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Elusive Ethylene Detected in Saturn's Northern Storm Region

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Abstract

The massive eruption at 40°N (planetographic latitude) in December 2010 has produced significant and lasting effects in the northern hemisphere on temperature and species abundances [1]. The northern storm region has been observed on many occasions in between January and May of 2011 by Cassini's Composite Infrared Spectrometer (CIRS). In May 2011 temperatures in the stratosphere greater than 220K were derived from CIRS spectra in the regions referred to as "beacons" (warm regions in the stratosphere). Ethylene (C_2H_4) has been detected in a beacon in Saturn's northern storm region using CIRS. Ground-based observations using the high-resolution spectrometer Celeste on the McMath-Pierce Telescope on May 15, 2011 were used to confirm the detection. Early analysis indicate ethylene volume mixing ratios of 3x10^{-8} at 2 mbar.

1. Introduction

In December 2010 Saturn's northern hemisphere was spectacularly disrupted from its slow springtime warming by a massive storm eruption at approximately 40°N (planetographic latitude). This storm is only the sixth of its magnitude to ever be observed and the first one at this latitude in over a century [1]. Fortunately, the effects of the massive storm continue on through at least May 2011 and CIRS observations which were targeted 6 months in advance in order to study seasonal change at mid-northern latitudes have produced a spectacular dataset of this disturbance.

Previous investigations of Saturn's ethylene (C_2H_4) emission have been scarce [2, 3] and it remains a difficult species to study. The generation of warm beacon regions in Saturn's stratosphere in response to the upwelling of the storm [1] has resulted in the detection of ethylene in May 2011 using both Cassini/CIRS and the ground-based spectrometer Celeste on the McMath-Pierce Telescope.

2. Observations

The Cassini CIRS instrument in orbit around Saturn presents a unique opportunity to compare and contrast space-based observations with infrared ground-based observations using a high-resolution (resolving powers up to 30,000) cryogenic grating spectrometer (Celeste). In this situation the Celeste observations were performed as an independent confirmation of the CIRS detection of ethylene.

CIRS is a dual Fourier transform spectrometer covering the thermal infrared with three focal planes: FP1 which is a single detector covering 10-600 cm^{-1}, FP3 an array of 10 detectors covering 600-1100 cm^{-1}, and FP4 an array of 10 detectors covering 1100-1500 cm^{-1} [4]. The CIRS observations were performed on May 4, 2011 using a spectral resolution of 2.5 cm^{-1} while the spacecraft was targeted at 35N (planetographic latitude) for a 11 hour integration.

Our ground-based instrument, Celeste, is a cryogenic grating spectrometer with an array detector that can achieve resolving powers of 30,000 [5]. The Celeste observations were performed at the McMath-Pierce Telescope on May 15, 2011 with an effective spectral resolution of 0.1 cm^{-1} over a 2.0 cm^{-1} bandpass. Saturn was imaged with the slit oriented in the east/west direction so that all longitudes over the northern storm latitude range were observed simultaneously to ensure the detection of ethylene emission in the beacon region of the storm.

3. Results

The May 2011 CIRS data show that the two warm beacons originally observed by CIRS in January 2011 [1] have merged into one hot beacon. Temperatures of ~220 K in the stratosphere are being retrieved from CH_4 CIRS spectra in the beacon region. The spectra resulting from the CIRS observations of the northern storm region on May 4, 2011 are shown in Fig. 1; the Celeste data taken on May 15, 2011 are shown in Fig. 2.

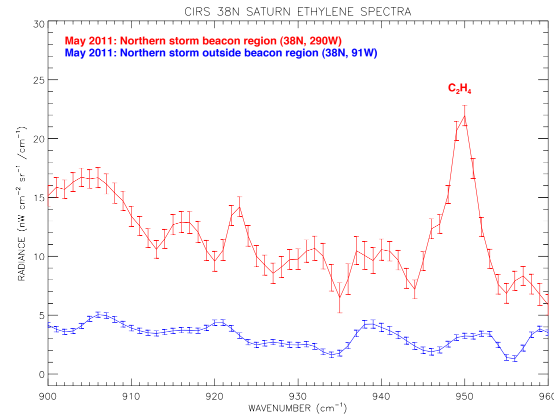

Figure 1: The 2.5 cm^{-1} CIRS spectra inside the hot stratospheric beacon (red curve) and outside the region (blue curve). Ethylene is detected as a single line at 950 cm^{-1}.

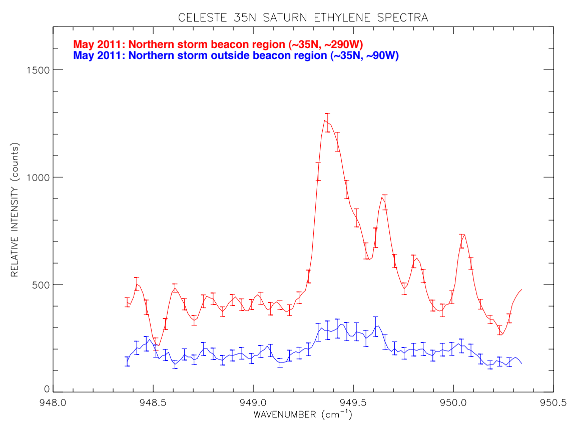

Figure 2: The 0.1 cm^{-1} Celeste spectra inside the hot stratospheric beacon (red curve) and outside the region (blue curve). Ethylene is detected as a set of lines around 949.5 cm^{-1}.

These observations are being modeled using temperatures retrieved from CH_4 emission between 1250-1350 cm^{-1} (FP4) to constrain stratospheric temperatures and collision-induced H_2 opacity between 600-680 cm^{-1} (FP3) to constrain the tropospheric temperatures. The CIRS spectra are modeled using Nemesis [6] by applying temperature profiles retrieved from the CIRS data and photochemical profiles which are calculated using the retrieved temperatures. A best-fit scale factor of the ethylene photochemical profile is retrieved in this analysis. The beacon CIRS data of Fig. 1 are best-fit with the ethylene photochemical profile scaled by a factor of 75. This scale factor gives an ethylene volume mixing ratio of 3.3×10^{-8} at 2 mbar.

4. Summary

Thus far we have obtained an ethylene volume mixing ratio of $\sim 3 \times 10^{-8}$ at the 2 mbar level in the northern beacon region. The next step of our analysis will be to model the Celeste data and compare our results between the two data sets.

Acknowledgements

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