ABSTRACT

Ninety two IUE observations of the Jovian equatorial region taken by Johns Hopkins University observers between 2 Dec 1978 and 1 Feb 1988 were averaged together by date of observation, resulting in 22 averaged spectra which were fit with a model to determine the amount of H₂ Lyman band emission in the region 1552–1624 Å. The data suggest that the H₂ emission may vary with time. Especially suggestive is the marked downward trend of the emission between 1983 and 1987, during which time the strength of the emission in the 1552–1624 Å region decreased by about a factor of 10. Uncertainty in the existing data and a gap in the later in 1980 and 1981 preclude a positive identification of a correlation between the brightness of the H₂ emission and the major solar cycle.

INTRODUCTION

Molecular hydrogen emission from Jupiter's atmosphere was first detected in the Lyman bands of the Rydberg band systems by sounding rocket experiments in the early 1970s (Refs. 1, 2). Positive identification of the Werner bands was not made until the Voyager 1 flyby (Ref. 3) when two distinct phenomena were also identified: intense emissions confined to the northern and southern auroral ovals and diffuse emission uniformly distributed over the sunlit hemisphere of the planet and not apparently connected with auroral activity (Ref. 4). The same distinct phenomena were subsequently observed by Voyager 1 on Saturn and Uranus (Refs. 5, 6). The most obvious source for the diffuse UV emissions is photoelectron excitation of H₂, the predominant constituent of the atmospheres of Jupiter, Saturn, and Uranus. However, the intensity of the diffuse emissions on all three of these planets is much higher than that predicted by calculations of the solar energy input into the atmosphere via photoelectron excitation of H₂. The discrepancy on Jupiter and Saturn is about a factor of 5 and on Uranus about a factor of 15 (Ref. 7). Although the emission must be triggered by solar photons because it is only seen in the dayside atmosphere, the energy for the emission process must be produced locally in the atmosphere (Ref. 8). Because the origin of the diffuse emissions is unknown, yet is common to the three outer planets visited by Voyager 1 to date, Broadfoot et al. (Ref. 6) coined a new term, “electroglow”, to describe this unexplained phenomenon.

Several different explanations for the electroglow have been put forward (Refs. 7, 8, 9, 10). Since all theories depend on some process which is triggered by solar energy input, the relationship of electroglow to the major solar cycle is “a matter of vital interest” (Ref. 9). Reanalysis of early observations of Jovian atmospheric emissions by Shemansky and Judge (Ref. 11) showed relatively little variation in the disk-averaged (that is, auroral plus diffuse) H₂ band emission compared to a large variation in the H I Lyα emission brightness between 1972 and 1979. Nine years (1979–1987) of virtually continuous observations of the Jovian atmospheric emissions with the International Ultraviolet Explorer (IUE) satellite spanning solar cycle 21 (with maximum in ~1980 and minimum in ~1986) are also available for such an analysis. Skinner et al. (Ref. 12) used this database to show that the (non-auroral) Jovian H I Lyα emission brightness varied with the long-term solar Lyα output, decreasing by a factor of ~2 over the time period covered by the observations. However, as can be seen from Fig. 1, the
H₂ band emission signal is very weak and not easily separated from the background, in sharp contrast to the very strong Lyα emission, which is easily measured. The Lyα emission (the so-called Lyα “bulge”), tentatively confirming the Voyager 1 detection of no significant enhancement in bulge to non-bulge emission for H₂.

One of the most serious uncertainties in the Coplin analysis was the assumption of a linear background over the region of the Lyman band emission. In addition, observations made between 1978 and 1981 (and observations subsequent to the Coplin study, 1987–present) were not included in the analysis. Presented below is a more sophisticated determination of the background which has been substituted for the linear one used in the Coplin model. The H₂ emission from the expanded data set was then evaluated using the same least squares analysis as that of Coplin to determine the variation with time (if any) of the H₂ Lyman band emission in the 1552–1624Å region.

For our purposes the observed flux in an IUE spectrum of Jupiter can be thought of as simply

\[ \text{Observed flux}(\lambda) = \text{Background}(\lambda) + H₂ \text{ emission}(\lambda) \]

\[ = \omega \left( \frac{A(\lambda) F_\odot(\lambda)}{\pi R_J^2} \right) + H₂ \text{ emission}(\lambda) \]

where

\[ \omega = \text{IUE slit size} \]
\[ R_J = \text{sun–Jupiter distance in AU (5.203 AU)} \]
\[ A(\lambda) = \text{the albedo of Jupiter} \]
\[ F_\odot(\lambda) = \text{the solar flux measured at the earth} \]
Note that the shape of the background with wavelength is determined by the solar flux incident on Jupiter's atmosphere and the amount of the incident flux which is "reflected" by the atmosphere (the albedo). The albedo is determined by the major constituents of Jupiter's atmosphere, namely H$_2$ and He, which scatter the incident radiation, and hydrocarbons such as acetylene (C$_2$H$_2$) and ethane (C$_2$H$_6$), which absorb the incident solar flux. We use a theoretical model of the Jovian albedo by Gladstone and Yung (Ref. 14—model #2) which is based on a homogeneous atmosphere with constant mixing ratios of H$_2$ = 0.89, He = 0.1, C$_2$H$_2$ = 1.1 x 10$^{-7}$, C$_2$H$_6$ = 6.5 x 10$^{-6}$, C$_4$H$_2$ (dicetylene) = 2.6 x 10$^{-9}$, and C$_2$H$_4$ (ethylene) = 4.9 x 10$^{-10}$. This model is known to match a typical equatorial IUE spectrum well over the wavelength range 1500–1750Å. The background is computed at 1Å intervals and then smoothed to IUE resolution (∼10 Å). The model albedo, solar flux (scaled) and the resulting "background" used in determining the H$_2$ emission are shown in Fig. 2. Note that the small scale features (∼10Å) come mainly from the solar spectrum, whereas the general rise in the background over the region of the Lyman band emission is determined by the albedo.

With the improved background determination, the model used in the least squares fit to the data becomes

$$\text{Model}(\lambda) = a_0 + B k(\lambda) + a_2 + \text{auroral flux}(\lambda)$$

The 1552–1624Å region of a typical spectrum and the fit to the data are shown in Fig. 3.
RESULTS

Ninety two IUE observations of the Jovian equatorial region by Johns Hopkins University observers taken between 2 Dec 1978 and 1 Feb 1988 were averaged together by date of observation, resulting in 22 averaged spectra, which were then fit with the model described above to determine the amount of H2 Lyman band emission in the region 1552-1624Å. The results of this analysis are shown in Fig. 4.

Although still preliminary, the data suggest that the H2 emission in this region may vary with time. Especially suggestive is the marked downward trend of the emission between 1983, when the H2 1552-1624Å Lyman band brightness was ~1 kR, and mid-1987, when it was ~0.1 kR. The low emission in 1978/79 and late 1981, 82, and 83, and the lack of data in 1980 and 81 preclude an unambiguous identification of a correlation between the H2 emission and the major solar cycle. However, note that the late 1982 and 83 data points also have the largest uncertainties. The addition of data from observers other than those at Johns Hopkins, as well as analysis of the H2 Werner bands continues and may allow more definitive conclusions to be drawn in the near future.

Acknowledgements. M. McGrath wishes to thank D. Strobel, W. McMillan, R. Gladstone, and R. Yelle for their helpful discussions. We gratefully acknowledge the help of the National Space Science Data Center at NASA/Goddard Space Flight Center, in particular C. M. Perry, in obtaining image files for the early IUE observations via the SPAN network. This work has been supported by NASA grant NSG5393.

References


Fig. 4.