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EMIR: first results of the commissioning at the GTC

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Abstract

We report the results on the EMIR (Espectrógrafo Multiobjeto Infra-Rojo) performances after the first two commissioning periods of the instrument at the Gran Telescopio Canarias (GTC). EMIR is one of the first common user instruments for the GTC, the 10 meter telescope operating at the Roque de los Muchachos Observatory (La Palma, Canary Islands, Spain). EMIR is being built by a Consortium of Spanish and French institutes led by the Instituto de Astrofísica de Canarias (IAC). EMIR is primarily designed to be operated as a MOS in the K band, but offers a wide range of observing modes, including imaging and spectroscopy, both long slit and multi-object, in the wavelength range 0.9 to 2.5 μm. The development and fabrication of EMIR is funded by GRANTECAN and the Plan Nacional de Astronomía y Astrofísica (National Plan for Astronomy and Astrophysics, Spain).

EMIR was shipped to the GTC on May 2016 for its integration at the Nasmyth platform. Once in the observatory, several tests were conducted to ensure the functionality of EMIR at the telescope, in particular that of the ECS (EMIR Control System) which has to be fully embedded into the GCS (GTC Control System) so as to become an integral part of it. During the commissioning, the main capabilities of EMIR and its combined operation with the GTC are tested and the ECS are modified to its final form. This contribution summarises the EMIR operation at the GTC as it has been tested so far, on the first two commissioning periods.

1 Introduction

EMIR (Espectrógrafo Multi-objeto InfraRrojo – Infrared Multiobject Spectrograph, [1] and [2]) is a common-user, wide-field camera-spectrograph operating in the near-infrared (NIR) wavelengths 0.9-2.5 μm, using cryogenic multi-slit masks as field selectors. As a reminder, its main instrumental features and expected capabilities, in terms of sensitivities in the two main observing modes, are given in Table 1. EMIR will provide GTC with imaging, long-slit and multi-object spectroscopic capabilities. The EMIR consortium is formed by the IAC, Universidad Complutense de Madrid (UCM, Spain), the Laboratoire d'Astrophysique de Toulouse-Tarbes (LATT, France) and the Laboratoire d'Astrophysique de Marseille (LAM, France). EMIR was shipped to the GTC on May 19th, 2016; it was integrated on the Nasmyth A platform on June, 3rd, 2016; and the first commissioning periods were run from June 13th to 23rd and July 9th to 15th. This phase is being funded by GRANTECAN and the Plan Nacional de Astronomía y Astrofísica (AYA2012-33211).

Table 1: Top level specifications of EMIR

Wavelength range	0.9-2.5 μm	Multi-object spectroscopic mode	
Top priority obsmode	K band MOS	Slit area	$6.7' \times 4'$, 55 slitlets $\sim 7''$ long
Spectral resolution	5000,4250,4000		width between $0.4''$ and $1.2''$
	(JHK)@3px slit	Sensitivity	K=20.1, t=2hrs, S/N=5
	$\sim$1000 HK + YJ		per FWHM (continuum)
Spectral coverage	Single (ZJHK)		$F = 1.4 \times 10^{-18} erg\ s^{-1} cm^{-1}$Å^{-1}
	per exposure		t=4hr, S/N=5 per FWHM (line)
Array format	2048x2048 Hw2	Image mode	
Scale at detector	$0.2''$/pixel	FOV	$6.7' \times 6.7'$
Image quality	$\theta_{80} < 0.3''$	Sensitivity	K=22.8, t=1hr, S/N=5

2 The commissioning

The overall aim is to integrate EMIR as part of the GTC; test the performance of EMIR; learn and then optimise the operation of EMIR; and, finally, demonstrate that EMIR is ready for science operations. Let us start with a few words on the commissioning plan itself as it has been prepared and developed up to now. There are many constrains on the overall plan and these have to be allowed for within the plan. They include:

- Limited telescope time (+expensive)
- Limited staff (both telescope and EMIR)
  - One person cannot work 24 hours a day.
  - It is pointless taking data that cannot be reduced in a timely manner. The more complex data sets, particularly those using low S/N objects may take a significant

Table 2: List of the tests planned for the first commissioning periods

Before Sky	Sky calibration
Check that the instrument can be rotated.	Find centre of rotation; calibrate offsets
Check the instrument temperature.	Photometric Calibration
Basic communication test	Plate scale, distortion and orientation
Detector noise and detector calibrations	Backgrounds
Operation and calibrations of mechanism	Stray light from bright stars
Check operation and calibration of CSU.	Persistence.
Focus detector onto CSU	Operations
Obtain dome flats in all modes.	Accuracy using fast and slow guiding
Obtain arc images with the ICM in all bands	Offsetting accuracy over 1" to 30"
Run sample sequences	Offsetting accuracy over 30" to 30'
Getting Started	Long term guiding accuracy
Pointing and Initial Focus	Main offsetting patterns
Initial Instrument orientation on sky	Use of point origin offsets
Initial Instrument plate scale	Non-Sidereal Guiding
Orientation of image on Screen	Spectroscopy
Find initial centre of Rotation	Source acquisition for long slit
Measure the sky flat	Source acquisition for MOS
Zero points	Zero point and saturation per grating
Saturation magnitude	% flux/spectral resolution with slit width.
Check Alignment/initial image quality	Narrow slits with over sampling with DTU
Opt. Quality	Obs. Opt.
Fine Focus	Imaging of single point sources
Variation of Focus Across Field of View	Imaging of star fields
Variation of PFS Across Field of View	Imaging of extended sources
Alignment of the pupil	

amount of time to reduce and analyse before all of the effects become obvious.

- Cannot guarantee observing conditions. Therefore, where possible there should be a number of possible tasks available at any one time so that the most suitable can be chosen in real time.

There may be other constraints such as a wish to have certain modes available in as short a time as possible where as other may take longer. This paper only deals with the on sky commissioning of EMIR and not with the integration of EMIR onto the telescope. At the beginning of the commissioning, and thanks to the excellent work of the engineering and technical teams, EMIR was integrated in full at the GTC and that the operability and functionality of all subsystems, with special attention to the ECS at the GTC, were in situ tested. All these were done in a very tight schedule. Fig. 1 shows the lifting of EMIR to the platform.

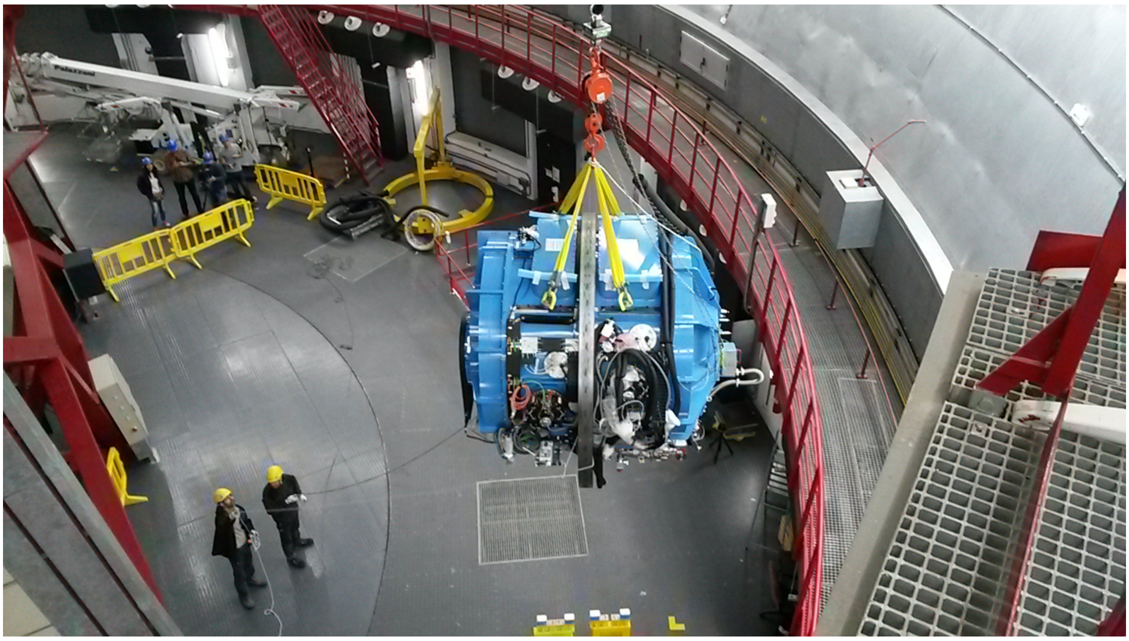

Figure 1: Main body of EMIR being lifted to the Nasmyth platform on June 2nd.

2.1 The overall plan

The test plan breaks the overall commissioning into a series of logically connected tasks. Each task has an aim, a procedure and expected result. Each task also has an expected duration. This duration however will assume no significant problems and suitable observing conditions. Accounting the estimated duration of the full set of tasks, the total time for the commissioning program was initially set as 21 nights, with a maximum of 5 lost nights, and no contingency included.

To optimize the performance of the EMIR team, part of the commissioning runs have been carried out during half nights. Hence, there is time to look at the results and make changes before the next night. This is particularly true for the ECS and the on line reduction pipeline (DRP), which have been fine tuned virtually every day. The same format will also be adopted for the subsequent period, while we will use full nights during part of the periods in the last runs. That implies that the total observing time will be distributed over longer time period. The list of tasks to be accomplished during the first runs, grouped according to their goals and methods, are listed in Table 2

In order to make effective use of the telescope time the total time has been split into four runs: from June 13th to 23rd; from July, 9th to 15th; from July 24th to 28th; and some yet unspecified period on September. The original goal of separating each period by at least one month cannot be achieved due to organisational constraints, so we were committed to analyse the data virtually in real time, and we are still doing. In view of the very good

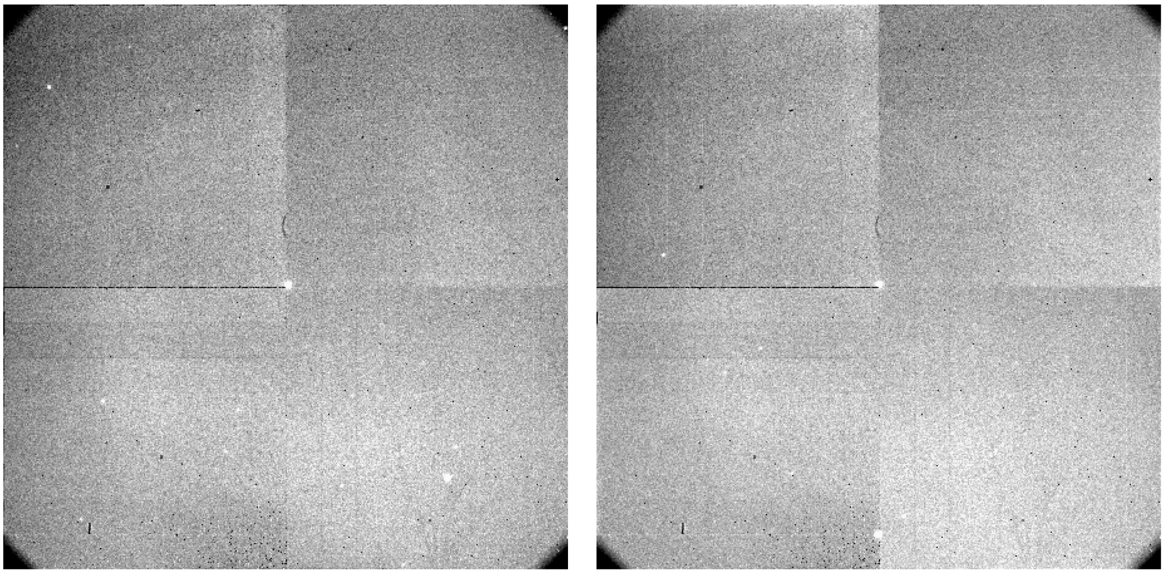

Figure 2: Left: the very first image of EMIR, with the test star right on the centre. Right: second image, with the instrument rotated by 30 showing the very good alignment of the centre of rotation with the centre of the detector.

preliminary results of the first two runs, subject of this paper, we feel confident that most, if not all, the planned tasks can be successfully executed in the allocated time. It is expected, however, that some specific tests would be moved to a later run, in a new observing period(s) still undefined.

3 The first runs

In this first runs, a series of tasks, see Table 2 for reference, were performed several days ahead of the start of the night work. Most of them aim at calibrating different aspects of the instrument and take benefit of the ability of operating EMIR with the external cover closed and multi-slit pattern in the CSU, which then forms an artificial sky. Most of them were successfully performed. The next subsections give a brief description of the main results obtained so far. All together, they give an impression of the performances of EMIR at the GTC. Judging them, one must bear in mind that the results depicted here are from the very first runs of the commissioning and those periods just happened, so only light analyses have been conducted. Given the technical complexity of EMIR and its many configurations attainable, it is easily foreseeing that the instrument will necessitate a much longer period to reach its routine operations. In our view, the sooner the instrument will be used by the community, in the scientific verification phase, the better so as the assessment from many groups external to the instrument team could be used to fine tune the instrument operations. This goal is one of the main drivers of the commissioning being executed in this very compact format.

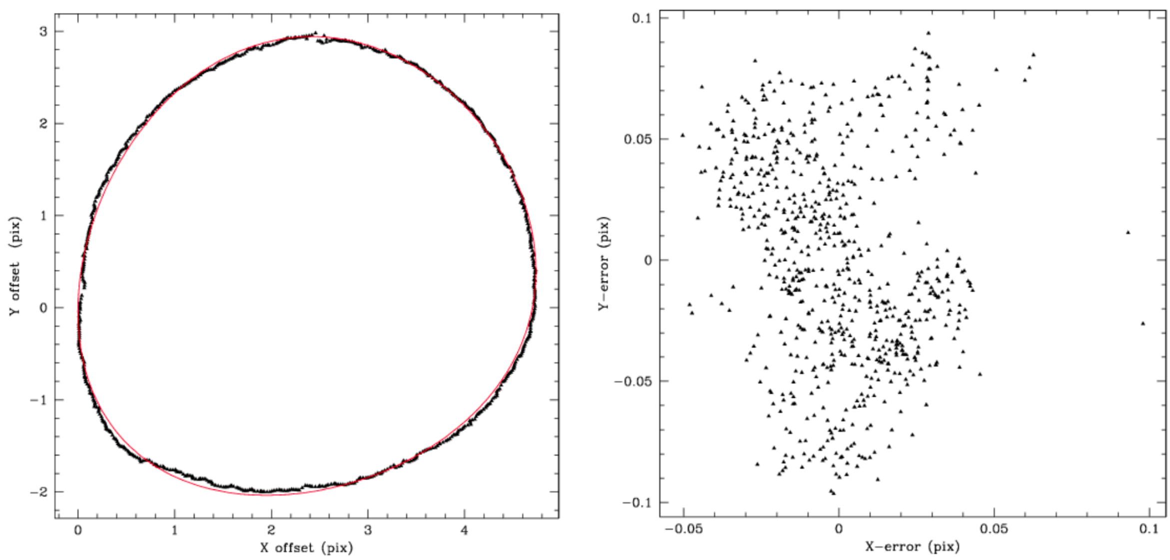

Figure 3: Left: the X and Y offsets plotted for no movement of the DTU. The red line shows the result of a fit to the X and Y data. Right: difference between the fit and the measured points.

3.1 The first image

On Monday June 13th, the first day of the commissioning, we opened EMIR to the sky and took the images depicted in Fig. 2

3.2 Correction of internal flexures with the DTU

The Detector Translation Unit (DTU) lies on the heart of EMIR. It consists in a 3D motion system which can move the detector along the optical axis for focusing and in a plane perpendicular to that axis. The latter is used to freeze the sky image on the detector as the instrument rotates during tracking, which causes internal flexures of the instrument. Should these flexures be not corrected it would result in image wander of as much of 6 detector pixels in a complete turn of the instrument, as seen in Fig. 3 left. Fig. 3 shows the image motion of the image of sources in the EMIR focal plane without intervention of the DTU and the residual image drift with the DTU correction activated.

3.3 Astrometry

The images from the two clusters used along the commissioning, NGC5053 and NGC6811 see Fig. 4, have been cross correlated with the 2MASS Point Source Catalogue3, which offers a standard reference for astrometry at the accuracy level intended in this first commissioning. Some results are depicted in Fig. 4 The initial guess, left panel, is quite good, without additional correction, except in the corners. As can be seen, right panel, the geometrical distortion can be modelled using the radial distance from the centre of the image as indepen-

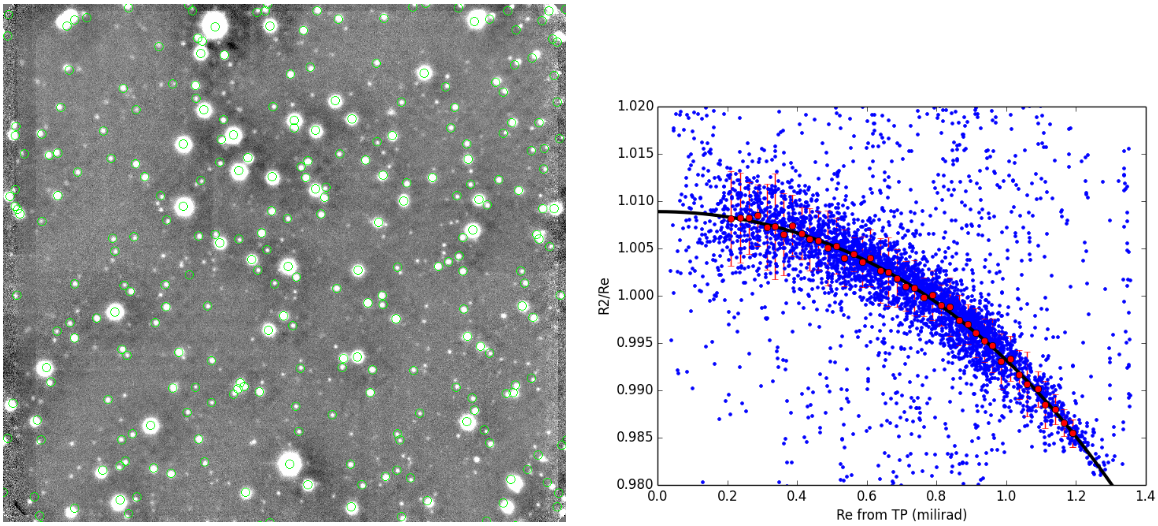

Figure 4: Left: cross matches between EMIR images and 2MASS. Right: radial fit of the distortion.

dent variable. A 5th order polynomial can then be fitted to the data, in fact to the median points of each radial bin. This information is since then stored in the header of each frame and so can be corrected. The maximum distortion measured at the edges is at 1.5% level, well within specifications

3.4 Photometry: zero points and noise parameters

We have compiled, using a large set of stellar objects, the zero points of the EMIR broad band photometrical system. These figures have to be taken with some caution as the sky subtraction procedure is not yet weel stablished, so one could expect some improvement in the near future. Anyhow, the zero points show clearly the potential of EMIR for deep images in the NIR.

- $ZP_J = 25.25 \pm 0.08$
- $ZP_H = 25.50 \pm 0.31$
- $ZP_{Ks} = 25.04 \pm 0.14$

Also, we have characterized the detector noise in real conditions at the observatory. The figures are:

- GAIN: 4 ± 0.47 e-/adu
- RON: 5.23 adu, in single read, which translate to 14.66 e- using a ramp with 10 reads.
- DC: 0.09 adu/s, or 0.36 e-/s

4 Short term plan

At the time of this writing, we are about to begin the last commissioning period, scheduled to start at November 14. It is expected that around this date, the Scientific Verification Phase can be opened to the whole GTC community. The commissioned modes include imaging, both in stare sky–object and dithered frameworks, and spectroscopy in long-slit mode only. The multi-object spectroscopic mode should be incorporated to the list soon after the launch of this phase.

We are tentatively seeking the instrument being delivered to the GTC TAC for the semester 2017A, which would imply initiating scientific operations by September 2017.

Acknowledgments

The commissioning of EMIR is being performed at the Gran Telescopio Canarias as the final part of the development of the EMIR. EMIR was integrated by a dedicated team composed by engineers and technicians of the IAC, in close collaboration with the GTC technical staff. All of them deserves special thanks for an extremely professional job executed in very short time under pressing conditions and with excellent results. EMIR is supported by the Spanish Ministry of Economy and Competitiveness (MINECO) under the grant AYA2012-33211, GRANTECAN, S.A., via a development contract, and the EMIR partnership institutions, in alphabetical order, IAC, LAM, LATT and UCM.

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