EPSC Abstracts
Vol. 6, EPSC-DPS2011-513-2, 2011
EPSC-DPS Joint Meeting 2011

The energy of the auroral electrons in Jupiter's atmosphere: remote sensing and thermal consequences

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Abstract

Saturn's north aurora has been observed between January and May 2011 with the Hubble Space Telescope. The objective was to collect spatially resolved spectra at the different local time from dawn to dusk and compare them with laboratory or synthetic spectra. For this purpose, HST was programmed to slew from mid-latitudes through the auroral oval up to above the limb while collecting data in the timetag mode. The spectra show signatures of absorption by hydrocarbons present above the peak of the auroral emission. The amount of absorption and implications in terms of penetration of the auroral electron beam into Saturn's atmosphere will be discussed and compared with other determinations of the altitude of the aurora. The effects of the auroral heat import on the thermal structure of the atmosphere both at high and low altitudes will be examined in the light of these results.

1. Introduction

The aurora of giant planets exerts a major influence on the thermal structure and the chemistry of the planets' upper atmosphere. Cowley et al. [1] suggested that the auroral oval at Saturn (unlike Jupiter's main auroral oval) corresponds to a ring of upward current bounding the region of open and closed field lines. They estimated that the aurora is produced by magnetospheric electrons accelerated to a few keV to a few tens of keV energy. A large number of FUV images of Saturn's aurora has been collected during previous HST programs. These observations made it possible to investigate the auroral morphology and its response to the solar wind activity. Coordinated HST-Cassini observations have indicated that field-aligned currents and potential acceleration play a key role in Saturn's aurora [2]. Although the general location of the precipitation is generally well predicted by this model, Saturn's aurora appears considerably more complex and dynamical than initially expected. Unfortunately only few spectral observations have completed these extensive imaging programs.

A physical understanding of Saturn's magnetosphere and acceleration mechanisms requires a firm knowledge of the energy of precipitating particles producing the aurora. Such information can only be obtained through spectroscopic remote sensing. An estimate of the altitude of the aurora relative to the hydrocarbon homopause may also be derived from the comparison between the observed spectra and a laboratory spectrum attenuated by methane. The methane column which bring the best fit determines the altitude of the auroral emission and allows to derive the energy of the precipitating electrons. Previous observations demonstrated that the S/N ratio in Saturn auroral spectra is sufficient for this comparison if the aperture is correctly positioned on the bright aurora. Images of Saturn's aurora show that the morning sector is statistically brighter than other parts of the oval but it can also be of comparable intensity or dimmer.

Conflicting information exists concerning the altitude of the aurora. A small set of HST/STIS spectra obtained along the central meridian show that the wavelengths below 130 nm are absorbed by methane [3], suggesting that the aurora is emitted near the homopause, located at about 620 km in standard atmospheric models based on low-latitude stellar occultation observations by Voyager. Analysis of FUSE EUV spectra has located the emission peak at a pressure level of 0.1 micro bars [4]. On the other hand, direct determination of the altitude from ACS images indicates that the emission originates from ~1100 km, well above the low-latitude homopause. A series of HST observations of Saturn's aurora and its FUV spectrum have been obtained in 2011 to address this question by combining FUV auroral images and low resolution spatially-resolved spectra.

2. Observations

Using the method described before, we have scanned the auroral region extending from the equatorward boundary of the aurora to above the north limb of the planet. The slit was approximately parallel to the planetary equator to optimize the use of the STIS long slit and maximize the chances to catch the strongest emission regions (Figure 1). The observations were divided into 3 visits of two orbits each. They took place on March 17, April 17 and May 10 2011. Spectra were successfully obtained with STIS FUV-MAMA in the G140L mode with the 52x0.5 arc sec aperture.

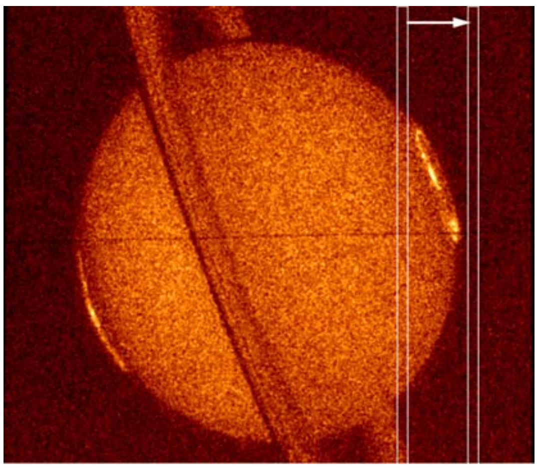

Figure 1: HST/STIS image obtained with the STIS camera on board the Hubble Space Telescope. The extreme positions of the STIS slit during the telescope slew are shown by the white rectangles.

The aperture pointing selected to reveal any variations in the incident particle energy along or across the arcs and/or with local time. In addition, at the beginning of each orbit, one STIS image of the aurora was collected to visualize the global auroral context. The spectra were collected during most of the observing time also in the time-tag mode while the slit scanned the high-latitude disk. The slit was oriented with the minimum inclination on the equatorial plane compatible with the spacecraft orientation constraints. This angle remained less than 20° during all three visits.

3. Results

The spectra show clear signatures of absorption by methane, quite similar to the earlier spectra obtained perpendicular to the auroral oval along the central meridian. The S/N ratio appears high enough to isolate the spectra from different local time regions and make a study of the spatial distribution of absorption by hydrocarbon. We discuss possible differences between the low-latitude atmospheric models used so far to analyze the auroral observations and the atmospheric structure required to reconcile the altitude and electron energy determined from spectral measurements with the altitude derived from the images. This procedure implies differences in the vertical thermal profile that may be derived from high-latitude solar occultation in the extreme ultraviolet or global three-dimensional modeling.

Acknowledgements

JCG and DG acknowledge support from the Belgian Fund for Scientific Research (FNRS). Partial funding for this research was provided by the PRODEX program of the European Space Agency managed in collaboration with the Belgian Federal Science Policy Office.

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