GMOS at Gemini: an update

G. Gimeno[1], V. Firpo[1] & H. Kim[1]

[1] *Gemini Observatory, La Serena, Chile*

Contact / ggimeno@gemini.edu

Resumen / Se presenta una descripción de las novedades acerca del espectrógrafo GMOS del observatorio Gemini, en particular sobre el desempeño y mejoras recientes, asi como de su impacto en la calidad de los datos cienttíficos. Se destacan el mantenimiento óptico de GMOS-S en 2018 y la actualización de los detectores en GMOS-N en 2017, entre otros

Abstract / An update is presented on the GMOS instruments at Gemini, in particular about performance, recent upgrades and their impact on the delivered science data. Highlights are the GMOS-S optical maintenance in 2018 and the GMOS-N detector upgrade in 2017, among others.

Keywords / instrumentation: spectrographs — instrumentation: detectors — techniques: image processing

1. Introduction

The Gemini Multi-Object Spectrographs (GMOS; Hook et al. (2004)) are the workhorse instruments at both Gemini Observatory 8 m telescopes. The GMOS instruments at both Gemini North and South have proved to be the most heavily requested Gemini instruments contributing to more than half of the observing queue. After a few years of continuous operation, Gemini has been planning and executing upgrades for both instruments, notably several detector upgrades in order to improve the on-sky efficiency (Gimeno et al., 2016; Roth et al., 2012). We present here an update on the GMOS instruments at Gemini, in particular about performance, recent upgrades and their impact on the delivered science data. Highlights are:

- GMOS-S optical maintenance in 2018
- GMOS-S/N new narrow band filters in 2018
- GMOS advanced reduction tips
- GMOS-N detector upgrade in 2017.

2. GMOS-S optical fix

The optical system of GMOS is comprised of a collimator and a camera, each of which has three groups of lenses. In turn, these lens groups are formed by three to four lenses. Within each lens group, the lenses are not in contact but separated by a 0.1 mm gap, filled with index-matching oil.

Over the years, air bubbles have developed when oil is lost from the lens interfaces. These can have a measurable impact on light transmission and image quality, in the affected parts of the field of view. In particular, the flat-fielding in imaging mode had become particularly difficult due to the presence of such air bubbles in the collimator lens groups. This has been a long-standing problem, affecting both GMOS-N and GMOS-S.

Fig. 1 (top) shows as an example an image of one lens group, in which the air bubbles are clearly visible.

While some of the lens interfaces can be refilled during regular instrument maintenance (this is the case for the lenses of the camera), other refill ports are inaccessible without major intervention. Such an intervention, in which the collimator was removed for the first time since the instrument was built, was performed on GMOS-S between July 17 and August 30 at the Cerro Pachon (CP) Instrument Lab. It involved not only refilling the lens interfaces but also modifying the oil piping, so that the refilling ports of the innermost lens groups can be accessed from the outside, thus eliminating the need of removing the collimator again in the event of potential future oil leaks.

Once installed again in the instrument, the realignment of the collimator was performed with the aid of two independent techniques, namely an alignment telescope and a laser beam propagated through the optical axis. Final alignment resulted better than 4 pixels as measured on the CCD. Fig. 1 (bottom) shows the collimator after the intervention. As a result of the optical fix, the flat-fielding performance of GMOS-S is restored.

3. New narrow-band filters

As part of the Gemini Instrument Upgrades Program (IUP, https://www.gemini.edu/sciops/future-instrumentation-amp-current-development/instrument-upgrade-projects), two pairs of narrow band filters were acquired for both GMOS-S and GMOS-N. These are OVI (683.5 nm) and OVIC (678 nm), for the project ORaman OVI narrow-band imaging with Gemini/GMOS.O (see R. Angeloni et al. in this bulletin).

Fig. 2 shows the transmission curves for the set of filters at GMOS-S, measured at the CP Instrument Lab. The performance on-sky was tested successfully in 2017. The filters acceptance tests have been completed, and the new capability will be offered to users in 2019.

Figure 1: Top: Bubbles in collimator lens group 3 before the intervention. Bottom: Collimator after the oil refill (as seen from lens group 1). Bubbles are gone.

4. GMOS-N new CCDs

The installation of fully-depleted Hamamatsu CCDs in GMOS-N in February/March 2017 marked the conclusion of the CCD upgrade project for the two Gemini Multi-Object Spectrographs. The new CCDs have superior quantum efficiency (QE) at wavelengths longer than 680 nm, with significant sensitivity extending beyond 1 μm (Scharwaechter et al., 2018), similar to that in GMOS-S. Fig. 3 presents the focal plane array. It includes three CCD types with different anti-reflective coatings, referred to as "HSC" in reference to the Subaru Hyper Suprime-Cam instruments, and "BB" for "BetterBlue" (Gimeno et al., 2016). The spectral response of the Hamamatsu chips extends from roughly 360 to 1030 nm, with slightly different relative quantum efficiency characteristics due to the different arrangement of CCD types in the focal plane array. The Hamamatsu CCDs provide a significant improvement in sensitivity (especially at longer wavelengths) compared to the original EEV devices. Compared to the interim GMOS-N e2v DD devices (Roth et al., 2012), the Hamamatsu CCDs show an obvious higher throughput (see Fig. 4), albeit at the expense of 0.8 e^- higher readout noise. Fringing in the i' and Z filters is found to be negligible for the Hamamatsu CCDs. The GMOS-N upgrade concluded the Hamamatsu CCD upgrade project for both GMOS instruments.

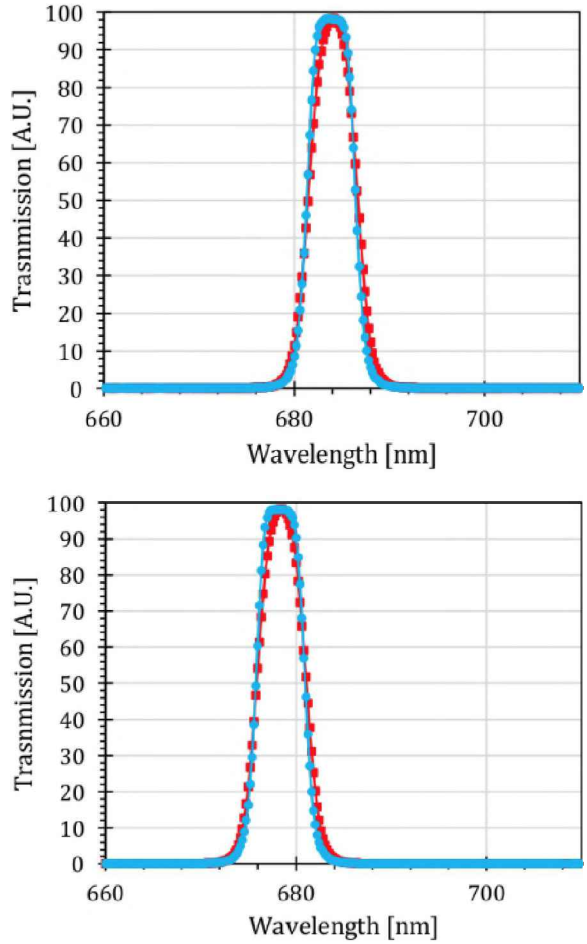

Figure 2: Transmission of the OVI - 683.5 nm (top) and OVIC - 678 nm (bottom) new filters, as measured at GS with the CARY 500 spectrometer (red), and as provided by the manufacturer (blue).

5. GMOS advanced data reduction tips

A new tutorial on some advanced GMOS data reduction has been assembled by the instrument team. This tutorial will provide some tips that will hopefully help users to solve some of the most serious issues that may arise during data processing, as a consequence of the problems related to the detectors and the instrument. These solutions were compiled from the numerous requests from the user community within the last few years, coming mainly from GMOS-S users. In particular it provides some techniques on how to deal with difficulties with flat fielding issues, detector effects, bad columns, etc. These are not universal, fail-proof solutions; they may work well with some datasets and not so well on others, depending on what was the initial observing strategy and the quality of the raw data. It is available for imaging mode only (https://gmos-data-reduction-problems-and-solutions.readthedocs.io/en/latest/), however it is to be

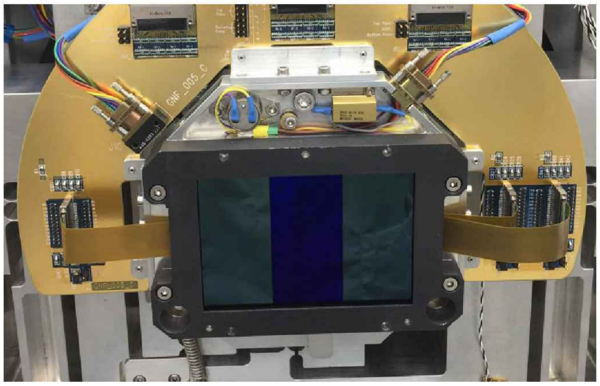

Figure 3: Photograph of the GMOS-N Hamamatsu focal plane array. The left- and right-most CCDs (CCDr and CCDb) are of type "BB". The middle CCD (CCDg) is of type "HSC". The golden semi-circular plate behind is the electrostatic discharge (ESD) protection board.

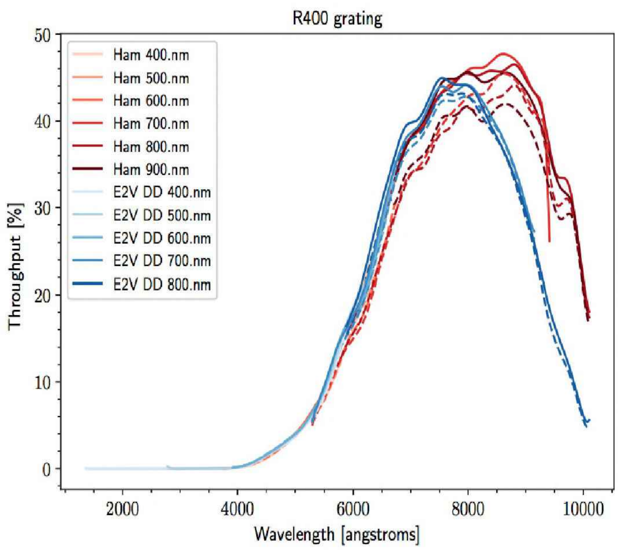

Figure 4: Comparison of spectroscopic throughput measurements for the GMOS-N Hamamatsu (red) and interim e2v DD (blue) CCDs based on two different sets of spectrophotometric standard star observations, respectively. All observations were obtained under photometric conditions using a 5 arcsec-wide slit. The central wavelength settings are indicated in the legend. All data sets using central wavelength settings $\leq$ 700 nm were obtained through the OG515 order-blocking filter and clipped at $<$ 530 nm where the filter cuts off. All data observed without OG515 were clipped at $>$ 673 nm to remove residual 2nd-order overlap. At the long-wavelength end, all data were clipped at $>$ 1030 nm, where the upturn of the throughput is due to 2nd-order overlap from the wavelength region beyond the OG515 cut-off wavelength.

extended to spectroscopy in the future.

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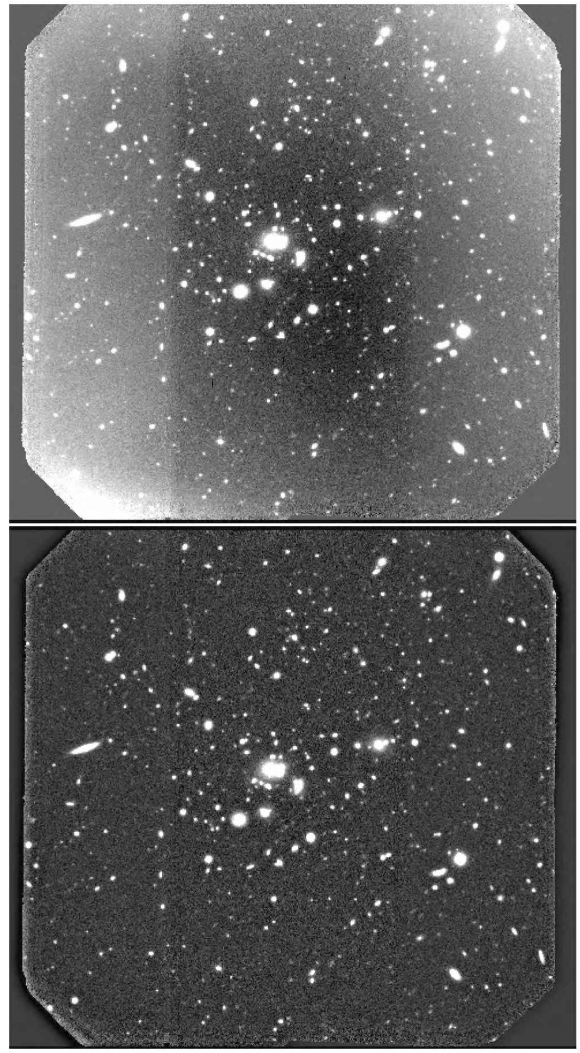

Figure 5: Example flat-fielded image obtained using the standard procedure (top) and the improved flat-fielding (bottom) described in the GMOS advanced data reduction tips tutorial (Sec.5).

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