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Short-term and long-term variability of Jupiter's auroral stratosphere

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Abstract

We will present an analysis of multiple datasets, which capture the mid-infrared stratospheric emission of Jupiter's auroral regions on different timescales. A time series of 7.8-µm CH_4 emission images measured by Subaru-COMICS as well as high-resolution spectral measurements of CH_4, C_2H_2, C_2H_4 and C_2H_6 emission recorded by TEXES on NASA's Infrared Telescope Facility and Gemini-North will be presented and analysed. We find the magnitude and morphology of emission, and thus the thermal structure and chemistry of the stratosphere, exhibit both a short-term (daily) and longer-term (> 1 year) variability . On timescales of days, we find the magnitude of CH_4, C_2H_2 and C_2H_4 emission within the auroral region to be variable in accordance with the external solar wind dynamical pressure. Over longer timescales, retrieved 1-mbar temperatures in the northern auroral region indicate a net cooling over the 2014 to 2018 period, which we attribute to the overall decrease in solar activity following solar maximum in 2014 and the approaching solar minimum in 2020-2021.

1. Introduction

Jupiter's auroral regions exhibit enhanced mid-infrared CH_4, C_2H_2, C_2H_4 and C_2H_6 emission (e.g. [1, 2, 3]). This indicates auroral processes can modify the thermal structure and composition of the neutral stratosphere at pressures between 1 mbar and 1 µbar (or between ∼250 km and 550 km above the 1-bar level). This altitude range of the atmosphere is not probed by the Juno spacecraft due to the lack of mid-infrared remote-sensing instrumentation. In addition, ∼1.7 MeV electrons or ∼30 MeV protons precipitate at the 1-mbar level, which is an energy range outside of Juno's particle and field instrumentation [4, 5]. Thus, in order to enhance the science return of the Juno mission, we have performed a series of Earth-based mid-infrared measurements during the approach phase of the mission and *perijove* flybys occurring every 53.5 days. In this work, we will present an analysis of TEXES (Texas Echelon Cross Echelle Spectrograph, [6]) spectra obtained on NASA's Infrared Telescope Facility and Gemini-North as well as COMICS (Cooled Mid-Infrared Camera and Spectrograph, [7]) images on the Subaru telescope, which capture the variability of Jupiter's mid-infrared auroral emission on timescales of days to years.

2. Observations

Table 1: Details of the measurements.

	Subaru-COMICS	IRTF-TEXES	Gemini-TEXES
Type	Imaging	Spectroscopy	Spectroscopy
λ	7.8 (CH_4)	8.03 (CH_4) 10.53 (C_2H_4) 12.21 (C_2H_6) 13.70 (C_2H_2) 17.03 (H_2 S(1))	8.03 (CH_4) 10.53 (C_2H_4) 12.21 (C_2H_6) 13.70 (C_2H_2) 17.03 (H_2 S(1))
$\lambda/\Delta\lambda$	-	60-85 x 10^3	60-85 x 10^3
Spatial resolution	0.25"	0.7 - 1.4"	0.25 - 0.55"
Dates	Jan 11, 12, 13, 14, Feb 4, 5, May 17, 18, 19, 20 2017	Dec 10-11 2014 Apr 30-May 1 2016 Jan 17 2017 Jun 3, 4 2017 Jul 13 2017 Feb 8 2018	Mar 17, 18, 19 2017

3. Short-term variability

The cadence of Subaru-COMICS and Gemini-TEXES measurements highlight the daily variability of the mid-infrared auroral emission. For example, Subaru-COMICS measurements in the January 11-13 2017 period (Figure 1) demonstrate both the morphology and magnitude of the auroral CH_4 emission is variable on timescales of days. From January 11th 15:50 UT to January 12th 16:13 UT, there was a brightening of the southern auroral CH_4 emission, which coincided with a solar wind compression event. The northern auroral region was on the opposing hemisphere on January 11th and so we cannot tell whether it also brightened during this time range. However, on January 12th, during the solar wind compression, the northern auroral emission exhibited a duskside (eastern) brightening, which was not present the following night on January 13th 12:30 UT. A similar 'active

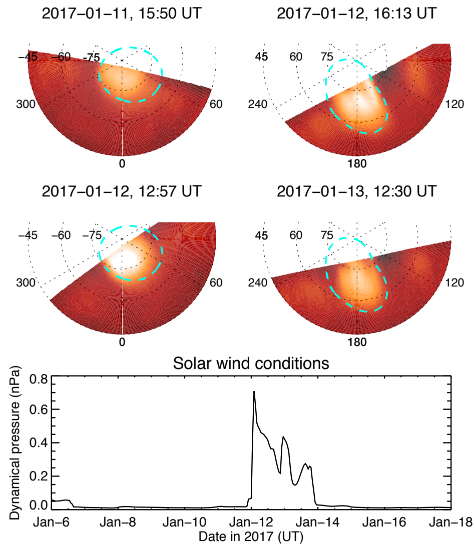

Figure 1: Southern (left column) and northern (right column) polar projections of 7.8-µm CH_4 emission from January 11-13 2017, as measured by Subaru-COMICS. The bottom plots shows the predicted solar wind conditions [8] during this time period. The dashed, cyan lines mark the extent of the main ultraviolet *oval* emission [9].

duskside' morphology is exhibited in the ultraviolet auroral emission and is thought to be related to solar-wind induced reconnection in the nightside magnetopause [10].

4. Long-term variability

IRTF-TEXES measurements measured between December 2014 and February 2018 capture the longer-term variability of the auroral stratosphere. As shown in Figure 2, 1-mbar temperatures in the northern auroral region appeared invariant in time (within uncertainty) until mid-2017 and then significantly decreased by more than 10 K. Given that temperatures outside the northern auroral region in the same latitude band did not change significantly (outside of uncertainty), the observed temperature changes in the auroral region cannot be due to changes in the solar insolation alone. Instead, we believe the drop in 1-mbar temperatures in mid-2017 are a phase-lagged response of decreasing solar activity following solar maximum in 2014 towards the predicted solar minimum in 2020-2021. Oddly, the southern auroral region warmed by greater than 15 K from December 2014 to April 2016, independent of the north [11]. In mid-2017, the southern auroral region cooled back to similar temperatures as in December 2014 only to increase again 2-3 K by February 2018. This strongly suggests the northern and southern auroral regions behave very differently in time and exhibit

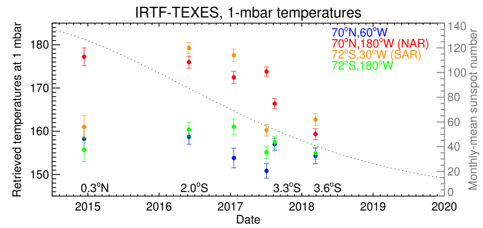

Figure 2: Retrieved temperatures at 1-mbar from IRTF-TEXES measurements between December 2014 and February 2018. Red and orange results indicate the northern and southern auroral regions, blue and green indicate non-auroral longitudes in the same latitude band for comparison. The grey, dotted line shows the monthly-mean sunspot number (https://solarscience.msfc.nasa.gov/greenwch/), according to the right-hand axis, as a proxy of longer-term solar activity.

differing responses to external magnetospheric and solar wind conditions, as is observed at other wavelengths [12].

5. Summary and conclusions

Jupiter's mid-infrared auroral emission exhibits both a short-term and long-term variability. Subaru-COMICS observations acquired over 2-3 days demonstrate that a component of the mid-infrared emission increases and decreases in accordance with the external solar wind pressure. Over longer timescales, a preliminary analysis of IRTF-TEXES measurements indicate 1-mbar temperatures in the northern auroral region exhibited a net cooling of more than 10 K, which we believe to be a phase-lagged response of decreasing longer-term solar activity following solar maximum in 2014. The northern auroral region appears to behave independently of the southern auroral region and vice-versa.

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