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HDO and SO_2 thermal mapping on Venus above and within the clouds

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Abstract

Sulfur dioxide and water vapor, two key species of Venus photochemistry, are known to exhibit significant spatial and temporal variations above the cloud top. We have started an observing campaign using the TEXES high-resolution imaging spectrometer at the NASA InfraRed Telescope Facility to map sulfur dioxide over the disk of Venus at two different wavelengths, 7 µm (probing atop the H_2SO_4 cloud) and 19 µm (probing a few kilometers below within the clouds). Observations took place on January 10-12, 2012 (evening terminator) and October 4-5, 2012 (morning terminator). Both HDO and SO_2 lines are identified in our 7-µm spectra and SO_2 is also easily identified at 19 µm. The CO_2 lines at 7 and 19 µm are used to infer the thermal structure. An isothermal/inversion layer is present at high latitudes (above 60N and S) in the polar collars, much more visible when the morning terminator is observed; such an effect was not detected in October 2012. The HDO map is relatively uniform over the disk of Venus, with a mean mixing ratio of about 1 ppm above the clouds (P < 100 mbars. In contrast, the SO_2 maps at 19 µm show intensity variations by a factor of about 2 over the disk within the cloud, less patchy than observed above the cloud top at 7 µm. In addition, the SO_2 maps seem to indicate significant temporal changes within an hour. There is evidence for a cutoff in the SO_2 vertical distribution several kilometers above the cloud top, also previously observed by SPICAV/SOIR aboard Venus Express and predicted by photochemical models. New observations have been obtained on February 26 - March 1, 2014, when the diameter of Venus was 34 arcsec. Another run is planned on July 6-9, 2014.

1. Introduction

The sulfur and water chemical cycles are known to play a key role in the atmospheric chemistry of Venus [1, 2]. Below the clouds, H_2O and SO_2 are both present with mixing ratios of about 30 ppm and 100–150 ppm, respectively [3]. Both species are transported from the deep troposphere above the main cloud deck by Hadley convection and are deeply depleted above the H_2SO_4 cloud by photodissociation and condensation processes. The mixing ratio of H_2O above the clouds is in the range of 1–2 ppm [4], i.e. 15–30 times less than below the clouds. The SO_2 mixing ratio above the clouds has been found to be 10–100 ppb from Venera 15 and Pioneer Venus measurements [5] and more recently in the 10–1000 ppb range by SPICAV aboard Venus Express [6], i.e. hundreds to a thousand times less than below the clouds. Over the past six years, the photochemistry and dynamics of Venus mesosphere have been extensively monitored by the Venus Express mission, supported by ground-based campaigns. In particular, large latitudinal and temporal variations of the SO_2 abundance have been reported from the data recorded by SPICAV-UV, SPICAV/SOIR and VIRTIS aboard Venus Express [6, 7].

2. Observations and Results

We have started an observing campaign using the high-resolution imaging spectrometer TEXES in the thermal infrared range. Two campaigns took place on January 10–12 and October 4-5, 2012, at the InfraRed Telescope Facility (IRTF). Maps of HDO and SO_2 were simultaneously recorded at 7 µm and 19 µm with a spatial resolution of 1.5 arcsec and a spectral resolving power of about 80 000. CO_2 lines were used to infer the thermal profile. The 7-µm range probes atop the cloud while the 19-µm range probes a few kilometers below the 7- µm range, i.e. within the cloud.

Assuming a D/H ratio of 200 times the terrestrial value [4], we derived a H_2O mixing ratio of about 1 ppm, with no significant variations over the disk. The H_2O mixing ratio is also found stable over a timescale of two days. In contrast, the SO_2 maps showed strong spatial variations over the Venus disk, both at 7 and 19 µm, and also strong temporal variations over a timescale of a few hours or less [8, 9]. Figure 1 shows maps of SO_2/CO_2 recorded on Oct.4, separated by less than 2 hours. Spatial and temporal variations of the SO_2 distribution are clearly visible. In contrast, HDO maps recorded in January and October 2012 were much more uniform, and showed no significant temporal variations.

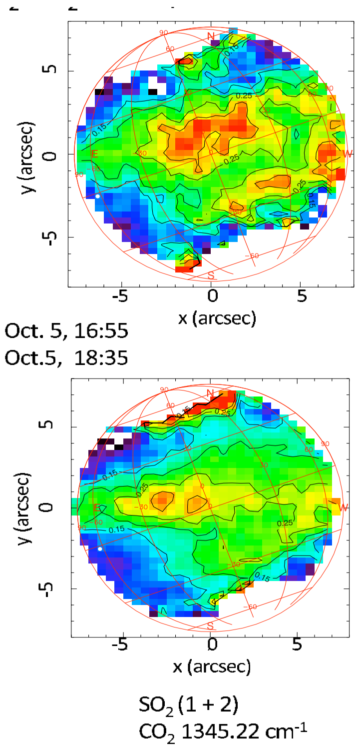

Fig. 1. *SO2/CO2 maps recorded on October 5, 2012. Average of two maps using different SO2 transitions. Top: Oct.5, 16:55; bottom: Oct. 5, 18:35. There is evidence for actual temporal variations on timescales less than two hours.*

2. New observing run (Feb. 2014)

New TEXES data of Venus were recorded on Feb. 26 - March 1, 2014, in the SO_2 bands at 7 μm (ν_3), 19 μm (ν_2) and 8.7 μm (ν_1). In addition CO_2 bands were recorded at 12.6 μm (isotopic band, Fig.2) and 10.4 μm (hot band) in order to retrieve the thermal profile on both dayside and nightside. At that time, the diameter of Venus was 34 arcsec, the illumination factor was 34% and the morning terminator was observed. Full maps and equatorial scans were recorded, in order to search for short term temporal variations (< 1 hour).

Another observing run with TEXES is planned at IRTF on July 6-9, 2014.

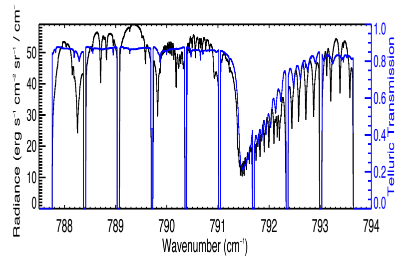

Fig. 2*. The TEXES spectrum of Venus in the 792 cm^{-1} CO_2 band (12.6 μm), recorded in the central part of the planet, on Feb. 26, 2014. Black: TEXES data; blue: atmospheric transmission.*

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