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OSIRIS/GTC: status and prospects

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Abstract

OSIRIS is the optical Day One instrument, and so far the only Spanish instrument, currently operating at the GTC. Building and testing an instrument for a 8-10m-class telescope with nonprevious commissioning in turn, has represented a truly unique experience. In this contribution, the current status, the last commissioning results and some future prospects are given.

1 Introduction

OSIRIS is the imaging system (with either broad- and narrow-band via tunable filters) and a low-resolution long-slit & multi-object spectrograph operating since the Day One at the Nasmyth "A" focus of the GTC. The instrument works in the wavelength range from 365 to 1000 nm with an unvignetted FOV of 7.8×7.9 and 7.8×5.2 arcmin^2 in direct imaging and spectroscopy, respectively [1].

The Scientific Commissioning of OSIRIS begun in December 2008, almost simultaneously to the one of the GTC. Since such date until this time, several observing modes of the instrument has been commssioned, that is, broad-band imaging, narrow-band imaging with the Red (651–935 nm) Tunable Filter (RTF) and long-slit spectroscopy. Although they are not still fully commissioned, the fast photometry observing mode, multi-object spectroscopy (MOS) and the Blue (375-675 nm) Tunable Filter (BTF) have been tested. Remaining - transversal- possibilities (Nod+Shuffle, μ-shuffling and Multiplex) are subject to the completion of the MOS commissioning. This contribution contains the highlights of the instrument status (hardware & software) and preliminary results of the observing modes in commssioning phase.

2 OSIRIS - Hardware

Essentially, the OSIRIS main hardware in the focal station at the telescope is fully operational. The Mask Magazine was repaired, and is currently operating with the maximum load of 13 masks. However, some spurious faults of the RTF and electromagnetic interferences between controllers of the Red and Blue TFs have been detected. It has been decided to operate with only one of the TF switched–on at a time for avoiding interferences. However, switching–off one TF and on the other take only few minutes, and the calibration has found to be stable even after switching a TF off and back on.

On the other hand, the technical commssioning of the Mask Driller machine is under way at the supplier headquarters and the acceptance by OSIRIS team is scheduled for December 2012. New linear encoders for higher accuracy have been installed and tests are under way.

Finally, the purchase of the remaining Order-Sorting filters (365 to 450 nm) for the BTF is being handled, and the final manufacturer has been selected.

3 OSIRIS - Software

The appropriate operation of the instrument, as well as the common procedures for the reduction of OSIRIS data depends on different software applications whose final develoment and tuning are still on going or near completion.

The first example is the RTF Calculator (as a part of the OSIRIS SNR Calculators and TF Setup tool system, developed by J.I. González-Serrano). The calculators have demonstrated high reliability since the beginning of the scientific operations. A new calibration has been implemented in the TF Setup tool, according to new calibration (González et al., in preparation), but it is not implemented yet. This new calibration allow wavelength and FWHM tuning accuracies of 0.2 and 0.3 Å, respectively, in the whole spectral range of the RTF. The BTF calculator is being prepared.

Another software package developed during the last years is the Mask Designer (MD). This is the main tool for design and preparation of the manufacturing process of the slitmasks to be used in multi–object spectroscopy with OSIRIS. The MD is a `Java` plug-in to the well-known `JSky` application, described in [2], whose user's interface was finally developed with the

`PORIS` toolkit [5]. The beta version of the MD was released in 2011 and it is now undergoing different tests. The MD is an interactive application which allows a visualization of the mask design in three simultaneous domains: the mask model, the CCD mosaic, and the sky. This is possible through a same number of `JSky` based editors. The user can interact with each editor if desired. Mask designing is a user's tasks that can use either a list of equatorial coordinates with proper motions (if apply), or through a list of rectangular coordinates referred to the system of a pre-image from OSIRIS. As can be inferred, an accurate coordinate mapping by the MD is essential. Different coordinate transformations (via high–order polynomials) are needed to determine the position of an object in the mask from its sky position, and from the mask to the detector mosaic. In the current version of the MD, the former transformation was derived from the nominal positions of 110 pinholes in a special mask manufactured for this purpose, while the latter comes -provisionally- from the analysis of archive OSIRIS images of the VOph8142 field, which was astrometrically calibrated by using the USNO-B1 catalogue [4].

Last but not least, the OSIRIS Offline Pipeline Software (OOPS, [3]) is the package whose development has held the team's efforts since the beginning of the OSIRIS Commissioning. The Pipeline is based on `Python` scripts with nested `Pyraf` and `NumPy` tasks, and it is oriented to solve automatically the main common procedures in the reduction of OSIRIS data from its different observing modes. The OOPS (including the MOS mode) is in validation phase by users of the Extended Scientific Team, and a few minor bugs have been detected and corrected. Some features are not yet implemented (e.g. 1D spectra extraction), and the official scope for a desired pipeline has been revised by the GTC Users Committee in late June 2012. On the other hand, the stability of the OOPS depends, among other, on stable `fits` headers in the output of the instrument, a final definition of calibration lamps, and on the settling of the instrument control parameters. All these guarantees should be provided by the proprietary of the instrument. Is expected that the public OOPS release will be available via OSIRIS blog (here) in the last months of 2012.

4 MOS: the first tests

Since November 2011, a preliminary version of an automated script for MOS target acquisition at the GTC is operating. This application calculates the offsets and rotation needed to align the positions of the fiducial marks, in the detector mosaic domain, with the corresponding positions of acquisition stars. The release of the beta version of the MD met by chance with the early tests of the automated acquisition procedure at the GTC. Thus, it was decided to design four test masks using both equatorial coordinates lists (two masks) and pixel positions from OSIRIS pre–images, in order to obtain useful information for the improvement of the designing, manufacturing and acquisition processes.

The equatorial coordinates of 53 stars (V<20, from [6]) in a selected field of the Galactic cluster M67 were selected to build the input list for the first test slitmask, whereas the the following test masks were prepared using either OSIRIS pre–images on the field of two galaxy clusters (Abell 2219 and CL0024+17), or a target list given in celestial coordinates. In such cases, the target galaxies were selected with R<22.5. From February to August 2012 the

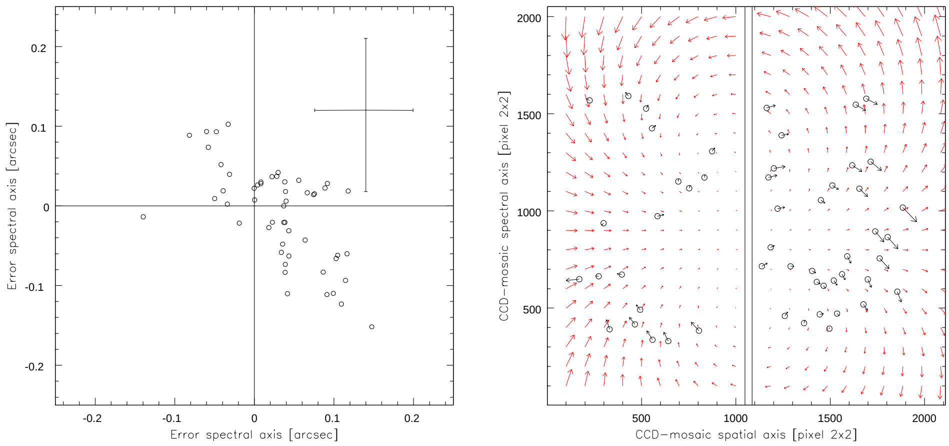

Figure 1: *Left panel:* Positional errors distribution, obtained by comparing the projected positions on the mosaic and the measured positions of the slits in a flat frame. The bars in the first quadrant represent the maximum positional deviation of the slits after manufacturing. *Right panel:* Map that represents such errors magnified 400 times, together with the OSIRIS known geometrical distortions (red arrows) magnified by a factor 5. It is clear that there are not a dependence of the errors on such distortions.

slitmasks were tested at the instrument. Unfortunately, bad seeing conditions dominate during the acquisition of the M67 field, while in the case of the three remaining masks there arose the need to reduce the sky background level using broad-band filters when the pre-images were obtained, and also when the corresponding acquisition was accomplished, since due to scheduling conflicts at the telescope, the tests necessarily had to be performed in bright time. Even so, some interesting results could be derived from the tests, from which the following are the more remarcable ones:

- After a first–order correction for acquisition residual ($\leq$0.15 arcsec), the maximal amplitude of the positional errors of the slits in the first mask, obtained by comparing the projected positions on the mosaic and the measured positions of the slits in a flat frame, was $\pm$0.1 arcsec. Figure 1 (left) depicts the distribution of these errors, which are also represented at the right side of the same Figure but in a map of the detector mosaic, together with the geometrical distortions measured in the whole OSIRIS FOV. Such errors are a prediction of those that could be obtained in the case of a mask with a design based on a pre–image, and they are independent of higher-order effects.
- By comparing the position of the targets in the acquisition image with that of the slits in a flat frame, the positional errors are encircled by an envelope $\sim$2 times bigger than the maximum error in Fig. 1 (left). Taking into account the manufacturing errors, as well as the thermal fluctuation, mechanical flexures, and the positional errors of the targets in the input list, the final position of the slits in the mask must be better than 6% of the slit width [2]. Thus, for the slits in the first test mask (width=1 arcsec) the

maximum measured amplitude of the positional deviations should be 0.1 arcsec, that is, the maximum positional error at present is slightly more than ∼0.1 arcsec above specs.

- Because the limitations pointed out above, the tests with masks based on pre–images are inconclusive in what refers to the estimation of positional errors.

5 Some examples of OSIRIS exploitation

The OSIRIS Tunable Filters provides GTC with extraordinary capabilities for low-resolution 2D spectroscopy. One example is the OTELO project (see the related contribution in this volume), which is now furnishing the flux-deepest emission line object survey of the universe up to z∼7. Another example of the OSIRIS scientific advantages is the 2D spectroscopy of extended sources, i.e., the HII regions of the nearby spiral galaxy NGC 6946 (Cedrés et al. in preparation). Figure 2 (left) shows the synthesis of an Hα+[NII] RTF scan of this galaxy. The successful strategy of investing observing time in the outfield sampling of airglow emission lines, allowed a very accurate subtraction of these features. Subsequent analysis of the scan slices provided pseudo-spectra of the isolated HII regions. Figure 2 (right) depicts the observed pseudo-spectrum of a selected HII region in NGC 6946 and its deconvolution of the instrumental profile.

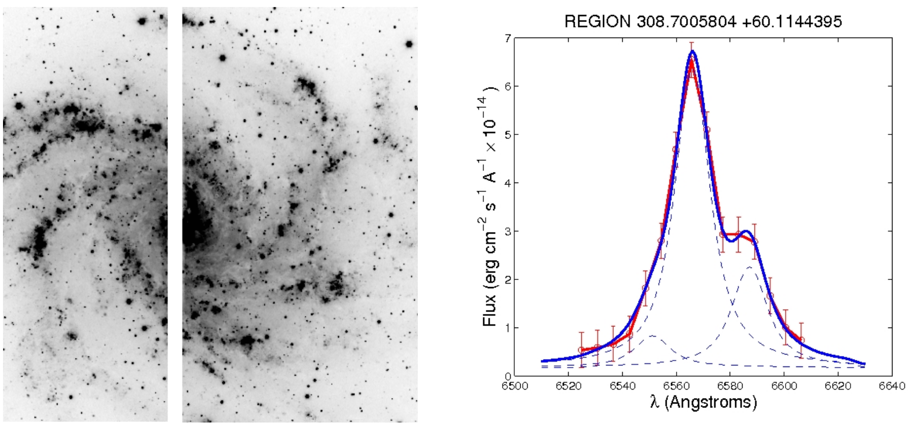

Figure 2: *Left panel:* Coadded image from an Hα+[NII] RTF scan of NGC 6946. *Right panel:* Pseudo–spectrum of a selected HII region of NGC 6946 (red), the sum of three Voigt profiles fitted to each emission line (blue), and the Gaussian profiles resulting from its deconvolution of the Airy profile (dashed line). Courtesy of B. Cedrés.

Even with the position errors detected in the MOS tests, the masks designed from a pre–image of the galaxy cluster fields were useful for obtaining scientific quality data. The slit width for the targets was fixed in 1.2 arcsec, and the reduced spectra were obtained from the coaddition of 2×1200s integrations with the OSIRIS R1000R grism. The raw 2D spectra of the selected galaxies in the field of Abell 2219 can be apreciated in Fig. 3 (left). A sample of reduced spectra of this test are shown in Fig. 3 (right).

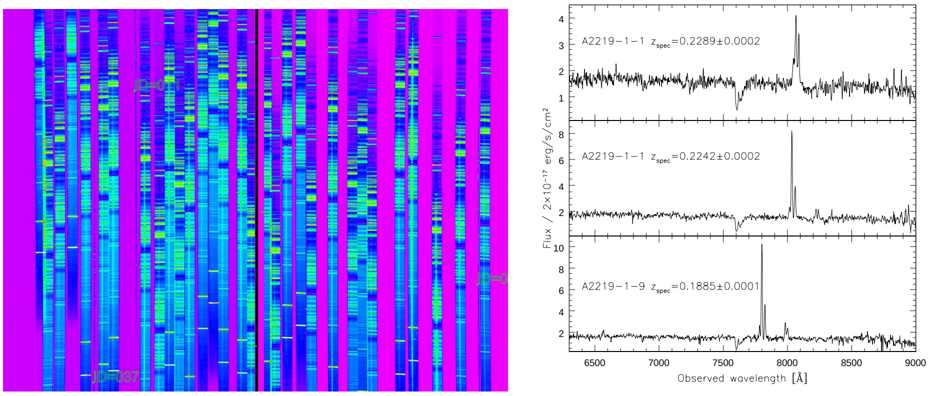

Figure 3: *Left panel:* Raw image of a MOS test on the field of the cluster Abell 2219. *Right panel:* Some reduced OSIRIS–MOS spectra of selected emission line galaxies in this field.

6 Summary

About the OSIRIS hardware, main pending issues are related with the remaining filters for the BTF and the delivery of the Mask Driller machine. On the other hand, a beta version of the OSIRIS Pipeline (OOPS) is expected to be released in short. The BTF setup tool and calculator is expected to be ready when the Commissioning of this sub-system is completed.

Although the initial tests of the MOS have not been made under appropiate conditions, the results obtained are so far satisfactory: it results that the MOS using pre–imaging approach could be scientifically exploited at the present time. The upgrading of the MD polynomial transformations coefficients, and thus the minimization of the positional errors, depends on high-quality calibration data which only can be provided by the telescope. This is one of the ongoing tasks in the MOS Commissioning.

References

[1] Cepa, J., et al. 2003, SPIE, 4841, 1739

[2] González-Serrano, J.I., et al. 2004, ExA, 18, 65

[3] Ederoclite, A. 2011, Highlights of Spanish Astrophysics VI, 380

[4] Monet, D., et al. 2003, AJ, 125, 984

[5] Vaz-Cedillo, J.J. 2010, SPIE, 7738, 58

[6] Yadav, R.K.S. 2008, A&A, 484, 609