FAR ULTRAVIOLET IMAGING OF JUPITER'S NORTHERN POLAR REGIONS WITH THE FOC *

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ABSTRACT

A Lyman-α image of the north polar region of Jupiter was obtained with the Faint Object Camera (FOC) on board the Hubble Space Telescope. The F/96 optical relay was used with two UV filters in series to isolate the HI emission at 1216 A. The presence of high latitude regions of enhanced emission is clearly observed. A comparison with the location of the "UVS oval", the Io (L = 6) and high-latitude field-lines footprints shows that a better agreement is obtained with the $L \geq 15$ footprint in the sector ($30^o < \lambda_{III} < 210^o$) observed here. These two families of L-shells correspond to two possible sources of precipitation: particles originating respectively from the plasma torus of Io or particles from the distant magnetosphere in a distorted magnetic field by analogy with the terrestrial aurora.

1. INTRODUCTION

Observations made with the Voyager 1 Ultraviolet Spectrometer (UVS) in 1979 (Broadfoot et al., 1979) and subsequent spectrometric measurements (Herbert et al., 1987) obtained with the Voyager 2 and International Ultraviolet Explorer (IUE) (Clarke et al., 1980) detected the existence of emissions due to H_2 and HI Lyman-α around the poles of Jupiter. Meridional scans of the north H_2 UV aurora with the UVS slit were used to define the UVS oval which appeared to lie close to the Io orbit field line footprint (Broadfoot et al., 1981). However, so far, no imaging of the jovian ultraviolet aurora was possible. We demonstrate here that the Hubble Space Telescope provide a unique opportunity to survey the morphology of the jovian (and possibly other giant planets') auroras and their possible temporal variations.

2. FOC CONFIGURATION

An image of the north polar region of Jupiter was obtained after a 16-minute exposure at 02:58 UT on February 9, 1992 about 15 hours after the closest approach of the ULYSSES spacecraft with Jupiter. The F/96 optical relay of the FOC was used with the F120M + F140W filter combination. The FOC and the filter characteristics are described in detail by Paresce (1992). During the observations, Jupiter was at a distance of 4.47 AU from the Earth, the phase angle was 4.2° and the latitude of the sub-Earth point 1.72° S. The angular equatorial diameter of the planet was 43.94 arcsec. Consequently only a fraction of the northern hemisphere could be imaged in the 22" × 22" field of view of the camera. The image was obtained in the 1024 × 512 zoomed pixel format with 22 × 44 milliarcsec pixels projecting onto a 143 x 286 km^2 area on the planet at 60°. The north pole was kept at the center of the detector during the exposure. The possible error on the position of the planet in the FOC field of view is of the order of 1" whereas the tracking error is less than 0.02". The central meridian longitude $\lambda_{III}(1965)$ was 120° and the Io orbital phase angle was 96° W, measured from inferior geocentric conjunction (sub-Earth meridian) that is close to maximum western elongation.

The filters in use for this exposure isolate the HI Lyman-α emission from the other light components due mainly to the H_2 auroral and airglow UV emissions and sunlight scattered by the planet's atmosphere. It was found necessary to use two filters in series due to contamination by the near-UV and visible light ("red

*Based on observations with the NASA/ESA Hubble Space Telescope, obtained at the STScI, which is operated by AURA,Inc., for NASA under contract NAS5-26555.

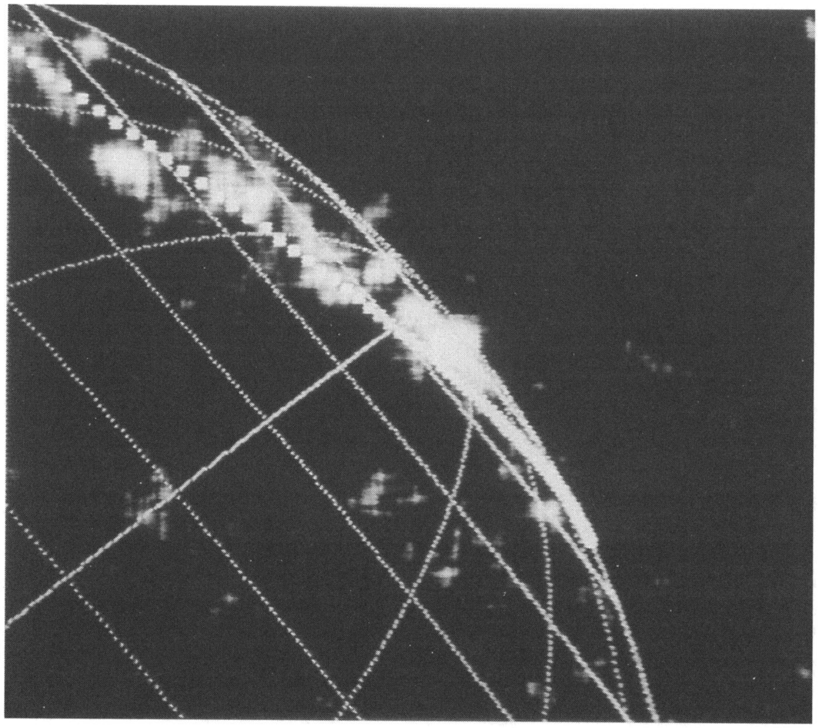

Figure 1: Lyman-α image of the jovian northern polar region observed with the FOC. The λ_{III} longitude of the central meridian is 120° and meridians increase by steps of 20° toward the upper left corner. The bright patchy feature extending from the vicinity of the north pole to the eastern (left hand side) limb is interpreted as the Lyman-α signature of the aurora. The regular shape is the trace of the "UVS oval" derived from the Voyager UV spectrometer mapping.

leak") of the UV filters when used to image an object with extensive brigthness at longer wavelength such as a planetary disc. This filter combination has an approximately gaussian transmission profile reaching 0.64 % at the peak (1250 A) and 0.42 % at 1216 A with a full width at half maximum (FWHM) of 90 A. The intensity contribution of the hydrogen bands has been determined by integrating the intensity distribution calculated with a H_2 synthetic spectrum over the effective passband of the filters. It is estimated that the relative contribution of the H_2 Lyman and Werner bands in the auroral signal is about 28% of the total.

A maximum of about 3×10^{-3} C pix^{-1} s^{-1} was obtained, well below the threshold of non linearity of the detector of 0.3 C pix^{-1} s^{-1}. Due to the spherical aberration of the primary mirror, the encircled energy within a 0.1" of the central peak is about 15 % of the total energy. As a consequence of the low count rate, standard restoration techniques cannot be applied in this case to improve the image quality. Instead, smoothing and rebinning on a number of pixels were applied to improve the signal/noise ratio.

3. LYMAN-α IMAGE DESCRIPTION

Figure 1 shows the corrected image with an effective 28 × 14 pixel size (0.62" × 0.62"). A grid of meridians and parallels has been overlaid. A region of enhanced intensity is clearly observed extending from the vicinity of the north pole to the (astronomical) eastern limb near a latitude of 55°. It appears quite inhomogeneous although the intensity variations may be due in part to the low count rate. The count level was determined by fitting a gaussian function to the count rate measured in 20-pixel wide areas across the emission regions. The peak level reaches 1.0 C pix^{-1} in the bright area near the pole and 0.9 C pix^{-1} in the bright spot located near 57° N and λ_{III} = 150° whereas the mean disc level is about 0.7 C pix^{-1}. The additional count rate of 0.2 C pix^{-1} in the aurora translates into an emission rate of about 100 kR above the disc background. Large variations are observed along the oval, with no measurable auroral increase above the background at some longitudes. In this case, the detectability limit set by the noise is estimated to be $\sim$ 25 kR. The present observations are not incompatible with previous Ly-α intensity estimates.

Figure 2 compares the observed morphology with the locations of the footprints of the L = 6 (Io orbit which is imbedded into the plasma torus region where wave-particle interaction is expected to diffuse the energetic particles into the atmospheric loss cone) and L = 15 (plasmasheet where plasma instabilities such as the tearing instability are likely to occur by analogy with the Earth) and L = 30 (so called "open") magnetic field lines in the GSFC O_4 model and the "Voyager UVS oval". In spite of the low count level, it appears that, in this sector, the observed aurora is in reasonable agreement with the UVS oval, although centered a few degrees poleward. The L = 6 footprint does not match the Lyman-α aurora satisfactorily. A better fit is obtained with the L-shells = 15 or 30 projections calculated with the O_4 plus current sheet magnetic field model (Connerney et al., 1981).

In contrast to most previous observations made with UV spectrometres, there is no indication of an intensity enhancement above the disk mean level associated with the $\lambda_{III} \approx 180^o$ meridian but the brightest region is located near the north pole, between the western limb and $\lambda_{III} \approx 100^o$. This result may be the result of the nearly tangential viewing of the arc which increases the optical path.

4. DISCUSSION

In conclusion, our results provide evidence that monitoring of the Lyman-α aurora, its morphology and intensity variations can be performed from Earth orbit with the Hubble Space Telecope. More observations in different configurations are needed to fully characterize the structure of the Lyman-α aurora in comparison with the Voyager and IUE observations, ground-based infrared images and model predictions (Prangé, 1991). However, the initial results reported here do not conflict with previous auroral measurements in this longitude sector. They indicate that the main auroral process is probably not located at the footprint of the theoretical Io footprint. They suggest that the emission could take place on high latitude field lines and that the stucture of the brightest features is patchy, exhibiting large longitudinal inhomogeneities. A confirmation of these findings as well as the understanding of the longitudinal variation of the intensity and a comparison between the H_2 and the HI aurora will require additional observations.

ACKNOWLEDGEMENTS

We are very grateful to the STScI moving target scheduling team especially Alex Storrs for crucial assistance and support throughout the program. One of the authors (JCG) acknowledges support from the Belgian National Fund for Scientific Research (FNRS). This work was supported in part by the PRODEX ESA program of the Belgian Science Policy Office - Prime Minister's Services.

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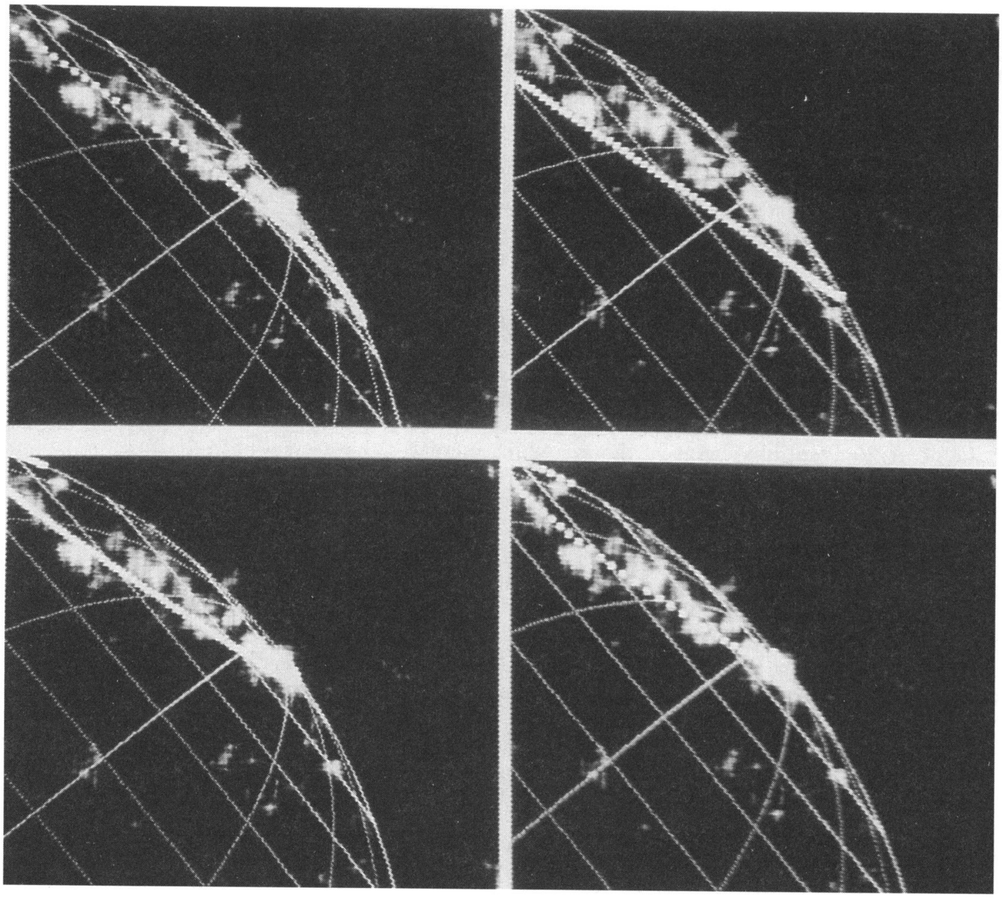

Figure 2: comparison of the Lyman-α aurora of figure 1 with:

(a) top left: the UVS oval observed with the Voyager spectrometer (Broadfoot et al., 1988);

(b) top right: the footprint of the L = 6 magnetic field lines crossing the Io orbit (O_4 GSFC model);

(c) bottom left: the footprint of the L = 15 magnetosheet field lines;

(d) bottom right: the footprint of the L = 30 magnetosheet field lines.

Future HST Instruments