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# CUVE - Cubesat UV Experiment: Unveil Venus' UV Absorber with Cubesat UV Mapping Spectrometer

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## Abstract

Our Venus mission concept Cubesat UV Experiment (CUVE) is one of ten proposals selected for funding by the NASA PSDS3 Program - Planetary Science Deep Space SmallSat Studies. CUVE concept is to insert a CubeSat spacecraft into a Venusian orbit and perform remote sensing (Fig. 1) of the UV spectral region using a high spectral resolution point spectrometer to resolve UV molecular bands, observe nightglow, and characterize the unidentified main UV absorber. The UV spectrometer is complemented by an imaging UV camera with multiple bands in the UV absorber main band range for contextual imaging. CUVE would complement past, current and future Venus missions with conventional spacecraft, and address critical science questions cost effectively.

## 1. Figures

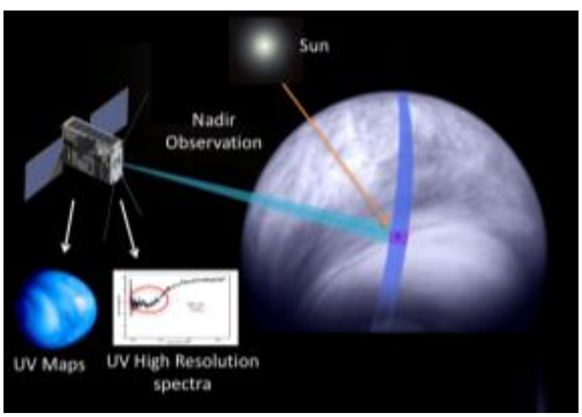


Figure 1: CUVE – Cubesat UV Experiment – in orbit around Venus will observe dayside and night side.

## 2. Introduction

The Venusian upper cloud deck, situated at an altitude range 60-70 km, is formed of small droplets comprising a mix of ~80% sulfuric acid ($H_2SO_4$) and water. These clouds are the reason for Venus' high albedo in the visible, where 70-80% of the incoming solar radiation is backscattered to space. For this reason, despite Venus being closer to the Sun than Earth, it absorbs a similar quantity of energy to that absorbed on our home planet. The maximum absorption of solar energy by Venus occurs in the UV where we observe spectral contrast features that originate from the non-uniform distribution of unknown absorbers within its clouds. This opacity source affects the energy balance in the Venusian atmosphere. The efficient absorbing power of the unknown UV absorbers in the clouds controls Venus' atmospheric engine. Determining the nature, concentration and distribution of these absorbers will increase the understanding of the overall radiative and thermal balance of the planet, in particular the atmospheric dynamics and the chemistry of the upper clouds. Sulfur dioxide $SO_2$ and the later discovered sulfur monoxide SO are strong UV absorbers present in Venus' spectrum between 200 and 340 nm; however, these species do not explain the strong absorption at longer wavelengths, around 365 nm which signifies a different substance (in gas or aerosol form) distributed non-uniformly in the cloud top and absorbing in the UV (for overview see [1]). Some candidate species have been proposed to explain the spectral contrast features in the UV: $SO_2$, $FeCl_3$, $Cl_2$, Sn, $SCl_2$, $S_2O$ (e.g., [2], [3], [4], [5], [6]), elemental sulfur ($S_8$ o $S_x$) ([7]) and the recently hypothesized $S_2O_2$ (OSSO) ([8]). Spectroscopic measurements that reveal spatial and temporal variability will constrain contributions from these species.

The dayside nadir view UV spectrum of Venus is composed of solar light back-scattered by the cloud particles in the atmosphere. This solar radiation interacts with Venus' atmosphere and experience extinction in in its path to the clouds top and back and therefore contains spectroscopic signatures of the atmospheric gases and scattering particulates. Venus' top-of-the-atmosphere UV spectrum contains diagnostic signatures: a component of Rayleigh scattering; pure absorption of $CO_2$ below 200 nm; two strong bands of $SO_2$ at 215-225 nm and 270-310 nm; absorption of SO around 200-220 nm, blended in one of the $SO_2$ bands; other possible species absorbing in that range and continuum absorption believed to be due to the UV unknown absorber responsible for the contrast features observed in the UV at 365 nm. On the nightside, we can also observe nightglow emissions by NO, CO, $O_2$.

Previous missions and studies did not successfully detect the origin of the absorber. Venus Express instruments didn't have sufficient resolution, spectral range and UV sensitivity to study the relation between the unknown absorber and sulphur bearing species. VMC on Venus Express and Akatsuki are UV cameras with filters and not spectrometers. Pioneer Venus resolution was 1.3 nm and spectra were very noisy (*e.g.,* [9]). It is hard to investigate the UV absorber from Earth's surface due to strong UV absorption in Earth's atmosphere; it is challenging to investigate the UV absorber with the Hubble Space Telescope due to Sun-avoidance requirements. Venus was observed by HST ([10]), but there will be unlikely other future observations.

## 3. CUVE concept

CUVE is a targeted mission, with a dedicated science payload and a compact spacecraft bus capable of interplanetary flight independently or as a ride-share with another mission to Venus or to a different target.

CUVE Science Objectives are: 1) Nature of the "Unknown" UV-absorber; 2) Abundances and distributions of $SO_2$ and SO at and above Venus's cloud tops and their correlation with the UV absorber; 3) Atmospheric dynamics at the cloud tops, structure of upper clouds and wind measurements from cloud-tracking; 4) Nightglow emissions: NO, CO, $O_2$.

CUVE has a high spectral resolution spectrometer capable of resolving SO and $SO_2$ lines. The payload measures a broad spectral range spanning all relevant UV absorbers, and also includes a UV imager.

## 4. Summary and Conclusions

CUVE will produce high spectral resolution UV spectra of Venus and broad spectral range imaging maps. These maps will characterize the nature of the components in its atmosphere that absorb in the UV. This mission will be an excellent platform to study Venus' cloud top atmospheric properties where the UV absorption drives the planet's energy balance.

## Acknowledgements

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