EPSC Abstracts
Vol. 11, EPSC2017-962-1, 2017
European Planetary Science Congress 2017

A new method to analyze UV stellar occultation data

D. Evdokimova (1, 2), L. Baggio (2), F. Montmessin (2), D. Belyaev (1). J.-L. Bertaux (1,2)
(1) Space Research Institute of RAS, Moscow, Russia, (2) LATMOS, Paris, France (evd.dar@yandex.ru)

Abstract

SPICAV stellar occultation measurements in the UV composed a huge dataset concerning vertical distributions of CO_2, SO_2 and O_3 abundances on the night side of Venus mesosphere (80-130 km). Beside those absorption features the instrument was also sensitive to emissions from different extended sources in addition to a star light in spectral range from 110 to 320 nm. These emissions, hereafter «stray light», result in systematic errors when retrieving gaseous abundances from transmission spectra. In this paper we present a new method of data processing and a classification of different types of stray light at SPICAV UV stellar occultations. The method was developed on a basis of Richardson-Lucy algorithm including: (a) deconvolution process of measured star light and (b) separation of extra emissions registered by the spectrometer.

1. Introduction

Chemistry and dynamics of Venus CO_2-atmosphere are greatly affected by vertical distribution of trace gases (SO_2, O_3, HCl, H_2O, etc.). The most powerful method to achieve high vertical resolution in atmospheric profiles is occultation. Stellar occultation experiment onboard the ESA's Venus Express mission allowed to study night Venus atmosphere within altitude range of 80-130 km that was being observed by an imaging UV spectrometer SPICAV in 2006-2014 [1]. The instrument's spectral range of 118-320 nm was sensitive to absorption bands of CO_2, SO_2, SO and O_3 [5, 6].

SPICAV simultaneously records 5 spectra binned within neighbor pixel lines on the CCD matrix. The light from a point star mainly comes to the central bin, while it is spatially and spectrally distributed by the instrument point-spread function (PSF) over the CCD. When star is occulted in the atmosphere some additional light (hereafter "stray light") will come to those five spectral bins from different altitudes on 80-130 km. The present work is devoted to the stray light extraction from the stellar occultation spectra to improve the atmospheric transmission retrieval.

2. Stray light registering in stellar occultations

Nitric oxide (NO) glow, Lyman-alpha emission and reflected sun light are main sources of the stray light.

NO emission in the spectral range of 180-280 nm is formed at altitudes about 110 km at night [2]. It is the most intense and well defined type of stray light. Its spatial distribution within the FOV makes the CCD illumination vary as a function of the relative position of the bright limb in the FOV.

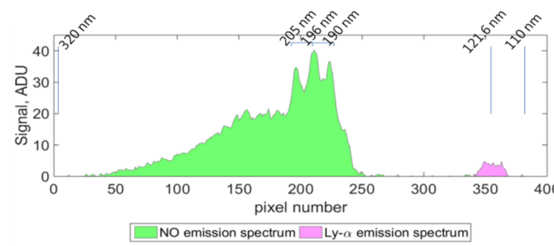

Figure 1: NO emission and atmospheric Lyman-a in the shadow of the atmosphere (40-60 km), orbit 2721A05. Observation was done with slit.

Lyman-a emission is produced by interplanetary and Venusians hydrogen at 121,6 nm [3,4]. Lyman-a distorts star signal at altitudes where CO_2 absorption is weak. The Lyman-a line is well distinguishable in spectra measured with slit. For others it is integrated in large FOV and spread over about 250 pixels.

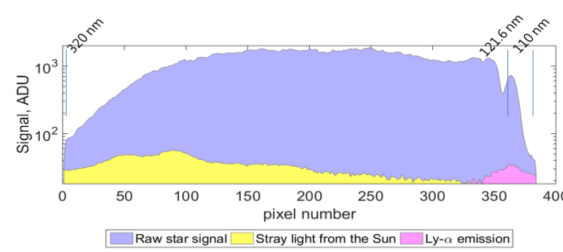

Figure 2: Star signal above 200 km with separated sun and Lyman-a illumination, orbit 2721A05.

The third type of stray light is sun light reflecting on Venus crescent or spacecraft surfaces. Its intensity is noticeable in the spectral range of 200-300 nm that overlaps the range of NO emission.

3. A new data processing algorithm

Taking into account the PSF distribution and stray light pollution [5] the spectra of five bands are

$$S_{expi} = \alpha_i S_{ref} T + S_{straylighti}, i = 1 \dots 5 \quad (1)$$

where α_i is the fraction of the PSF in the i-th band, S_{ref} is the star signal outside the atmosphere, T is atmospheric transmission determined by gases.

The gaseous profiles are retrieved by modeling the atmospheric transmission in the observing layers (see in details [5]). Equation (1) shows the need to add stray light as additional parameter in the synthetic spectra of transmission.

The new method allowed separating the partly absorbed star light (S_{orig}) and stray light emissions before the retrieving process of gas concentration. The star signal is restored using a damped Richardson-Lucy iterative algorithm [7]. Equation (2) describes deconvolution iteration process of observing spectrum from the known PSF function (f_{PSF}) and binning factor (f_{bin}). The process starting from approximation S_{orig} = S_{obs} gives original stray light ($S_{str. light}$) spectra in the end.

$$S_{obs} = f_{bin}\left(f_{psf} S_{orig} + S_{str.light}\right) \quad (2)$$

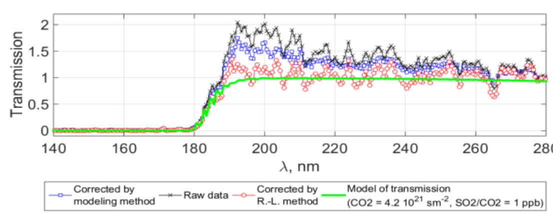

Figure 3: Example of the observation where R.-L. algorithm improves the result (2111A01, 109 km).

It takes ~40 iterations (with acceleration techniques) to reach the good estimation of original spectrum without adding any hypothesis of atmosphere composition and structure.

4. Summary and Conclusions

The new method of data processing allowed distinguishing the different sources of stray light in transmission spectra at UV stellar occultations. Thanks to this method one can extract UV emissions independently on gaseous absorption features.

Extra light illuminated the matrix of the SPICAV instrument had 3 distributed sources: NO and Lyman-a emissions and sun illumination. That provides more data with good vertical resolution to study behaviors of the emissions.

Acknowledgements

D. Evdokimova and D. Belyaev acknowledge support of the RSF grant #16-12-10453. We would like to thank our LATMOS colleagues for their kind collaboration. J.-L. Bertaux acknowledges support of the Russian government grant #14.W03.31.0017

References

[1] Bertaux J.-L. et al.: SPICAV on Venus Express: Three spectrometers to study the global structure and composition of the Venus atmosphere. Planet. Space Sci., Vol. 55, pp. 1673-1700, 2007.

[2] Royer, E., Montmessin, F., Bertaux, J.-L.: NO emissions as observed by SPICAV during stellar occultations. Planet. Space Sci., Vol. 58, pp. 1314–1326, 2010.

[3] Chaufray, J.-Y., et al.: Hydrogen density in the dayside venusian exosphere derived from Lyman-a observations by SPICAV on Venus Express. Icarus, Vol. 217, pp. 767–778, 2012.

[4] Chaufray, J.-Y., et al.: Observations of the nightside venusian hydrogen corona with SPICAV/VEX. Icarus, Vol. 262, pp. 1–82, 2015.

[5] Belyaev, D., et al.: Night time distribution of SO2 content in Venus' upper mesosphere. Icarus, Vol. 294, pp. 58-71, 2017.

[6] Montmessin, F., et al.: A layer of ozone detected in the nightside upper atmosphere of Venus. Icarus, Vol. 216, pp. 82–85, 2011.

[7] Richard L. White.: Image restoration using the damped Richardson-Lucy method. The Restoration of HST images and spectra II. Space Telescope Science Institute, 1994.