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TWO MICRON QUADRUPOLE LINE EMISSION OF H_2 FROM THE JOVIAN AURORAL ZONE

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Energetic electron bombardment of the H_2 atmosphere in the Jovian auroral zone has been studied using a theoretical model for the vibrational-rotational excitation processes. A non-relativistic electron energy deposition program originally developed by Peterson et al. *(1973,* Computer Phys. Comm. 5, *239-262) was used. Assuming an incident energy electron spectrum from IUE observations, the calculated intensities of the two micron quadrupole lines from the Jovian auroral zone are shown to be comparable to the intensities of infrared objects in the Orion nebula. Jupiter is fairly dark in the 2-2.5 micron spectral range because of strong absorption of CH_4 and NH_3 vibrational-rotational bands. Consequently, assuming no significant decrease in Jovian auroral activity since the Voyager encounter with Jupiter in 1979, the two micron quadrupole emission of H_2 may be observable by ground-based telescope through the two micron atmospheric window.*

Strong 10 micron infrared emission of hydrocarbons in the Jovian auroral zone has been observed from the ground and from the Voyager 1 IRIS instrument. Figure 1 illustrates the infrared emission at 7.8 μm from ground-based observations of the auroral zone. Ultraviolet emission of H_2 has been also detected by Voyager 1 and 2 UV instruments and by the IUE. Yung *et al.* (1982), analyzing the ultraviolet aurora, estimated the electron energy spectrum to be in the range of 1-30 keV.

There are several outstanding scientific questions for these auroral phenomena. Are the particles causing UV aurora also responsible for 10 and 2 micron IR aurora? The derived 1 to 30 keV electrons from UV aurora may not produce the 10 micron IR aurora because these energetic electrons cannot reach hydrocarbon layers in the stratosphere of Jupiter (Fig. 2). A second observation requiring explanation is the discovery of C_2H_4, C_3H_4 and possibly C_6H_6 in the Voyager 1 IRIS spectra of Jupiter's north polar region. To date, we don't have a plausible energetic particle chemistry for creation of these molecules. The third area of investigation is heating and cooling processes in the Jovian auroral zone. This mechanism has been only partially understood.

This presentation is one contribution to solving these outstanding problems. We describe a theoretical model for vibrational excitation and de-excitation processes of H_2, and estimate the 2 micron quadrupole emission flux of H_2. We modified a non-relativistic electron energy deposition program originally developed by Peterson (1973) for calculating the number of vibrational-rotational excitation states of H_2. In the calculation, a continuous slowing-down approximation was used for the energy of incident auroral electrons.

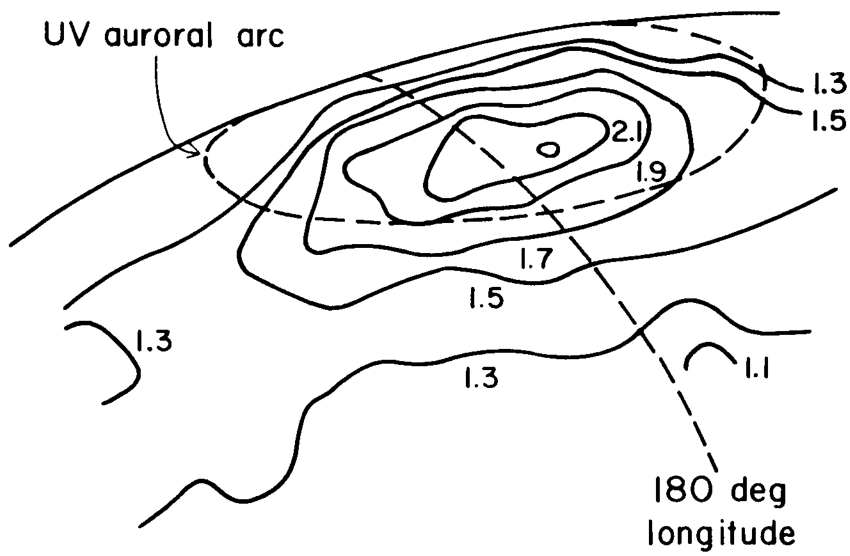

Figure 1. Infrared emission at 7.8 μm for the Jovian auroral zone. Brightness contours are in units of the background intensity.

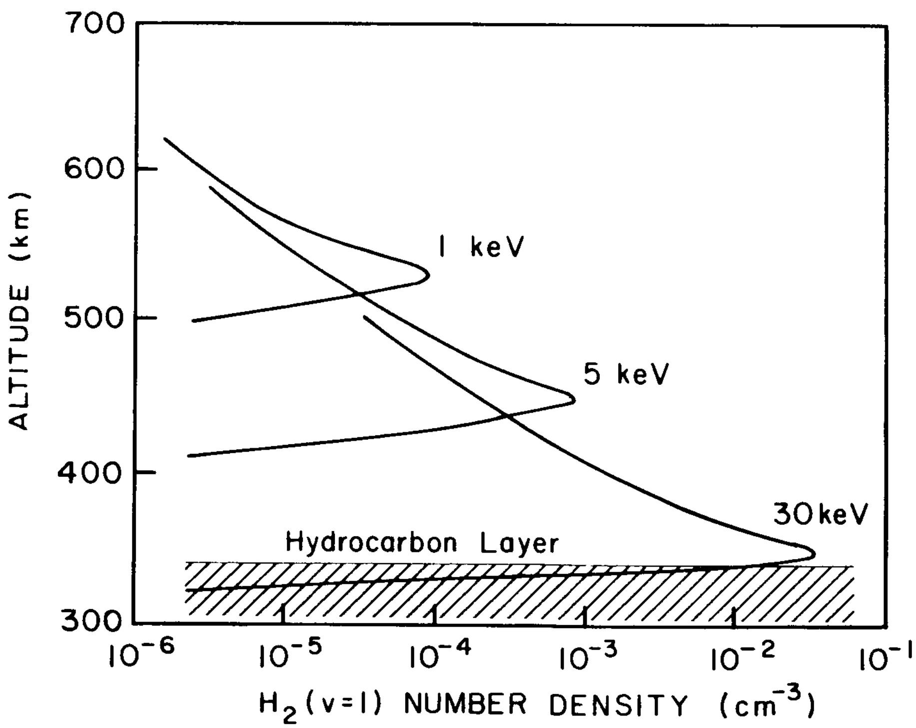

Figure 2. Number densities of H_2(v=1) resulting from the precipitation of an electron of the indicated energy.

An updated cross section compilation for electronic transitions, dissociative excitations, dissociative ionizations, vibrational and rotational excitations was prepared for the input parameters to the electron deposition program. We excluded ohmic dissipation due to currents driven by auroral electric fields. At the present time, we do not have any information about the Jovian auroral electric field. The most uncertain part of the model calculation is the energy flux spectrum of incident electrons on the auroral zone. We used the 1-30 keV electron spectrum derived from UV observations by Yung *et al.* (1982) for our calculations. For total energy flux, Yung *et al.* used 10 ergs $cm^{-2}s^{-1}$. This value may be a lower limit for realistic calculations because infrared auroral flux of the 7.8 micron band of CH_4 alone is about 9 erg $cm^{-2}s^{-1}$. Therefore we used 10-100 erg $cm^{-2}s^{-1}$ for the total incident electron flux on the auroral zone. Figure 2 shows results of the number densities of $H_2(v=1)$ as a function of altitude after 1 second irradiation of an auroral electron. The upper, middle, and lower curves correspond to a 1 keV, 5 keV, and 30 keV electron, respectively. Here we arbitrarily set z=0 km at the 1 bar pressure level. A time dependent model of excitation and de-excitation of H_2 has been constructed, with equilibrium number densities of the vibrational de-excitation rate equal to the vibrational excitation rate. The intensity of a quadrupole line is given by

$$I = \frac{h\nu}{4\pi} \int N \frac{A_{ji}}{(A_{ji}+\eta n)} dz.$$

Here h is the Planck constant, ν is the frequency of the quadrupole line, N is the number of excited states per cm^3 per second, A_{ji} is the Einstein coefficient, n is the total number density, η is the total vibrational relaxation coefficient for H_2-He, H_2-CH_4 and H_2-H_2 collisions in units of cm^3 cm^{-1}, and z is the altitude. Table 1 gives a summary for the calculated intensities of the quadrupole lines for 5 keV electrons and a total energy flux of 100 ergs $cm^{-2}s^{-1}$.

Table 1

Calculated Two Micron Quadrupole Line Intensities
(5 keV Electrons, Total Energy Flux = 100 erg $cm^{-2}s^{-1}$)

Line	Position (cm^{-1})	Intensity (erg $cm^{-2}s^{-1}$ sterad^{-1})
$S_1(0)$	4497.84	5.9×10^{-3}
$S_1(1)$	4712.91	1.3×10^{-2}
$S_1(2)$	4917.01	1.9×10^{-3}
$Q_1(1)$	4155.26	2.5×10^{-2}
$Q_1(2)$	4143.47	6.4×10^{-3}
$Q_1(3)$	4125.87	1.2×10^{-2}

Our calculated intensities are comparable to those of infrared objects in the Orion nebula. Since Jupiter is fairly dark in the 2 micron region, the 2 micron quadrupole emission of H_2 may be observable by ground-based telescope through the 2 micron atmospheric window. The observed line intensities can provide the energy spectrum of incoming auroral particles.

REFERENCES

Peterson, L. R., T. Sawada, J. N. Bass, and A. E. S. Green (1973). Electron energy deposition in a gaseous mixture. *Computer Phys. Comm.* 5, 239-262.

Yung, Y. L., G. R. Gladstone, K. M. Chang, J. M. Ajello, and S. K. Srivastava (1982). H_2 fluorescence spectrum from 1200 to 1700 Å by electron impact: Laboratory study and application to Jovian aurora. *Astrophys. J. Lett.* 254, L65-L69.