

# Properties of energetic ions at Saturn's Magnetosphere with $>20$ keV Cassini/MIMI Measurements

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A very important use of the  $\kappa$ -distribution function is the determination of the macroscopic parameters that are fundamentally important for studying the properties of energetic plasma in planetary magnetospheres. Moments of the charged particle distribution function provide a compact way of studying the transport, acceleration, and interactions of plasma and energetic particles in magnetospheres. We analyze  $\sim 13$  years of  $> 20$  keV  $H^+$  and  $O^+$  energy spectra from Cassini/MIMI using  $\kappa$ -distributions (Dialynas et al. 2018), which are then used to calculate the energetic ion moments for both species inside Saturn's magnetosphere. A simple parametric model is then employed to simulate the energetic ion partial pressure, density, and temperature toward extracting the polytropic index ( $\Gamma$ ) for both species. We find that the non radiation belt energetic ions are heavily depleted inside  $\sim 8 R_S$  and the ion pressure and density drop to minimum, as a result of charge exchange losses at the Enceladus neutral gas. At this part of the magnetosphere, the behavior of  $H^+$  and  $O^+$  appears to be quasi-isothermal ( $\Gamma < 1$ ). The  $9.5 < L < 20$  region corresponds to a local equatorial acceleration region, where sub-adiabatic transport of  $H^+$  ( $\Gamma \sim 1.25$ ), and quasi-isothermal behavior of  $O^+$  ( $\Gamma \sim 0.95$ ), dominate the ion energetics, but energetic ion bundles from rotating energetic particle blobs within  $9 < L < 20$ , and especially beyond  $\sim 17-18 R_S$  result in enhancements in both the  $H^+$  and  $O^+$  pressure and density. All energetic ion moments show day-night as well as dusk-dawn asymmetries, that can be explained by considering the multiple injections and the azimuthal energetic ion flow properties inside the magnetosphere. Our calculated polytropic index indicates that the loss of heat from the plasma sheet is greater than the supply of new energy and although multiple injections at Saturn may account as the drivers of new energy, a cooling mechanism does not allow the plasma sheet to behave adiabatically. The neutral gas dominates over the ion densities, has a strong influence on the magnetosphere dynamics, and may act as an effective cooling mechanism. Furthermore, the entropy ( $S$ ) cannot be conserved in Saturn's magnetosphere, but should decrease with decreasing distance from Saturn, at least for the  $9.5 < L < 20$  region where  $\Gamma < 5/3$ , as happens at Earth's magnetotail.

Reference:

Dialynas, K. E. Roussos, et al. JGR, 123. <https://doi.org/10.1029/2018JA025820>, (2018).