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THE INFRARED AURORAE OF JUPITER

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ABSTRACT

Spectroscopic data between 7 and 15 microns obtained in 1979 by Voyager 1 and 2 Infrared Interferometer Spectrometer (IRIS) have been revisited. Using the spectral data, Jupiter images have been constructed at the emission bands of hydrocarbons, such as methane, ethane, and acetylene. The resultant images show differences in emission intensities in the polar regions, suggesting inhomogeneous distributions of the hydrocarbons over the auroral regions of Jupiter.

I. INTRODUCTION

The 10 micron Jovian infrared aurorae were discovered by ground and Voyager observations of the polar regions (Caldwell et. al., 1980; Kim et al. 1985). Studies of the 2 - 4 micron infrared aurorae did not progress until Trafton et al. (1987) observed 2 micron H2 quadrupole lines, which were theoretically predicted by Kim (1986). Subsequently, Trafton observed unidentified strong emission lines near 2.1 microns, which were eventually identified as the 2 2 band of H3+. Utilizing strong intensities of the fundamental band of H3+ at 4 microns, Kim et al. (1991) and Baron et al. (1991) successfully obtained auroral images, which revealed detailed structures and temporal variation of the infrared aurorae. A continuous auroral oval has been revealed in the 4 micron H3+ images by Y.H. Kim et al. (1994). Recently, small H3+ emission patches in the vicinity of the Jupiter's main aurora have been studied by Y.H. Kim and Kim (1995).

The IRIS (Hanel et al. 1979a, b) on Voyager 1 and 2 has yielded significant information on the atmospheres of outer planets. On Jupiter, in particular, IRIS data have been used to study the thermal structure, composition, and dynamics. These studies used primarily Voyager 1 data. In this paper, I investigate selected regions on Jupiter using Voyager IRIS data along with theoretical techniques available today. Although Voyager 1 data are utilized, I concentrate on the analysis of Voyager 2 results, which as yet, have not been fully evaluated, to study the north and south polar auroral regions, and the global composition of the stratosphere of Jupiter. The compositional studies include the major hydrocarbons, such as, methane, ethane, and acetylene, as well as less abundant species observed only in hot regions of the planet (e.g. north polar hot spot) (Kim et al. 1985).

II. DATA ANALYSIS

The IRIS aboard Voyager 1 and 2 acquired many infrared spectra of Jupiter's polar regions from 200 to 1400 cm-1. Observational sequences known as North/ South maps were performed as each spacecraft approached and receded from Jupiter. These maps have 360 degrees of longitude coverage of Jupiter, including the regions at 60 deg N and 60 deg S latitude. Additional sequences for both Voyager 1 and 2 of 50 spectra each centered near 60 deg N and 180 deg longitude were programmed in advance to determine the gas composition at the polar regions. This is serendipitous because this particular longitude was not known to have enhanced infrared emission at the time. Although the Voyager 2 spectrometer was noisier than its counterpart on Voyager 1, I have recently developed procedures to average the data in bins whose width is 20 deg of longitude. The radiance of Jupiter at frequencies corresponding to emission by methane, acetylene, ethane, and hydrogen molecules were extracted from each spectrum. Spectra at the same latitude but within +/- 10 deg longitude were averaged together to improve the signal-to-noise ratio (S/N).

Shown in Figure 1 are average radiances and error bars at selected frequencies chosen to illustrate infrared emission from hydrocarbons in Jupiter's stratosphere. The data were selected for latitude ranges above 52 deg N and below 52 deg S. A point is plotted every 4 deg longitude. Those longitudes with only 1 or 2 spectra in each bin have the largest error bars while the best measurements may have 75 or more spectra within +/- 10 deg longitude. In order to study infrared emission from Jupiter's stratosphere, one must carefully subtract the underlying tropospheric continuum. Stratospheric emission lines of acetylene and ethane are formed in the 5 to 10 mbar region, while hydrogen molecular emission at the same frequencies originates at the 400 to 500 mbar level. Although one could subtract the hydrogen molecular continuum level at nearby frequencies, this introduces noise. Instead we chose a different frequency in which unit optical depth in hydrogen molecule occurs at the same pressure level but where the S/N was much higher. For example, acetylene emission at 730 cm-1 is riding on a 124 K hydrogen molecular continuum. The absorption coefficient of hydrogen molecule is the same at 320 and 730 cm-1, but the radiance from a 124 K black body is 10 times higher at 320 cm-1 than at 730 cm-1. Thus, one can use measurements of the hydrogen molecular continuum at frequencies where both Voyager 1 and 2 have excellent S/N to remove tropospheric temperature

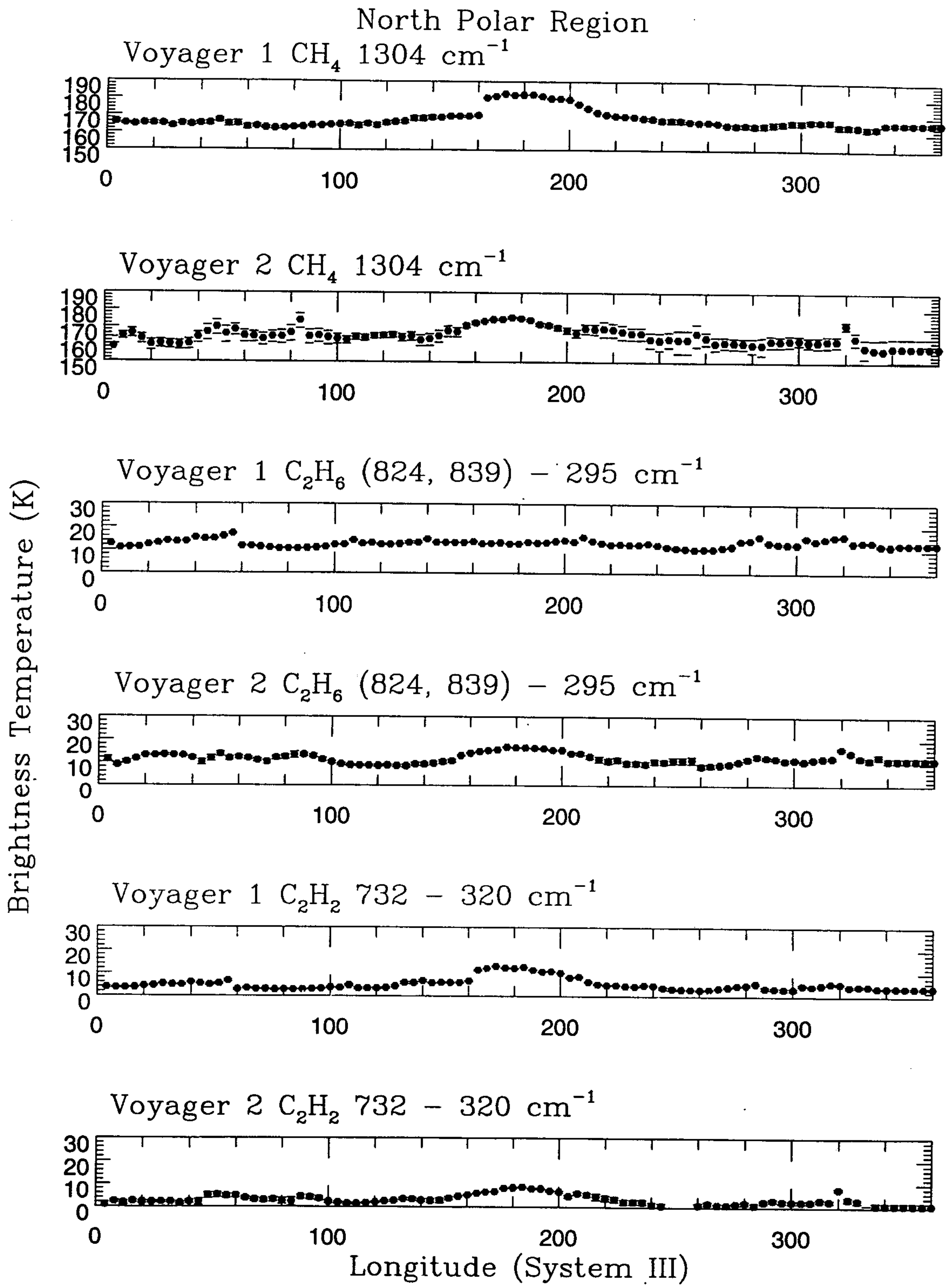
North Polar Region
Voyager 1 CH4 1304 cm-1
Voyager 2 CH4 1304 cm-1
Voyager 1 C2H6 (824, 839) – 295 cm-1
Voyager 2 C2H6 (824, 839) – 295 cm-1
Voyager 1 C2H2 732 – 320 cm-1
Voyager 2 C2H2 732 – 320 cm-1
Brightness Temperature (K)
Longitude (System III)
190
180
170
160
150
30
20
10
0
100
200
300

Fig. 1.

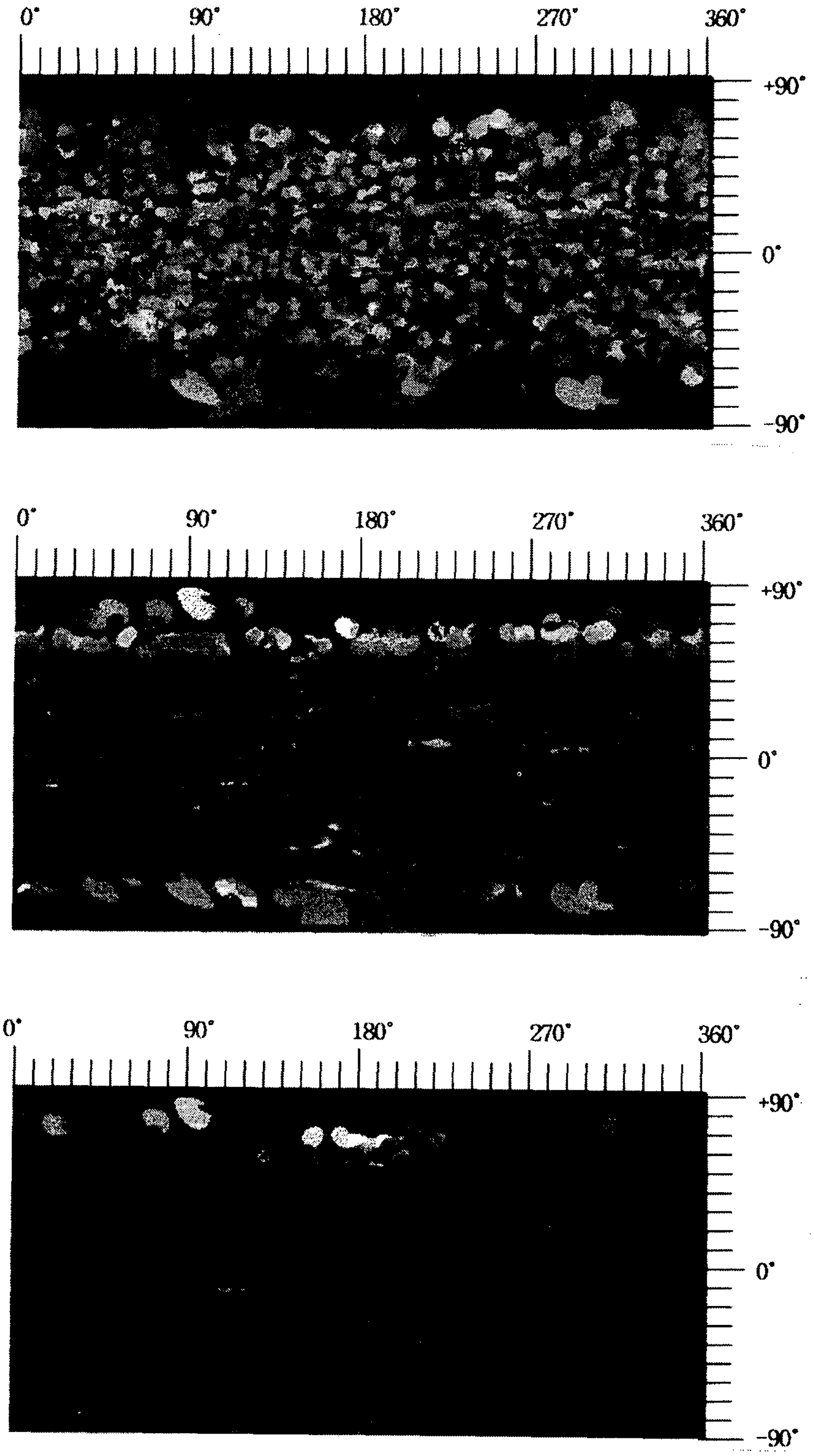

Fig. 2.

effects. Variation in hydrocarbon emissions with longitude must therefore reflect differences in the stratosphere alone.

Fig. 1 clearly shows enhanced emission in methane and acetylene for both Voyager data near 180 deg longitude. However, the emission is much brighter in Voyager 1 data. Enhanced emission by ethane in the hot spot is not obvious in Voyager 1, but is quite prominent in the Voyager 2 data. These results clearly demonstrate variability in the emissions with time scales on the order to months.

Figure 2 show 3 Jupiter images of methane (top), ethane (middle), and acetylene (bottom) band emissions obtained from Voyager 1 IRIS spectral data. Realistic IRIS aperture shapes projected onto the Jupiter's surface have been derived. Overlapping areas between the apertures have been considered. ¿From these images, it is clear that the hydrocarbon emissions in the auroral regions are not the same, ie., the methane and acetylene auroral emissions are confined around 60 deg N and 180 deg longitude, whereas there is no confined auroral emission for ethane.

These results should be first interpreted utilizing retrieved temperature profiles from the 7.8 micron methane band, and then precise abundances of other hydrocarbons should be derived. Without any detailed calculations, however, the results suggest inhomogeneous distributions of the hydrocarbons over the auroral regions of Jupiter. The construction of photochemical models in order to interpret the enhanced emissions, and the detailed abundance calculations are deferred to the next work.

III. CONCLUSION

Voyager 1 and 2 IRIS data have been reanalyzed to construct Jupiter images at the emission bands of methane, ethane, and acetylene. The comparisons of the Voyager 1 and 2 spectra show evidence of temporal variability over the 4 month period between the two Voyager Jupiter encounters. The constructed images clearly show differences in emission intensities in the polar regions, suggesting inhomogeneous distributions of the hydrocarbons in the polar regions.

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