Energetic H+ and O+ moments and polytropic index in the kronian magnetosphere with >20 keV Cassini/Mimi measurements

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The κ-distribution function is an essential form for analyzing the distributions of trapped ions, together with Energetic Neutral Atoms (ENAs) in planetary magnetospheres. Given that the particle populations at Saturn can have many different kinds of sources (solar wind, atmosphere, volcanic moons, etc.) and sinks (collisions with ambient neutrals or moon or ring surfaces, reconnection, etc.) and move under the influence of its dynamic magnetic field, it is advantageous to have a function flexible enough to allow the determination of the essential physical quantities of the energetic particle spectra, such as temperatures, densities, pressures, spectral indices, and convection bulk velocities. We utilize ~13 years of Cassini/MIMI observations and we model the >20 keV energetic ion (H+ and O+) energy spectra using κ-distributions [Dialynas et al. 2018]. The modeled spectra are then used to calculate the energetic ion moments for both species inside the Kronian magnetosphere, and a modified version of the Roelof and Skinner [2000] model is employed to simulate the energetic ion partial pressure, density, and temperature. Those simulations lead to extracting the polytropic index (Γ) for both H+ and O+. Our results are summarized as follows: [1] The >20 keV energetic ion spectra are consistent with κ-distributions. The 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 in conjunction with charge-exchange decay and/or the noon-midnight E-field. [2] The 9.5<L<20 region corresponds to a local equatorial acceleration region, where subadiabatic transport of H+, Γ~1.25 (<1.67), and quasi-isothermal behavior of O+, Γ~0.95 (<1), dominate the ion energetics. [3] Non radiation belt energetic ions are heavily depleted inside ~8 Rs. The ion lifetimes decrease significantly (due to charge exchange), so that the ion pressure and density drop to minimum. The behavior of both H+ and O+ appears to be quasi-isothermal (Γ<1) inside ~8 Rs. [4] Energetic ion bundles within 9<L<20, and especially beyond ~17-18 Rs, that possibly result from rotating energetic particle blobs, produce durable signatures (enhancements) in the H+ and O+ pressure and density. [5] The loss of heat from the plasma sheet is greater than the supply of new energy, which does not seem to have aground thermodynamic state. Multiple injections may account as the drivers of new energy entering the system, but 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. [6] Assuming a collisionally isotropic gas, the entropy (S) becomes a conserved quantity (in a purely adiabatic processes; S=T/n^2/3 , Γ=5⁄3). Our results indicate that 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 Γ < 5/3, as it happens at Earth's magnetotail.