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# Constraining SO<sub>2</sub> in the atmospheres of Venus and Mars using SPICAV-UV & SPICAM-UV in nadir mode

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## Abstract

Comparative studies of SO<sub>2</sub> in Mars and Venus atmospheres using the UV channel and nadir mode observations of SPICAV and SPICAM onboard *Venus Express* and *Mars Express* could be done thanks to the strong similarities between both instruments. In Venus' atmosphere extensive measurements of SO<sub>2</sub> column density above the cloud top have been made, and yielded strong spatial and/or temporal variability. For Mars, studies are still in progress and conclusions are not yet established; nevertheless local upper bounds for SO<sub>2</sub> column densities could be retrieved.

## 1. Introduction

The strong similarities between the UV channels of the SPICAV instrument onboard *Venus Express* and the SPICAM instrument onboard *Mars Express* enable common scientific objectives for the nadir observations of the atmospheres of Mars and Venus. One possible objective is the detection or measurement of sulphur dioxide (SO<sub>2</sub>) thanks to its two absorption bands near 210 and 280 nm. On Mars, the main goal is the detection of integrated SO<sub>2</sub> content down to the surface, or at least yielding an upper bound on its local column density – SO<sub>2</sub> detection would have far-reaching implications in terms of current geological activity as well as favouring an abiotic origin of CH<sub>4</sub>. On Venus, UV nadir sounding can only probe down to the upper cloud level between 65 and 75 km in altitude, but SO<sub>2</sub> has been measured at various latitudes since the 1970s [1, 2, 3]; the main goals here are to characterize the spatio-temporal variability of SO<sub>2</sub> and providing interpretation in terms of dynamics, chemistry and, ultimately, geological activity of the planet.

## 2. Observations

Our observations were exclusively acquired in nadir mode on the dayside between 170 and 320 nm and at

a medium spectral resolution  $R \simeq 200$ . Several tens of *Venus Express* orbits were processed to obtain radiance factors at various latitudes and local time. For *Mars Express*, the data we used included only the first Martian year, and we worked only with relative radiance factors taking a reference spectrum recorded above *Olympus Mons* using the same method as in [6].

## 3. Modeling

For both atmospheres, CO<sub>2</sub> absorption and Rayleigh scattering plays a major role. In the case of Venus, including SO absorption as well as accounting the thick cloud layers was necessary to explain the observations, whereas for Mars, O<sub>3</sub> absorption and dust opacity had to be taken into account. All these parameters were included in a radiative transfer model able to cope with high Solar Zenith Angles (SZA) thanks to the pseudo-spherical mode of SPS-DISORT. Inversion of the model provide estimates of SO<sub>2</sub> column density and scale height in the Venusian atmosphere. For Mars, simple heuristics for SO<sub>2</sub> detection among numerous spectra was used.

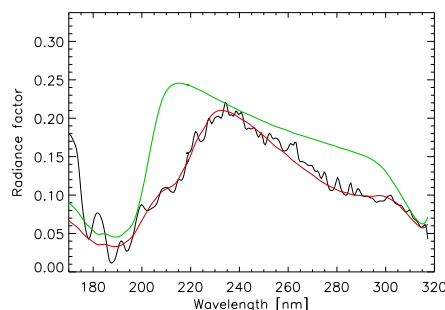


Figure 1: Radiance factor near the equator during orbit #325 for Venus and model with (red) and without (green) SO<sub>2</sub>+SO (from [7]).

## 4. Results

Venus' SO<sub>2</sub> column densities show strong variability (at least two orders of magnitude), but a latitudinal gradient with usual mixing ratios at cloud top between 0.1 and 1 ppmv at low latitudes and below 0.1 ppmv in the north polar region, usually correlated with changes in cloud top altitude as seen by SPICAV-IR and VIRTIS as well SO<sub>2</sub> scale height variations with a shorter scale height at higher latitudes. We are in agreement with previous observations [4, 5] regarding the scale height of SO<sub>2</sub>, but find an opposite latitudinal gradient. Furthermore, some polar regions exhibit a stronger SO<sub>2</sub> content and are yet poorly understood. The average mixing ratio lie in the high range of the measurements, indicating that the steady decline of SO<sub>2</sub> observed during the 1980s and early 1990s [3] may have stopped or even reversed.

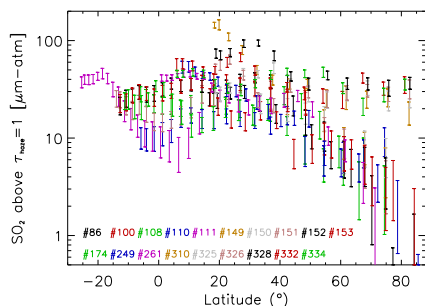


Figure 2: Variations of SO<sub>2</sub> column densities with latitude for several orbits (from [7])

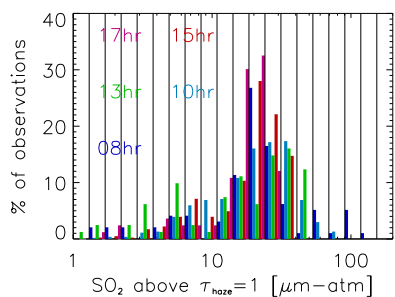


Figure 3: Histograms of SO<sub>2</sub> column densities with local solar time for several orbits (from [7])

Furthermore, there appears to be a steady decrease of the maximal SO<sub>2</sub> column densities within a given orbit from morning to evening, suggesting a lifetime

of SO<sub>2</sub> at cloud top close to 10<sup>5</sup> s. This suggests, along with the latitudinal gradient, that photochemistry is dominated by dynamics/advection for establishing SO<sub>2</sub> variations.

As for Mars, work is still underway with a local detection threshold ranging from 10 to 100 ppb for any single SPICAM observation. Results for Venus are currently under press [7].

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