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Lightning on Venus? Searching for optical evidence with VIRTIS on Venus Express

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Abstract

The Venus Express mission has been observing the Venusian Atmosphere continuously since 2006, producing great amounts of hyper-spectral data from the Visible to the Near InfraRed. Although the occurrence of lightning in the Venus atmosphere has been published several times in the past years, always on the basis of detected electromagnetic pulses, the subject is still controversial. It is generally agreed that an optical observation of the phenomenon would settle the issue. We will show here some details of the analysis of the whole data collection of hyper-spectral images produced by the VIRTIS instrument in the visible and infrared range, with description of the method and preliminary results.

1. Introduction

1.1 Venus-Express Mission

Venus Express (VEX) is the first European mission to Venus, launched on November 2005. VEX is in orbit around the planet since April 2006, following a polar elliptical orbit of 24 hour period, with the pericenter at 250km altitude over the north pole, while the apocenter is at 66000km over the south pole. The spacecraft carries a multi-purpose set of instruments for remote sensing and in-situ measurements, which is providing great amounts of data for the understanding of the planet, in particular with special attention to the atmosphere structure, morphology and dynamics, as well as the thermal emission from the surface and interaction with the solar wind.

1.2 VIRTIS instrument

The Visible and InfraRed Thermal Imaging Spectrometer (VIRTIS) is providing valuable insights into the Venus atmosphere. The instrument combines a double capability: high-resolution imaging in the visible-infrared range (0.28-5μm) at moderate spectral resolution (VIRTIS-M channel) and high-resolution spectroscopy in the 2-5 μm range (VIRTIS-H channel). The scientific objectives of VIRTIS cover a large field and span from the study of the thermal emission of the surface up to the composition and dynamics of the upper atmosphere. About 2.5 Gbit of raw compressed data are coming in average every day from the spacecraft, containing invaluable information about the phenomena in all the atmospheric layers.

1.3 Lightning on Venus

In our Solar System, lightning is known to occur in the atmospheres of Earth, Jupiter, Saturn, Uranus and Neptune. Its occurrence on Venus remains somewhat controversial. Most of the postulated events of Venus lightning come from electromagnetic pulse detections. Such pulses have been reported in the framework of the Venera, Pioneer Venus Orbiter and Galileo missions. The lightning origin of these pulses has often encountered skepticism in the scientific community. The Cassini mission was unable to detect any lightning activity, even though it easily detected activity on Earth. In recent years, the Magnetometer on board Venus Express has measured high levels of electromagnetic activity in the planet's atmosphere.

The record of optical observations of Venus lightning flashes starts at the time the Venera missions. Observations from ground-based telescopes have pursued the exploration of the Venus lightning. Yet, the failure of the Pioneer Venus Orbiter to detect any flashes during a dedicated exploration with the spacecraft's star tracker has been difficult to explain [1-6]. Thus, overall the occurrence of Venus lightning remains an open issue to which VEX may contribute.

2. Analysis of the VIRTIS data set

The VIRTIS instrument has been producing a huge data set of several terabytes of hyperspectral data in the Visible and Infra-Red ranges, and although the data set has been thoroughly studied by the science community and many important publications have been made, there is still an important amount of scientifically valuable information that has not yet been exploited.

2.1 Lightning signal expected in the data

In particular for the lightnings, several attempts have been made to analyze the presence of lightning in the data [8], but no clear evidence has yet been found. However, this is mainly due to the technical design of the instrument, which is a scanning slit spectrometer with limited field of view, and therefore any kind of quick temporary event such as the lightning would cause a signal variation only in a few pixels of the detector and be very difficult to identify. Moreover, these kind of singular events could even be identified by the calibration pipeline as anomalous pixels and be filtered out as spikes or even bad frames. For this reason, any dedicated lightning study has to be made based on the raw images and avoiding most of the post-processing techniques which could potentially eliminate any relevant trace of signal in the data. Still, if we consider the extensive coverage of the atmosphere by the instrument at all wavelengths, it is expected that some events should be present in the archive, and it is interesting to perform a dedicated analysis to obtain, if not a valid spectral signature, at least some statistical estimation of the possible presence of these transient events.

2.2 Search Method

For our study we are starting with an extensive analysis of all the raw visible images taken by the instrument in the night side of the planet, as it is expected that any lightning would have a stronger signal in the lower wavelengths, and also considering that the signal from the atmosphere in this range is almost negligible, so it would be in principle easier to identify any trace of signal from transient events. A dedicated search algorithm has been developed to find any singular event in the data, based on various search parameters. In particular the algorithm is looking for transient events present only in a single frame (a line in the 3-dimensional cubes) with a clear differentiated signal in at least a few spectral bands, and affecting one or more pixels. The number of spectral bands and pixels is configurable and we are performing the analysis with different options in order to optimize the search.

3. Preliminary Results

The first preliminary analyses of the archive are being performed and so far we can demonstrate that the concept is valid and we can easily find transient events in the data. However the impact of cosmic rays in the detector produce a signal which is comparable in intensity to the one that would be expected in the case of a lightning, and therefore the current algorithm is finding all kind of single events that have to be manually analyzed one by one to understand the particularities of the signal and assess whether or not the spectrum is physically representative.

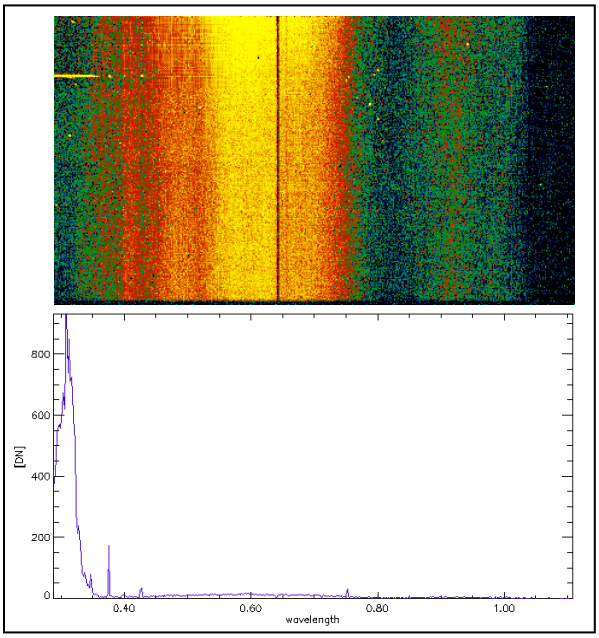

Figure 1: The top image shows a 2-dimensional frame observed by the Visible channel of VIRTIS in the night side of Venus, with the vertical dimension being spatial (samples along the slit) and the horizontal dimension being the spectral signature for each of the samples. The low background signal is radiance coming from the illuminated side of the planet and the single transient event is present on the top left corner. The bottom plot shows the spectral signature of the transient event, in uncalibrated digital counts with respect to the wavelength in microns.

6. Summary and Conclusions

Although the presence of lightning in the atmosphere has been published several times in the past years the subject is still controversial and there have been many attempts to find any evidence of these phenomena using the optical observations.

In this contribution we show a new analysis of the whole data collection of hyperspectral images produced by the VIRTIS instrument in the visible and infrared range. The preliminary results show the feasibility of the concept although there is still a lot of work to do to optimize the search parameters and analyze all of the results and exclude the effects of cosmic rays in the data.

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