The wide angle camera of rosetta

Giampiero Naletto
Department of Physics and Astronomy, University of Padova, Via Marzolo 8, Padova, Italy
giampiero.naletto@unipd.it

Keywords: Space Instrument, Wide Angle Camera, Rosetta

Abstract. Rosetta was the ESA cornerstone missions which investigated the comet 67P/Churuymov-Gerasimenko. One of the on board instruments was the OSIRIS imaging system, which included the Wide Angle Camera. This camera was designed, realized, integrated, aligned and tested at the Padova University. Several challenges had to be faced and solved, due to stringent requirements and the very peculiar mission profile which foresaw a long interplanetary travel with very different thermal environments. Rosetta has been a very successful mission which returned plenty of fundamental information about comets and more in general about the solar system origin. In this paper we summarize the main characteristics of the WAC and describe one of the many scientific results that it had returned.

Introduction

Rosetta was one of the ESA cornerstone missions, and it was dedicated to the investigation of the comet 67P/Churuymov-Gerasimenko. Launched on 2 March 2004, after a 10-year journey it arrived at the comet on 6 August 2014 and orbited around it until the controlled landing on the comet nucleus on 30 September 2016. One of the on-board instruments was the OSIRIS [1] imaging system, which consisted of two cameras, the Narrow Angle Camera and the Wide Angle Camera (WAC). The latter was realized under Italian responsibility, with contributions from other European partners. In particular, this instrument has been designed, realized, integrated, aligned and tested at the Padova University, with a coordinate effort of several departments.

The realization and testing of the WAC lasted several years during which also many young researchers have been involved, at their first work experience on a space instrument. The project started with the optical design and tolerance analysis, then the thermomechanical design followed. Different breadboard models were realized to check the subsystem's performance; then the camera qualification model was integrated and fully checked, and finally the flight model was prepared for launch after calibration. Several challenges had to be faced and solved during the instrument realization, due to the very peculiar mission profile which foresaw a long interplanetary travel with very different thermal environments. Rosetta has been a very successful mission which returned plenty of fundamental information about comets and more in general about the solar system origin.

The OSIRIS Wide Angle Camera

The two cameras of OSIRIS had complementary objectives. On one side, the Narrow Angle Camera had to be a system with high spatial resolution, to study the comet nucleus comet and in particular its structure and geological features. On the other, the WAC had a lower spatial resolution but a wider field of view and higher sensitivity, for observing the gas and dust flow around the nucleus [2]. The WAC optical configuration was an all-reflective two-mirror design, realized with an off-axis convex oblate ellipsoidal mirror followed by an almost on-axis concave oblate ellipsoidal mirror. The field of view was about 12°×12°, collected by a 2048×2048 CCD providing an average image scale of 21 arcsec/pixel. The optical performance was diffraction limited. The covered spectral range, 240-750 mm was selectable by 14 different filters, defined on the basis of the scientific requirements.

The WAC structure was based on a closed box made of aluminum alloy (see Fig. 1); it was lightweighted by electro-erosion machining. The structure was designed to prevent noise induced through vibration and to minimize vibration amplification at interfaces with mechanisms. Very challenging was the thermo-mechanical design [3], that had to satisfy the optical alignment tolerances. In fact, it was verified by ray-tracing simulation that the system could tolerate a relative shift of ±10 μm between the two mirrors, that is over a distance of 30 cm, during all mission lifetime: by thermal modelling, it was verified that to maintain this tolerance, the operational temperature of the WAC optical bench had to be maintained within the 12±5°C range. For an instrument that had to operate from 4 au to 1 au, that is with a great thermal excursion, having a square entrance aperture of about 15 cm side through with heat is exchanged with the space environment, this was a very critical requirement to be satisfied.

To guarantee the optimal optical performance notwithstanding the great thermal excursion over the mission, great care was dedicated to the thermo-structural design. In particular, the WAC interfaced with the payload spacecraft panel by three kinematic mounting feet, which minimized the heat exchange. A truss structure was designed to improve the thermal decoupling between the large external baffle (this was the most critical element for the thermal design, and at the end a glass reinforced epoxy structure with absorber coating, thermally insulated from the camera, was shown to be the best solution) and the optical bench and to minimize the temperature gradient. Finally, the telescope was covered by a thermal blanket. In addition, the optic supports were made of the same material as the optical bench to minimize distortion. Even if this allowed to limit the heat exchange of the WAC with the environment, it was necessary to introduce an active control system in the camera by suitable radiators (visible on the bottom of the optical bench in Fig. 1 left).

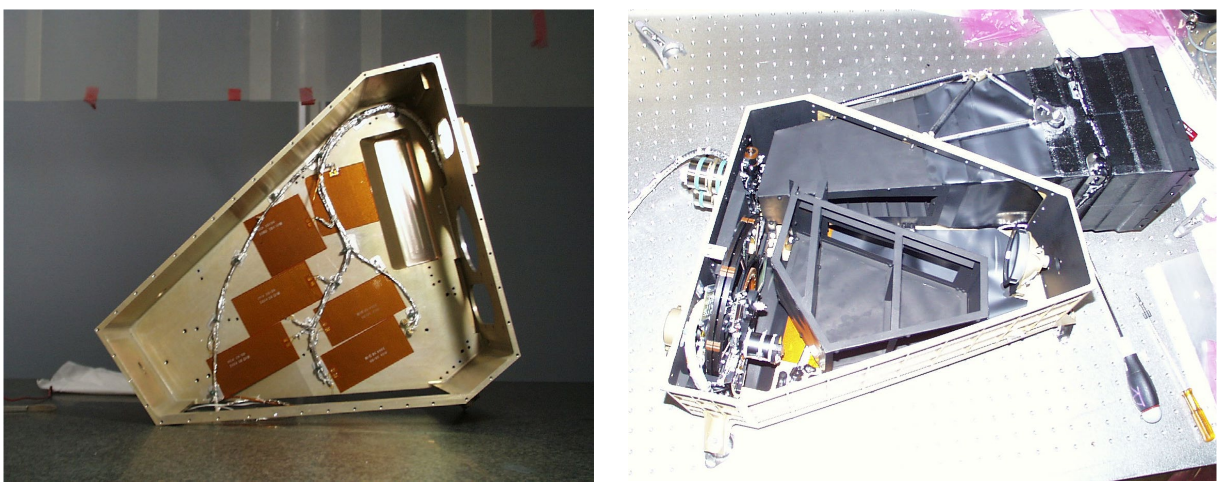

Fig. 1. On the left there is the WAC structure, obtained by excavating a single Al piece. On the right the WAC structure populated with all the optical elements.

As an example of the various mechanisms installed on the WAC, we describe here some of the characteristics of its shutter [4] (see Fig. 2), which has been the most operated one over the whole mission (more than 70k cycles). The shutter could expose a 28 × 28 mm^2 area (the sensor sensitive area was about 26 × 26 mm^2) with a uniformity better than 1/500. The shutter was realized by two blades travelling in front of the CCD, driven by a four-bar mechanism actioned by brushless dc motors. A customized encoder for each blade was mounted to the motor shaft and a position sensor at the final position verified that the first blade completed its travel, when reaching the lock device which kept it in open position. Then, when the exposure was completed, the second blade was released and unlocked the first, to back-travel together to the rest position by means of springs.

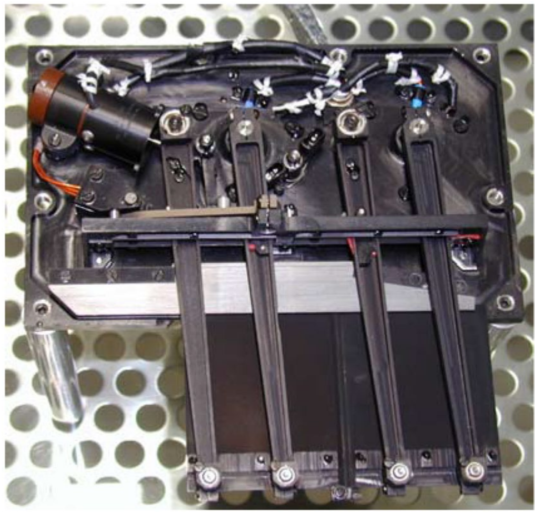

Fig. 2. WAC shutter mechanism; the blades are at the bottom, each joined to two moving bars.

WAC scientific results highlights

Rosetta, and in particular its imaging system OSIRIS, had a very large scientific return (e.g. [5],[6],[7]). Here we limit to recall one of the investigations realized with the WAC, and that took advantage of its extremely high contrast performance. In fact, this camera had as a target the observation of dust and gas in the comet coma and, because of the extremely low irradiance of these comet components, it was designed with an unobstructed optical configuration to minimize diffraction tails in the point spread function and nominally reach a contrast of more than 1000 at the comet nucleus-coma edge, and larger beyond. This optical design, coupled to the 16 bit detector dynamic range, allowed to detect extremely faint features close to the comet nucleus.

One of the key investigations of OSIRIS was monitoring the cometary jet activity and to look at the characteristics of the nucleus surface at the origin of these jets. In [8] the study of jets emitted in the period between Dec. 2014 and Oct. 2015, so including the perihelion, allowed to map the locations of jet sources on comet surface as a function of time. This confirmed the difference between the two comet "hemispheres", with different behaviors between North and South, following a seasonal trend. Thanks to the great quality images provided by the WAC, several extremely faint jets have been studied and their source located using a reverse propagation analysis (see, as an example, Fig. 3).

Acknowledgements

One of the main contributors to the WAC realization was Stefano Debei, who had been involved in the definition of the mechanical and thermal characteristics of the instrument since the beginning of his career. This paper is dedicated to his memory.

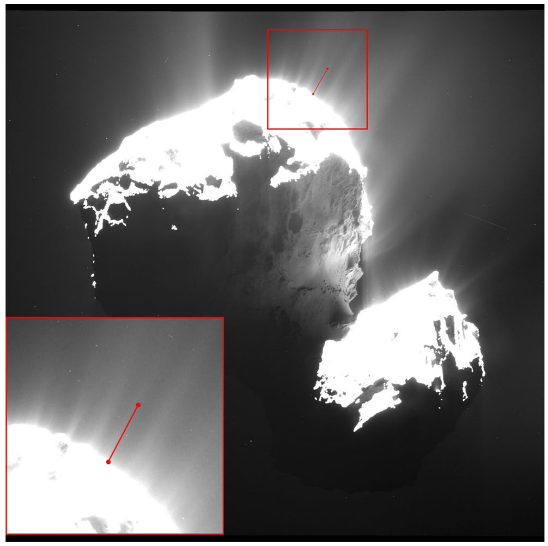

Fig. 3. WAC image (2014 Dec. 30): the image brightness has been adjusted to highlight the jets otherwise not visible. In the insert it is shown an example of jet identification. Image from [8].

References

[1] H.U. Keller, et al., "OSIRIS - The Scientific Camera System Onboard Rosetta", Space Science Reviews 128, Issue 1-4, pp. 433-506 (2007). http://doi.org/10.1007/s11214-006-9128-4

[2] G. Naletto, et al., "Optical design of the Wide Angle Camera for the Rosetta mission", Appl. Opt. 41(7), pp. 1446-1453 (2002). http://doi.org//10.1364/AO.41.001446.

[3] B. Saggin, et al., Thermal design of the Wide Angle Camera for Rosetta, presented at the International Astronautical Federation (IAF) Congress Bremen, Germany. Published Online (2012). http://doi.org/10.2514/6.IAC-03-Q.5.04

[4] De Cecco, M.,et al., "High performance shutter for space applications", SPIE Proc. 4771, pp. 186-197 (2002). HTTP://DOI.ORG/10.1117/12.482160

[5] H. Sierks, et al. "On the nucleus structure and activity of comet 67P/Churyumov-Gerasimenko", Science 347 Issue 6220, id. aaa0444, p. 6 (2015). http://doi.org/10.1126/science.aaa1044.

[6] A. Rotundi, et al. "Dust Measurements in the Coma of Comet 67P/Churyumov-Gerasimenko Inbound to the Sun Between 3.7 and 3.4 AU", Science 347 Issue 6220, id. aaa03905, p. 7 (2015). http://doi.org/10.1126/science.aaa3905

[7] N. Thomas, et al. "The Morphological Diversity of Comet 67P/Churyumov-Gerasimenko", Science 347 Issue 6220, id. aaa0440, p. 7 (2015). HTTP://DOI.ORG/10.1126/science.aaa0440.

[8] M.I. Schmitt, et al., "Long-term monitoring of comet 67P/Churyumov-Gerasimenko's jets with OSIRIS onboard Rosetta", MNRAS 469 (Suppl. 2), pp. S380–S385 (2017). http://doi.org/10.1093/mnras/stx1780