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# Spectral mapping of the FUV and energy distribution of the Jovian aurora

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## Abstract

Observations have been made with the Hubble Space Telescope in the timetag mode using the UVIS long slit. During the 40 min of the observations, the slit spatially scanned the polar regions to build spectral maps of the jovian aurora. The emission is composed of the HI Lyman-alpha line and the $H_2$ Lyman and Werner bands. The shorter wavelengths are partly absorbed by the methane layer overlying the bulk of the auroral emission. Since the $CH_4$ absorption cross section drastically drop above 140 nm, the longer wavelengths are not absorbed and the intensity directly reflects the precipitated energy flux carried by the electrons. Maps of the intensity ratio of the two spectral regions will be presented, together with the associated auroral electron energy. These values will be compared with those expected from current magnetosphere-ionosphere model. They will provide input into 3-D modeling of the auroral heat source into the high-latitude Jovian upper atmosphere.

## 1. Introduction

Previous observations with the Hubble FUV cameras made it possible to investigate the auroral morphology and its response to the solar wind activity. The energy powering the magnetospheric plasma finds its origin in the fast planetary rotation and its subsequent transfer into kinetic energy of magnetospheric electrons. Mapping the characteristic energy of the auroral electrons is thus a major scientific breakthrough for two reasons: (i) auroral electron energy bears the signature of the energization processes whose identification is essential to understand the magnetosphere-ionosphere coupling of giant and extra-solar planets and (ii) auroral precipitation on Jupiter provides over 1-5x1013 Watts, a value exceeding by far the contribution of solar radiation input into the upper atmosphere [4] which deeply modifies the thermal and wind structure in the upper atmosphere.

Conceptual models [5 and subsequent refinements] suggest that the relatively stable main auroral emission at Jupiter (unlike the Earth's and Saturn's cases) corresponds to the upward branch of a global current system flowing along magnetic field lines. Other acceleration processes appear to be at play in other regions of the magnetosphere. For example, pitch angle scattering of energetic electrons is thought to be the source of the diffuse aurora observed equatorward of the main oval [11]. Polar regions show rapidly varying and flaring structures whose origin is still largely unknown [12, 7, 6, 1]. Finally, the magnetic footprints of the Galilean satellite on the Jovian atmosphere appear to be generated by a parallel electric field associated with the propagation of Alfvèn waves [2, 9]. It is very likely that the characteristic electron energy associated with these various processes is different, but it is currently largely unknown.

Physical understanding of Jupiter's magnetosphere and acceleration mechanisms requires measurements of the energy distribution of precipitating particles producing the aurora. For example, images of Jupiter's FUV aurora show that the morning sector is generally thinner and more stable than other parts of the oval but was not known whether the precipitated electron energy is higher there than other regions. Such are currently inaccessible to in situ measurements on a global scale.

Auroral precipitation also has important consequences on the vertical distribution of auroral heat input. Models have demonstrated that the solar EUV heat input alone is insufficient to heat up the upper atmosphere to the observed 1000 K or so. A three-dimensional model of general thermospheric circulation (JTGCM) has investigated the role played by the aurora in the energy balance, transport by winds, thermal structure and composition of the
Jovian upper atmosphere [3, 10]. The atmospheric heat balance depends on the energy of the incoming

particles and the share of energy between particle and Joule heating, advection, UV emission, cooling by infrared $H_3^+$ radiation and by hydrocarbon thermal emission.

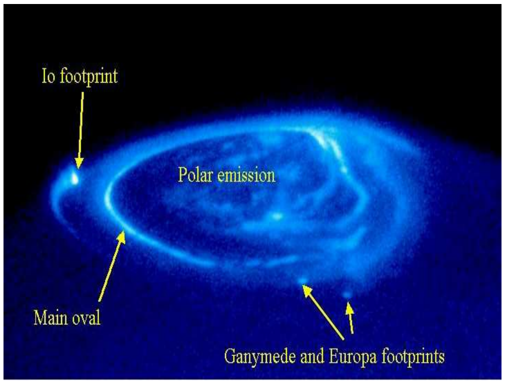


Figure 1: HST image of the Jovian FUV aurora in north. The different components are identified: Io footprint and trailing trail, Ganymede and Europa footprints, main and polar emissions.

## 2. Methodology

A determination of the altitude of the aurora relative to the methane homopause can be made from the amount of FUV absorption in FUV spectra [8]. It is related to the large drop in the $CH_4$ absorption cross sections at wavelengths >140 nm, leaving the longer wavelength $H_2$ Lyman band unattenuated, while the emissions at shorter wavelengths are significantly absorbed by overlying hydrocarbons. Therefore, the altitude of the auroral emitting layer relative to the methane homopause, and thus the electron energy, can be derived from the observed spectrum. Observations from other standpoints (different central meridian longitudes) are required to resolve the longitude-local time ambiguity and formulate conclusion on the acceleration mechanism. Additionally, one absorption map of the south polar region was also obtained for comparison. The combination of the unique STIS spectral/imaging capability with a spatial scan of the auroral region has provided spatially resolved measurements of the FUV absorption by methane that have been used to map the penetration of the auroral electrons relative to the homopause.

## 3. Observations

The HST observations were collected in January 2014 near opposition and in March in both hemispheres under different central meridian longitudes in the timetag spectral mode. The STIS FUV-MAMA with the G140L grating was used with the 26x0.5 arcsec aperture. The Space Telescope was slewed in such a way that the slit projection scanned the disk from above the polar limb down to mid-latitudes.

Maps of the color ratio defined as CR= I(1550-1620 Å)/I(1230-1300 Å) will be presented. They show that the amount of absorption by methane significantly varies between the different components of the aurora. For example, the Io footprint show weak or no absorption, indicating that most of the FUV emission is produced above the methane homopause by relatively soft electron precipitation. By contrast, the amount of absorption varies along the main emission. Some of the polar emissions are associated with harder precipitation, although the regions of strong electron precipitation do not necessarily coincide with the higher electron energies. An example of a map of the unabsorbed to the absorbed FUV emission is shown in Figure 2.

Comparisons with a 1-D electron transport model are used to determine the range of variations of the characteristic electron energies and their spatial distributions. Comparisons with values expected from magnetosphere-ionosphere coupling models will be discussed.

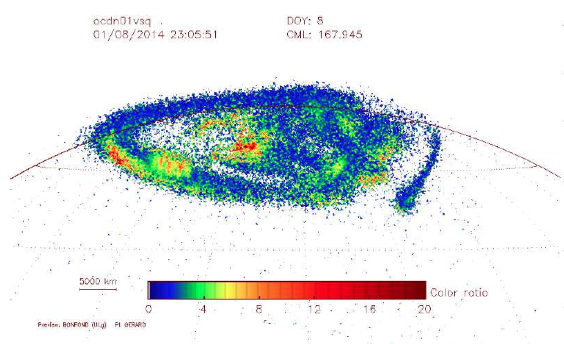


Figure 2: example of observed distribution of the FUV color ratio (unabsorbed/absorbed intensity ratio) in the north aurora. The amount of absorption by methane increases from dark blue (low absorption) to the red regions.

# 4. Summary and Conclusions

We present spectral images of Jupiter's ultraviolet aurora recently obtained with the STIS instrument on board Hubble. The exposures were made for different central meridian longitudes both in the north and in the south. They show that absorption by methane varies along the main emission and between the various components of the aurora. These results indicate that the penetration depth of auroral electrons changes with time and location. The most energetic precipitation appears to be associated with some of the polar flares observed at high latitudes, inside the main emission region.

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