Sounding the neutral upper atmosphere of Venus from orbit using CO2 non-LTE infrared emissions in nadir and limb geometries

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The temperature and density structure of the upper atmosphere of Venus is thought to be linked to the strong deposition of solar energy and to be an important driver of the particular dynamics of the region, very distinct from the super-rotation at lower altitudes. Its high variability, as recently found, may be partially connected to that at lower altitudes via propagation of tides and other wave activity. In spite of its large interest, a proper 3-D characterization is still poorly data-constrained, although it will be benefited from a number of on-going studies using Venus Express (VEx) data. These include sounding from orbit, recent in-situ data acquisition during aerobraking maneuvers, and validation campaigns from telescopic ground observations in Earth's atmospheric windows in the near infrared..

Here we review the main findings from the analysis of infrared emissions by CO2, as measured from orbit by the VIRTIS instrument on board VEx. This study is focussed on daytime measurements and on altitudes above about 100 km, where some of the strongest CO2 emission bands around 4.3 um become optically thin, and therefore, can be used for remote sounding most efficiently. It is well known that these emissions are enhanced during daytime due to a resonant fluorescence after the initial solar absorption in a number of CO2 ro-vibrational bands. This non-local thermodynamic equilibrium nature is complex due to the numerous competing radiative and collisional processes, but is thought to be well understood and modelled. Theoretical non-LTE models are key tools for their analysis and interpretation, although their simulations are subject to a number of uncertainties, mostly related to the difficult determination of some laboratory rate coefficients describing energy transfer between CO2 high energy states, as well as to the detailed description of radiative transfer in an a-priori not-well determined atmospheric profile. In this study we used the non-LTE model for the Venus atmosphere developed at the IAA/CSIC in Granada, Spain (Lopez-Valverde et al., PSS, 2007).

Virtis measurements were carried out in the two usual geometries, nadir and limb, and it was found that both datasets show a significant emission level of these CO2 bands around 4.3 um, which for the first time, allowed a characterization of these non-LTE emissions in a systematic manner in the Venus upper atmosphere.. The limb mode of observations is particularly useful for high altitude/low densities sounding and for a more precise altitude information due to its typically narrower weighting functions in the vertical, and was used to describe a variable non-LTE emission layer around 120 km. The first non-LTE model simulations showed an overall agreement in the peak altitude and intensity, and indicated that a precise simulation would be required for the determination of atmospheric density variations in the lower thermosphere of Venus (Drossart et al, Nature, 2007; Gilli et al., JGR, 2009). .

That study continues, adding further Virtis data during apoapsis and periapsis, using the two signals of the instrument, at two spectral resolutions, the Virtis-H (higher spectral resolution) and Virtis-M (lower spectral resolution but better spatial and temporal mapping), and including nadir observations, in order to compile the maximum information about the thermosphere of Venus. The analysis of these data has permitted the validation of the current non-LTE model and is offering a view of the global density structure of the thermosphere of Venus. Comparisons with diverse ground-based observations and with other VEx measurements (Spicav/SOIR, VeRA) will exploit further this valuable dataset.