EPSC Abstracts
Vol. 10, EPSC2015-294, 2015
European Planetary Science Congress 2015

Variability in Saturn's upper atmosphere from Cassini/UVIS occultations

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Abstract

We present new density and temperature profiles based on more than 20 stellar occultations by Saturn's upper atmosphere observed simultaneously by the EUV and FUV channels of the Cassini/UVIS instrument. With these results, more than 40 stellar and solar occultations from Cassini/UVIS [1, 2, 3] and 6 occultations from Voyager/UVS [4] have now been analyzed. The results provide valuable constraints on models of chemistry, dynamics and thermal structure in the upper atmosphere. They are also required to plan for the end of the Cassini mission.

1. Introduction

The occultations and airglow measurements of Saturn by the Voyager/UVS and Cassini/UVIS instruments constitute the most extensive dataset available on the upper atmosphere of any giant planet. For the first time, these observations can be used to probe spatial and temporal trends in the density and temperature structure of the upper atmosphere that are driven by changes in energy deposition, chemistry and dynamics. They are also required to plan the Grand Finale tour of the Cassini mission that includes several close orbits with the spacecraft passing through Saturn's thermosphere, followed by its final descent into the lower atmosphere.

Here we concentrate on the stellar occultations from the Cassini/UVIS instrument [5]. The EUV occultations are used to retrieve the H_2 density and temperature profiles in the thermosphere. The temperature in the thermosphere is generally much higher than expected from solar heating, and these observations constrain the heating mechanism. The FUV occultations, on the other hand, are used to retrieve the density profiles of minor hydrocarbons such as CH_4, C_2H_2, C_2H_4 and C_2H_6 in the upper stratosphere/mesosphere. These results provide constraints on models of photochemistry, thermal structure and dynamics [6, 7]. In fact, spatial trends in temperature and the mixing ratios of the minor species are one of the only available sources of information on circulation above the cloud tops [8].

2. Results

We present new results based on more than 20 stellar occcultations probing the atmosphere at different locations between 2004 and 2015. For each location, we construct a reference atmosphere model relying on the occultation data and observations of the stratosphere by the Cassini/CIRS instrument [9, 10]. These models allow us to convert density profiles into mixing ratios, estimate the pressure-temperature structure in Saturn's highly oblate atmosphere, and to derive values for the eddy mixing rate that depends on dynamics. Figure 1 shows an example of such a model for one of the occultations.

The EUV stellar occultations show that the exospheric temperature on Saturn ranges from about 350 K to 600 K [3], in agreement with the solar occultations [2] and the latest re-analysis of the Voyager/UVS occultations [4]. The temperature increases with latitude from the equator towards the poles, supporting the idea that high latitude (auroral) heating and the associated electrodynamics can explain the temperatures in the thermosphere. Under the assumption of gradient wind balance, which is a reasonable order of magnitude estimate in the non-auroral thermosphere, the data imply that easterly zonal jets with mid-latitude wind speeds of about 600 m s^{-1} exist in both hemispheres, consistent with high latitude heating [3].

The occultations also reveal that Saturn's equatorial thermosphere expanded by about 500 km between 2005 and 2010, followed by contraction after 2010 that may still be ongoing. These trends, that anticorrelate with solar activity, may be seasonal in nature. Since the thermosphere is not expected to react directly to changes in solar insolation, the changes could be indirectly linked to changes in dynamics of the upper stratosphere/mesosphere. The hydrocarbon profiles retrieved from the FUV channel provide further constraints on chemistry and dynamics below the thermosphere.

3. Figures

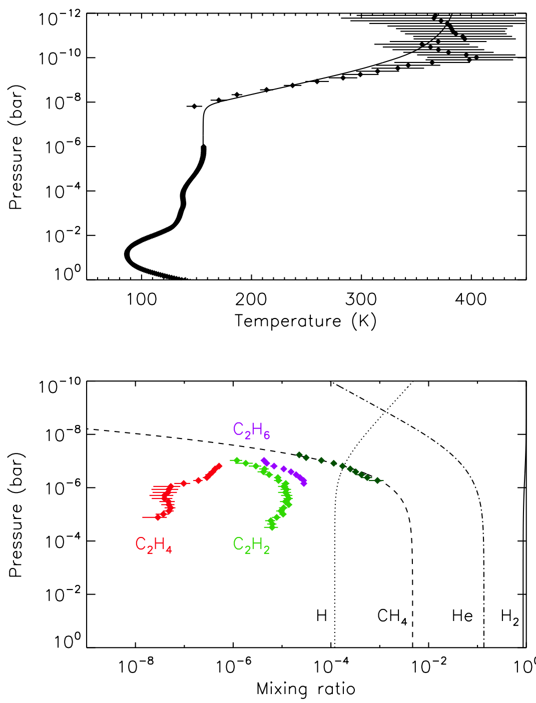

Figure 1: **Upper panel**: The solid line shows the model temperature profile based on the closest available coincidence of UVIS ($p < 10^{-8}$ bar) and CIRS ($p > 10^{-6}$ bar) data points (diamonds) from the spring of 2006 [9, 3]. The model T-P profile in the thermosphere is the best fit forward model profile fitted to the UVIS data while the data points result from direct inversion. **Lower panel**: Mixing ratios for some of the minor species. Lines show the mixing ratios in the atmosphere model that determine mean molecular weight while the data points show the retrieved number densities divided by the total density of the model atmosphere. The mixing ratio of H is limited by the solar occultations and the mixing ratio of He is uncertain (we assumed 13.55 % in the lower atmosphere).

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