EPSC Abstracts
Vol. 13, EPSC-DPS2019-1189-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Saturn's Ionosphere during Cassini's Final Plunge

L. Moore (1), M. Galand (2), K. E. Miller (3), J. H. Waite Jr. (3), M. E. Perry (4), L. Z. Hadid (5), T. E. Cravens (6), R. S. Perryman (3), M. W. Morooka (7), J.-E. Wahlund (7)

(1) Boston University, Center for Space Physics, Massachusetts, USA (moore@bu.edu); (2) Blackett Laboratory, Imperial College London, London, UK; (3) Southwest Research Institute, San Antonio, Texas, USA; (4) Johns Hopkins University Applied Physics Laboratory, Laurel, Maryland, USA; (5) ESA/ESTEC, The Netherlands; (6) Department of Physics and Astronomy, University of Kansas, Lawrence, Kansas, USA; (7) Swedish Institute of Space Physics, Uppsala, Sweden

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]. Whereas in situ electron density measurements for the Cassini proximal orbits was typically ~3000 cm^{-3}, Cassini was able to sample the ionospheric peak during its last orbit, finding a peak electron density, N_{MAX}, of ~10^4 cm^{-3} [6]. Here, we present ionospheric model comparisons with Cassini measurements during this "Final Plunge". We find that, in order to reproduce the observed electron density, we require enhanced ion production and a smaller flux of ring-derived gases, consistent with past modeling [7] and current data analysis [8]. Furthermore, based on these constraints, we find the major ion at the ionospheric peak to be HCO^+, potentially allowing for future ionospheric insight based on follow-up observations of emissions from this ion.

1. Introduction

An influx of ring-derived water has long been expected at Saturn, as that would act as a quenching agent in Saturn's ionosphere, reducing modeled electron densities to observed values. Water was indeed found by Cassini during its proximal orbits, but the bulk of the gaseous species detected appear to be methane and other organics [1]. 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.

2. Observations and Modeling

On 15 September 2017, known as Proximal 293 (P293) or the Final Plunge, the Cassini spacecraft dove into the planet's atmosphere, returning in situ data for as long as the antenna could be pointed at Earth. Whereas the periapsis of previous proximal orbits – which reached only as low as 1700 km altitude above the 1 bar pressure level – was near 6 deg. south latitude, P293 was able to sample Saturn's ionosphere down to ~1450 km altitude, below the ionospheric main peak, and lost signal at ~10^o N. Therefore, data from the Radio and Plasma Waves Science/Langmuir Probe (RPWS/LP) represents the first complete in situ sample of an outer planet electron density profile [6].

Cassini's Ion Neutral Mass Spectrometer (INMS), which sampled Saturn's upper atmosphere during the proximal orbits, provides additional insights. In particular for P293, INMS finds evidence for a reduction in the total ring-derived influx (which appears to peak at Saturn's equator and fall off rapidly with latitude), and for a different volatile composition [8].

We model Saturn's ionosphere here using a 1-D ion continuity and momentum module. Ion production follows from solar photons, and from production due to photoelectrons and associates secondary electrons. These details, along with the complete chemistry, are discussed in [7].

3. Figures

Two simulations of Saturn's ionosphere during the Cassini Final Plunge are shown below. Figure 1 uses the neutral gas mixing ratios derived from measurements near Saturn's equator and used in initial model comparisons there [7]. The peak electron density is at least a factor of 3 too small based on RPWS/LP measurements, which find N_{MAX} of ~10^4 cm^{-3} near 1550 km altitude. Figure 2 shows initial results using mixing ratios that are more appropriate for the Final Plunge latitude [8]. Both the magnitude and location of ionospheric peak are now in much better agreement with RPWS/LP data.

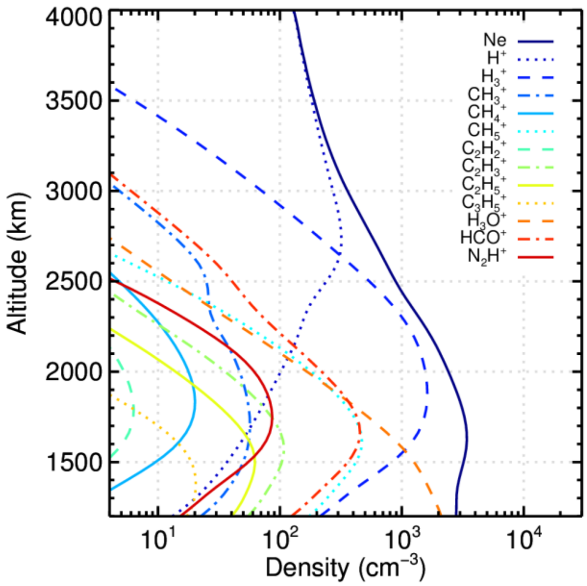

Figure 1: Initial model simulation of Saturn's ionosphere during Cassini's Final Plunge, using prior equatorial ring-derived mixing ratios.

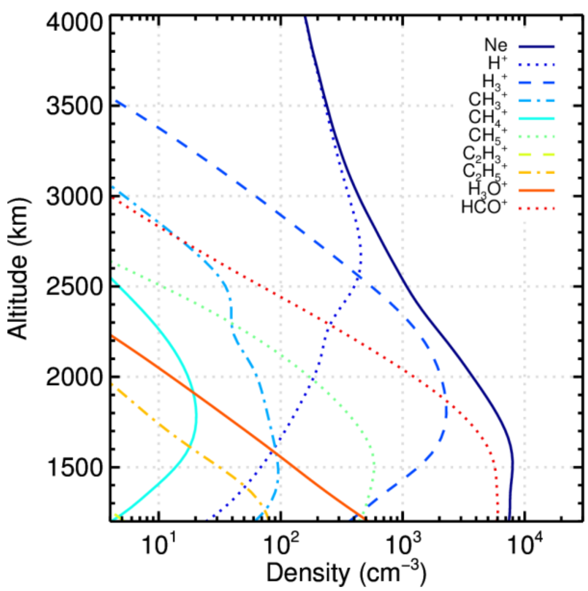

Figure 2: Model simulation of Saturn's ionosphere during Cassini's Final Plunge, using updated ring-derived mixing ratios suitable for P293 latitudes [8].

4. Summary and Conclusions

While these results are preliminary, they indicate that the chemistry in Saturn's near-equatorial ionosphere is more complex than anticipated. In particular, if HCO^+ is indeed the major ion at low altitude, as found here, then it may be possible to use future observations of this ion to provide further constraints on Saturn's ionosphere, thereby continuing to enhance Cassini's legacy over the coming decades.

Acknowledgements

This material is based upon work supported by the National Aeronautics and Space Administration under Grant NNX16AI34G issued through the Cassini Data Analysis Program.

References

[1] Waite, J.H., Jr. et al. (2018), INMS Observations of Chemical Interactions between Saturn's Atmosphere and its Rings, *Science*, 362, 6410, 10.1126/science.aat2382.

[2] Hsu, H.-W., et al. (2018), Cosmic Dust Analyzer onboard Cassini Collects Material from Saturn's Main Rings, *Science*, 10.1126/science.aat3185.

[3] Perry, M.E., et al. (2018), Material flux from the rings of Saturn's into its atmosphere, *Geophys. Res. Lett.*, 10.1029/2018GL078575.

[4] Yelle, R.V., et al. (2018), Thermal Structure and Composition of Saturn's Upper Atmosphere from Cassini/INMS Measurements, *Geophys. Res. Lett.*, 10.1029/2018GL078454.

[5] Cravens, T.E., et al. (2018), The Ion Composition of Saturn's Equatorial Ionosphere as Observed by Cassini, *Geophys. Res. Lett.*, 10.1029/2018GL077868.

[6] Hadid, L., et al. (2018), Saturn's ionosphere: Electron density altitude profiles and D ring interaction from the Cassini Grand Finale, *Geophys. Res. Lett.*, 10.1029/2018GL07800.

[7] Moore, L., et al. (2018), Models of Saturn's equatorial ionosphere based on in situ data from Cassini's Grand Finale, *Geophys. Res. Lett.*, 10.1029/2018GL078162.

[8] Miller, K. E., et al. (2019), Cassini INMS constraints on the composition and latitudinal fractionation of Saturn ring rain material, *Geophys. Res. Lett.*, under review.