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Earth as an exoplanet: VIRTIS-M/Venus Express data analysis.

F. Oliva, G. Piccioni, E. D'Aversa, G.Bellucci, G. Sindoni, G. Filacchione, and F. Capaccioni.

INAF-IAPS, Rome, Italy (fabrizio.oliva@iaps.inaf.it)

Abstract

The VIRTIS spectrometer on board the Venus Express spacecraft observed Earth several times. A subset of 48 observations has been taken from a distance at which our planet is imaged as sub-pixel size. We study this full subset to understand which spectral signatures, related to different surfaces and cloud types, can be identified from the integrated planet spectrum. As expected, we find that the cloud coverage has a key role in the identification of surface features. To investigate this finding we built a simple tool capable to simulate observations of an Earth-like planet as seen from a VIRTIS-like spectrometer, in order to infer the percentages that are required to identify each surface and cloud type when all the spectral information is integrated into a single pixel.

1. Introduction

One of the main objectives of exoplanets science is to find and characterize habitable planets. To this extent, a major role will be played by the direct imaging technique (first direct images of an exoplanet published in 2008 by [5]), taking advantage of a generation of adaptive optics assisted telescopes like ESO/VLT-SPHERE [1] and Gemini Planet Imager (GPI, [6]).
Radial velocity and transit searches indicate that Earth analogs are common. However, an extreme contrast at very small angular separations must be achieved in order to image them [7].
Disk averaged spectra of planets detected with this technique will allow the characterization of these worlds' atmospheres and, hopefully, their surfaces.
Sensitivity studies focused on what we can expect to detect on Earth-like planets have already been done by analyzing synthetic spectra consistent with ground based and satellite observations [9,3].
In this work we perform a sensitivity study, focused on the detectability of different surface and cloud spectral endmembers (Section 2), based on the use of data registered by the VIRTIS spectrometer [2,8] on board both the Rosetta and Venus Express (VEx) spacecrafts.

2. The planet simulator

We selected Earth spectral endmembers from an Earth observation registered by the Rosetta/VIRTIS-M spectrometer during the third flyby of the spacecraft around our planet, occurred in November 2009. From the observation, relative to a region at the north-west of Africa, we obtained endmembers for vegetation, ocean, desert, liquid water clouds and water ice clouds. Then, we mixed these endmembers with a randomization algorithm to generate planets observed by a VIRTIS-like spectrometer from user defined distances and observing geometries. At the first order, the Lommel correction has been applied to photometrically correct the selected endmembers.
We fixed the observing geometry to reproduce a secondary eclipse condition, with the emission angle equal to 0° at the center of the planet and the azimuth of the stellar boresight at 45° with respect to the center of the planet. Then, we investigated all possible combinations of percentages for the different endmembers to obtain the threshold values needed to detect each spectral class when the planet is observed as a single pixel. From this analysis, it results that clouds have a major impact on the detectability of the surface, confirming previous studies by other authors, based on models [9]. Our results suggest that, when the total cloud coverage is larger than 40%, surface features are undetectable.

3. Investigation of VEx data

We performed the same sensitivity analysis directly on VEx/VIRTIS data. It results that surface is never detectable in these observations and the signal from clouds is dominating the spectral information of the integrated spectrum. To verify this result, we studied the daily cloud coverage from MODIS spectrometer [4] data, available at the Nasa Earth Observations website. The average cloud coverage relative to VEx Earth observations is always larger than 40%, confirming the results we obtained with the tool described in Section 2.

4. Summary and Conclusions

The results from our simple planet simulator show that, when the planet is observed as a single pixel, the surface endmembers can be detected only when the total cloud coverage is less than 40% in the instrument field of view (Section 2). The analysis of VEx Earth sub-pixel observations shows that only clouds can be detected, in agreement with our results and with the computed daily Earth cloud coverage (Section 3).

We will update out planet simulator by refining the endmembers photometric correction. Then, we will investigate different viewing and illumination angles to check the dependence of the endmembers detection thresholds with the observing geometry. Moreover, we will investigate other possible spectral conditions to exploit more the wavelengths of VIRTIS-M infrared channel.

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