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A new arrival at the VLT: the commissioning of the X-shooter spectrograph

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Abstract. Starting from October 2009 a new ESO/VLT instrument will be offered to the astronomical community worldwide: the X-shooter spectrograph. This first second-generation VLT instrument is being built as a collaborative effort of several European Institutes (with INAF playing a prominent role, co-PI R. Pallavicini) and ESO.
The main features of X-shooter are high efficiency and the unique capability to cover in one "shot" a very broad spectral range, from U to K band, making the Instrument appealing for cutting-edge science. The present paper reports on the commissioning periods just held in Paranal and on the efforts made to meet all foreseen stringent requirements.

Key words. X-shooter, ESO/VLT instruments, control software, object-oriented

1. Introduction

On 14 March 2009 X-shooter, the first second generation ESO/VLT instrument, made the first astronomical observation in its full configuration. X-shooter is a single target, intermediate-resolution, high-efficiency spectrograph capable of observing simultaneously a wide wavelength range from UV (300 nm) to K (2500 nm) band (S. D'Odorico et al. 2004). It was installed on the Cassegrain focus of VLT UT2 (Kueyen) and will be offered to the astronomical community worldwide starting from October 1st, 2009.

In this paper, we first present the project and the consortia involved in its realization. We then describe the main characteristics of the Instrument (focusing on the control software) and the commissioning recently held in Paranal. Finally, we discuss the first results to demonstrate the achieved overall X-shooter capabilities.

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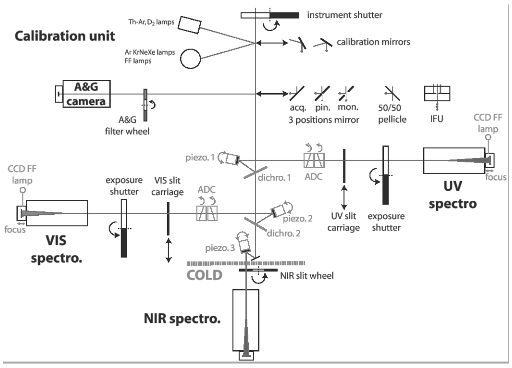

Fig. 1. X-shooter schematic overview.

2. X-shooter consortium

X-shooter is a joint project realized by 11 institutes in 5 countries: Denmark (Co-PI, PM: P. K. Rasmussen), The Netherlands (Co-PI: L. Kaper, PM: R. Navarro), France (Co-PI: F. Hammer, PM: I. Guinouard), ESO (Co-PI: S. D'Odorico, PM: H. Dekker) and Italy (Co-PI: R. Pallavicini, PM: F.M. Zerbi). The overall FTE amounts to 68 person-years with a global budget of about six million Euros. The INAF contribution has been prominent since the beginning with the involvement of four Observatories (Trieste - OATs, Brera - OABr, Catania - OACt and Palermo - OAPa), with responsability, in particular, for the optomechanical design and integration of the UVB and VIS part (OABr) and for the design, implementation and integration of the whole control software (OATs). As a whole, the joint effort of INAF amounts to 19 FTE with an investment of around 800 kEuros, awarded with almost 46 nights of Guaranteed Time Observations (GTO).

3. Technical description

To achieve the maximum sensitivity, X-shooter is split into three arms with optimized optics, coatings, dispersive elements and detectors. As shown schematically in Fig. 1, the instrument consists of a central structure, the Backbone, on which three spectrographs that cover the UV-Blue (300-550 nm), Visible (550-1000 nm) and Near-InfraRed (1000-2500 nm) spectral ranges are mounted.

- Backbone: it contains the Calibration system, a slide with the 3-position mirror, the Acquisition camera (a Peltier cooled, 13 μm pixel, 512x512 E2V broad band coated Technical CCD), the Atmospheric Dispersion Correctors (ADCs) and dichroics to split the light from the telescope in three wavelength bands; a small Integral Field Unit (IFU) can be optionally inserted in the Cassegrain focal plane.
- UVB and VIS arms: they contain a slit carriage, a focus motor, a flat field lamp and scientific CCDs (UVB-CCD is an E2V 2048x4102, 15 μm pixel, used in windowed readout, VIS-CCD is a MIT/LL 2048x4096, 15 μm pixel) . This is the only instrument at Paranal where the CCDs of the two arms are controlled by a single FIERA controller.
- NIR arm: it contains a slit carriage, an IR camera (a Teledyne substrate-removed HgCdTe, 2k×2k, 18 μ pixel, Hawaii 2RG, of which only 1k×2k is used) and a dedicated cryogenic housekeeping system, being the whole arm kept under cryogenic conditions.

The optical layout of all three arms is quite innovative and follows the "4C" principle, where "4C" stands for Collimator Compensation of Camera Chromatism. To achieve the required cross-dispersion, prisms are used in double pass. Altogether, these choises made it possible to build a compact, highly efficient spectrograph with relatively simple, inexpensive cameras.

Fig. 2 shows the X-shooter temporary on UT3 in March 2009. Among other details, the two boxes hosting the electronics and the NIR arm (the cylindrical vessel at the bottom) are clearly visible.

3.1. Instrument Control - the challenge

INAF-OATs was responsible for the design, implementation and commissioning of the control software for the whole instrument. As imposed by ESO (after all X-shooter is an

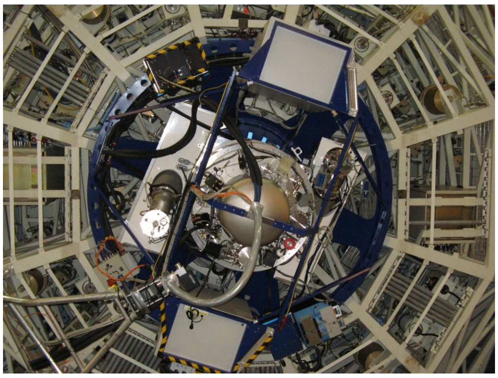

Fig. 2. X-shooter temporarily mounted at the Cassegrain focus on UT3.

ESO/VLT instrument), its control software architecture/implementation follows all the required rules and requests. The main packages and modules have been previously described elsewhere (M. Vidali et al. 2006). Here we outline one of the particular functionalities, not handled by standard VLT software, that was implemented specifically for X-shooter.

X-shooter is a moderately complex instrument consisting of 13 DC motors, 6 calibration lamps, more than 50 digital and analog sensors and 4 detectors (2 scientific grade CCDs, 1 technical grade CCD, 1 NIR array). Its complexity is because this is the first actively compensated instrument at Paranal.

The finite elements analysis of the mechanical structure showed that an Automatic Flexure Compensation (AFC) system was needed in order to fulfill the requirements of maximum slit displacement among the three arms of the Instrument. The slits movements are induced by backbone flexures under gravity, when the instrument is moved over its full range of operating positions. The adopted solution to compensate for these flexures consists of three flat mirrors placed in the optical path of the spectrographs (see Fig. 1), which can be tilted by piezoelectric actuators. The low-level correction system controls the actuators via the S-340 Tip/Tilt platform manufactured by Physik Instrumente in open-loop: when sent to a position, sensors are read and the feedback is used to check the correctness of the actual actuators position. Due to the insufficient stability of the PI devices over long times and to drift problems, an active optics-like approach has been adopted: the displacements due to the flexures is measured and corrected each time the telescope is preset to a new object (no observing time is lost, since the procedure is done in parallel with other telescope operations). The measurements are done on two couples of exposures (pair of spectra), one pair for each arm, obtained with two different configurations of the Instrument. A cross-correlation function computes the displacement of selected reference lines between the two exposures. The result, converted to voltage, is applied to the tilting mirrors controlling the three beams. The operation may be repeated (according to operator decision) to reach a good level of correction. After this initial correction the three subsystems are set to AUTO mode and continue to correct, according to a pre-defined model, during the rest of the observation.

A specific requirement for the Instrument was exploiting the parallelism of the exposures in its three arms. This is not fully provided by the VLT Common Software environment and has been specifically implemented for X-shooter. Multiple exposures, with different exposure times, may be defined and the Control Software manages to handle the Detectors of the three arms in parallel, re-starting each arm as soon as a previous exposures has ended and the data are read-out.

Another specific implementation for X-shooter is the possibility for the user to ask for synchronous exposures in the three arms. This means that whatever the exposure times in the three bands, at the end the mid-exposure times will be the same.

4. Commissioning periods

Despite the complexity and the high number of involved European institutes that partecipated in the X-shooter development, the whole project took a remarkably short time for completion, lasting five years from the kick-off meeting held in December 2003 (J. Vernet et al. 2007). Moreover, to take advantage of the fact that some parts (the

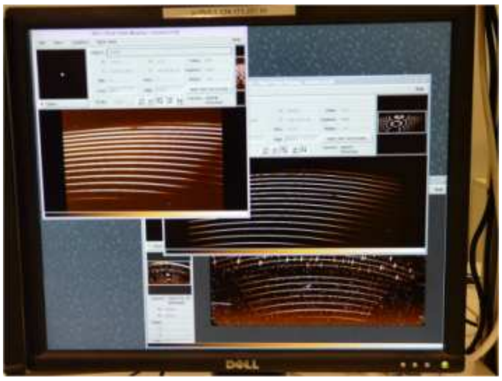

Fig. 3. First light with the full instrument achieved on 14th march 2009. 10 s of exposure on a standard star.

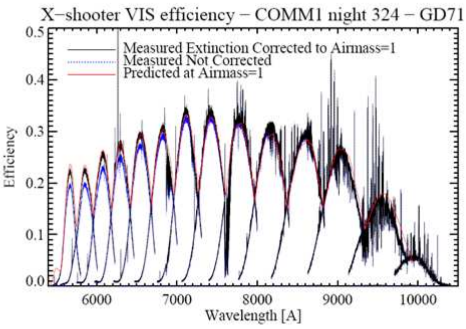

Fig. 4. Measured vs. predicted efficiency in the VIS band confirming the high achieved efficiency.

Backbone, the UVB and VIS arms) were ready well in advance with respect to others subsystems (the NIR part), the installation of the Instrument at Paranal was done in a "modular" way. Commissioning of the Backbone, UVB and VIS arms took place on UT3 in November 2008 and January 2009 (a total of 17 nights, no losses due to technical problems or weather conditions). The acquired data showed that the overall efficiency and all mechanical flexures reached specifications and that all the hardware, software and operational interfaces with the telescope environment worked as expected, in line with the desired "point and shoot" objectives for this instrument.

The NIR arm and associated electronics were mounted on the Backbone in March 2009. First light was achieved smoothly on March 14 (see Fig 3). Commissioning continued for 6 nights without significant losses due to problems with specific instrument hardware or software. Reduction of the spectra obtained with the Instrument in its full configuration showed that all the specifications are met or exceeded the predictions (see Fig 4). The overall efficiency is still being analyzed, but – except for the J band, still under investigation – no significant deviations from expectations have been found.

5. Conclusions

At the end of April 2009 X-shooter was moved from UT3 to its final location at the Cassegrain focus of UT2 and will be offered to the astronomical community from October 1st, 2009. The high demand for it and the expectancy is proven by the fact that more than 150 proposals were received for the first observing period for a total of 350 observing nights.

References

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