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Physical relevance of Independent Component Analysis of planetary radiance

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Introduction

Independent Component Analysis (ICA) applied to VIRTIS/Venus-Express nightside data [1] allowed us to separate various physical phenomena, based on their spectral signatures in reflected light (1-2.5 µm). Using the complete spectral range (instead of spectral parameters such as band depths) results in extracting complex patterns involving many spectral channels, in particular: O_2 recombination in the high atmosphere on the night side, cloud pattern, limb darkening, and surface emission visible through atmospheric windows.

However, the question of the physical relevance of the independent components retrieved has not been studied in detail, in particular for surface emission. It is here compared with an explicit physical modeling of the spectra performed to map surface temperature and its variations [2].

1. Physical modeling

The VIRTIS/Venus Express dataset was inverted to estimate surface temperature [2]. The flux is measured at 1.02 µm in a narrow window where the atmosphere is not entirely opaque, and is corrected for atmospheric effects. This modeling involves: subtraction of stray light (originating from the illuminated crescent close to the field of view, plus solar reflected light scattered on the night side); correction of limb darkening; correction of multiple reflections between the lower atmosphere and the cloud layer; conversion from radiance to temperature.

Stray light is estimated from residual radiance between the atmospheric windows at short wavelength. Multiple reflections in the atmosphere depend on cloud opacity. It is corrected by dividing out a function of the cloud pattern measured at longer wavelength (1.31 µm). A step-by-step application of this method is provided for session VI0373_01: Fig. 9e in [2] displays the flux from the surface, converted to brightness temperature. Since surface temperature is controlled by atmospheric pressure it essentially reflects surface elevation, with possible departures related to thermal anomalies or changing rock composition. This parameter therefore displays specific patterns when 1) the session covers an area with marked topography contrast and 2) cloud opacity is moderate.

2. Multivariate analysis

The same data where analyzed with Independent Component Analysis (ICA) by [1] so as to entangle several phenomena which may have overlapping spectral signatures. ICA being a linear analysis, all retrieved components consist in linear combinations of flux measured in the various spectral channels. By construction, ICA provides results that are less sensitive to measurement noise, and are more physically relevant than Principal Component Analysis (PCA) [3].

The surface emission in particular is estimated from all the spectral channels that contain a contribution from the surface (~10 channels in the 1.02, 1.1 and 1.18 µm windows), and the atmospheric effects are approximated by subtraction of flux measured at all wavelengths dominated by the cloud pattern. In the case of session VI0373_01, the cloud pattern is mostly estimated from several channels in the 1.29-1.31 μm range (which also includes limb darkening) and in the 1.74 μm peak (although in this session it is saturated in some places).

3. Comparison

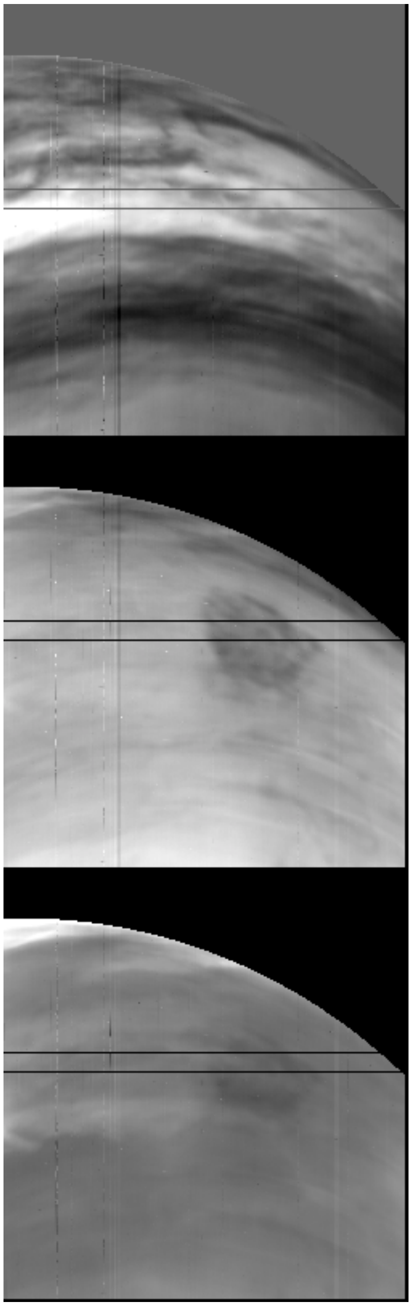

Figure 1: First 3 independent components retrieved on session VI0373_01.

Fig. 1 displays the first 3 components retrieved from the ICA: cloud pattern, surface emission, O_2 emission (from top to bottom). They are essentially decoupled, although a slight mixture between surface and O_2 emission is still apparent. The dark feature on Fig 1b is the high elevation area of Alpha Regio and Eve Corona.

The retrieval of surface emission is at least as good as the one from [2], being less noisy and equally similar to the Magellan altimetry. Both estimates are well correlated except near the limb (Fig. 2). However, the signal is difficult to calibrate in radiance and temperature estimates are biased. Component 1 is also very similar to the cloud pattern estimated in [2], their Fig. 9d. The major differences are low frequency variations along the horizontal direction in [2], now reduced thanks to an improved flat-field.

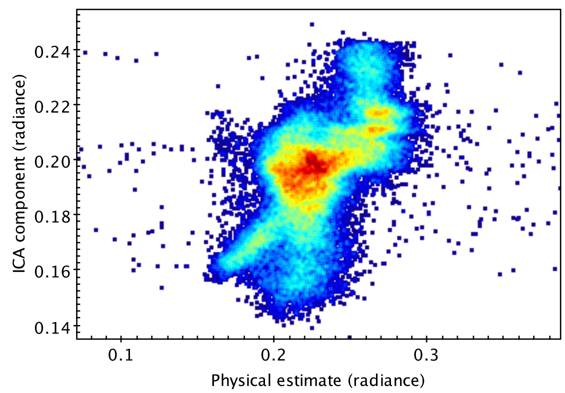

Figure 2: Surface component from ICA compared to physical model on session VI0373_01 (density plot).

This study confirms the ability of ICA to retrieve physical quantities that otherwise require sophisticated modeling, in spite of the linearization performed by ICA.

References

[1] Erard, Drossart and Piccioni (2009) Multivariate analysis of VIRTIS/Venus Express nightside and limb observations. JGR 114(E13), doi:10.1029/2008JE003116.
[2] Mueller et al (2008) Venus surface thermal emission at 1 mum in virtis imaging observations: Evidence for variation of crust and mantle differentiation conditions. JGR 113, doi: 10.1029/2008JE003118.
[3] Erard, S. (2015) ICA applied to imaging spectroscopy remote sensing. EPSC2015–426, Nantes, Fr.