OBSERVATIONS OF THE Io PLASMA TORUS

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ABSTRACT

The short wavelength spectrograph on the IUE satellite has been used to obtain spectra of the plasma torus near the orbit of Io about Jupiter. Three exposures of about 8 hours each taken in March and May 1979 show emission features due to SII, SIII, and OIII. The absence of features at other wavelengths permits upper limits to be set on other species in the torus.

INTRODUCTION

It is now known that ionic species are trapped in the orbital path of Io. The basic picture is that atoms ejected from the satellite are ionized and thus trapped on Jovian magnetic field lines. The field lines move with the 10 hour planetary rotational period, spreading the ions into a toroidal-like cloud along the orbital path. The only identified ionic emissions are those of sulfur and oxygen. However, a number of species have strong lines in the spectral region covered by the short wavelength spectrograph. For this reason, three observations of the Io torus were made near the times of the Voyager 1 and Voyager 2 flybys (5 March and 10 July 1979).

OBSERVATION DETAILS

Large aperture, low dispersion spectra of the torus were taken with the SWP camera on 1 March 1979, 3 March 1979 and 19 May 1979 (SWP 4448, 4463, 5302). The aperture, aligned approximately perpendicular to the orbital plane, was pointed between 3 and 6 R_J. The exposure times were 520, 445 and 440 minutes respectively.

Due to the long exposure times, the spectra contained in addition to readout noise, noise spikes due to fast particle hits, radioactive spots or blemishes on the camera face and geometry correcting reseaux marks. Running a median filter perpendicular to the dispersion direction before adding the line by line spectra was found to significantly reduce these noise spikes. The photometric error in SWP data during this time period has been corrected using the standard algorithim (IUE Newsletter #8). The three spectra were then summed to produce Fig. 1.

The Universe in the Ultraviolet
NASA SP 000, 1981, in press

To determine the baseline and noise signal, the averages and standard deviations were computed for the 1278 - 1376 Å, 1426 - 1651 Å, and 1776 - 1951 Å wavelength regions. The baseline varied (3121, 883 and 5030 FN respectively). The standard deviation was approximately constant with an average value of 3163 FN.

DISCUSSION

Fig. 1 shows the sum of the three observations. The features at 1256 Å and 1198 Å are identified as SIIλ 1257 and SIIIλ 1199. The 1729 Å feature has not been identified. There is a persistent blemish which produces a hit like feature near this wavelength in lengthy SWP exposures; however when this is removed either by hand or by a median filter perpendicular to the dispersion, the feature remains in the torus spectra. In addition, all three photowrite images show a distinct image of the entrance aperture indicating that the 1729 Å feature is real. The feature at 1664 Å is identified as OIIIλ 1664. However, the peak is only 10% above the 3σ noise level. Therefore, although statistically significant the identification must be considered marginal. Although the apparent peak at 1397 Å is close to the expected SIVλ 1406, it may be due to a shift in the background level near this point. In any case, a statistically significant signal does not exist at 1406 Å.

Table 1 lists a series of ionic species, in order of decreasing cosmic abundance, with strong emission lines in this spectral region. The measured brightness of the three identified species are listed. For the other species the upper limit to the brightness was determined from three times the standard deviation and the spectrograph sensitivity.

To estimate the number densities, a simple homogenous torus model similar to that used by Broadfoot _et al_ (ref. 1) was used. (In this case the torus was centered on the orbit rather than the magnetic equator.) Although it is likely that the emission structure was quite complex, these IUE spectra were averaged over most of a rotational period; thus, the simple model may be appropriate. The number densities were computed using an electron density of 2×10^3 cm^{-3} (ref. 2) an electron temperature or 10 eV and an average path length of 7.3 R_J. Also shown in Table 1 are the number densities reported by the Voyager I UVS group. These values are based on short wavelength transitions observed by the Voyager 1 extreme ultraviolet spectrograph and a model similar to ours (ref. 1). The most serious discrepancy is in the case of OIII where the IUE value is one sixth the Voyager value. The uncertainties in the number densities depend directly on those of the excitation coefficients used. A more detailed discussion of the data analysis and the sources of the excitation rates will be published at a later date.

We thank the IUE Observatory staff for their aid in the acquisition and reduction of the data. This work has been supported by a grant from NASA.

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REFERENCES

1. Broadfoot, A. L. et al 1979 Science 204, 979.

2. Bridge, H. S. et al 1979 Science 204, 987.

Table 1

OBSERVED IONIC SPECIES AND UPPER LIMITS

Species	λ (Å)	Brightness (Rayleighs)	IUE number density cm^{-3}	Voyager 1 number density† (cm^{-3})
O III *	1664	12 *	140	850
C II	1335	6.7	4.2	
C III	1909	8.5	8.6	
N III	1750	9.4	50	
N IV	1485	10	18	
Si II	1264	6.7	2.0	
Si III	1892	8.5	7.9	
Si IV	1395	7.9	1.1	
S II *	1257	43 *	140	
S III *	1199	30 - 60 *	160 - 320	95
S IV	1406	8.2	49	55
Al II	1671	11	0.22	
Al III	1856	8.4	0.72	
Ca II	1839	8.4	47	
P II	1308	6.4	12	
P III	1344	6.7	17	

† Reference 1

* Observed: The brightness value is a measured one rather than an upper limit.

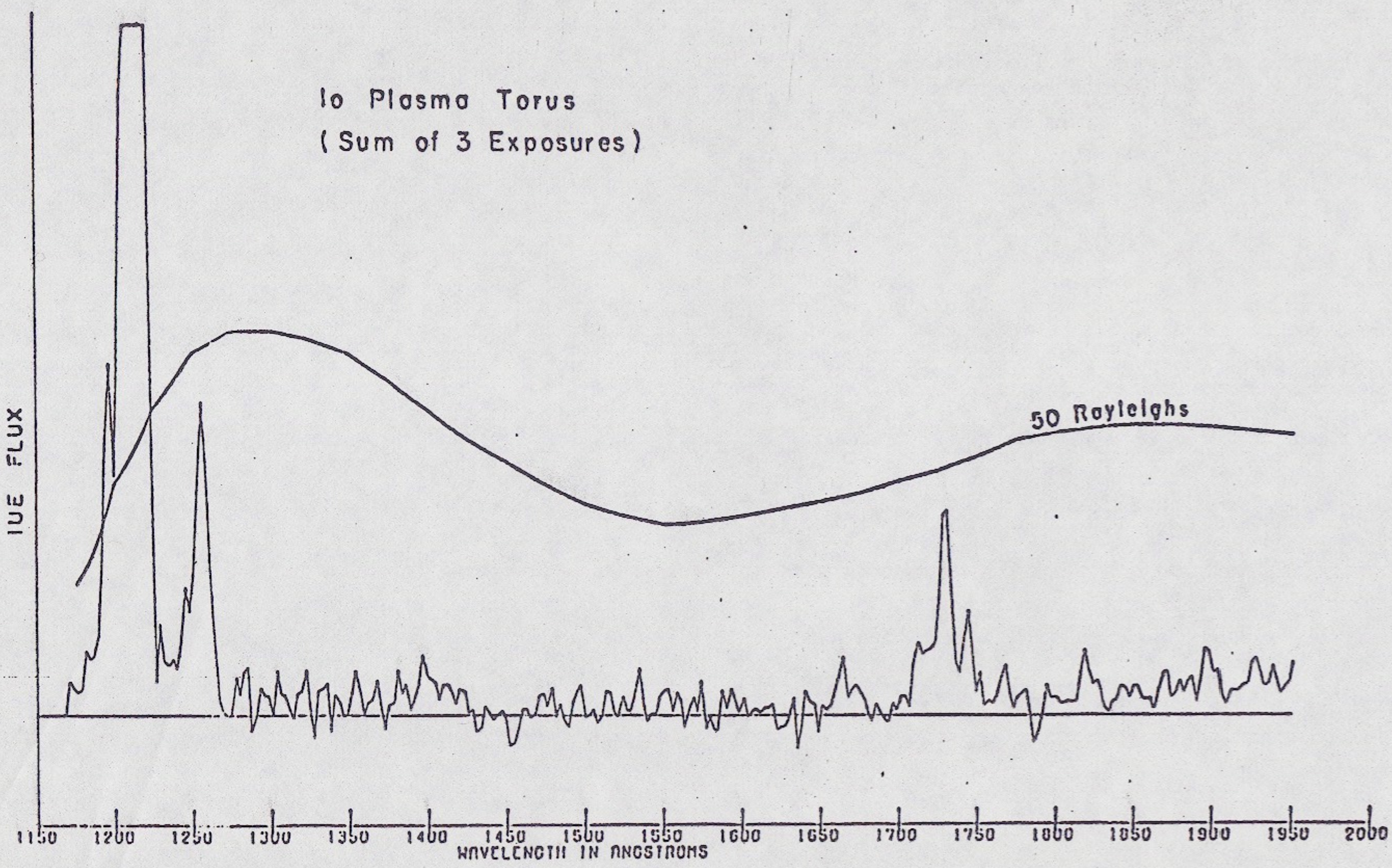
Io Plasma Torus
(Sum of 3 Exposures)
50 Rayleighs
IUE FLUX
1150
1200
1250
1300
1350
1400
1450
1500
1550
1600
1650
1700
1750
1800
1850
1900
1950
2000
WAVELENGTH IN ANGSTROMS

Fig. 1