Announcement of Opportunity for the selection of Co-Investigators for the PFS and VIRTIS experiments to be flown on the Venus Express mission

The Science Programme Committee (SPC) of ESA has approved the Venus Express mission for launch in November 2005 at its last meeting that took place in Paris on 4-5 November 2002.
SPC also approved a special funding for the assembly, integration, and testing of the Italian-provided spare kits of the PFS and VIRTIS experiments. In approving such funding, SPC has requested the experiment's principal investigators and the ESA Executive to proceed with a Europeanisation of the instrument's Science Teams.

We hereby invite the scientific community of the ESA Member States and Russia (as contributor) to submit scientific proposals to become a Co-Investigator of the PFS or VIRTIS instruments. **For this opportunity, we particularly encourage young scientists to submit proposals.**

Proposals of a maximum of 5 pages, dealing with the scientific usage of PFS and VIRTIS, should be submitted to ESA not later than **13 January 2003**.

Proposals written in Microsoft Word should be submitted via e-mail to:

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And in copy to:

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The proposer will find in the following text some information relative to the mission and its payload.

For more information on the Venus Express Mission Definition Report and the technical documentation for the VIRTIS and PFS instruments, these documents can be downloaded from this location:

http://sci.esa.int/content/doc/d3/31187_.htm

Venus Express

Venus Express, an Orbiter for the study of the atmosphere, the plasma environment, and the surface of Venus, started as a mission proposed to ESA in response to the *Call for Ideas* to re-use the Mars Express platform issued in March 2001. Venus Express, together with two other missions, Cosmic DUNE and SPORT Express, was selected for a Mission Definition Study by ESA's Space Science Advisory Committee. The industrial study, supported by representative science teams, of the three missions was conducted in parallel by Astrium-SAS (Toulouse, France) from mid-July to mid-October 2001. After study completion the Venus Express mission was selected as the best of the three and was eventually approved by SPC in November 2002.

The payload included in Venus Express comprises five original Mars Express/Rosetta instruments, ASPERA/MEx, PFS/MEx, SPICAM/MEx, VeRa/Rosetta and VIRTIS/Rosetta. During the Study it was found scientifically reasonable and technically feasible to replace the standard Mars Express engineering Video Monitoring Camera by a scientific instrument, the Venus Monitoring Camera (VMC) and later a Magnetometer (MAG) was added to further enhance the payload.

The first phase of Venus spacecraft exploration (1962-1985) by the Venera, Pioneer Venus and Vega missions established a basic description of the physical and chemical conditions prevailing in the atmosphere, near-planetary environment, and at the surface of the planet. At the same time, they raised many questions on the physical processes sustaining these conditions, most of which remain as of today unsolved. Extensive radar mapping by Venera-15,-16 and Magellan orbiters, combined with earlier glimpses from landers, have expanded considerably our knowledge of Venus' geology and geophysics. A similar systematic survey of the atmosphere is now in order. This particularly concerns the atmosphere below the cloud tops, which, with the exception of local measurements from descent probes, has escaped detection from previous Venus orbiters. Many problems of the solar wind interaction, in particularly those related to the impact on the planetary evolution are still not resolved. The Galileo Venus fly-by 1990 and later ground based measurements demonstrated the near IR windows in the atmosphere that allow probing of all levels of the atmosphere down to the surface.

The fundamental mysteries of Venus are related to the global atmospheric circulation, the atmospheric chemical composition and its variations, the surface-atmosphere physical and chemical interactions including volcanism, the physics and chemistry of the cloud layer, the thermal balance and role of trace gases in the greenhouse effect, the origin and evolution of the atmosphere, and the plasma environment and its interaction with the solar wind. Besides, the key issues of the history of Venusian volcanism, the global tectonic structure of Venus, and important characteristics of the planet's surface are still unresolved. Beyond the specific case of Venus, resolving these issues is of crucial importance in a comparative planetology context and notably for understanding the long-term climatic evolution processes on Earth. The above problems can be efficiently addressed by an orbiter equipped with a suite of adequate remote sensing and *in situ* instruments. Compared with earlier spacecraft missions, a breakthrough will be accomplished by fully exploiting the spectral windows in the near-infrared spectrum of Venus' night side, in which radiation from the lower atmosphere and even the surface escapes to space and can be measured. Thus, a combination of spectrometers, spectro-imagers, and imagers covering the UV to thermal IR range, along with other instruments such as a plasma analyser and a magnetometer, is able to sound the entire Venus atmosphere from the surface to 200 km, and to address specific questions on the surface that would complement the Magellan investigations. This mission will also tackle still open questions of the plasma environment focusing on the studies of non-thermal atmospheric escape.

The instruments developed for the Mars Express and Rosetta missions are very well suited for this task. The following available instruments: SPICAM – a versatile UV-IR spectrometer for solar/stellar occultations and nadir observations, PFS – a high-resolution IR Fourier spectrometer, ASPERA – a combined energetic neutral atom imager, electron, and ion spectrometer, VIRTIS – a sensitive visible spectro-imager and mid-IR spectrometer, a radio science experiment VeRa, a wide-angle monitoring camera VMC and a Magnetometer, will form the payload of the Venus Express mission. Taken together, these experiments can address all the broad scientific problems formulated above.

The Mars Express spacecraft can accommodate the above mentioned experiments with minor modifications. The launch with Soyuz-Fregat will deliver this payload to a polar orbit around Venus with a pericenter altitude of ~250 km and apocenter of ~66,000 km. This orbit will provide complete coverage in latitude and local solar time. It is also well suited for atmospheric and surface sounding, as well as the studies based on solar and radio occultations. In comparison to the Pioneer Venus spinning spacecraft, Mars Express is an advanced 3 axis stabilised platform which provides significantly enhanced spectroscopic and imaging capabilities. The duration of the nominal orbital mission is two Venus days (sidereal rotation periods), equivalent to ~500 Earth days, with a possibility for an extension of another two Venus days.

Mission scenario

The Venus Express spacecraft is planned to be launched in the beginning of November 2005 by a Soyuz/Fregat launcher from Baikonur. In April 2006 after ~150 days of cruise the spacecraft will be inserted into highly elliptical polar orbit around Venus. The observational phase will begin after about one month of commissioning phase. The orbit around Venus is inertially fixed, so that the full coverage of planetocentric longitudes will be accomplished in one Venus sidereal day (243 Earth days). The nominal mission orbital life-time is two Venus sidereal days. The first day will be devoted to the global latitude, longitude, and local time coverage of the planet. The second day will provide opportunity for filling observation gaps suffered during the first year, for returning and studying in more details selected objectives, for observing specific surface or atmosphere locations, for looking at time variability of phenomena observed during the first year. Favorable conditions for solar/stellar occultation's will occur in seasons during each of two Venus days.

Launch and mass budgets

The Soyuz/Fregat launcher will inject Venus Express directly into interplanetary orbit. It has a launch capability of 1260 kg for a Venus transfer orbit. However, the Mars Express spacecraft is designed for a maximum launch mass of 1200 kg. This latter number has been used for the mission design described here.

Venus has a synodic period of 16 months; therefore an optimum launch window to Venus occurs every 16 months. The launch opportunity in November 2005 with the launch window of about 2-3 weeks is assumed for Venus Express. The capture burn at Venus (Delta-V) is large. Therefore an initial capture burn will be followed by a series of apoapsis lowering maneuvers. A highly elliptical orbit with pericenter at ~250 km altitude a period of approximately 5 days, can be reached with a burn of approximately 1250 m/s. The apoapsis is then lowered by subsequent smaller burns, to achieve the operational orbit altitude.

Operational orbit

The Venus Express mission aims at exploring the Venusian atmosphere, the plasma environment and the surface geology of Venus from orbit. The preliminary selected orbit is quasi-polar with a pericentre altitude at ~250 km and apocentre altitude at around 66000 km with a period of about 24 hours. A high-inclination elliptical orbit provides complete latitudinal coverage and gives the best compromise for allowing both high-resolution observations near pericenter and global observations during the apoapse part of the orbit, and for in-situ measurements of the Venusian environment and its interaction with the solar wind. The altitude of the apocenter, hence the length of the orbit period depends upon the fuel load that can be embarked within the launcher lift capability. The lower the apoapse, the more fuel is required to achieve the final orbit. The range of acceptable apocentre altitudes provides a degree of flexibility for the development phase, and allows one to cope with the uncertainties that have been designed in the current mass budget, which includes a comfortable margin. The lower apocentre is preferred from the point of view of scientific return. It is preferable to have a pericentre latitude at about 60-70° N in order to study all latitudes in at least one hemisphere with high spatial resolution. The selected baseline orbit provides full latitude and local solar time coverage for the atmospheric observations and convenient conditions for tracking the cloud features from the apocentre. This orbit allows high-resolution surface observations of high latitudes in the northern hemisphere. For example, it allows good coverage of Ishtar Terra.

The final choice of the apocentre altitude at Venus orbit injection will be made later during the spacecraft development, and could even be adjusted during the transfer phase to Venus. It will be the result of trade-offs, balancing observation requirements with telecommunications periods, payload and spacecraft performances, and available fuel after trajectory correction about 60 days after launch.
Due to the low value of the J2 term of Venus gravity field, orbit apse rotation and nodal regression are very small. The only major orbit perturbation is the effect of solar gravity, which raises the periapse. Over one Venus sidereal day (243 Earth days) the periapse will raise by approximately 170 km. Fuel has been budgeted to lower the periapse as needed over the duration of the mission.

Orbital science operations

The “store and forward” concept of the orbital operations, implemented for the Mars Express and the Rosetta missions, fits the Venus Express requirements. The experiments will collect the data in the vicinity of pericentre and store them in the mass memory. The apocentre part of the orbit will be shared between global remote sensing observations, in-situ observations and data transmission periods. Some of the experiments will be designed for collecting data in the apoapse part of the orbit when it does not interfere with the downlink to the Earth. The solar/stellar occultation experiments will operate in short time slices per orbit off pericentre. The radio occultation experiment VeRa requires the high-gain antenna to point to the Earth or to Venus for providing radio occultation measurements of atmospheric structure or bistatic sounding of the Venus surface. This experiment will require pure carrier signal with telemetry "off".

Science payload

The payload is composed of seven instruments:

- ASPERA: Analyser of Space Plasmas and Energetic Atoms
- PFS: High-resolution IR Fourier spectrometer
- SPICAM: UV and IR spectrometer for solar/stellar occultation's and nadir observations
- VeRa: Venus Radio science instrument
- VIRTIS: UV-visible-IR Imaging Spectrometer
- VMC: Venus Monitoring Camera
- MAG: Dual Fluxgate Magnetometer

The Mars Express flight spare units will be used for the ASPERA, PFS and SPICAM experiments onboard Venus Express. VeRa and VIRTIS will be built from Rosetta flight spares. VMC is a newly developed instrument that will replace the Mars Express engineering Video Monitoring Camera. MAG is built new but has a strong heritage from the Rosetta Lander. Both these instruments will use existing interfaces of the Mars Express bus.

Minor modifications of some instruments in order to adapt them to the new environments and to improve them for specific tasks at Venus are foreseen within the time schedule imposed by the delivery of Flight Units in March 2004. Despite low costs they will significantly increase the scientific output.

Scientific Objectives and Payload Synergy

The experiments included in the Venus Express payload provide comprehensive and versatile investigation of various phenomena in the atmosphere, plasma environment, and on the surface of Venus. Combination of different observational tools gives the mission high level of synergy and redundancy ensuring the achieving of mission scientific objectives.

The ***temperature sounding*** of the atmosphere will be carried out in PFS, VeRa, VIRTIS, and SPICAM experiments. PFS measurements in the thermal infrared range will provide most unambiguous and accurate sounding of the mesosphere. VIRTIS will support these measurements in the apocenter portion of the orbit due to its narrow field of view. VeRa will expand the temperature sounding down to 35 km with vertical resolution of ~100 m that will give an opportunity to study small scale wave phenomena. Solar and stellar occultations by SPICAM will cover the altitudes from the clod top up to ~180 km.

The ***atmospheric composition*** will be investigated by VIRTIS, SPICAM, and PFS. In particular the lower atmosphere will be studied by spectroscopy and spectro-imaging in the near-IR transparency "windows". High-resolution measurements by VIRTIS and PFS in 2.3 µm "window" (H2O, CO, COS, SO2 at 30-40 km) will be complemented by SPICAM spectroscopy in the “windows” at $\lambda \leq 1.7$ µm that sound deeper in the atmosphere (H2O at 0-20 km). After modification PFS will be able to study the 1.74 µm “window” (H2O and HCl at ~20 km) and sub-micron emissions (surface and atmosphere above it) with even higher resolving power (up to 5000). The three experiments will provide additional data on the composition at the cloud top. Especially valuable will be high-resolution SPICAM observations in solar and stellar occultations that will give the atmospheric composition and isotope abundance up to the altitudes of ~180 km.

The ***atmospheric dynamics*** will be studied by tracking the motions of the cloud features in the VIRTIS and VMC images corresponding to the altitudes of 50 and 70 km. These observations will combine advantages of local imaging with moderate spectral resolution with global view of the planet taken in few spectral channels. These measurements will be complemented by the thermal wind field retrievals from the temperature sounding by PFS, VeRa, and VIRTIS. Comparison of simultaneous direct and indirect observations of winds will allow one to verify the hypothesis of cyclostrofic balance in the Venus atmosphere. Thermospheric dynamics will be derived from the airglow patterns observed by VIRTIS and VMC in the UV, visible, and near IR.

The ***escape processes*** will be investigated by the ASPERA imaging of the charged particles outflow via associated ENA:s as well as by direct detection of the escaping ions supported by the MAG measurements of magnetic fields imbedded in the plasma at orbit altitude. These observations in combination with vertical distributions of trace gases and their isotopes measured by SPICAM will help to derive escape rates of different molecules that is of crucial importance for understanding the atmospheric evolution.

The processes in the near Venus plasma environment will be studied by ASPERA, and VeRa. Combination of *in situ* plasma flow measurements by ASPERA and complementary remote sensing of ionospheric structure by VeRa will significantly contribute to our understanding of mechanisms of ionospheric composition, plasma transport, ionosphere-“magnetospheric” coupling, and the origin of the nightside ionosphere of Venus. These observations will be supported by local magnetic field measurements provided by MAG. Solar wind parameters measured by ASPERA will give a comprehensive picture of the interaction of the solar wind with Venus atmosphere. All four experiments will study the behaviour of ionosphere as function of local solar time, latitude and solar wind conditions.

Bi-static sounding in VeRa experiment will complement the study of surface properties. Spectroscopic, spectro-imaging, and imaging instruments onboard Venus Express (VIRTIS, PFS, SPICAM) will study the composition of the lower atmosphere and near surface lapse rate that will help to constrain the models of surface-atmosphere interaction. Mapping the surface temperature by VIRTIS and VMC would allow us to search for evidences of *volcanic activity*. Spectroscopic measurements in the upper atmosphere by VIRTIS and PFS will be able to detect waves indicative of the *seismic activity* on the planet.

The Planetary Fourier Spectrometer ,PFS

SCIENTIFIC AND TECHNICAL DESCRIPTION

The Planetary Fourier Spectrometer for the Venus Express mission is an infrared spectrometer optimised for atmospheric studies able to cover the wavelength range from 0.9 to 45 µm divided in two channels (LW and SW respectively) with a boundary at 5 µm. The spectral resolution is better than 2 cm^{-1} . The instrument field of view FOV is about 1.6° FWHM for the Short Wavelength SW channel and 2.8° for the Long Wavelength LW channel which corresponds to a spatial resolution of 7 and 13 km footprint when Venus is observed from a height of 250 km (nominal height of the pericentre). PFS can give unique data necessary to improve our knowledge not only of the atmosphere properties above the clouds deck, but also in the lower atmosphere, and therefore about the surface-atmosphere interaction.

PFS-VEX GOALS

The Venus Express mission focuses on the global investigation of the atmosphere and soil. The PFS is the key instrument onboard Venus Express to study the middle and lower atmosphere. The PFS-VEx experiment will provide basic new data about characteristics of the Venus climate and atmosphere that will be important for studying some important basic problems , namely:

PFS LW channel

- Long-term global 3-D measurements of the temperature field in 55–100 km altitude range.
- Subsequent determination of zonal and meridional components of the wind in the altitude range 55–100km.
- Monitoring of the upper cloud structure and composition;
- Measurements of abundance of SO_2, H_2O at 60–75 km altitude;
- Measurements of the outgoing thermal spectral fluxes (radiative balance);
- Investigation of the thermal tides and periodicities in the temperature and zonal wind fields, in the upper clouds and possibly in the abundance of minor compounds.

PFS SW channel (Day side observations)

1. Optical properties of the upper clouds. Determination of the optical properties of the upper clouds from the observations at different zenith and phase angles
2. Mixing ratio of minor compounds (H_2O, SO_2, CO, HCl, HF) in the atmosphere above the clouds and near the cloud tops.

Night side observations

- Study of the atmospheric composition (CO, COS, H_2O, SO_2, HCl) below the clouds[V)]
- Study of the cloud opacity and its variations[V)];

- Measurements of the temperature gradient at 0–10 km and the surface temperature$^{V)}$;
- Search for volcanic activity$^{V)}$.
- Thermal mapping of the surface in the 1 μm windows region (monitoring).

(day and night) Monitoring of the airglow emission of the O_2 $^1\Delta$ ro-vibrational band at 1.27 μm.

(Index $^{v)}$ designates items that require modifications of PFS-VEx as compared to the PFS-MEx)

Figures 2.4.1–2.4.3 present synthetic spectra of Venus in the range of PFS sensitivity. The spectrum of Venus outgoing radiation (as that of every planet) consists of two main parts: the solar reflected radiation and planetary thermal radiation. The boundary between both is near 2500 cm^{-1} (4 microns) for the dayside . All pronounced spectral features are CO_2 bands. There are many other spectral features that belong to minor constituents like CO, H_2O, etc. (see section 2.8) and can be used to estimate their abundances at different altitudes.

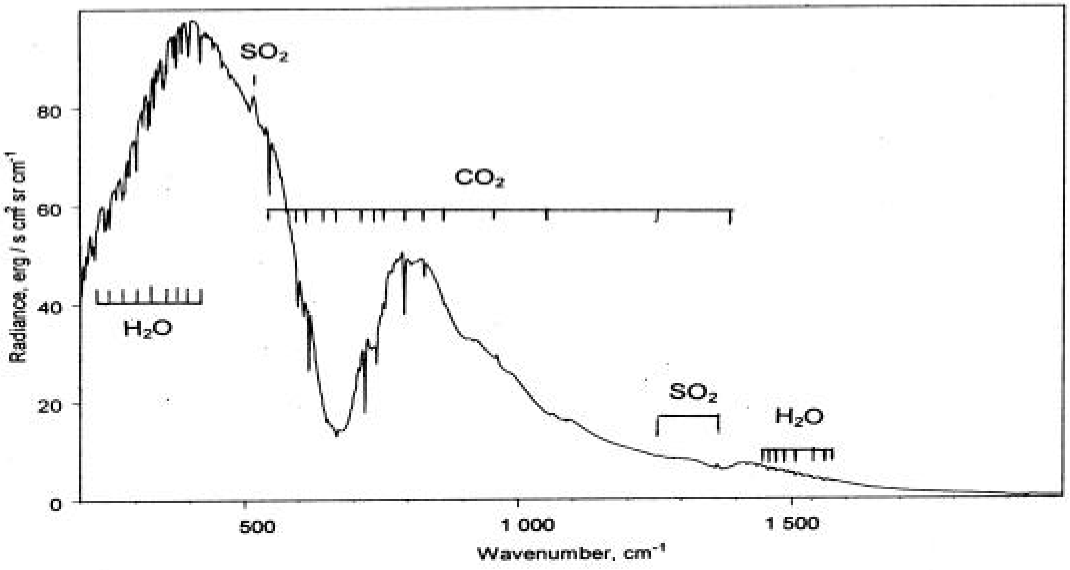


Figure 2.4.1. Venus synthetic PFS LWC spectrum. It is practically the same on the day and night side of the planet. If presented in terms of brightness temperature, the spectrum would be similar to that measured by Venera 15 shown in Figure 2.3.1 but with about 3 times better spectral resolution.

The shape of the LWC spectra is governed by the following factors:

(1) temperature profile;
(2) aerosol vertical profile, which defines the level of formation of radiation outside of the gaseous absorption bands:
(3) vertical profile and mixing ratios of the absorbing gases. Among them there are CO_2, the main constituent, and two minor: H_2O and SO_2.

The most pronounced CO_2 spectral feature is 667 cm^{-1} (15 μm) fundamental band. Other CO_2 features of special interest are 961 and 1064cm^{-1} hot bands, and 1259 and 1366 cm^{-1} isotopic ($^{12}C^{16}O^{18}O$).

H_2O is visible in two parts of spectrum: 280–475 cm^{-1} rotational band; 1590 cm^{-1} (6.3 μm) roto -vibrational fundamental band.

There are three bands of SO_2: ν_2 (519 cm^{-1}), ν_1 (1150 cm^{-1}) and ν_3 (1360 cm^{-1});

Some features belong to the liquid sulfuric acid: 450, 580, 900, 1150 cm^{-1} (the 580 cm^{-1} feature is in the wing of the 667 cm^{-1} CO_2 band)

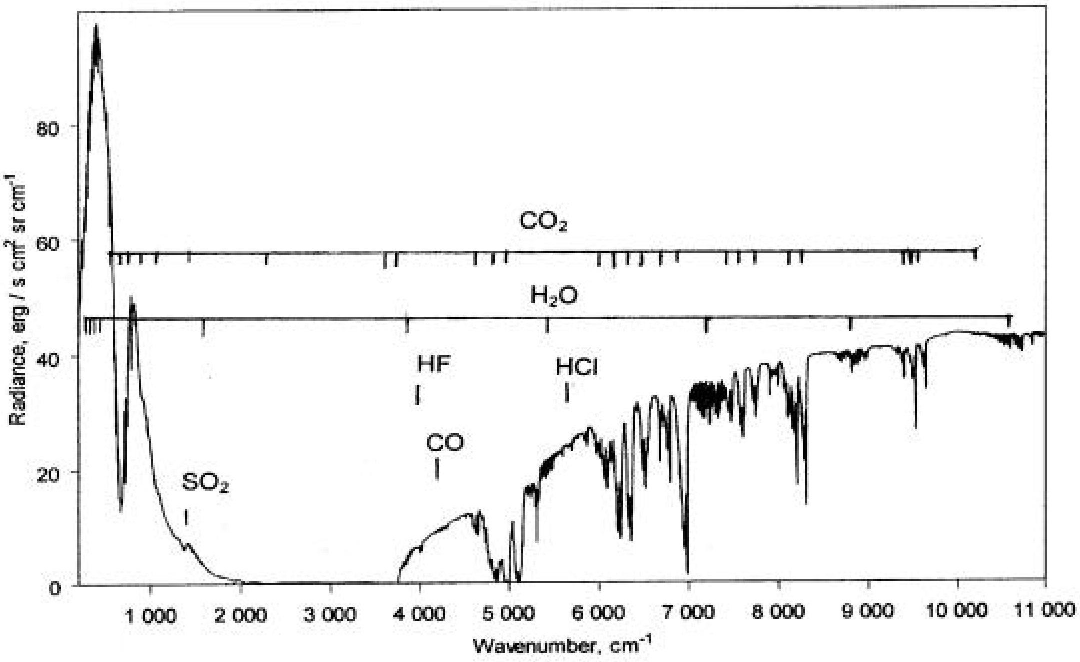


Figure 2.4.2. Venus synthetic PFS spectra for the day side of the planet. SWC range starts from 2000cm^{-1} (5 ìm).

The shape of the SWC spectra of the day side of the planet is governed by:

1. multiple scattering of the solar radiation by clouds particle clouds dominating above approximately >4000 cm^{-1};
2. true absorption of the of the solar radiation by the liquid H_2SO_4 in clouds particle dominating below <4000 cm^{-1};
3. abundances of absorbing gases (CO_2, H_2O, CO, HCl, HF) within and above upper clouds.

CO2 features are dominating everywhere. H_2O, CO bands are much weaker, but clearly visible. HCl, and HF are extremely weak.

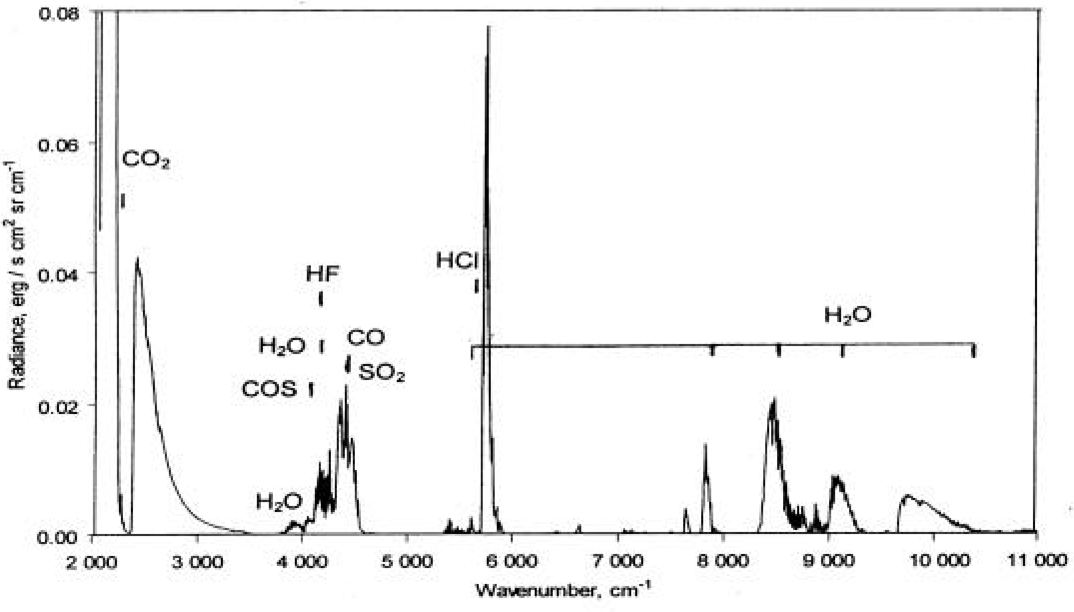


Figure 2.4.3. Venus synthetic PFS SWC spectrum for the night side of the planet.

The shape of the SWC spectra of the night side of the planet is governed by the following factors:

(1) temperature profile;
(2) vertical profile and mixing ratios of the absorbing gases. Among them there are CO_2, the main constituent, and several minor: H_2O, SO_2, CO, COS, HCl, HF. Spectral features of minor constituents are observable in “windows" between much stronger CO_2 bands.
(3) attenuation of radiation by clouds (for ν>3500 cm-1);
(4) thermal radiation of clouds (for ν<3500 cm-1);
(5) thermal radiation of surface (near 10000 cm-1);

The fundamental ν_3 CO_2 band near 2349 cm^{-1} is observable both in night and day side spectra but in the latter case its formation is more complicate due to superposition of the thermal and solar scattering radiation.

THE INSTRUMENT

The experiment is a double pendulum interferometer that will measure Venus radiation from 0.9 to 45 microns in two channels with a resolution of 1.5 - 2 cm -1 . The experiment will have real time FFT on board to be able to select the spectral range of interest for data transmission to ground, preferred , however , will be to transmit interferograms . Measurement of the 15 micron CO_2 band is very important .Its profile gives, by means of a complex temperature profile retrieval technique, the vertical pressure temperature relation, basis of the global atmospheric study. Essential for this study is the possibility to measure not only Venusian radiation , but also space (3 K black body) , a calibration B.B. These measurements are allowed by the presence of a pointing device with one axis of rotation. Consequently the FOV of the experiment requires an **unobstructed field view of 4 deg x 120 deg in a plane**

Summary of PFS parameters

	SW	LW
Spectral range, µm	0.9 - 5.0	5.0 - 45
cm^{-1}	2000 - 11000	222 - 1750
Spectral resolution, cm^{-1}	1.5	1.5
FOW, rad	0.02	0.044
NEB, W cm-2 sr-1	5 10^{-9}	4 10^{-8}
Measurement cycle duration, s	10	10
Detector Type	Photoconductor	Pyroelectric
Material	PbSe+PbS	LiTaO$_3$
Interferometer Type	Double pendulum	
Reflecting elements	Cubic corner reflectors	
Beamsplitter	CaF$_2$	CsI
Max.optic. path differ., mm	+- 5	+- 5

roughly perpendicular to the orbital velocity vector . In this field of view both Nadir and Space directions (at 90 deg from each other) should be contained.

PFS is made of 4 modules called O,E,P and S being respectively the Interferometer and proximity electronics, the digital control unit, the power supply and the pointing device. **Total mass of the experiment is 31.2 Kg** (O,E,P,S being respectively 21.5,3.0,2.1,3.6 Kg, Harness being 0.8 Kg) . **Peak power will be 45 W**, while the sleeping power is of the order of 14 W. PFS has two channels SW and LW , the first has a detector of PbSe+PbS that needs to be cooled to 200-220 K , therefore **we request a passive cooling (3 Watts radiated)** to the spacecraft. The second detector works at fixed room temperature. The interferogram of Venusian light is measured every 112,5 nm of physical mirrors displacement , corresponding to 450 nm optical path difference, by using a laser diode monochromatic light interferogram (a sine wave), whose zero crossings control the double pendulum motion and the light intensity acquisition time. PFS will be working not only around the pericentre of the orbit , with a footprint that in the best case is of 7 Km or 12 Km size for the SW and LW channels respectively. Being the repetition time of the measurements 1 every 10 sec, and the working time being +/- 1 hour around pericentre, a total of more than 700 measurements per orbit will be acquired corresponding to 224 Mbits per orbit. Compression of data on board is achieved in several ways (for example by computing the FFT of the interferogram on board). In the two hours of data taking, the atmospheric measurements will be made at high altitude, because atmospheric studies do not need high space resolution, while surface oriented measurements will be taken closer to pericenter, where higher space resolution can be achieved.. An important requirement of PFS is that we need to **measure at all local times** in order to have the atmospheric vertical temperature profiles also in the night side.

This will be the first Fourier spectrometer in orbit around Venus covering the wavelength range 1 to 5 microns.

The Visible and Infra Red Thermal Imaging Spectrometer, VIRTIS

VIRTIS is a complex instrument initially devoted to the remote sensing study of comet Wirtanen on the Rosetta mission, at wavelengths between 0.3 and 5 µm. The focal planes, with state of the art CCD and infrared detectors achieve high sensitivity for low emissivity sources. Due to the high flexibility of the operational modes of VIRTIS, these performances are also ideally adapted for the study of Venus atmosphere, both on night and day sides. VIRTIS is therefore aimed to provide a 4-dimensional study of Venus atmosphere (2D imaging + spectral dimension + temporal variations), the spectral variations permitting a sounding at different levels of the atmosphere, from the ground up to the thermosphere. The infrared capability of VIRTIS is especially well fitted to the thermal sounding of the night side atmosphere (Taylor et al, 1997), which give a tomography of the atmosphere down to the surface.

Precursors: First attempts of imaging spectrometry on the Venus night side from space in the near infrared were made by NIMS/Galileo (Figure 1) in 1990 (Carlson et al, 1990) and VIMS/Cassini in 1999 (Baines et al, 2000). These fast fly-bys gave an idea of how powerful this method of investigation could be at Venus. Unfortunately, the limited duration of the fly-bys allowed only limited investigations, in particular on the meteorological evolution of the clouds. Observation of Venus with a new generation imaging spectrometer like VIRTIS would provide a unique opportunity to continue these investigations on an extended basis.

General description: VIRTIS is a sophisticated imaging spectrometer that combines three unique data channels in one compact instrument. Two of the data channels are committed to spectral mapping and are housed in the Mapper (-M) optical subsystem. One frame records a spectral image, and the second image dimension is obtained through a scanning mirror, to be combined with S/C motion. The third channel is devoted solely to spectroscopy and is housed in the High resolution (-H) optical subsystem. Both channels operate simultaneously, or separately, depending on observing modes. They are boresighted, and combined operations therefore provide a spectral image of 64 mrad from the 2 VIRTIS-M channels, associated with one spectral image. In Figure 2, a simple graphic representation of the output data is given.

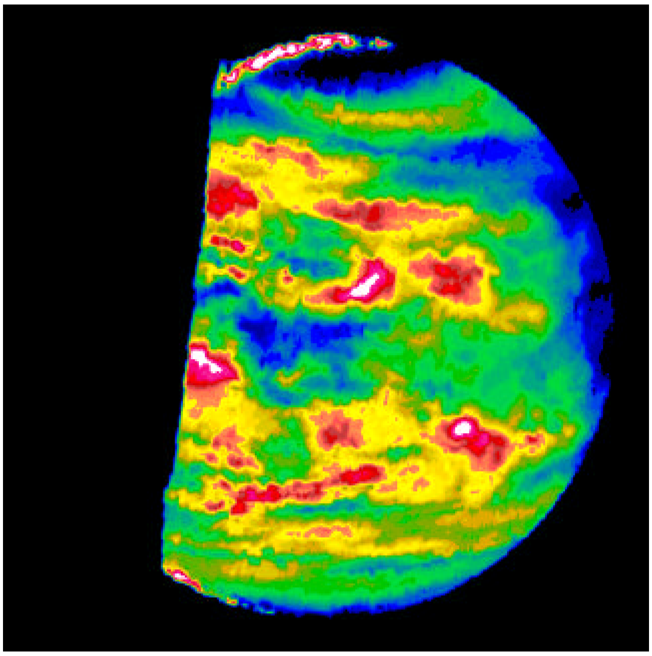
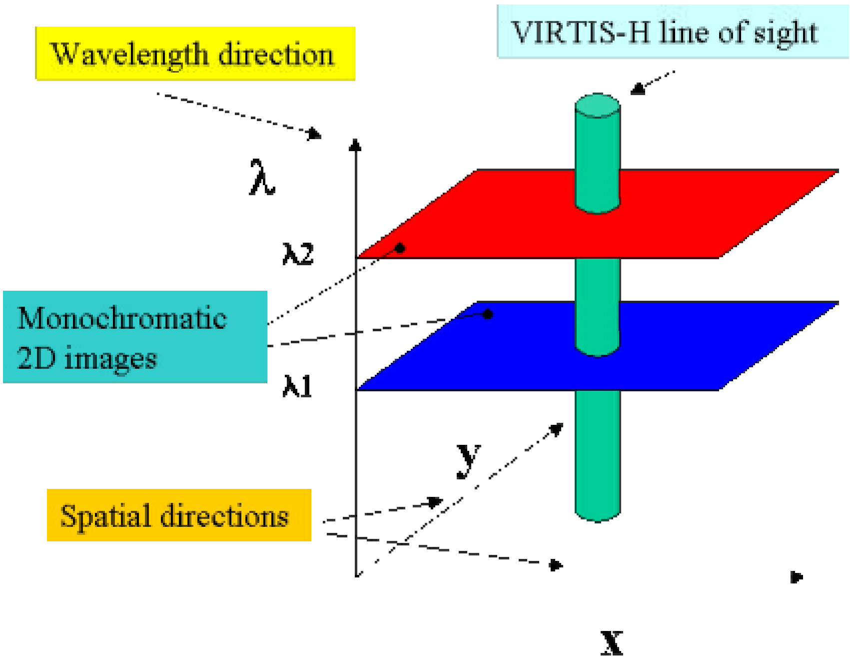


Figure 1:

Image of Venus (night side) at 2.3µm, taken by Galileo (Carlson et al, 1990). The thermal emission from the deep atmosphere is modulated by the cloud structure of the deeper atmosphere. Cloudy regions appear in blue (lower emission), when bright regions (in red) correspond to less cloudy regions.

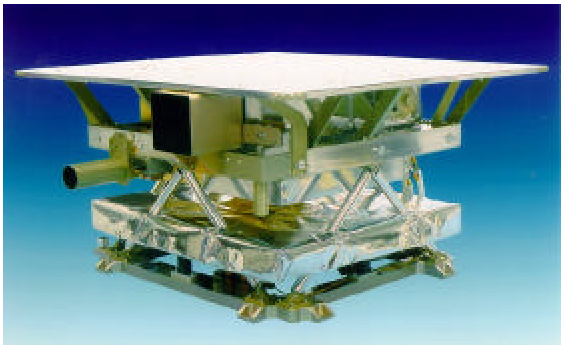
Figure 2:

The output from VIRTIS-M can be considered to be a large set of stacked monochromatic two-dimensional images in the range between 0.25 to 5 µm, at moderate spectral resolution. The field of view of VIRTIS-H centered in the middle of the –M image provides spectra at high spectral resolution in this small portion of the frame.



HARDWARE DESCRIPTION : VIRTIS is an imaging spectrometer combining three data channels in one compact instrument. Two of them are devoted to spectral mapping (Mapper optical subsystem: -M). The third channel is devoted to spectroscopy (High resolution optical subsystem: -H). The Optics Module is electrically connected by the Inter-Unit Harness to the -M and -H Proximity Electronics Modules and to the Main Electronics Module, which are internally mounted to the spacecraft.

The -M utilizes a silicon charge coupled device (CCD) to image from 0.25 µm to 1 µm and a mercury cadmium telluride infrared focal plane array (IRFPA) to image from 1 µm to 5 µm. The -H employes the same HgCdTe IRFPA to perform spectroscopy from 2 µm to 5 µm. The electronics to drive the CCD and the two IRFPAs are housed inside the Proximity Electronics Modules, while the remaining electronics boards are housed inside the Main Electronics Module. Both IRFPAs require active cooling to minimize the detector dark current (thermally generated Johnson noise). To minimize the thermal background radiation seen by these two



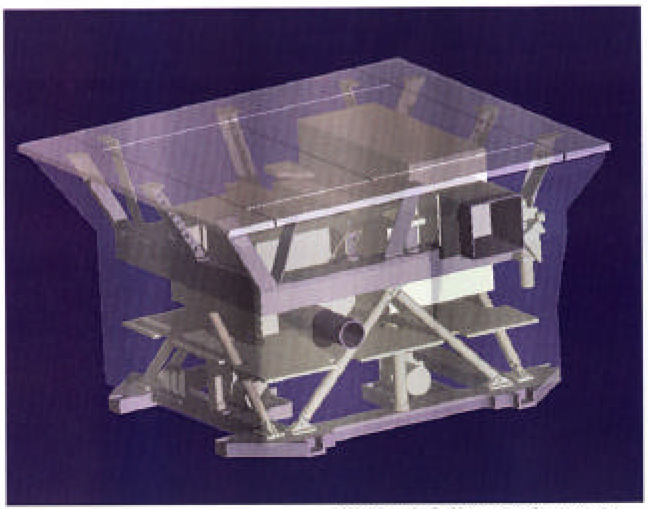


Image Officine Galileo

IRFPAs, the Cold Box must be passively cooled to less than 130 K by radiating one of its surfaces toward cold space. While the coolers are housed inside the Optics Module Pallet, which directly interfaces with the warm spacecraft, the cold detectors and optical systems are housed in a cold structure that must be rigidly mounted to the much warmer Pallet while remaining thermally insulated from it. The structure of VIRTIS/Rosetta will be adapted to the Venus Express spacecraft, with different conditions from the Rosetta mission. Models show that for temperatures of the optics module lower than 150 K, scientific specifications for Venus atmospheric studies should still be guaranteed. The team intends to work closely with the spacecraft engineers to ensure that the interface to the spacecraft is likewise kept simple and straightforward.

VIRTIS technical specifications:

Table 1. Expected parameters of the measurements of the atmospheric composition below the clouds by VIRTIS-H and -M (for wavelength shorter than 2µm)

Trace gas	**Wavelength, mm**	**Altitude,km**
H_2O	1.1- 1.18 1.74 2.40-2.43	0-12 20 33
HDO	2.38-2.46	33
CO	2.3	30-40
COS	2.43	30-40
SO_2	2.46	40

VIRTIS/M channel: mapping spectrometer with moderate spectral resolution (R ~ 200) and high spatial resolution of 0.25 mrad (250m at 1000 km altitude), which uses two detectors (1) CCD (0.25 - 1 µm) and (2) IR FPA (1-5µm);

VIRTIS/H - echelle high resolution spectrometer (R ~ 1200) using an IR FPA detector (2-5µm).

The IR/FPA are high sensitivity detectors (HgCdTe arrays of 270 x 438 pixels) specially designed to provide high sensitivity and low dark current (10 fA at 80 K), with a read noise lower than 500 e^-. For 1 sec integration, the noise equivalent spectral radiance is of the order of $5\ 10^{-5}$ W $m^{-2}sr^{-1}\mu m^{-1}$ for both Virtis H and M at 2.3 µm. According to the Figure 3 above, the maximum expected flux on Venus on the night side in this window is as high as 0.15 W $m^{-2}sr^{-1}\mu m^{-1}$, ensuring a S/N higher than 100, even for colder area. The FPA of both channels is actively cooled by cryocoolers down to the operating temperature of 80 K. On Rosetta, the spectrometer is passively cooled down to T= 130 K by the radiator on the cold panel pointing to the deep space. Due to the thermal constraints on Venus Express, and the comfortable Signal to Noise ratio expected on Venus, the specification on the Optical Module temperature can be relaxed. Simulations on Virtis H show that a temperature of T=150 K on the optical module still provide a S/N higher than 100 for a 1 sec integration time. The spectrum expected from VIRTIS/H is shown in Figure 3 while VIRTIS-M will systematically obtain maps of surface brightness distribution similar to that shown in Figure 1.

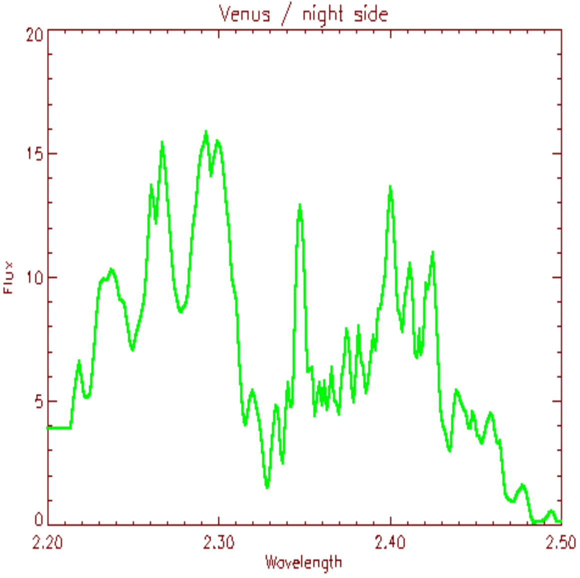


Figure 3:

Synthetic spectrum of Venus night Side at the spectral resolution of VIRTIS-H. Spectral features absorb the themal emission of the surface, with absorptions of CO_2, H_2O, CO, OCS and SO_2. The unit of radiance is in $\mu W cm^{-2} sr^{-1} \mu m^{-1}$

Scientific goals: The main scientific goals of VIRTIS at Venus are the following:

Study of the lower atmosphere composition below the clouds and its variations (CO, OCS, SO_2, H_2O) (see Table 1) from night side observations (Collard et al., 1993; Drossart et al., 1993);

Study of the cloud structure, composition, and scattering properties (day side observations) (Roos et al., 1993);

Cloud tracking in the UV (~70 km, day side) and IR (~50 km, night side);

Measurements of the temperature field with subsequent determination of the zonal wind in the altitude range 60-100km (night side);

Lightning search (night side);

Mesospheric sounding: understanding the transition region between troposphere and thermosphere

(1) non-LTE O_2 emission (night/day side) at 1.27 µm (95-110 km) (Drossart et al., 1993);

(2) CO_2 fluorescence (day side): non LTE emissions at 4.3µm (>80km) (Roldan et al., 2001)

(3) limb observations (CO, CO_2): atmospheric vertical structure (> 60 km) (day/night side);

Search for variations related to surface/atmosphere interaction, dynamics, meteorology, and volcanism;

Temperature mapping of the surface, search for hot spots related to volcanic activity;

Search for seismic waves from propagation of acoustic waves amplified in the mesosphere: search for high altitude variations of pressure/temperature in CO_2 4.3 µm band (Artru et al, 2001).

VIRTIS will also provide true colour high definition images of Venus that are of great value for public outreach programme.

Observation strategy for VIRTIS: To achieve the scientific objectives, VIRTIS must observe both day and night side, and to work with full imaging spectroscopy capabilities, VIRTIS must be able to reconstruct spectral images from the orbit of Venus Express. With the orbit of Venus express (24h/400-66000 km), the spatial resolution of VIRTIS is always better than 20 km at apoapsis. This spatial resolution is consistent with the science objectives of cloud structure (Galileo/Venus global observations had a 15-30 km resolution). It is also consistent with surface studies in the IR, because the scattering in the Venus clouds blurs the thermal flux coming from the surface over a scale range comparable to the cloud height (30 km). Therefore, the altitude of the S/C is not a limiting factor for VIRTIS observations.

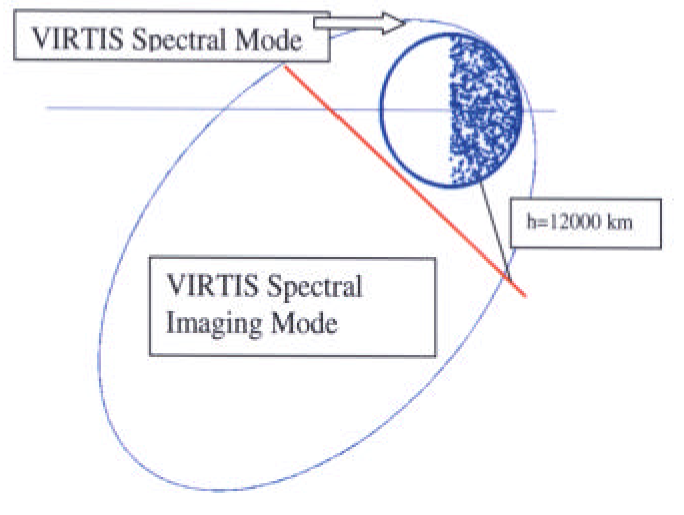


Figure 4 VIRTIS modes of observations.

Due to a minimum repetition time between two VIRTIS spectral images of the order of 2.5 sec, the observation strategy is divided into two parts on the orbit, depending on the dwell time on Venus being shorter than the repetition time (no image reconstruction) or larger (image cubes can be obtained). Therefore, the VIRTIS observations are separated into two categories, corresponding to altitudes lower than 12000 km (spectral mode) or higher (spectral imaging mode) (Figure 4):

Spectral mode (h < ~12000 km): This mode will be used for joint VIRTIS/PFS observations. Only a partial coverage of the surface is obtained in this mode, but the coverage reaches about 15% of the surface after 7 orbits, covering a statistically significant part of the disk. In particular, the cloud variability and related atmospheric composition variability will be tracked, as in the Galileo/NIMS studies (Collard et al, 1993; Drossart et al, 1993). Data volume is of the order of ~ 144 Mbits/hour of observation.

Spectral Imaging mode (h > ~12000 km): cube reconstruction is possible by scanning mirror operations.. Data volume: total amount of 240 to 600 Mbits.

Repetition of observations. Due to the atmospheric rotation in 4 days, an atmospheric program will consist in observation campaigns to cover the time variability in short medium and long term. A definition of science operation strategy will of course need a global discussion between instrument teams and satellite operator, to define the best compromise for science return.

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