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Vertical Thermal Structure and Winds in Venus's Mesosphere from HHSMT

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Abstract:

The Venusian atmospheric dynamics is one of the fundamental questions in planetary sciences, and its mesosphere is poorly constrained. Two international missions recently joined efforts and carried out multi-point observations of the Venusian atmosphere on June 6 for several hours: NASA's MESSENGER spacecraft swung by Venus for a second time on 6 June 2007 at 23:10 UTC on its way to Mercury, and ESA's Venus Express is orbiting around Venus since 11 April 2006. Among the space-based observations, ground-based sub-millimeter line observations together with a description of the physics of the radiative transfer through the mesosphere, and with retrieval algorithms for planetary atmospheres provide a means to monitor the wind field and the thermal vertical structure in the middle atmosphere. Within the framework of our observations of CO lines with the **Heinrich Hertz Submillimeter Telescope** in Arizona [11,12], we have retrieved the vertical thermal structure and zonal wind velocities in the Venusian mesosphere during several days in June 2007.

We report a temperature peak detection at 90-100 km which seems to support the newly found of the extensive layer of warm air detected by SPICAV onboard Venus Express [7]. Day-to-night temperature variations and short-term (day-to-day) variations of winds and temperature are evident in our data.

These data are part of a coordinated observational campaign in support of the ESA Venus Express mission. Furthermore this study attempts to contribute to crosscalibrate space - and ground-based observations, to constrain radiative transfer and retrieval algorithms for planetary atmospheres, and to a more thorough understanding of the global patters of circulation of the Venusian atmosphere.

1. Introduction

NASA's MESSENGER spacecraft swung by Venus for a second time on 6 June 2007 at 23:10 UTC on its way to Mercury. ESA's Venus Express, on the other hand, is orbiting around Venus since 11 April 2006. Both spacecrafts carried out multi-point observations of the Venusian atmosphere on June 6 for several hours. Among the space-based observations, a world-wide Earth-based Venus Observation campaign from 23 May to 9 June 2007 (and later) was initiated to remotely observe the Venusian atmosphere. It contributes to the growing information on Venus's atmospheric characteristics and complement the space-based data.

2. Observations

CO Venus observations were made with the 10m Heinrich Hertz Submillimeter Telescope (HHSMT), operated and owned by the Arizona Radio Observatory (ARO). The observations were obtained on 8, 9, 10, 14 and 15 June from 18:30 to 0:30 UT. We used the 345 Superconductor-Insulator Superconductor (SIS) and the 2mmJT/1.3mmJT ALMA receivers, operating respectively at 320-375 and 210-279 GHz to observe the CO J = 2—1 (at a frequency of 230.538 GHz), ^{12}CO J = 3–2 (at 345.79 GHz), and ^{13}CO J = 2-1 (at 220.398 GHz). Seven different backends were used simultaneously, although we concentrated on the 215 MHz CHIRP Transform spectrometer (CTS, resolution of 40 kHz) [1,2]).

The CO J = 2–1 line was mapped on 8 different beam positions on Venus disk, ^{12}CO J = 3–2 line on 8 positions, and ^{13}CO J = 2-1 line on one. The later one represents the first detection of this line at HHSMT..

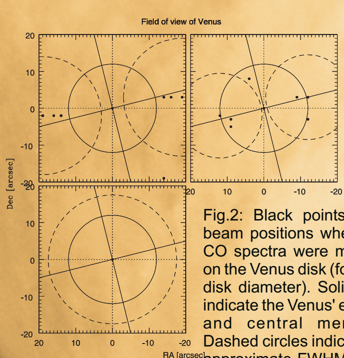
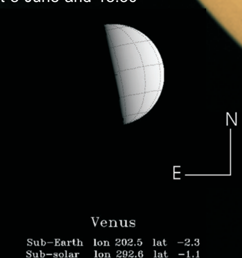


Fig.2: Black points show beam positions where the CO spectra were mapped on the Venus disk (for a 24" disk diameter). Solid lines indicate the Venus' equator and central meridian. Dashed circles indicate the approximate FWHM beam diameter. Left upper, right upper and left lower panels represent the positions for CO J = 2–1, ^{12}CO J = 3–2, and ^{13}CO J= 2-1 lines.

Fig.1: Synthetic image of Venus that approximates the telescopic view of Venus as seen from the Earth at 8 June and 18:30 UT.



3. Retrieval of mesospheric parameters: Thermal structure, CO abundance, and wind

We have applied a retrieval technique described by C. D. Rodgers as optimal estimation [3]. We used a radiative transfer code [4,5,6] which describes the physics of the radiative transfer through the atmosphere, to calculate the synthetic spectra which best fit the observed spectra.

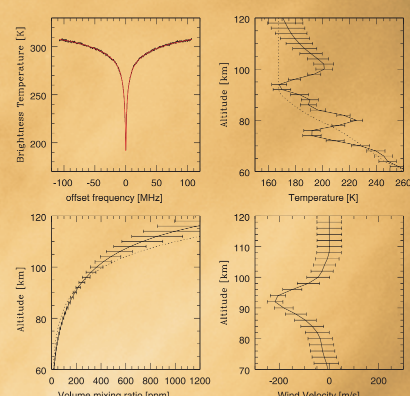


Fig.3: example of a spectrum (Obs. No. 34) observed on 15 June 2007. A best-fit synthetic line (red line) is displayed. Top right panel: retrieved vertical temperature profile (solid line). Bottom-left panel: retrieved mesospheric CO volume mixing ratio (solid line). Bottom-right panel: wind velocity.

Day-to-day and day-to-night temperature variations and short-term fluctuations of the mesospheric zonal flow were evident in our data. Furthermore, retrieved winds showed variations of around 100 m/s between June 14 and June 15. We found a temperature peak at 90-100 km that seems to support the new finding of the extensive layer of warm air detected by SPICAV onboard Venus Express [7].

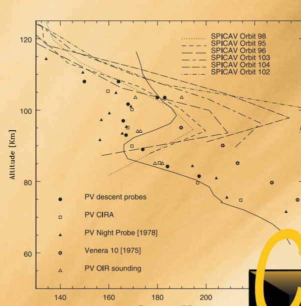


Fig.4 : Temperature profile retrieval (Obs. 36) compared to the profile from the stellar occultations with the SPICAV onboard Venus Express [7], PV descent probes [8], from the OIR sounding measurements [9], and from the PV night probe. The Pioneer-Venus derived VIRA reference profile for latitudes <30 are indicated by the squares. The anomalously warm temperatures returned by the Venera 10 probe in 1975 are shown as stars symbols. The absolute uncertainty for the temperatures derived here is ±15 K.

Conclusion

We have carried out several CO mm-wave line observations on different beam positions on Venus disk during June 2007.

From spectra of ^{12}CO J=2-1 and CO J=3-2 we retrieved well-resolved and accurate vertical profile of temperature and CO mixing ratio for the June 2007 mesosphere of Venus.

The temperature peak detection reported here at 90-100 km seems to support the newly found of the extensive layer of warm air detected by SPICAV onboard Venus Express.

Retrieved winds showed variations of around 100 m/s between June 14 and June 15.

References

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Mariner 10 Image of Venus