EPSC Abstracts
Vol. 12, EPSC2018-624, 2018
European Planetary Science Congress 2018
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Saturn's equatorial ionosphere: dominance of heavy ions and model comparisons with Cassini Grand Finale data

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Abstract

The first in situ measurements of Saturn's upper atmosphere were obtained by the Cassini spacecraft from proximal orbits (spanning April – September 2017) during the Grand Finale phase of the 13-year mission. These data find definitive evidence for a strong influence of Saturn's rings on its equatorial upper atmosphere, manifesting as an influx of grains and related material [1-5].

An influx of ring-derived water was expected, as that would act as a quenching agent in Saturn's ionosphere, reducing modeled electron densities to observed values. Water was indeed found, but the bulk of the gaseous species detected appear to be methane and other organics. The first-order impact of these more complex molecules on Saturn's ionosphere is similar to that of water, in that they reduce the modeled electron density by converting long-lived ions to short-lived ions. However, they also significantly complicate the ionospheric chemistry.

Here, we present model comparisons with in situ ion and electron density measurements. While some model-data discrepancies remain, we are able to demonstrate that:

(1) based on Ion Neutral Mass Spectrometer (INMS) measurements, the light ions (H^+, H_2^+, H_3^+, and He^+) are broadly consistent with the makeup of the observed neutral species [5-6]; and

(2) molecular ions dominate Saturn's low altitude equatorial ionosphere, with H_3O^+ playing a major role, even for the reduced levels of water influx [6].

Other important heavy ions are uncertain, but are likely to include HCO^+, HCO_2^+, N_2H^+, CH_5^+, $C_2H_3^+$, and other hydrocarbon ions [6]. The dominance of such heavy ions is a surprise, as expectations based on previous model-data comparisons were that H^+ and H_3^+ would be the only major ions above the homopause, with H_3O^+ becoming more prominent in regions of enhanced water influx. Future Earth-based observations of some of these ion species may help to track the evolution of Saturn's rings as they lose mass to its atmosphere.

References

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