Venus Spectrophotometry During the MESSENGER Mission Fly-by

S. Pérez-Hoyos, A. Sánchez-Lavega, R. Hueso, J. Peralta, G. Holsclaw, and W. McClintock

Abstract The NASA mission MESSENGER fly-byed planet Venus on June 2007 on its route to Mercury. This chance was took to produce coordinate observations between Messenger and ESA Venus Express spacecrafts. This work shows spectra in the wavelength range between 320nm and 1450 nm retrieved with the instrument MASCS (Mercury Atmospheric and Surface Composition Spectrometer). Spectra are calibrated in absolute reflectivity (diffuse reflection by Venus clouds) and wavelength, and they are navigated in order to retrieve their position in the planet's disk. Comparing synthetic spectra with these ones for each viewing geometry we will obtain information on the vertical distribution of cloud particulates between 60 km and 75 km height, approximately, as well as the SO_2 abundance, among others. This will be combined with almost simultaneous data gathered by the visible and infrared spectrograph VIRTIS onboard Venus Express spacecraft. The results of the atmospheric modelling will be presented elsewhere.

1 The mission and the instrument

The MESSENGER (MErcury Surface, Space Environment, GEochemistry and Ranging) mission of the NASA was launched on August 3, 2004 from Cape Canaveral and it fly-byed Venus twice (October, 2006 and June, 2007) on its route to Mercury. The main goal of the mission is the intensive study of this planet during the next years but the instruments onboard the MESSENGER spacecraft have also provided valuable information on Venus atmosphere [1].

S. Pérez-Hoyos, A. Sánchez-Lavega, R. Hueso, and J. Peralta
Grupo de Ciencias Planetarias UPV/EHU, Dpto Física Aplicada I, E.T.S. Ingeniería, Bilbao (Spain), e-mail: santiago.perez@ehu.es

G. Holsclaw and W. McClintock
University of Colorado, Laboratory for Atmospheric and Space Physics, Boulder (USA)

Together with other six instruments onboard MESSENGER, MASCS (Mercury Atmospheric and Surface Composition Spectrometer) is an ultraviolet and infrared spectrograph that will measure the abundance of atmospheric gases and the composition of the rocks on the surface of Mercury.

MASCS is, in fact, two spectrometers: VIRS (Visible and InfraRed Spectrometer) and UVVS (UltraViolet and Visible Spectrometer). VIRS is a point spectrometer that covers the wavelength range between 320 and 1450 nm with a field of view of 0.023°. This will be the configuration used in the data acquisition that will be presented in section 2

The instrument is a Cassegrain type telescope that simultaneously feeds the two spectrometers with their detectors: a silicon one for the visible channel and the GaAs one for the infrared. The spectral resolution is 5 nm.

2 Venus observations

The MESSENGER encounter with Venus on June 5, 2007 was brief but allowed retrieving about 500 spectra in the day side and 460 in the night side. Some of these spectra were taken simultaneously with the images obtained by the instrument MDIS (Mercury Dual Imaging System).

The MASCS spectra are concentrated in the equatorial band of the planet ranging from latitudes 2° N to 11° S and longitudes 90° W to 170° W. This path during 2007 observations is summarized in [1].

The localization of the spectra is complimentary to the data obtained by the Venus Express mission (VEX). This ESA spacecraft follows a polar orbit that only allows

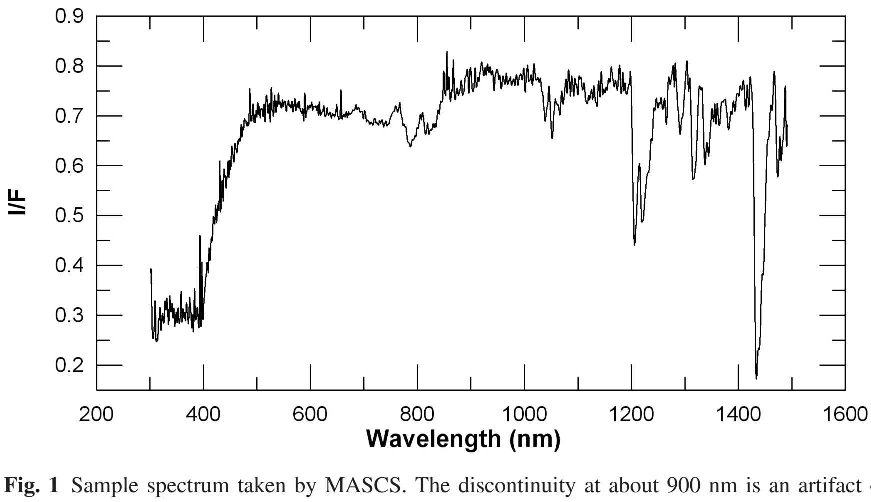

Fig. 1 Sample spectrum taken by MASCS. The discontinuity at about 900 nm is an artifact of the reduction process that will be debugged at a later stage. Note the gas absorption bands in the infrared and also the absorption of an unknown origin in the ultraviolet, below 400 nm.

an oblique vision of the equatorial latitudes. This means that the combination of VEX observations with VIRTIS (Visible and InfraRed Thermal Imaging Spectrometer) is a potential value for the understanding of the distribution of atmospheric species and cloud particulates in the atmosphere of Venus.

The calibrated spectra from MASCS have been transformed to absolute reflectivity(often known as I/F), calculating the ratio between the observed intensity and that of the perfect lambertian reflector at the same distance. An example of MASCS spectrum is shown in figure 1.

These spectra between the near ultraviolet and the near infrared show the absorptions by SO_2 and CO_2, but also by an unknown specie in the shortest wavelengths which produces most of the contrasted features observed in the cloud tops [2].

The information contained in those spectra is two-fold. On the one hand, we get information on the wavelength dependence of the reflectivity, which gives the spectral component of the reflectivity. But, on the other hand, the dependence of the reflectivity with the observing and illuminating angles makes it possible to study the geometrical component of the reflectivity. The different geometrical configurations allow sounding different atmospheric levels at a given wavelength.

This information is summarized in figure 2 where we show the variation of the measured reflectivity depending on the emission angle. The limb-darkening (that is, the falling of reflectivity with increasily oblique observations) depends strongly on the wavelength, and this is in fact providing information on the vertical structure of the atmosphere including the distribution of absorbing and scattering particles.

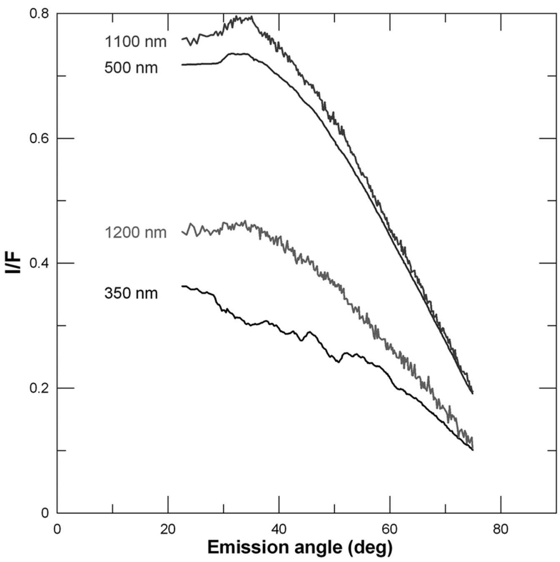

Fig. 2 Dependence of the observed reflectivity with the emission angle for some selected wavelengths. The limb darkening geometrical information is a valuable tool for diagnosing the vertical cloud structure.

3 Atmosphere modelling

Our numerical code is based on the method called 'doubling-adding', which separates an inhomogenous atmosphere in a number of homogeneous layers in order to numerically solve the radiative transfer equation [3]. This code has been successfuly to the giant planets Jupiter and Saturn [4, 5] and it is been adapted now for Venus, including some of its peculiar characteristics.

In the Venus case, the Rayleigh scattering gas diffusion is produced by a mixture of CO_2 and N_2 which are in general uniformly distributed throughout the atmosphere. This scattering would dominate at short wavelengths in a clean atmosphere (free of clouds and aerosols) , but becomes almost negligible at the infrared.

Contrarily to the giant planets, where the main gas absorption is also well mixed, the main absorbers in Venus (SO_2, CO_2 and H_2O) and other minor components show a vertically variable abundance [6]. Data retrieved by VIRTIS on the vertical distribution of atmospheric species will be extremely valuable.

Our code also includes the scattering by cloud particles, and it has been adapted to reproduce the phase functions and size distributions known to be characteristic of Venus atmosphere [7].

The modelling will allow us to study the geometrical and spectral dependence of the reflectivity as a function of the assumed vertical cloud structure model and thus to find the most plausible parameter values to explain the observations. The results of this work will be presented elsewhere.

Acknowledgements This work has been funded by Spanish MEC AYA2006-07735 with FEDER support and Grupos UPV 15946/2004 and Grupos GV IT464-07.

References

1. Holsclaw, G., McClintock, W., Robsinson, M., Izenberg, N. : The MESSENGER Venus flyby: first results from the Mercury Atmospheric and Surface Composition Spectrometer. In: 2007 AGU Meeting (2007)
2. Esposito, L.W., Knollenberg, R.G., Marov, Y.M., Toon, O.B., Turco, R.P. : The clouds and hazes of Venus. In: Hunten, D.M., Colin, L., Donahue, T.M., Moroz, V.I. (eds.) Venus, pp. 484-464. Univ. of Arizona Press, Tucson (1983)
3. Hansen, J.E., Travis, L.D. : Light scattering in planetary atmospheres. Space Sci. Rev. **16**, 527–610 (1974)
4. Acarreta, J.R., Sánchez-Lavega, A. : Vertical cloud structure in Saturn's 1990 Equatorial Storm . Icarus. **137**, 24–33 (1999)
5. Pérez-Hoyos, S., Snchez-Lavega, A., French, R.G., Rojas J.F. : Saturn's cloud structure and temporal evolution from ten years of Hubble Space Telescope images (1994-2003) . Icarus **176**, 155–174 (2005)
6. Esposito, L.W., Bertaux, J., Krasnopolsky, V., Moroz, V.I., Zasova, V. : Chemistry of the lower atmosphere and clouds. In: Bougher, S.W., Hunten, D.M., Philips, R.J. (eds.) Venus II, pp. 415-458. Univ. of Arizona Press, Tucson (1997)
7. Ragent, B., Esposito, L.W., Tomasko, M.G., Marov, M.Y., Shari, V.P., Lebedev, V.N. : Particulate matter in the Venus atmosphere. Adv. Space Res. **5**, 85–115 (1985)