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Investigating the Interactions between Saturn's Upper Atmosphere and Rings from Cassini INMS Measurements

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Abstract

The Ion and Neutral Mass Spectrometer (INMS) aboard the Cassini spacecraft at Saturn returned a surprisingly complex mass spectrum from the planet's upper atmosphere. These first ever direct measurements enable the investigation of the chemical composition of the upper atmosphere, the thermal structure and energetics of the upper atmosphere, and the transfer of material from the rings to the atmosphere. These topics will be addressed through analysis of the mass spectra returned by INMS during Cassini's final orbits, as well as modeling efforts to understand the density, temperature structure, and diffusion processes at play in the upper atmosphere. These analyses are vital to improve our understanding of the interactions between Saturn and its rings, and the results are critical to advance photochemical modeling efforts of Saturn's upper atmosphere.

1. Cassini INMS Observations

In September 2017, the Cassini-Huygens mission to the Saturn system came to an end as the spacecraft intentionally entered the planet's atmosphere. Prior to entry, the spacecraft executed a series of 22 highly inclined orbits, the Grand Finale orbits (26 April 2017 to 15 September 2017), through the previously unexplored region between Saturn and its extensive ring system, yielding the first ever direct sampling of the planet's upper atmosphere.

During these proximal orbits, the spacecraft obtained measurements near the equatorial ring plane at various heights above the planet's 1-bar pressure level. The final five of these orbits directly sampled Saturn's upper thermosphere. The spacecraft's last encounter, known as the final plunge, represents the deepest sampling of Saturn's atmosphere and provided measurements down to approximately 1370 km above the 1-bar pressure level before losing contact with Earth.

The measurements were taken with the Closed Source Neutral (CSN) mode of INMS, which measures neutral species by ionizing the sampled molecules in order to detect the signature of the fragmented species. INMS has a mass range of 1 to 99 Da with a resolution of 1 Da.

2. Results

During the final six orbits (including atmospheric entry), INMS measurements revealed that Saturn's upper atmosphere is much more chemically complex than previously believed (see Figure 1) [1, 2, 3]. Additionally, the unexpectedly large amount of CH_4 observed must have an external origin, most likely from Saturn's rings. Recent work has also suggested that the mass influx of this neutral ring material entering the atmosphere is unsustainably large, approximately 10^4 kg/s. An influx of such magnitude would deplete the entire ring system in less than 10^6 years, leading to the speculation that the observed influx is time-dependent [2, 3].

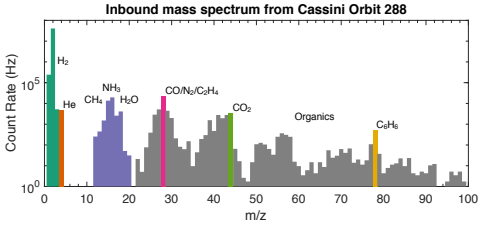

Figure 1: This mass spectrum of Saturn's upper atmosphere contains complex organic molecules that were not predicted prior to Cassini's proximal orbits.

Ongoing work is expanding our understanding of this complex mass spectrum and constraining the relative abundances of species present within the spectrum. Density profiles of major and minor constituents suggest that multiple species (along with CH_4) exhibit behavior indicative of an external source, and that Saturn's upper atmospheric composition is heavily influenced by infalling ring material.

References

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