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Stratospheric temperature and composition of Jupiter's polar aurora from IRTF-TEXES

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Abstract

We perform an analysis of TEXES (Texas Echelon Cross Echelle Spectrograph, 5- to 25-μm,[1]) spectra of Jupiter's high latitudes observed in December 2014 in order to study the jovian polar aurora. The high resolving power (R $\sim$ 85000) of TEXES allows a large altitude range (10 mbar to 0.01 mbar) in Jupiter's stratosphere to be sounded. Retrievals of temperature and stratospheric composition of these measurements therefore: 1) allow the vertical deposition of auroral energy to be determined and 2) quantify how the auroral processes modify the thermal structure and composition of the jovian stratosphere

1. Introduction

The neutral atmosphere of Jupiter's poles is highly coupled with the external magnetospheric environment. Energetic particles of the solar wind are deflected along Jupiter's magnetic field lines and penetrate the jovian atmosphere at high latitudes. The atmosphere serves as a form of resistance to the charged particles generating the Joule heating responsible for producing the auroral-related *hot spots* observed in the thermal infrared. Figure 1 shows brightness temperature maps of H_2 S1, C_2H_2 (acetylene), C_2H_6 (ethane), C_2H_4 (ethylene) and CH_4 (methane) emission of Jupiter's high-latitudes from IRTF-TEXES scans obtained in December 2014. The enhanced CH_4 emission at high-northern latitudes (north of 50°N and longitudes 120°W - 220°W) and at high-southern latitudes (south of 70°S and longitudes 20°W to 90°W) marks the positions of the auroral-related hot spots that have been observed previously (e.g. [2,3,4,5,6]) and indicates the enhancement of stratospheric temperatures in this region. The enhanced emission of C_2H_2, C_2H_4 and C_2H_6 may also be a result of the warmer stratospheric temperatures in the pressure region in which their lines form and/or may indicate an enrichment in concentration of these molecules: a retrieval analysis is required to disentangle these two contributions.

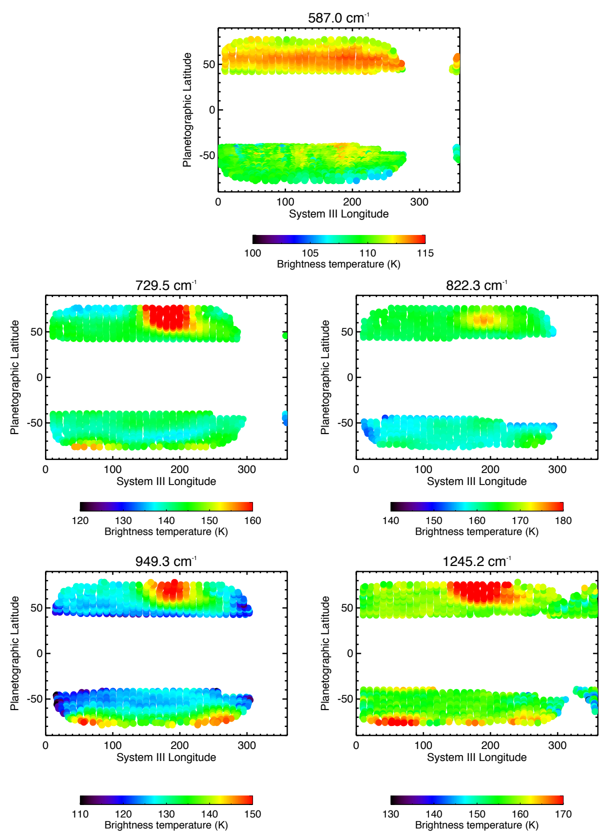

Figure 1: Brightness temperature maps of Jupiter from IRTF-TEXES at 587.0 cm^{-1} (H_2 S1 emission), 729.5 cm^{-1} (C_2H_2 emission), 822.3 cm^{-1} (C_2H_6 emission), 949.3 cm^{-1} (C_2H_4 emission) and 1245.2 cm^{-1} (CH_4 emission).

Similar behaviour as well as enhanced emission of C_3H_4, C_4H_2 and C_6H_6 has been observed in previous studies using Voyager-IRIS (Infrared Interferometer Spectrometer) and Cassini-CIRS (Composite Infrared Spectrometer) spectra (e.g. [3,4,6,7]). However, in these earlier studies, often only qualitative conclusions about temperature and/or concentration contrasts have been made from the spectra alone. In addition, these spacecraft measurements are of limited spectral resolving power (R < 2500) and thus only sound a single stratospheric level at approximately 5 mbar and thus only capture the effects of the aurora at one altitude. In contrast, ground-based high-resolution (R > 10^4) heterodyne spectra of C_2H_4 features were used to probe the 10-μbar region of Jupiter's aurora [5]. However, without independent temperature information, discrimination between thermal and chemical enhancements inside the aurora was a challenge.

Thus, we aim to quantify the temperature and composition contrasts inside Jupiter's auroral regions by an analysis of IRTF-TEXES spectra acquired in December 2014. The high resolving power of these observations (R = 85000) have sounded a large pressure range in Jupiter's atmosphere (10 mbar to 0.01 mbar), which will allow the effects of the auroral processes on Jupiter's neutral atmosphere to be studied as a function of latitude, longitude and importantly, height. Our method of data acquisition allowed us to obtain independent temperature and composition information at each latitude and longitude, which will allow the degeneracy between temperature and composition in fitting the spectra to be removed.

This work will provide a much needed context for the short-wavelength data that will be returned by the Juno mission upon its arrival at Jupiter in 2016. Juno does not include a thermal infrared instrument that would allow temperature and composition to be determined.

2. Observations & Analysis

TEXES observations at NASA's Infrared Telescope Facility (IRTF) were acquired on December 11th, 2014. At this time, Jupiter's doppler shift exceeded a magnitude of 20 km/s such that telluric and jovian CH_4 lines could easily be distinguished. Initially, in the 587 cm^{-1} spectral setting, the slit (6-12" in length) of the spectrograph was aligned east-west on Jupiter and scanned south, from dark sky off the northern limb of Jupiter, to approximately 50°N (planetographic). Spectra of the dark sky served as a flatfield and as a telluric divisor and a room-temperature blackbody was used as a radiometric standard. These scans were then repeated for the 730 cm^{-1}, 823 cm^{-1}, 950 cm^{-1} and 1248 cm^{-1} settings and subsequently, a similar set of scans were taken for Jupiter's southern hemisphere.

This process was repeated such that Jupiter's rotation allowed longitudinal coverage to be extended and such that observations of a common latitude, longitude and emission angle range could be averaged together to increase the signal-to-noise ratio. Figure 2 shows example spectra at 64°N in all 5 spectral settings, which include the molecular features indicated in the Figure. The enhanced emission inside the auroral hot spot is prominent, in particular for CH_4, C_2H_2 and C_2H_4.

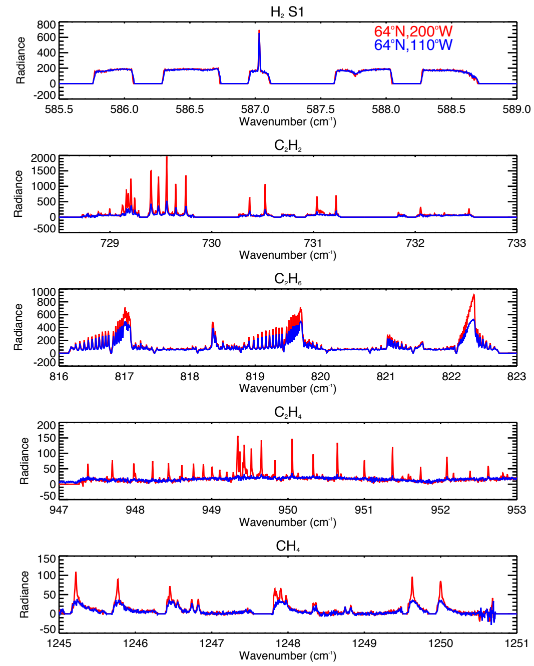

Figure 2: Reduced and calibrated IRTF-TEXES spectra of H_2 S1, C_2H_2, C_2H_6, C_2H_4 and CH_4 emission at 64°N (planetographic), 200°W (red: on the aurora) and 110°W (blue: quiescent). Radiances are in units of nW cm^{-2} sr^{-1} $(cm^{-1})^{-1}$. Regions of zero radiance correspond to breaks in the spectrum between the orders of the diffraction grating.

Retrievals of temperature and composition from these spectra will be conducted using Nemesis [8], a forward model and retrieval radiative-transfer tool. The vertical temperature profile is retrieved using the H_2 S(1) and CH_4 spectra while the C_2H_2, C_2H_6 and C_2H_4 spectra will be used to retrieve their respective concentrations.

References

[1] Lacy et al., 2002, *PASP* 114(792), 153-168
[2] Caldwell et al., 1980, *Icarus* 44, 667-675
[3] Kim et al., 1985, *Icarus* 64, 233-248
[4] Drossart et al., 1993, *JGR* 98, E10, 18803-18811
[5] Kostiuk et al., 1993, *JGR* 98, E10, 18823-18830
[6] Flasar et al., 2002, *Nature* 427, 132-135
[7] Kunde et al., 2004, *Science* 305, 1582-1586
[8] Irwin et al., 2008, *JQSRT* 109, 1136-1150