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VenSpec-H, infrared spectrometer onboard EnVision to study Venus' volcanism

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Abstract

The VenSpec-H instrument is part of the EnVision M5 mission payload which has been selected by ESA to enter Phase A in January 2019 for a potential mission selection in 2021. EnVision is a medium class mission to determine the nature and current state of geological activity on Venus, and its relationship with the atmosphere, to understand how Venus and Earth could have evolved so differently. VenSpec-H will target different molecular species in nadir viewing geometry, as to better characterize the surface-atmosphere interaction. The scientific preparation and the preliminary design will be presented.

1. Introduction

VenSpec-H is part of the VenSpec suite, including also an IR mapper and a UV spectrometer suite. The science objectives of this suite is to search for temporal variations in surface temperatures and tropospheric concentrations of volcanically emitted gases, indicative of volcanic eruptions; and study surface-atmosphere interactions and weathering by mapping surface emissivity and tropospheric gas abundances.

Recent and perhaps ongoing volcanic activity has been inferred in data from both Venus Express and Magellan. Maintenance of the clouds requires a constant input of H_2O and SO_2. A large eruption would locally alter the composition by increasing H_2O ; decreasing D/H ratio and increasing SO_2. The latter effect is probably underestimated with respect to the others, since the Venusian interior is thought to be much drier than Earth's, so that the outgassed SO_2/H_2O ratio may be much higher on Venus. Observations of changes in lower atmospheric SO_2 and H_2O vapour levels, cloud level H_2SO_4 droplet concentration, and mesospheric SO_2, are therefore required to link specific volcanic events with past and ongoing observations of the variable and dynamic mesosphere, to understand both the importance of volatiles in volcanic activity on Venus and their effect on cloud maintenance and dynamics.

To contribute to this investigation, VenSpec-H will be designed to at least measure H_2O and HDO contents in the first scale height of Venus' atmosphere and probe H_2O, HDO, OCS, SO_2 in the 30 to 40km altitude range.

How spectral simulations and determination of Signal-to-Noise ratios led to the design of the instrument will be presented in this communication.

2. Scientific preparation

ASIMUT-ALVL, a line-by-line radiative transfer code developed at BIRA-IASB [1], is used to simulate spectra of the Venusian atmosphere in the infrared range (1.0 – 2.5 μm). CO_2, H_2O, HDO, CO, SO_2, HCl, HF, OCS and NO, as well as aerosols were included. The concentration profiles of the molecular species are based on the literature [2, 3, 4, 5, 6] while aerosols' description originates from the standard cloud model updated by [7]. 3 aerosols' modes were considered spanning the altitude range from 47 to 90 km altitude. Rayleigh scattering and the CKD CO_2 continuum were included.

Simulations of the day side and night side atmosphere of Venus were performed, as shown on Fig.1. The radiance in the nightside comes from the thermal

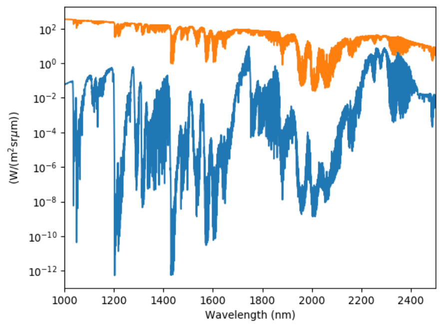

Figure 1: Simulated spectra for the nightside in blue and the dayside in orange.

emission of the surface and atmosphere while on the dayside, there is an additional solar contribution (solar zenith angle = 30°). Noise was then added to these simulations, in order to assess the lowest SNR necessary. In order to determine the best spectral ranges to be used, G, the gain matrix from the Optimal Estimation Method [8] was calculated using ASIMUT-ALVL:

$$G = S_a K^T (K S_a K^T + S_e)^{-1} \quad (1)$$

where S_a is the covariance matrix associated to the a priori ; K is the weighting function matrix (or Jacobian) and S_e is the covariance matrix associated to the measurement noise. The Jacobians were also plotted in order to identify in which altitude ranges the retrievals will be sensitive.

A specific analysis was carried out in order to determine the required SNR and resolving power in each of the spectral bands. Four spectral bands were selected to characterize the molecular species of volcanogenic origins in the troposphere and in the mesosphere of Venus.

3. Summary and Conclusions

The wavelength ranges of interest, SNR and resolving power for each of them were determined using radiative transfer simulations. Based on these results and on the mission science objectives, the design of the instrument will be optimized. VenSpec-H is based on NOMAD (Nadir and Occultation for MArs Discovery), a suite of three spectrometers on ExoMars Trace Gas Orbiter. Specifically, VenSpec-H is a redesign of the LNO (Limb, Nadir and Occultation) channel of NOMAD, retaining much heritage from the original but with minor modifications to meet the science objectives of the EnVision mission. Different optical solutions need to be envisaged. The results of the trade-off between the different layouts will be presented.

Acknowledgements

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