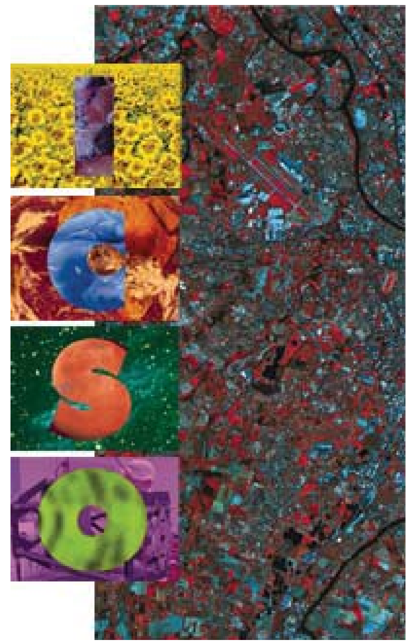
International Conference on Space Optics—ICSO 2000

Toulouse Labège, France

5–7 December 2000

Edited by George Otrio



The ground calibration of the VIRTIS/Rosetta experiment

Guillaume Bonello

esa icso proceedings cnes

International Conference on Space Optics — ICSO 2000, edited by George Otrio, Proc. of SPIE Vol. 10569
105692J · © 2000 ESA and CNES · CCC code: 0277-786X/17/$18 · doi: 10.1117/12.2307863

THE GROUND CALIBRATION OF THE VIRTIS/ROSETTA EXPERIMENT

Guillaume BONELLO

Institut d'Astrophysique Spatiale
Université Paris-Sud - Bât. 121 - 91405 Orsay Cedex – France
guillaume.bonello@ias.u-psud.fr

RESUME – L'expérience VIRTIS, compte tenu de ses objectifs scientifiques, a franchi une étape technologique en terme de performances d'analyse dans le domaine des instruments de spectro-imagerie. L'étalonnage au sol devient, dès lors, une étape essentielle dans la préparation de la mission. Après une description générale du dispositif expérimental d'étalonnage au sol et de ses objectifs, je présenterai les performances attendues nécessaires pour la conduite de cet étalonnage.

***ABSTRACT** – The VIRTIS experiment, due to his scientific objectives, has made a technologic gap in terms of analysis performances in the field of imaging spectrometers. The ground calibration is, thus, a fundamental step to achieve a meaningful preparation of the scientific data reduction and analysis. Following a general description of the experimental set-up and its goals, I will present the expected performances that are needed in order to make the ground calibration of VIRTIS experiment.*

1. INTRODUCTION

The ROSETTA mission, third ESA corner stone, will be launched in january 2003 to rendezvous with comet 46 P/WIRTANEN in 2011 at large heliocentric distance (> 3 AU) and to provide an in-depth study over several months, till it reaches perihelion (1 AU). Comets are supposed to be very primitive objects, with most of their properties acquired at the time of their accretion with little further evolution: their study have the potential to describe the conditions prevailing when the Solar System formed, some 4.5 billions years ago. On board ROSETTA, the VIRTIS investigation is designed to determine the composition and the properties of both the nucleus and the coma, as it will develop while approaching the Sun.

2. THE VIRTIS EXPERIMENT

To achieve this goal, VIRTIS will combine imaging and spectrometry, providing for each resolved pixel the entire spectrum, from 0.25 to 5.2 µm, in roughly 800 contiguous spectral channels. In addition, VIRTIS will give, for the bore-sight pixel (point spectrum), a very high resolved spectrum ($\lambda/\Delta\lambda > 1500$) to unambiguously identify all species, including the complex organic likely to constitute the major C-rich components. VIRTIS is thus constituted of two co-aligned channels (VIRTIS-M and VIRTIS-H), each with a telescope and a spectrometer, and three focal planes: a visible CCD matrix (254x421 and 19µm pixel pitch), and two IR bi-dimensional HgCdTe arrays (270x434 and 38µm pixel pitch), each cooled down <70K by a dedicated cryocooler, the spectrometers being passively cooled down <130K by a radiator facing the sky. The table 1 summarises the expected performances attached to each detector (Coradini 99).

	VIRTIS-M (Vis)	VIRTIS-M (IR)	VIRTIS-H
Spectral range	0.25 - 1.0 µm	0.95 - 5.0 µm	2.0 - 5.0 µm
Spectral resolution	6 nm (default) 2 nm (high)	30 nm (default) 10 nm (high)	1 to 2.5 nm
S/N ratio	> 100	> 100	> 100
Radiometric sensitivity Absolute Relative	 < 20 % < 1 %	 < 20 % < 1 %	 < 20 % < 1 %
Field of view	64mrad - 3.6°	64mrad - 3.6°	0.58x1.74mrad - 2'x6'
Instantaneous FOV	0.250mrad - 51.5"	0.250mrad - 51.5"	< 1 mrad

Table 1 : Performances of VIRTIS

VIRTIS is developed in international co-operation, with A. Coradini (Italy) PI; IAS (France) is responsible for the ground calibration; this final development phase is critical for the scientific reduction of the data that will be down-linked from the S/C.

3. THE GROUND CALIBRATION

3.1. Goals of the ground calibration

The goals of the calibration can be summarised as follows: to validate all operation modes; to determine the instrument response, in a variety of environmental conditions likely to match those VIRTIS will experience around the comet. VIRTIS operating as a spectral imager, it is required to acquire its absolute radiometric, spectral and geometrical responses, as a function of the various instrument temperatures (focal plane, spectrometer), in the entire field of view. During calibration, the instrument must be maintained in an environment (mechanical, optical, thermal) simulating the space, illuminated by a variety of reference sources, and controlled by a GSE (Ground Support Equipment) equipped with a Spacecraft simulator so as to validate all interfaces, including the data transfer and acquisition.

3.2. Experimental set-up overview

The VIRTIS calibration facility at IAS, presented on the figure 1, includes: an ultra-clean vacuum chamber, equipped with a variety of thermal regulation systems; a two-axis rotating

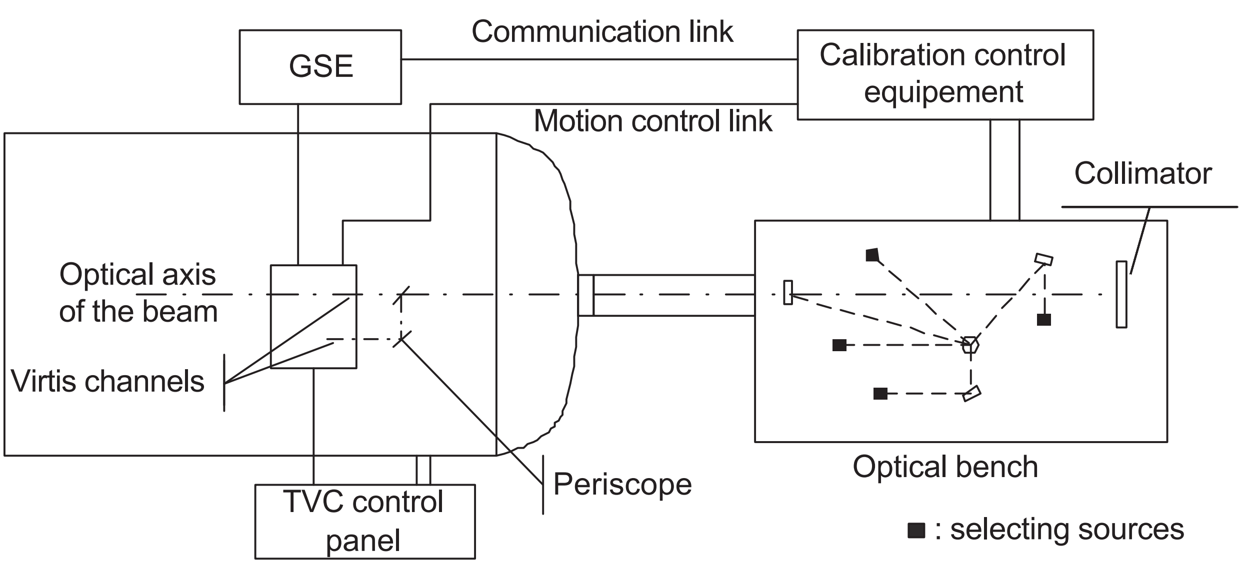


Fig 1 : Overview of the ground calibration set-up

platform, with a 5 arcsec angular sampling within a ± 45° total range to explore the straight light contamination; an optical bench with several radiometric and spectral sources; a carousel with reference solid and gaseous samples; the hardware and software interfaces required both to control the facility and to acquire all environmental data, operating with the VIRTIS GSE in a master/slave I/F, so that each science data acquired by the instrument will be coupled to the relevant parameters of its environment (optical sources, temperatures...).

4. PERFORMANCES OF THE EXPERIMENTAL SET-UP

4.1. Environment

The vacuum chamber provides an 10^{-7}mbar environment. A 250mm diameter CaF_2 window let incoming light beam to illuminate the entrance pupil of the VIRTIS channels. The thermal regulation is provided by a system combining cooling by a liquid nitrogen circulation and heating by resistive heaters. The thermal control system can regulate four different subsystems of the instrument at temperature ranging from 120°K to 313°K, with an accuracy high enough to explore instrumental response. A decontamination cold plate, located inside the vacuum chamber, avoid deposits on the flight model optics.

The VIRTIS ground support equipment includes a fully functional control system of the experience and a simulator of the spacecraft. The calibration control equipment, on its side, allow to run the calibration sessions by controlling the configuration of the experimental set-up. A communication protocol between the GSE and the calibration control equipment make the data acquired by the instrument synchronised with the environment data files, which is critical to achieve a meaningful calibration.

4.2. Optical

The optical bench provides an homogeneous beam which brings the light from the sources to the entrance pupil of the channel. In order to simulate remote observations, the sources are located in the focal plane of a four meters focal length collimator. This configuration makes the sources seen by the experiment like at infinity. On this optical bench, four different sources can be selected by a rotating mirror. Table 2 gives the characteristics of these sources.

	Size/FOV	Main characteristics	Calibration
Variable blackbody	30mm/7.5mrad	Temperature range : 100°C to 1200°C Emissivity : 0.99 %	Radiometric Geometric
Cold blackbody	80mm/20mrad	Temperature :80°K	Radiometric
Monochromatic source	4mm/1mrad	Spectral range : 0.25µm to 5µm Spectral resolution : 1nm Spectral scanning step : 0.1nm	Spectral
Ribbon lamp	0.1mm/25µrad	Filament temperature : 2500°C	Geometrical

Table 2 : Properties of the calibration sources

The exit pupil of blackbody with variable temperature is magnified by a factor two which gives the ability to cover a larger portion of the VIRTIS-M field of view and to illuminate, in the focal plane of the magnified image, reticles with grid or pinhole patterns used as geometric reference.

In addition, the ribbon lamp, also magnified, will support the presence of gas cells to provide real absorption spectra and a bi-conical reflectance spectra equipment that will allow analysing reference samples.

One goal of the geometrical calibration is to evaluate the misalignment of the two channels. This is particularly critical to locate the point-spectrum acquired by VIRTIS-H in the VIRTIS-M map. Thus both channels must be illuminated by the same beam to achieve this measurement. The dimension of such a beam is 360mm in diameter. Due to technical constraints, the solution adopted is to pick a part of the 250mm beam provided by the collimator and redirect it on the VIRTIS-H entrance pupil. This system is the periscope on the figure 1.

4.3. Mechanical

The sampling for the geometrical calibration can be done either by the motion of the sources in the focal plane of the collimator or by moving the optical incident beam axis relatively to the optical channels axis. This second solution has been chosen for VIRTIS calibration. A dedicated mechanical interface provides a fine two rotations axis motion. The position of these rotations axis have been optimised to minimise the dimension of the incoming beam and to allow an exploration of the straight light contamination in the range of ϒ 45°. Its characteristics are summarised in the table 3.

	Rotations speed	Rotation resolution	Rotation range
Moving platform	1°/s	175µrad	+ 45° to - 45° in both rotations axis

Table 3 : Moving platform characteristics

5. CONCLUSION

I present the rationale for and the performances of all subsystems of this facility, which are of relevance, beyond VIRTIS/ROSETTA, for the calibration of imaging spectrometers for a number of applications. Indeed, similarity in the design of the remote sensing instruments that use the technique of spectral-imagery is high enough to provide the same experimental set-up for their calibration. At IAS, following VIRTIS, we will use the same experimental set-up to calibrate the OMEGA/MARSEXPRESS instrument, which will map the entire surface of Mars in 2004-2005 using similar techniques as VIRTIS. The table 4 presents the performances expected for the OMEGA experiment (Puget 95).

	VNIR	SWIR-C	SWIR-L
Spectral range	0.35 - 1.05 µm	1.0 - 2.77 µm	2.65 - 5.2 µm
Spectral resolution	2.5 nm	14 nm	20 nm
S/N ratio	> 100	> 100	> 100
Radiometric sensitivity Absolute Relative	 < 20 % < 1 %	 < 20 % < 1 %	 < 20 % < 1 %
Field of view	154mrad - 8.8°	154mrad - 8.8°	154mrad - 8.8°
Instantaneous FOV	1.2mrad - 4.125'	1.4mrad x 1.1mrad 4.95' x 3.71'	1.4mrad x 1.1mrad 4.95' x 3.71'

Table 4 : Performances of OMEGA

This approach will provide the capitalisation of experience on implication of ground calibration in the analysis and the reduction of scientific data. This is a major challenge in order to prepare the amount of spectral-imagery data that will be produce by remote sensing spaces experiments for the study of the Solar System bodies in the next ten years.

6. REFERENCES

[Coradini 99] A. Coradini, F. Capaccioni, P. Drossart, A. Semery, G. Arnold, U. Schade "VIRTIS: the imaging spectrometer of the Rosetta mission", *Adv. Space Res.*, 1999, Vol. 24, pp. 1095-1104.

[Puget 95] P. Puget, J. L. Beney, J. P. Bibring, Y. Langevin, A. Semery, A. Soufflot "OMEGA IR spectal imager for Mars 96 Mission", *Proceedings of SPIE's International Symposium*, 1995, Vol. 2583, pp. 323-330.