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Thermal structure and minor species of Venus mesosphere by ALMA submm ground-based observations

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Abstract

Submillimeter observations obtained with the Atacama Large Millimeter Array (ALMA) offer the possibility to monitor the temporal evolution of sulfur species and water in the upper atmosphere of Venus. Here, we report on the first ALMA retrievals of CO temperatures, HDO, SO, and SO_2 obtained over the entire disk of Venus on November 14, 2011.

1. Introduction

Venus upper atmosphere (70 – 150 km altitude) is one of the most intriguing regions on the planet. It corresponds to a transition region characterized by a complex dynamics and circulation: strong retrograde zonal winds dominate the lower mesosphere while a solar-to-antisolar circulation driven by a day-to-night temperature gradient can be observed in the upper mesosphere/lower thermosphere [1]. In addition, photochemical processes play an important role at these altitudes and affect the thermal structure and chemical stability of the entire atmosphere [2,3]. Sulfur dioxide and water vapor are key species in the photochemical cycles taking place in the troposphere and mesosphere of Venus [4, 5]. Both molecules are abundant in the lower troposphere (150 ppm and 30 ppm respectively [6,7]). They are carried by convective transport, together with the Hadley circulation, up to about 60 km where SO_2 is photodissociated and oxydated, leading to the formation of H_2SO_4 which condenses in the clouds enshrouding the planet. Previous observations obtained by several instruments on board Venus Express and during ground-based campaigns have shown evidence of strong temporal variations, both on day-to-day as well as longer timescales, of density, temperature and SO_2 abundance [2,8,9]. Such strong variability, especially near the terminators, is still not well understood.

2. ALMA observations

Ground-based observing campaigns of Venus were organized in support of space exploration observations since the early stage of Venus Express operations in 2006 [2,3,10]. Earth-based observations provide complementary information to spacecraft data by allowing a complete view of the planetary disk at a given time and a long-term coverage, which is of particular interest in view of the official end of Venus Express operations in January 2015.

The Atacama Large Millimeter Array (ALMA) offers a unique opportunity of probing Venus' upper mesosphere (60 – 120 km) and of monitoring minor species, winds and the thermal structure. A first set of observations was obtained in November 2011 during the first ALMA Early Science observation cycle [11,12]. These observations targeted SO_2, SO, HDO and CO transitions around 345 GHz during four sequences of 30 minutes each. The Venus' disk was about 11" with an illumination factor of 90%, so that mostly the dayside of the planet was mapped.

In a preliminary study, [11] analyzed the ALMA observations acquired on November 14 and 15, 2011. Assuming a nominal dayside CO abundance profile from [13], the CO line at the disk center was used to retrieve a vertical temperature profile, later used to derive the abundances of minor species averaged over the disk. Maps of SO and HDO acquired on Nov. 14, 2011 show significant local variations over the disk, with an enhancement in the northern hemisphere towards the evening terminator (**Fig.1**).

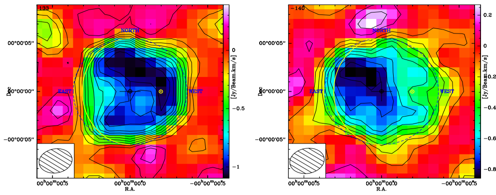

Figure 1: Maps of: (Left) the SO line depth at 346.528 GHz on Venus, and (Right) HDO at 335.395 GHz, recorded on November 14, 2011. The planet size is 11″; the FOV is 1.2 × 2.4″. The evening terminator is indicated by the yellow line (From [11]).

Spectra of SO and SO_2, integrated over the disk, are consistent with mean mixing ratios of 4 ppb and 6 – 7 ppb respectively, above an altitude of 85 km. The HDO spectrum integrated over the disk is best fitted with a H_2O mixing ratio of 1 to 1.5 ppm, assuming a D/H enrichment of 200 in the Venus mesosphere. These results are consistent with previous single dish submillimeter measurements [14,15,2]. In addition, the high resolution CO map obtained during ALMA Cycle 0 was used to infer mesospheric wind field [12]. The upper mesospheric winds are consistent with a dominant subsolar-antisolar circulation.

3. CO thermal structure

Assuming nominal night-time and dayside CO abundance profiles from [13], we retrieved vertical temperature profiles over the entire disk as a function of latitude and local time for the first day of observation on Nov. 14, 2011 (**Fig. 2**).

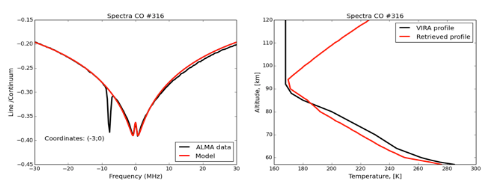

Figure 2: (Left) ALMA spectrum of CO with continuum subtracted (black line) compared to model spectrum (red line). (Right) Temperature profile inferred from the inversion of the CO spectrum (red line) compared to VIRA profile.

4. Mapping of Water and sulfur species

We plan to use the retrieved temperature profiles to derive the abundances of minor species (HDO, SO, SO_2) in each pixel of the disk for the first day of observation in order to study their variability with latitude and local time. In a further step, we will extend our analysis to the four days of observation.

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References

[1] Schubert, G. et al. (2007) *Exploring Venus as terrestrial planet*, Geophys. Monogr. Ser. Pp. 121–138.

[2] Clancy, R. T. et al. (2012) *Icarus*, 217, 779-793.

[3] Rengel, M. et al. (2008) *PSS* 56, 1688–1695.

[4] Mills F. et al. (2007), in Exploring Venus as terrestrial planet, Vol. 176, GMS, p. 73.

[5] Zhang X. et al. (2012) *Icarus*, 217, 714.

[6] Marcq E. et al. (2008) *JGR (Planets)*, 113.

[7] Bézard B. et al. (2009) *JGR (Planets)*, 114.

[8] Mahieux A. et al. (2015) *PSS*, Accepted.

[9] Piccialli A. et al. (2015) *PSS*, Accepted.

[10] Sonnabend, G. et al. (2012) *Icarus*, 217, 856–862.

[11] Encrenaz, T. et al. (2015) *PSS*, Accepted.

[12] Moullet, A. et al. (2013) *AAS-DPS meeting* #45, abstract #202.01.

[13] Clancy R. T. et al. (2003) *Icarus*, 161, 1.

[14] Sandor B. J. et al. (2005) *Icarus*, 177, 129.

[15] Gurwell M. A. et al. (2007) *Icarus*.