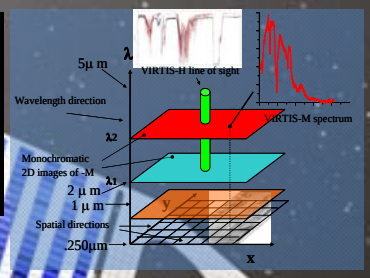
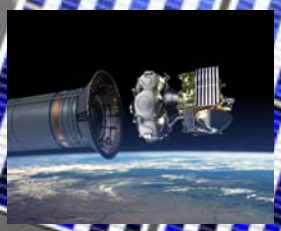
Venus as seen by VIRTIS on Venus Express

G. Piccioni, P. Drossart and the VIRTIS-Venus Express team
IASF-INAF (Rome, Italy, via del Fosso del Cavaliere, 100, 00133, giuseppe.piccioni@inaf.it)
LESIA, Obs de Paris (5, Place J. Janssen, 92195, Meudon - France)

VIRTIS (Visible and InfraRed Thermal Imaging Spectrometer) *is an imaging spectrometer on board the Venus Express ESA mission [1,2].*
The output from VIRTIS-M, the mapper, is a set of 864 stacked monochromatic two-dimensional images in the spectral range from 0.25 to 5 μm, at moderate spectral resolution (resolving power RP of 100-500). VIRTIS-H, a point spectrometer centered in the middle of the –M image, provides spectra at higher spectral resolution (RP 1000-2000) in this small portion of the image but in the range from 2 to 5 μm.

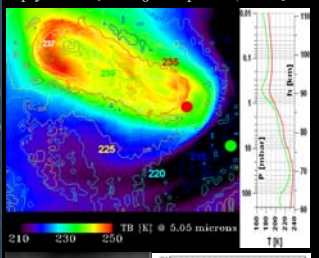


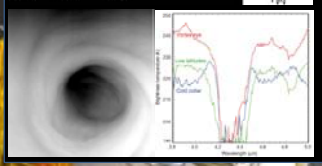


Venus Express *is the first mission to Venus by ESA, the European Space Agency.*
Venus Express has been launched on 9 November 2005. On 11 April 2006 it was inserted into the Venus orbit. Venus Express is currently operative.

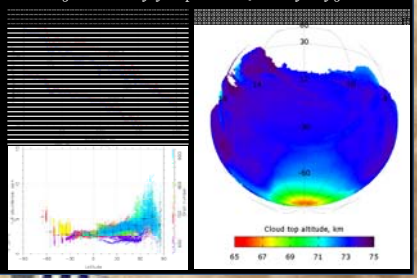
The polar vortex

The Venus pole hosts a giant polar vortex with a large depression of the clouds top due to the subsidence. By analysing the carbon dioxide absorption around 4.2 μm, see spectrum in the figure bottom left, the VIRTIS data allowed to record its peculiar 3-D thermal structure [3]. The thermal contrast is highest in the polar region on the clouds top at about 65 km altitude, with the highest temperature in the center of the vortex, often as a dipole shape, and coldest in the sorrounding cold collar, see figure below [4]. The thermal map at 3.8 (see image bottom left) and 5.2 μm, probes on the clouds top of the vortex, with higher temperature (the darker in the image bottom left) associated to lower altitude.



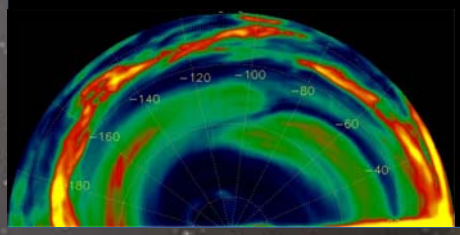


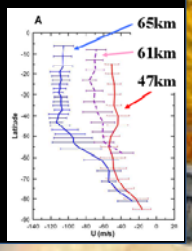
Spectral reflectance measurements on the day side allows to retrieve the clouds top altitude fom the carbon dioxide absorption band in the region from 1 to 2.5 μm. In average the altitude of the clouds top is 74 km but it shows an evident large depression in the polar region where it decreases down to 65 km, see figure on bottom [5]. The water abundance above the clouds can be retrieved from other bands, see spectrum below. Water abundance is relatively constant at mid-low latitudes while it starts to increase with a large spread above 60 deg, in the vicinity of the polar vortex boundary, see figure below [6].



Dynamics and super-rotation

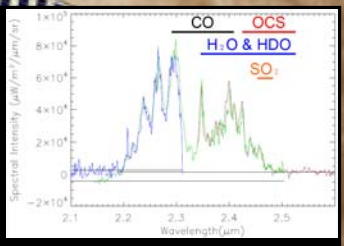
Clouds tracking has been used to measure the winds speed [7]. Measurements at different altitude level are possible by using the UV and IR solar reflected radiances at 350 nm and 980 nm in the day side. These two wavelengths probe the altitude level at about 65 and 61 km altitude respectively. Additionally, in the night side of the planet, the radiance in the window at 1.74 μm provides the way to measure winds in the lower clouds at about 47 km altitude. The winds speed shows a significant vertical shear at low latitudes with values from about -50, -70 and -110 m/s in the 3 probed layers, with a speed relatively constant poleward up to about -60°S where the vertical shear disappeared in combination with a decreasing speed toward the pole , see bottom right. Bottom left, a view of the Venus night-side at 1.74 μm from the south pole.

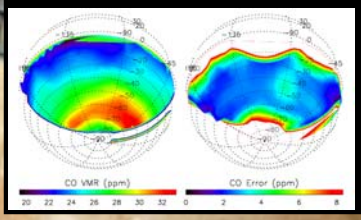


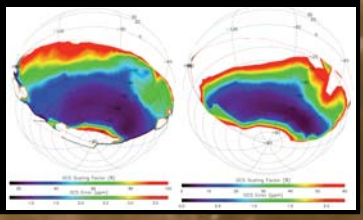


Atmospheric Composition

Radiance originating in the deep atmosphere and escaping in the atmospheric windows has been used to infer the chemical composition in the dark side of the planet below the clouds [8]. In particular, the window in the region at about 2.3 μm is effectve to retrieve the abundance of CO, H2O, OCS and SO2 at about 30-35 km altitude [3,4], see right. CO, which is considered a tracer of the global dynamics, is typically found to be in the range 25-30 ppm with significant meridional gradient with a maximum at about 60° latitude. OCS results to be anticorrelated with CO and its abundance is in the range 2.5-4 ppm, see below [9]. H2O and SO2 are found to be relatively more spatially homogeneous with an abundance around 30 and 130 ppm respectively.

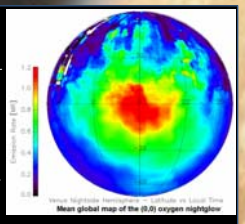




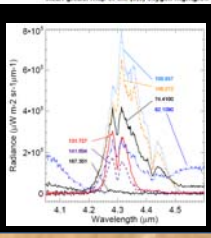


Nightglow and Non-Local Thermal Equilibrium (NLTE) effects

The most intense nightglow emission is observed at 1.27 um and it is due to the (0-0) Oxygen transition. The peak altitude in limb view is typically found at 96-97 km, with a maximum emission at low latitudes and near the antisolar point [10]. The nadir measurements shows an almost perfect symmetry of the SS to AS circulation, with a maximum of the emission rate in the antisolar region of about 1.2 MR, as shown in the mean map on the right. The hydroxyl nightglow has been recently discovered on Venus at 2.8 (1-0 transition) and 1.46 (2-0 transition) μm [11]. It peaks a couple of km lower than the oxygen. The most probable mechanism is the Bates-Nicolet from the combination of H and O3, thus the hydroxyl emission is diagnostic for Ozone.

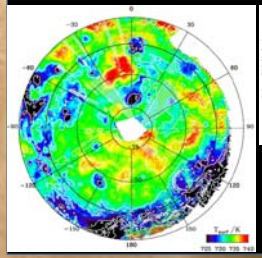


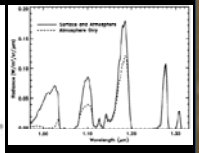
CO2 fluorescence at 2.7 and 4.3 μm has also been observed and studied in the day side of Venus and compared with the models. The emitting layers are placed in a range of altitudes from 100 to 140 km. On the left, a false colours image in limb view, spectra on the right at different tangent altitude [12].



Surface

The surface of Venus can be seen only in the night side and in the near infrared range, see picture below right from Meadows and Crisp 1996. **VIRTIS** *allowed to have a thermal map of the Venus' surface, see bottom left, by using the thermal emission at about 1 micron, once corrected for de-clouding [13].*





Summary and Conclusions

Venus is perhaps one of the most probable terrestrial-type world in the exoplanets (EPs) scenario. Venus Express and in particular the VIRTIS imaging spectrometer on board provided a large set of valuable data able to properly support and validate the Venus Global Circulation Models and consequently the future GCM applicable to the exoplanets. The spatially resolved spectroscopic data, once reduced as point source target, closer to the EPs case, will be essential to better understand the global scenario and climatic conditions of an EP, in particular the potential habitable ones.

References

[1] Piccioni, G. et al., Tech. Rep. ESA-SP-1295, ESA, The Netherlands
[2] Drossart, P., et al., (2007), , Planetary and Space Science 55(12), 1653—1672
[3] Grassi, D. et al. (2008), JGR, VOL. 113, E00B09, 12 PP.
[4] Piccioni, G., et al. (2007), nature, 450, 637-640
[5] Ignatiev, N., et al., (2009), JGR, VOL. 114, E00B43, 10 PP.
[6] Cottini, V., et al., (2009), JGR, VOL. 114, E00B43, 10 PP.
[7] Sanchez-Lavega, A., et al. (2008), GRL 35(13).
[8] Marcq, E., et al., (2008), JGR, VOL. 113, E00B07, 9 PP.
[9] Tsang, C., et al., (2008), JGR, VOL. 113, E00B08, 13 PP.
[10] Piccioni, G., et al. (2007), JGR, VOL. 114, E00B38, 18 PP.
[11] Piccioni, G., et al., (2008), A&A 483, L29–L33
[12] Gilli, G., et al., (2009), JGR, VOL. 114, E00B29, 19 PP.
[13] Mueller, N., et al., (2008), JGR, VOL. 113, E00B17, 21 PP.

http://venus.esa.int
http://venus-express.iasf-roma.inaf.it