

**N 9 3 - 1 1 1 6 6**

**Lyman Alpha Line Shapes from Electron  
Impact H<sub>2</sub> Dissociative Processes  
in the Jovian Auroral Zone**

**J. H. Waite, Jr.<sup>1</sup> and G. R. Gladstone<sup>2</sup>**

**<sup>1</sup>Space Sciences Department  
Southwest Research Institute  
San Antonio, Texas 78228-0510**

**<sup>2</sup>Space Physics Laboratory  
University of California, Berkeley  
Berkeley, California**

## Introduction

Over the past two years several Lyman alpha line profile spectra of Jupiter have been obtained using the International Ultraviolet Explorer (IUE) telescope facility. Several different regions of the planet have been observed including the auroral zone [Clarke et al., 1989], the low and mid latitudes [Clarke and Gladstone, 1990], and the equatorial region which includes the Lyman alpha bulge region [Clarke et al., 1991]. These results have presented a very interesting, but yet understood picture of atomic hydrogen at Jupiter with explanations that range from ion outflow in the auroral zone to large thermospheric winds at low and mid latitudes. New data are needed to address the outstanding questions. Almost certainly, high resolution spectra from the Hubble Space Telescope will play a role in new observations. Better data also require better models and better models new laboratory data as inputs. The purpose of this letter is two-fold: 1) to introduce a method by which the new laboratory electron impact measurements of H<sub>2</sub> dissociation of Ajello et al. [1991] can be used to calculate both the slow and fast H(<sup>2</sup>S) and H(<sup>2</sup>P) fragments in an H<sub>2</sub> atmosphere, and 2) to determine the predicted Lyman alpha line shape that would result from electron impact production of these dissociative fragments in the Jovian auroral zone.

## Determination of Electron Impact Produced H<sub>2</sub> Dissociative Products

The calculation of fast and slow H(<sup>2</sup>S) and H(<sup>2</sup>P) rely heavily on the new cross section presented in Ajello et al. [1991]. In this letter, we reproduce Table 1 and Table of the Ajello et al. paper as reference and provide a cook book method for using that information to construct production rates for fast and slow H(<sup>2</sup>S) and H(<sup>2</sup>P) production from electron impact on H<sub>2</sub>.

1. Slow H(<sup>2</sup>P) production due to singlet and triplet H<sub>2</sub> excitation is found by simply adding together the fit parameters from Table 1 [Ajello et al., 1991] for processes 1, 2, and 3.
2. Slow H(<sup>2</sup>S) production was calculated using the derived values of H(<sup>2</sup>P)/H(2I) for energies above 50ev of 59% from the Ajello et al., [1991] experiment.
3. Fast H(<sup>2</sup>P) production due to doubly excited states is found in a similar manner by adding the cross sections from processes 4, 5, and 6 of Table 1 of Ajello et al. together.
4. Values found in Table 2 of the Ajello et al. reference were then used to deduce a value of for the H(<sup>2</sup>S) relative to the H(<sup>2</sup>P) production for fast H(<sup>2</sup>S) production. The number is 0.82.

## The Model and Results

The results of the above determination of electron impact produced H<sub>2</sub> dissociative products provides production rates for fast and slow H(2S) and H(2P) when included in the context of an electron transport calculation of the auroral energy dissipation. This was accomplished by inclusion of the H<sub>2</sub> dissociative production rates in the two -stream electron transport equation which has been used in the past to model Jovian electron aurora (cf., Waite et al., 1983). The precipitating electron energy spectrum was specified by the equation:

$$J(E) = J_{op} (E/E_{op}) e^{-E/E_{op}} \quad \text{where } E_{op} = 100 \text{ keV and } J = 10^6 \text{ cm}^{-2} \text{ s}^{-1} \text{ keV}^{-1}.$$

This results in an integrated electron energy influx of 10 ergs cm<sup>-2</sup> s<sup>-1</sup> which is sufficient to explain the bulk of the H<sub>2</sub> Lyman and Werner band emissions observed in the Jovian aurora if the particles are indeed electrons. The resulting production rate profiles for the fast and slow H\*, H<sub>2</sub> Lyman and Werner band, and direct excitation of atomic hydrogen by electron impact as a function of altitude are presented in Figure 1.

These production rate profiles were then used as inputs into the radiative transfer model of Gladstone [1982] to produce a Lyman alpha line profile as viewed from the top of the atmosphere. The line profile is shown in Figure 2 where we have labeled the various contributions independently: 1) e + H<sub>2</sub>(slow) is the solid line, 2) e+ H<sub>2</sub>(fast) is the dotted line, and 3) e + H is the dashed line. Here we have assumed that all H(2S) is rapidly turned into H(2P) by collisions with H<sub>2</sub>, a good assumption for the energetic electron beams chosen which deposit their energy near the homopause at a pressure level of 0.1 millibars.

## Conclusions

Although the line broadening produced from including fast H<sub>2</sub> dissociative fragments from electron impact cannot explain the highly broadened features indicative of the present data sets, high temporal, spatial, and spectral resolution data from HST must include these processes in future quantitative models. Inclusion of this data in future models will allow quantitative estimates of winds and atmospheric turbulence to be determined from this high resolution data. Such an understanding of the atmospheric dynamics of the Jovian auroral zone is crucial to determination of the global structure of the Jovian thermosphere due to the dominance of the auroral energy input over solar EUV processes (> a factor of 10, cf. Waite et al., 1983).

## Acknowledgements

Partial support for this work has been provided by NASA Planetary Atmospheres grant NAGW-1657, NASA IUE and ROSAT Observations of Jupiter's Aurora grant NAG5-1429, and by SwRI Internal Research project 15-9634.

## References

- Ajello, J.M., D.e. Shemansky, and G.K. James, "Cross sections for production of H(2p, 2s, 1s) by electron collisional dissociation of H<sub>2</sub>, *The Astrophysical Journal*, 371, 422, 1991.
- Clarke, J.T., J. Trauger, and J.H. Waite, "Doppler shifted H Ly  $\alpha$  emission from Jupiter's aurora", *Geo. Res. Lett.*, 6, 587, 1989.
- Clarke, J.T. and G.R. Gladstone, The center to limb variation in Jupiter's H Ly- $\alpha$  emission, submitted to *J. Geophys. Res. Brief Rpts.*, 1990.
- Clarke, J.T., G.R. Gladstone, and L. Ben Jaffel, "Jupiter's Line Profiles", *Geophys. Res. Lett.*, in press, 1991.
- Gladstone, G.R., "Radiative transfer with partial frequency redistribution in inhomogeneous atmospheres: application to Jovian aurora, *J. Quant. Spectrae. Radiat. Transfer*, 27, 545-556, 1982.
- Waite, J.H., T.E. Cravens, J. Kozyra, A.F. Nagy, S.K. Atreya, and R.H. Chen, "Electron precipitation and related aeronomy of the Jovian thermosphere and ionosphere", *J. Geophys. Res.*, 88, 6143, 1983.

## Figure Captions

Figure 1: Lyman alpha production rates from all electron impact processes on H<sub>2</sub> and H as a function of altitude for the 100 keV auroral case.

Figure 2: Lyman alpha line profile, intensity in kilo Rayleighs per angstrom as a function of relative wavelength from line center.

# H and H<sub>2</sub> Initial Production Rates - Hunter '91

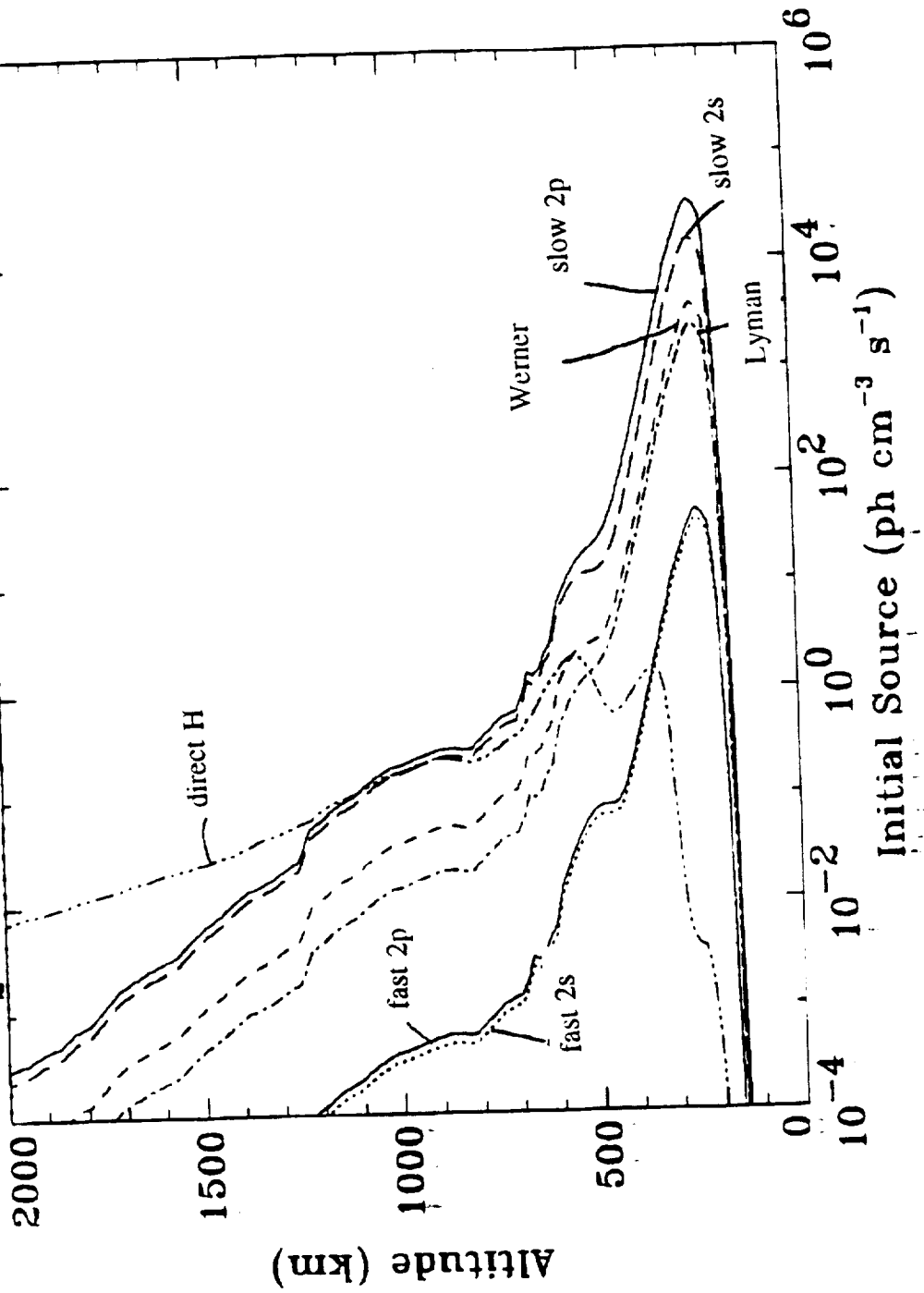


Figure 1

# Jupiter Auroral Ly $\alpha$ Line Profiles

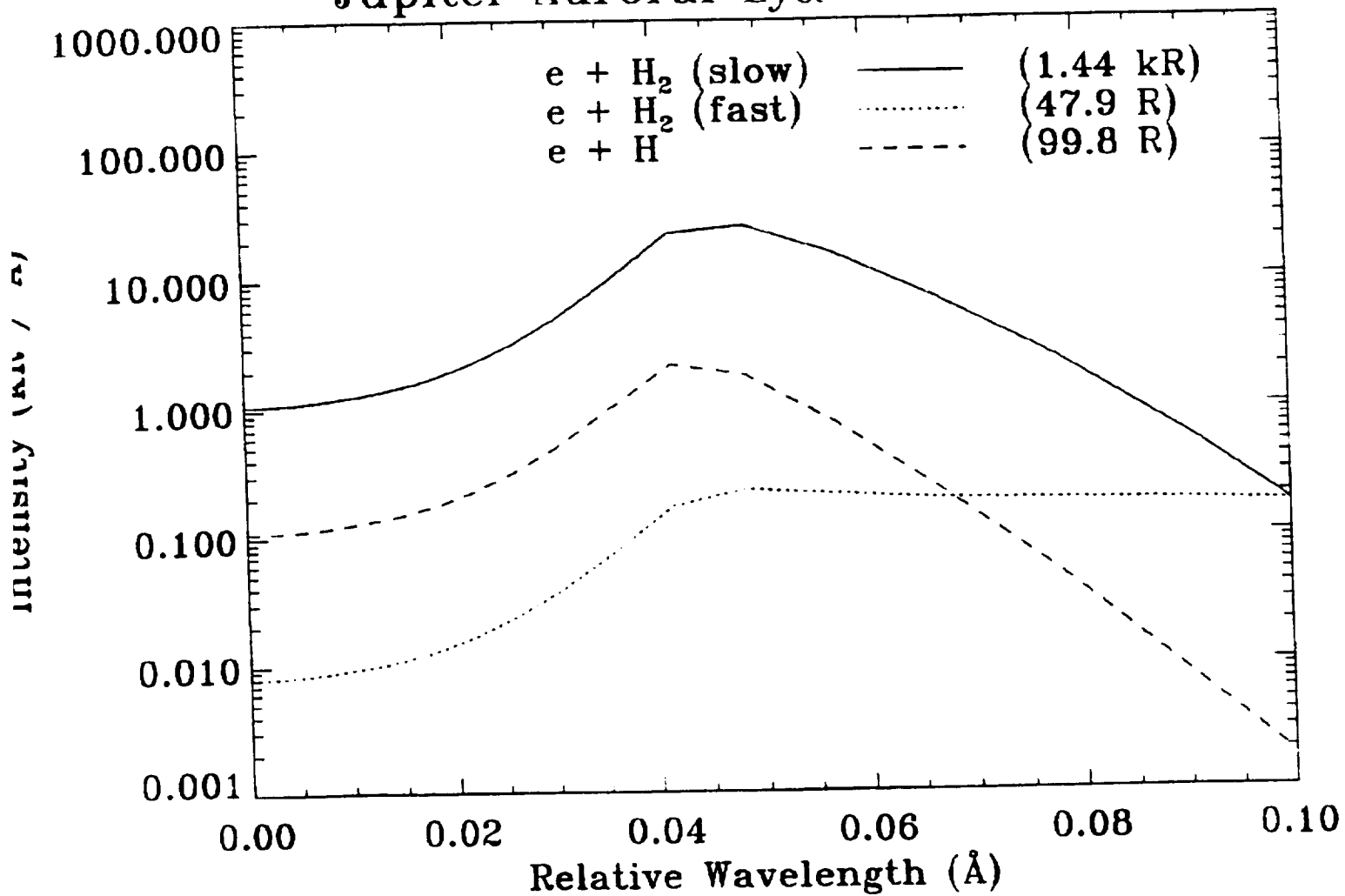


Figure 2

## APPENDIX E