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Identify the H_2 source of the Saturnian ring atmosphere using numerical modelling and the INMS measurements from the Cassini Grand Finale Mission

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Abstract

During the Cassini Grand Finale mission, this spacecraft, for the first time, acquired in-situ measurements of Saturn's upper atmosphere and its rings and provided critical information for understanding the interaction between the main rings and the Saturnian system. The ring atmosphere is the source of neutrals, which are primarily generated by photolytic decomposition of water ice, and of plasma in the Saturnian magnetosphere. In addition, the main rings have strong interactions with Saturn's atmosphere and ionosphere possibly through the grain impacts, neutral diffusion and current exchange. The data from Cassini Grand Finale mission shed light on the dominant physics and chemistry in this region of Saturn's magnetosphere. For example, finding the presence of carbonaceous molecules around the main rings [1] and a large amount of nano-sized grains [2] [3]. With the updated Cassini measurements, we will revisit the details in the ring atmosphere/ionosphere model, and incorporate a DSMC model of Saturn's H_2 exosphere, to study the measured H_2 density distribution in this interaction region.

1. Introduction

At Saturn Orbital Insertion (SOI) of the Cassini spacecraft in 2004, the Cassini Plasma Spectrometer (CAPS) and the Ion and Neutral Mass Spectrometer (INMS) instruments had observed O_2^+ and O^+ ions when flying over Saturn's main rings (e.g., [4] [5] [6]). It confirmed the existence of the ring atmosphere and ionosphere which was suggested to be formed mainly by photolytic decomposition of water ice producing H_2 and O_2 in a ratio of 2:1 [7]. It was also found that the effect of slow ion-molecule collisions occurred in the main ring region plays an important role in the morphology of the ring atmosphere and ionosphere [8]. In addition to computing the density distribution of the scattered O_2 in the Saturnian magnetosphere, [8] also predicted that Saturn's ring atmosphere and ionosphere would show a seasonal dependence due to the variation of orientation of Saturn's ring plane to the Sun. The seasonal variations of the ring plasma have been confirmed by the following measurements using with several independent instruments onboard Cassini (e.g., [9], [10]). In this work, we aim to explain the H_2 densities observed by the INMS in this intermediate region of the mixed neutral sources (i.e., Saturn's exosphere and inflow from the rings).

2. Numerical modelling

A test-particle model of the ring atmosphere/ionosphere [8] is revisited with the updated Cassini data. In addition, a 3-dimensional free molecular flow (FMF) Monte Carlo model is also constructed to simulate Saturn's exosphere constrained to the Cassini Ultraviolet Imaging Spectrograph (UVIS) observations [11]. Using with the above combined model of Saturn's exospheric H_2 and the ring H_2 atmosphere, we will examine the morphology of the combined H_2 density distribution and compare with the INMS measurements in order to provide additional constraints for the respective H_2 source rates.

3. Preliminary results

All the species detected by the INMS (H_2, CH_4, $CO/N_2/C_2H_2$, and CO_2) exhibited very similar profiles for the density vs distance from the ring plane: ~0.5 -1 x10^4 cm^{-3} and with the vertical scale heights of ~0.05 Rs [12]. A common scale height shared by all neutral species is contradictory to our modeling results. Since any neutrals released from particles in the tenuous ring would be thermally accommodated to the local ring temperature, the scale height of each species would be determined by a factor of 1/(square of its mass) (as shown in Figure 1). Therefore, we suggest that the INMS measurements during the F-ring flybys are highly likely due to impact-induced vaporization of small grains inside the INMS chamber. In addition, our comparisons of the modeled H_2 density and the INMS data during the proximal orbits suggest a robust H_2 ring atmosphere existed in the region of > 4,000 km above Saturn (as shown in Figure 2).

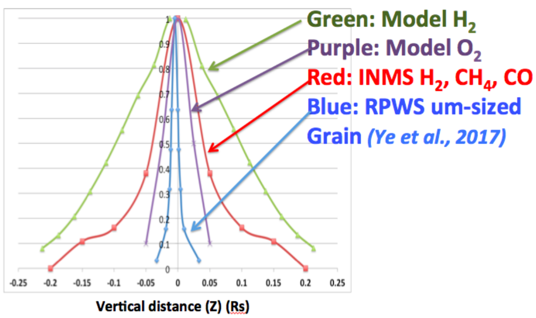

Figure 1: The modeled H_2/O_2 density distributions and the INMS data collected in the F-ring orbits. The distribution of the micron-sized dust (>0.1 micron) observed by RPWS is also shown [13]. The presence of abundant nanograins in the F-ring had been predicted by [14].

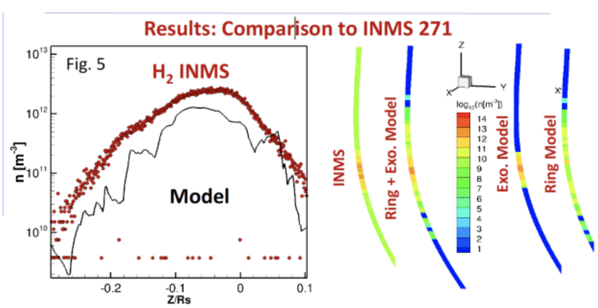

Figure 2: The comparison of the modeled Saturn's exopheric H_2 density distrbution and the INMS data.

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