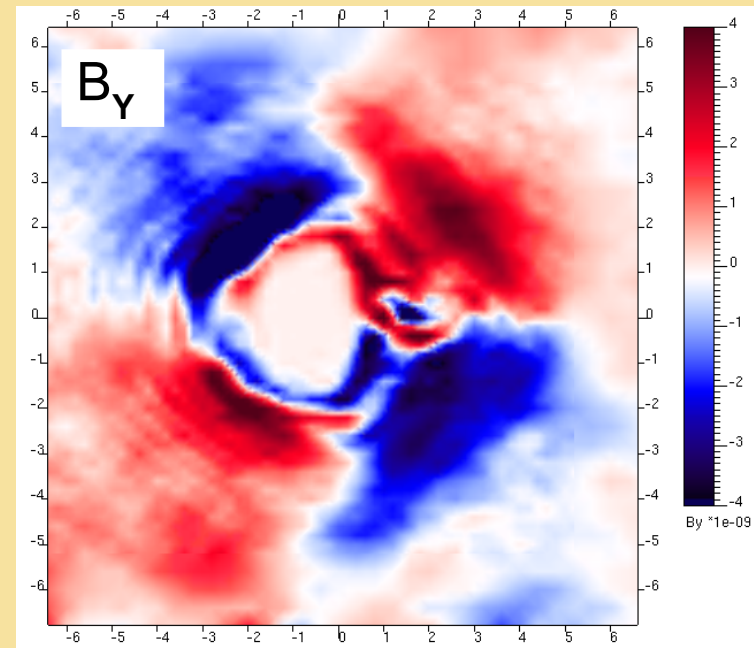
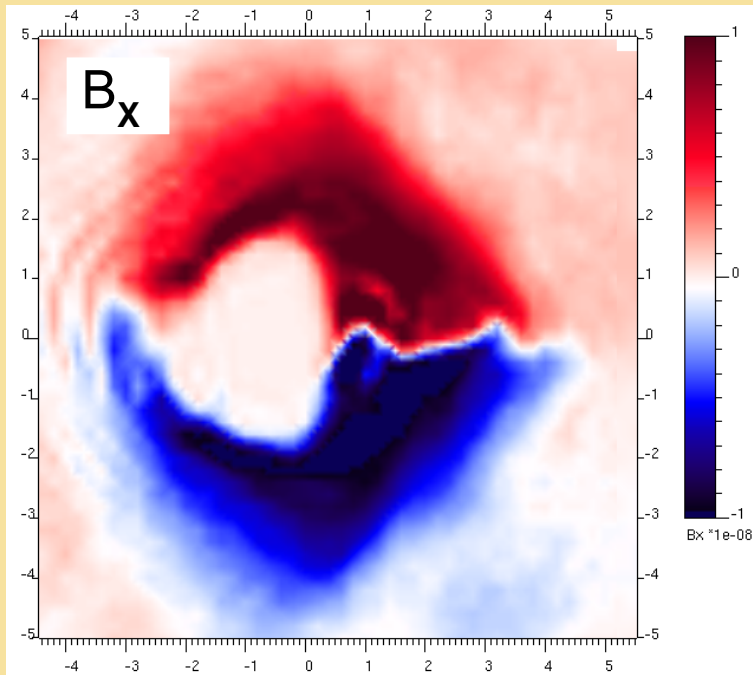


$$\frac{\partial \vec{B}}{\partial t} = -\nabla \times \vec{E}_C = -\nabla \times \{-\vec{U}_e \times \vec{B}\}$$

$$\frac{\partial B_Y}{\partial t} = -\partial_{Z'} \{U_{ey} B_Z - U_{ez} B_Y\} - \partial_{X'} \{-U_{ex} B_Y + U_{ey} B_X\}$$

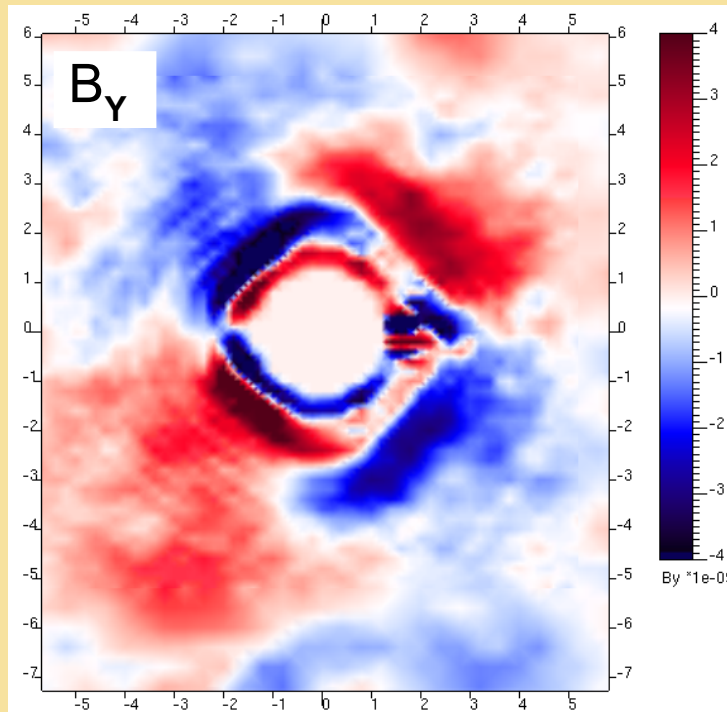
$$\frac{\partial B_Y}{\partial t} = -\partial_{Z'} \{U_{ey} B_Z\} - \partial_{X'} \{U_{ey} B_X\}$$

Appendix Results – B_X and B_Y on $X=-2 R_T$ plane

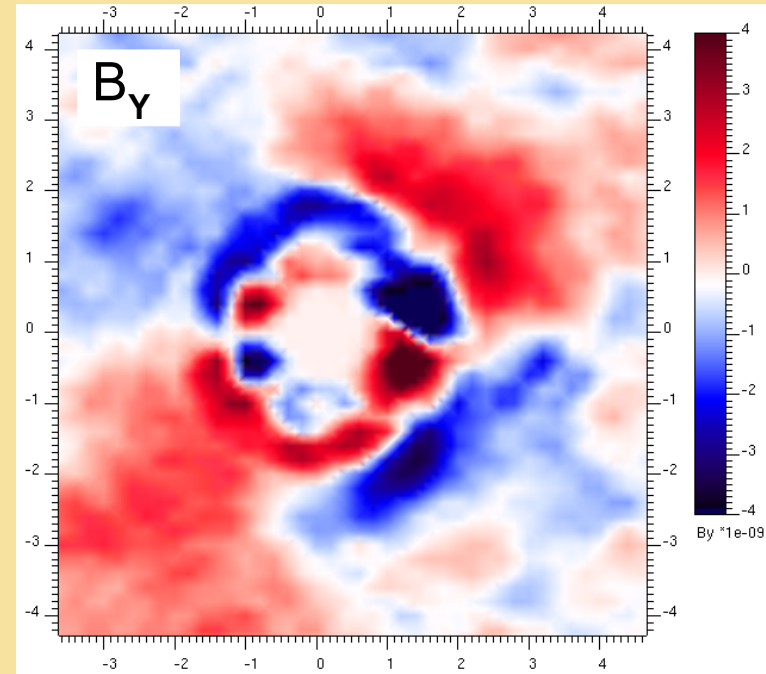


Appendix Results – B_Y on $X=0$ and $X=1 R_T$ planes

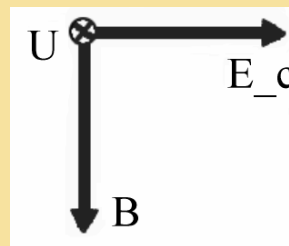
$X=0$



$X=1 R_T$



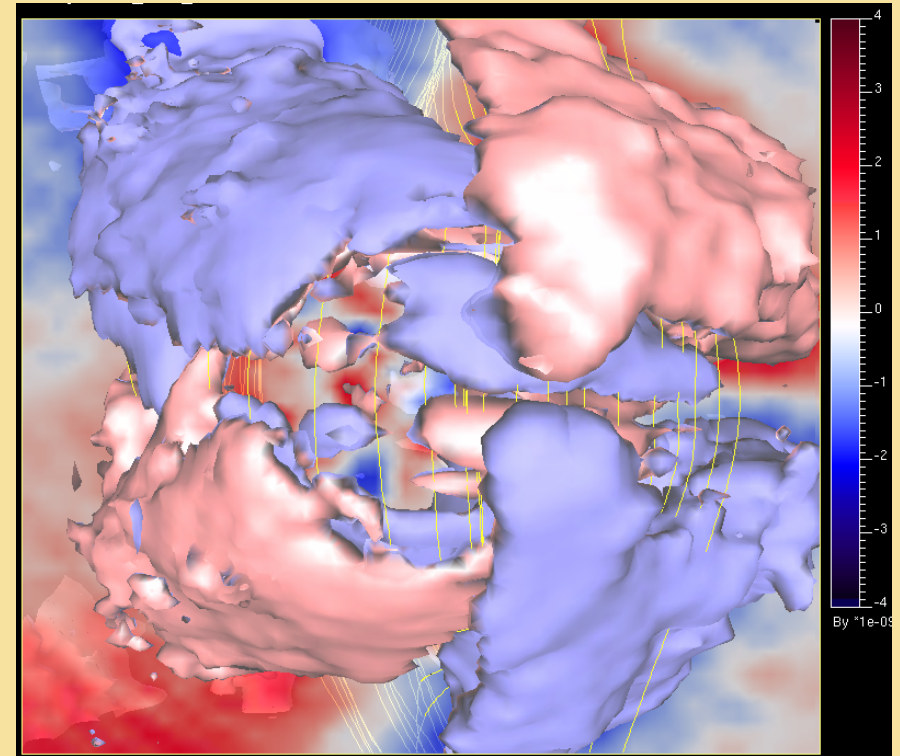
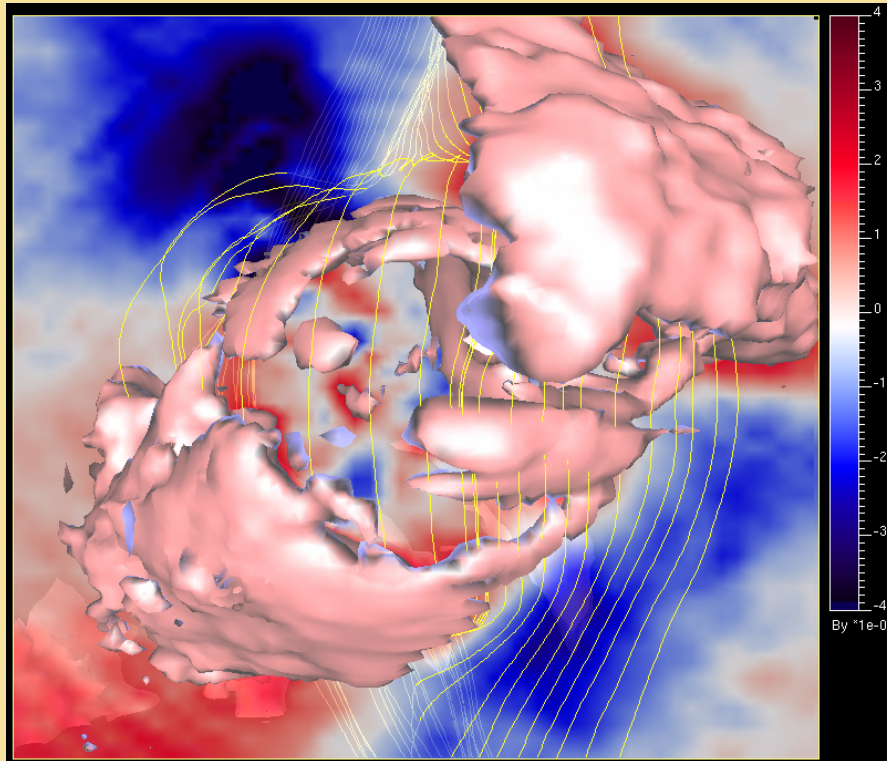
To Saturn
←



Appendix Results – B_Y surfaces

$B_Y = +2$ nT

$B_Y = +/- 2$ nT



To Saturn
←

