JOHNS HOPKINS
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Effects of Titan's magnetospheric interaction on its atmosphere

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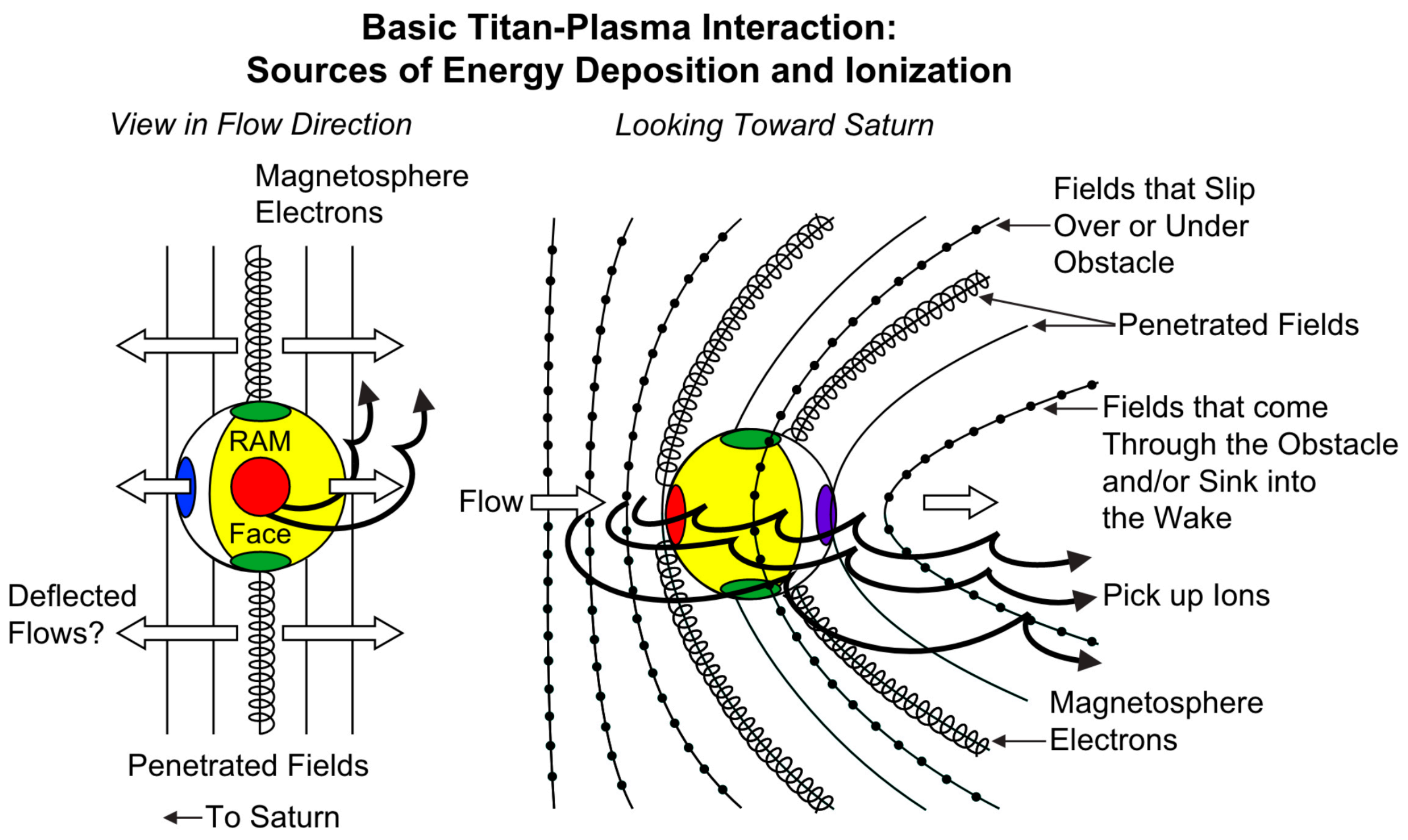
Titan's magnetospheric interaction



Luhmann et al. 2012

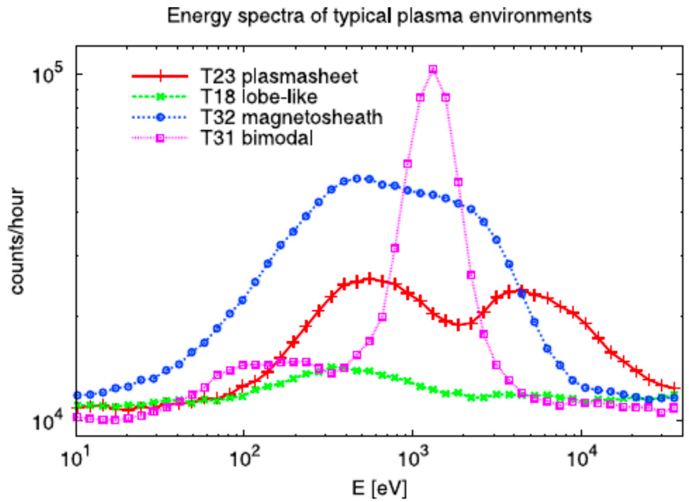
Titan's magnetospheric interaction

- Only moon with significant atmosphere.
- Orbits at 20 R_S, very close to stand-off distance of magnetopause.
- Spends most of the time inside the magnetosphere, but was observed by Cassini at least twice in the magnetosheath (e.g. Wei et al. 2011) and once in the solar wind (e.g. Bertucci et al. 2015).
- When inside the magnetosphere, the flapping motion of the magnetodisk (Arridge et al. 2007) makes it possible for Titan to be located inside the plasma sheet, but also at the lobes.

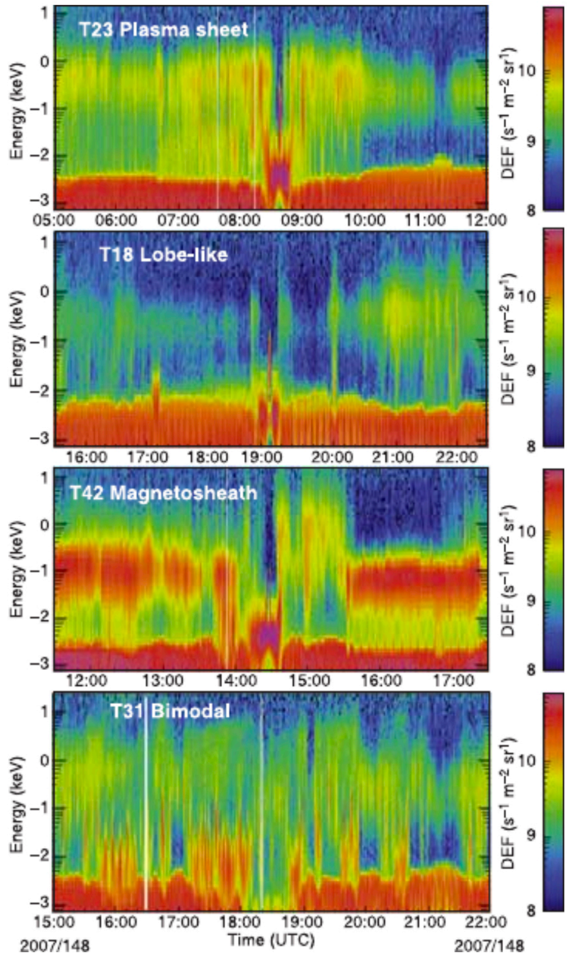
Titan’s magnetospheric interaction

Rymer et al. 2009

- Upstream environment categorized using:
  - Electrons (Rymer et al. 2009).
  - Thermal ions (Németh et al. 2011).
  - Magnetic field (Simon et al. 2011).
  - Energetic protons (Regoli et al. 2018).

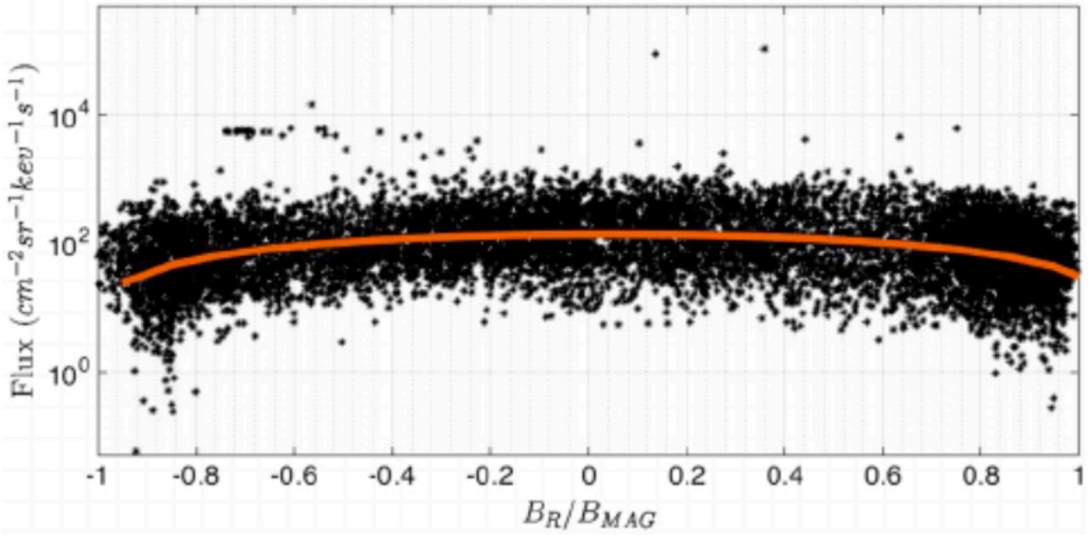


Németh et al. 2011



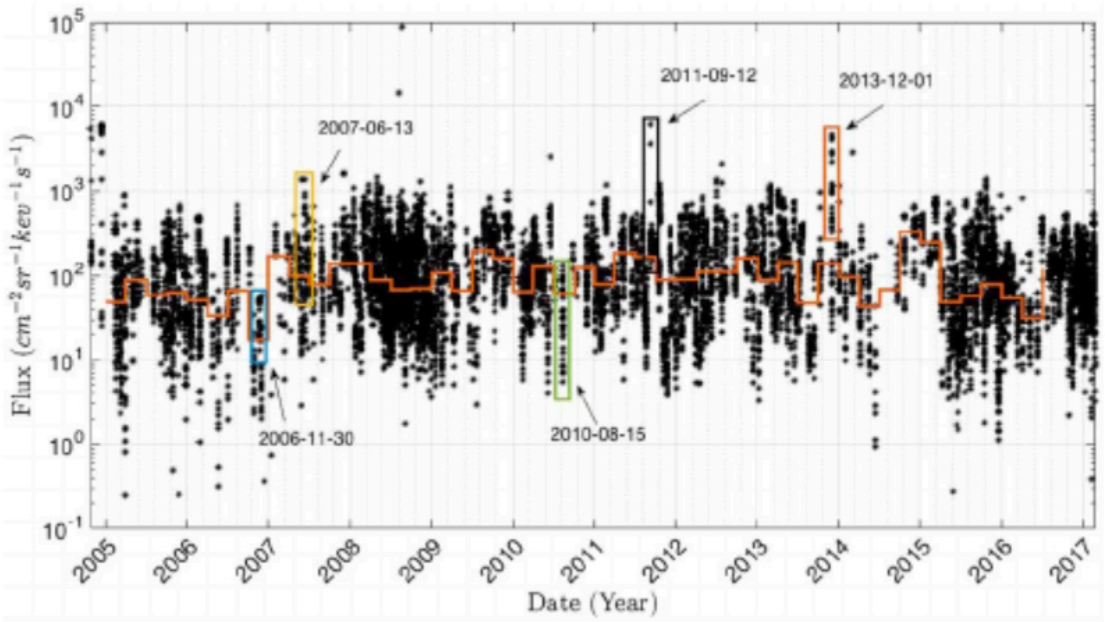
Energetic environment at Titan

- Energetic proton environment at Titan analyzed using Cassini/MIMI data in Regoli et al. (2018).
- Environment is highly variable, with some level of organization based on location (plasma sheet, lobes, magnetosheath).



Energetic environment at Titan

- No clear seasonal dependence observed, but location does have an influence in observed fluxes, although highly variable.



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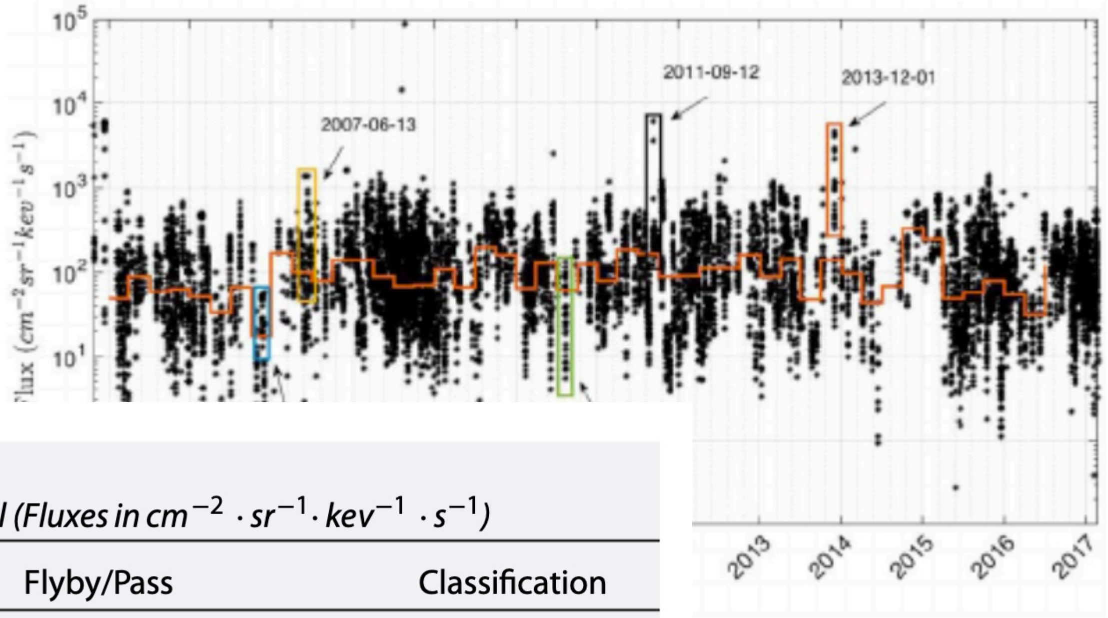


Table 3

Characteristics of Four Selected Data Points for Ion Fluxes From the A0 Channel (Fluxes in $cm^{-2} \cdot sr^{-1} \cdot kev^{-1} \cdot s^{-1}$*)*

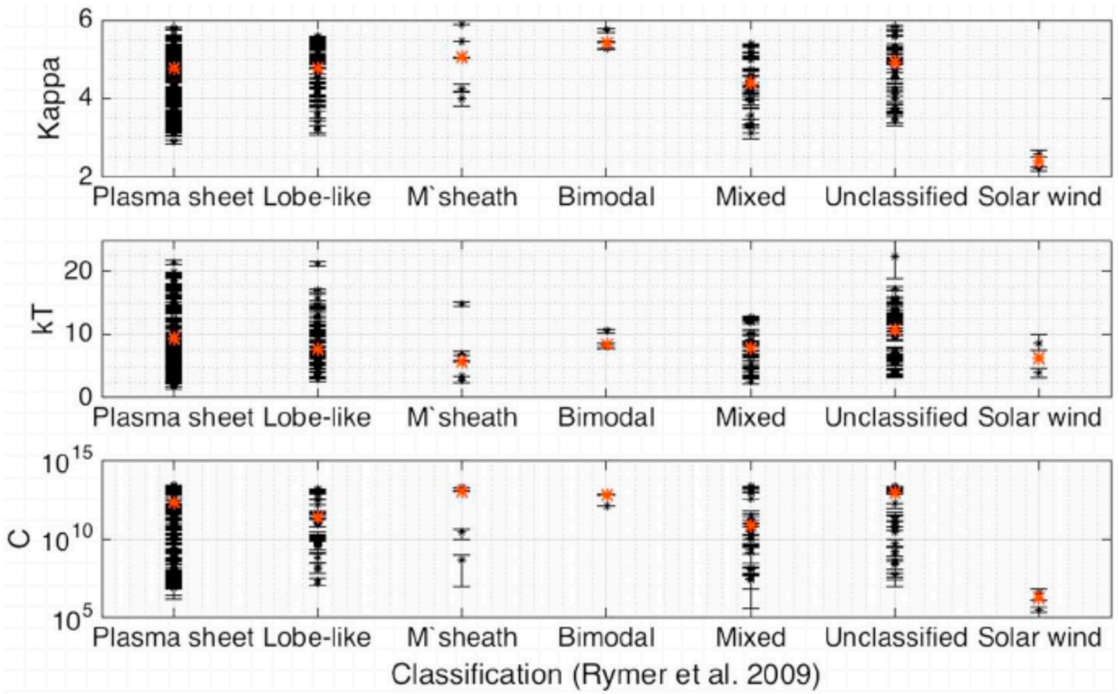
Date	A0 flux	SLT	Flyby/Pass	Classification
2006-11-30	57.15	2.17	Pass	Lobe-like
2007-6-13	1.36×10^3	13.56	Flyby (T32)	Magnetosheath
2010-8-15	130.02	15.90	Pass	Current sheet
2011-9-12	6.15×10^3	17.69	Flyby (T78)	Current sheet
2013-12-1	4.62×10^3	12.37	Flyby (T96)	Solar wind

Note. Dates are formatted as year-month-day.

Empirical model for energetic protons

- Using a modified Kappa distribution (Dialynas et al. 2009), an empirical model for each environment was built.

$$j = C \cdot E[E + kT(1 + \kappa)]^{-(1+\kappa)}$$



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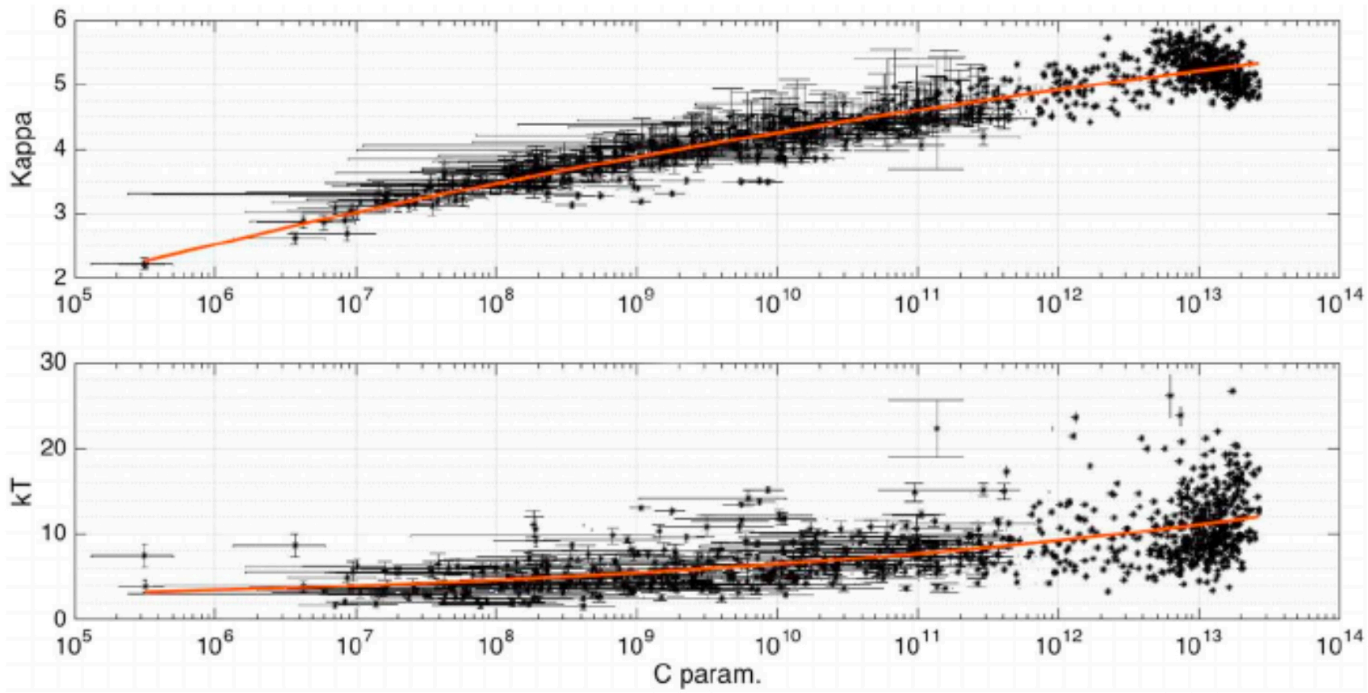
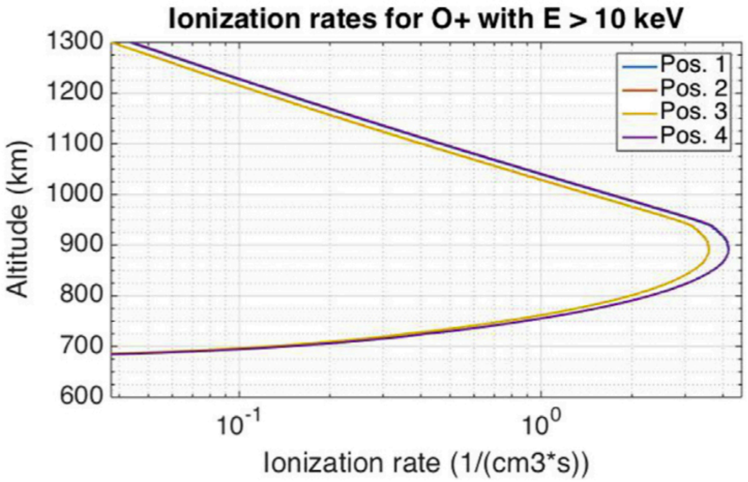


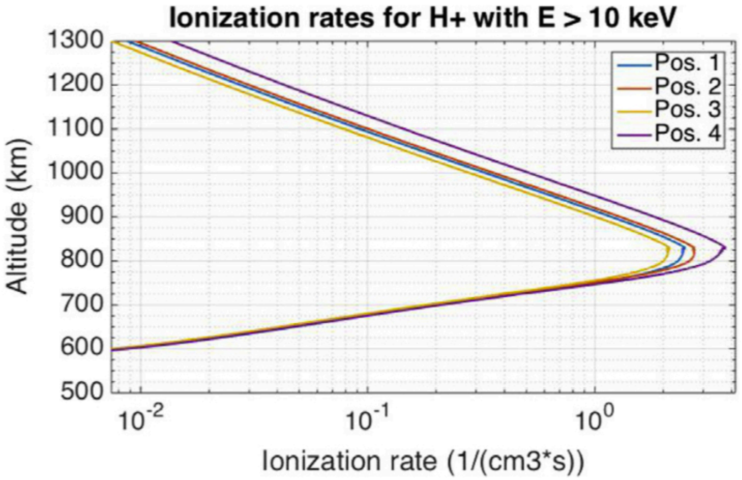
$$\kappa = -9.915 \cdot C^{-0.03768} + 8.421$$

$$kT = 0.7155 \cdot C^{0.08844} + 1.028$$

Effect of environment on the atmosphere

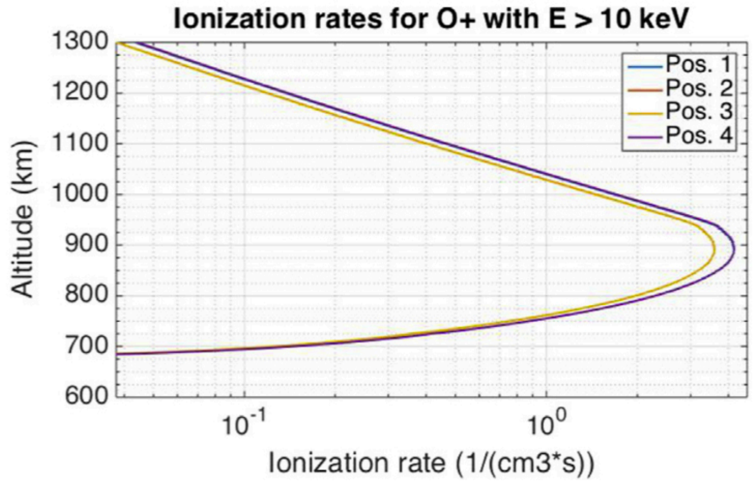
- Several studies have focused on precipitation of thermal (e.g. Snowden et al. 2021) and energetic plasma (Cravens et al. 2008, Regoli et al. 2016).
- The variability of the upstream environment requires an analysis exploring a wide parameter space.
- Gyroradius effects shown to be important for energetic ions.

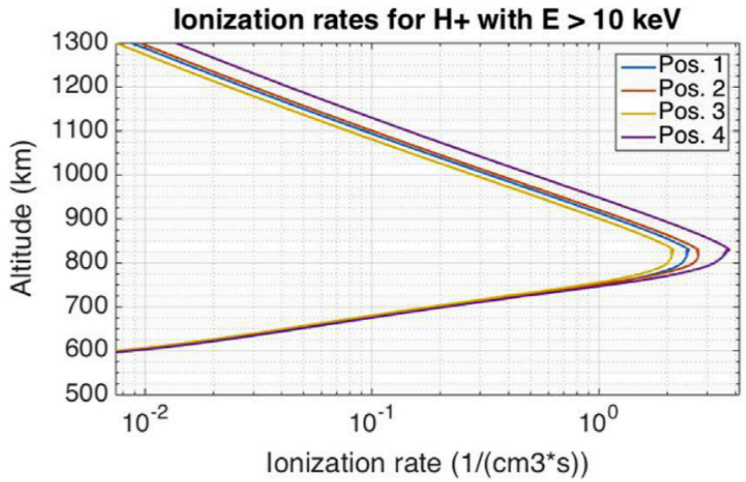




Effect of environment on the atmosphere

- Tracing of energetic H+ and O+ in background fields produced by hybrid code (AIKEF, Müller et al. 2011).
- Specific flyby: T9.
- Asymmetries in the precipitation patterns of the ions due to gyroradii being comparable to size of the moon.
- Simplistic ion transport model (grazing angle not taken into account, all energy going into ionization).





Next steps

- Improve transport model:
  - Geant4 Monte Carlo model.
  - Particles from all primary and secondary interactions tracked discretely in the geometry.
  - The relevant physics for electrons is considered (gradual energy loss, ionization/production of secondaries, bremsstrahlung).
  - Processes are evaluated at each step along each particle's trajectory.
  - Using Livermore low energy physics libraries for electromagnetic physics.
  - See T. Nordheim's talk for more details.

Next steps

- Build empirical model for energetic W^+ and e^-.
- Simulate energetic electrons:
  - Gyroradius effects will not be as significant, but electron impact ionization more important than charge exchange.
  - Tracing code already modified to account for returning electrons; tricky at Titan due to strong draping pattern.
- Extend the parameter space by simulating Titan in different environments (plasma sheet, lobes, magnetosheath, solar wind).