# Observation of Outer Planets at Lyman Alpha

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DARIUS : In your SWP spectra, did you make any attempt to rescue Uranian photons from geocoronal and interplanetary Lyman alpha?

CALDWELL: We haven't tried that.

DARIUS : In that case you may be interested to learn

Three weeks ago at the IUE ground station near Madrid we carried out a triple planetary observation in one IUE shift to measure the Ly-$\alpha$ reflectivity of Jupiter, Saturn, and Uranus. The exposures were planned to take account of the light travel times, Sun to planet and planet to Earth, in order to assess the response of the three atmospheres to essentially the same incident solar flux. Automatically eliminated are all additional uncertainties introduced when different instruments are used for such a comparative measurement.

Jupiter and Saturn were observed at the centres of their discs in the large aperture of the SWP camera at low resolution. With an angular diameter of 38.″7, Jupiter completely filled the large aperture and tracking was checked using an ephemeris for Ganymede (J3) in the (x,y) co-ordinate system of the Fine Error Sensor (FES). Saturn (17.″4) effectively filled 70% of the large aperture, and any deviation from the applied drift rate could be checked by the FES counts. The disc of Uranus (3.″8) was centered in the small aperture and a simultaneous exposure carried out in the SWP large aperture to facilitate correction for non-planetary Lyman $\alpha$ emissions.

Integrated flux numbers $\int FN d\lambda$ were obtained from the line-by-line spectrum by fitting a Gaussian bell curve with a low order polynomial as background estimate. This method effectively removes isolated hot spots and the scattered light in the dispersion direction. Interpolation in the mean sensitivity table of Bohlin et al., (1980) yield $1.82 \times 10^{-3}$ photons cm$^{-2}$ Å$^{-1}$ FN$^{-1}$ at Lyman $\alpha$. If we apply this calibration and combine the photon statistical error with the error in $\int FN d\lambda$, we obtain the first line in Table 1.

Now the contaminating sky signal at Lyman $\alpha$ (large aperture) can be subtracted from the Uranus+sky signal (small aperture) by scaling up by the ratio of the exposure times and scaling down by the ratio of solid angles subtended by the two aperatures. The former is uncontroversial; but whereas the official value of the latter, $\omega_{LA}/\omega_{SA}$, is $26.5 \pm 3.7$ based on pre-flight measurements (Bohlin et al. 1980), independent in-flight evidence from six images of geocoronal Lyman $\alpha$ (Ojanguren 1979), lend credence to a ratio of $31.7 \pm 1.5$ for the energy received in the two apertures. The succeeding argument will be invalidated should this contention prove incorrect.

For the sake of a preliminary analysis, without prejudice to application of a better model for the interplanetary and geocoronal hydrogen in due course, we take the ratio of interplanetary to geocoronal Lyman $\alpha$ emissions to be 7:3 (IUE being near apogee) and assume that we shall have overestimated the contaminating interplanetary emission by 20% at Uranus, by 40% at Saturn, and by 70% at Jupiter - granted that the geocoronal contribution remains constant in each case. These figures include a geometric correction for planetary position with respect to the upwind direction. The configurations of the outer planets, the brightest satellites, and the large-aperture orientation on April 14 does not compel us to correct for additional non-planetary signal.

The column emission rates at the planets (in kiloRayleighs) in Table 1 are derived in the usual fashion after dividing the corrected fluxes by the size of the aperture and the length of exposure. An upward adjustment has been applied for the estimated line-of-sight absorption by neutral hydrogen and for the center-to-limb variation on the planet. Allowing for the inverse-square sun-planet distance falloff of the illuminating solar flux and normalizing to Jupiter, we obtain the relative Ly-$\alpha$ reflectivities in the last line of Table 1. (We draw attention also to the apparent drop in the Ly-$\alpha$ brightness of Jupiter from its March 1979 (Broadfoot et al., 1979) value back to the 1978 Copernicus level (Cochran and Barker 1979), and shall comment elsewhere.)

Within the errors, it could not be claimed on the basis of these recent IUE observations that the albedos of Jupiter and Saturn at Ly-$\alpha$ substantially differ; indeed, prior studies support a normal $1/r^2$ dependence (Weiser et al. 1977). On the other hand, the relative albedo of Uranus is so high as to disarm though not quell suspicion that it can be explained by errors inherent in our presently naive model. (One issue to be satisfactorily resolved, of course, is the disagreement over the correct aperture ratio. Bohlin (1980) has commented that the official large-aperture area may have been over-estimated, in which case we contend that the small aperture must be further diminished.) Assuming the high reflectivity to be real, one may be able to account for it in several ways. The possibility that it reflects a fluctuation in incoming solar flux is fortunately excluded by the way the present observations were conducted.

The observational geometry was such, that at Jupiter and Saturn the centre of IUE field of view lies in the planets' equatorial, but for Uranus in high northern latitudes. As the phase angle are small, the same is essentially true for the solar illumination direction. Production of neutral hydrogen atoms will proceed via solar EUV ionization with follow up ion molecule reactions. The total production rates at the planets will scale with the inverse squared distance from the Sun. For the rapidly rotating planets the global average is one fourth of the total production rate. This implies that with the present viewing geometry for Uranus the average production rate on the sunlit hemisphere will be relatively enhanced over the scaled average production rates of Jupiter and Saturn, unless rapid interhemispherical convection exists. Additionally, the eddy diffusion coefficient, which controls the downflow of the dissociated H-atoms to the recombination altitude, (Wallace and Hunten, 1973) may vary with latitude as it is known to do in the terrestrial atmosphere. Both processes may lead to a greater reservoir of H scatterers above the absorbing methane layer, and correspondingly contribute to the observed high Ly-α albedo. Brown (1976) has reported radio emissions, which possibly originated at Uranus. If the direction was indeed correctly identified, this observation would imply the existence of a magnetic field and hence magnetosphere at Uranus, from which particles may precipitate and cause greatly enhanced Ly-α emissions in the auroral zones (see e.g. Figure 5 of Broadfoot et al., 1979). If the Uranian dipole is approximately aligned with the spin axis, one complete auroral zone was in the central part of the IUE field of view during our observation. Such additional emissions besides resonantly scattered solar photons would greatly help to explain the large observed Uranian Ly-α albedo.

Albedo measurements of Uranus by Savage et al. (1980) using ANS reveal a suspected decline below 2000 Å which may require the presence of both aerosol particles and an additional absorbing agent (micron-size particles or gaseous compounds like $CS_2$ of $PH_3$). In the far ultraviolet, however, the potential depressive effect of the former becomes negligible.

In any case, new IUE measurements (Caldwell et al. 1980) do not support the 20% shortward albedo drop inferred from the uncertain ANS measurement at 1800 Å and moreover do not necessarily require an absorption stratospheric haze. Further study of relative brightness among the outer planets is in progress.

## REFERENCES


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Table 1

Lyman Alpha Measurements of Jupiter, Saturn, and Uranus

| | Jupiter | Saturn | Uranus |
|---|---|---|---|
| Observed signal (photons $cm^{-2}$) | 1072 ± 44 | 1792 ± 58 | 148 ± 12 |
| Contaminating emission (photons $cm^{-2}$) | 85 | 740 | 94 |
| Column emission rate at planet (kR) | 9.3 | 3.6 | 1.9 |
| Relative reflectivity for Ly-$\alpha$ | 1.0 | 1.2 | 2.7 |

DISCUSSION

CALDWELL: I am not too surprised by your results; they may be explicable in terms of the presence of methane vapour in the upper atmospheres of Jupiter and Saturn suspected to be absent in Uranus.