Detector Upgrade for FLAMES: GIRAFFE Gets Red Eyes

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In May 2008, a new CCD, called Carreras, was installed in the GIRAFFE spectrograph to replace Bruce, the old detector. Carreras is more sensitive to wavelengths redward of 700 nm. The main characteristics and results obtained in the commissioning of Carreras are reported.

FLAMES is the multi-object, intermediate and high resolution fibre facility of the VLT. Mounted at the Nasmyth A platform of UT2 it offers a rather large corrected field of view (25 arcmin diameter) and consists of several fibre modes (see Pasquini et al., 2002 for details). Most of the FLAMES fibre modes feed GIRAFFE, a medium-high resolution spectrograph (R = 6000–33 000) for the entire visible range (370–950 nm).

Shortly after the beginning of operations, we started to look for a new detector for GIRAFFE to boost the instrument's red quantum efficiency (QE) capabilities, while still retaining very good blue response. We aimed also at reducing the strong fringing present in the red spectral range. It has taken some time for devices to become available which meet our strong requirements. The solution finally offered by e2v was a custom two-layer AR (Anti-Reflection) coated Deep Depletion CCD (CCD44-82). This device was made in a new e2v AR coating plant and delivered to ESO in mid-2007 with a performance that matches predictions.

Carreras

The new detector Carreras (e2v serial number 06383-13-01) is a CCD44-82 2 k × 4 k. It is electrically and mechanically identical to the existing detector (Bruce), thus making the upgrade a simple plug-in replacement. Bruce is a standard silicon (nominal thickness 16 μm) CCD44-82 and has a single layer AR coating optimised for the blue. Carreras (the new detector) is a Deep Depletion device (nominal thickness 40 μm) that has a special custom two-layer coating (HfO/SiO2) optimised for broadband QE response over the wavelength range of 370–950 nm.

The upgrade was performed by assembling a new cryostat and installing Carreras. Carreras was fully characterised in this new system. The GIRAFFE detector head and cryostat were then shipped from Paranal to ESO Garching to enable the field lens to be swapped into the new system.

Read-out modes

For scientific applications (in service mode) it was decided to retain the 225 kpx, 1 × 1, low-gain (read-out noise 4.3 electrons (e^-)) as the default mode. The improvement in signal-to-noise (S/N) ratio of the 225 kpx, 1 × 1, high-gain (read-out noise 3.1 e^-) with respect to the low-gain is negligible as soon as the counts go over 110 e^- (S/N ratio 7.5, assuming that the signal is extracted over six pixels). Since this mode has a much higher dynamical range, we decided to keep it as the standard one.

Other interesting modes such as the ultra-fast read-out 625 kpx, 1 × 1, low-gain and the 50 kpx, 1 × 1, high-gain (with a read-out noise of only 2 e^-) were commissioned and can be offered in visitor mode for instance. The low read-out noise in the 50 kpx, 1 × 1, high-gain mode, along with the improvements in the QE and the reduction of the fringing (see below), make this mode very appealing for studies of faint objects, especially if coupled with the binning 1 × 2. The available read-out modes of Carreras are summarised in Table 1.

Cosmetics and linearity

As far as cosmetics are concerned, Carreras is a very good detector. The master bias shows no hot pixels. Similarly, the master dark (1-h-long) shows only one bad pixel. Image flats show 62 dark pixels (i.e., pixels with less than 50 % of the local mean). As expected, the cosmic hit rate is higher for Carreras than for Bruce because Carreras has over twice the thickness. The cosmic hit event rate measured in Paranal is 3.14 ± 0.18 events/min/cm^2. Translated into pixels, 20 000 pixels out of a total of 2 k × 4 k (or 0.25 %) are affected by cosmic ray hits for a 1-h dark.

The linearity of both the left and right amplifiers was measured to be better than ± 0.5 % in the main default scientific mode (225 kpx, 1 × 1, low-gain).

Fringing

In addition to the QE improvement, Carreras was expected to have much lower fringing due to its increased thickness and reduced reflectivity at red wavelengths. The reduction of the fringing amplitude is immediately seen by looking at the raw flat frames taken with the L881.7 wavelength setting (Figure 1). The improvement is impressively shown in Figure 2, where flat-field spectra of fibre flats are compared. Flats collected with Bruce (black line) have a fringing level of 30 % with respect to the continuum. This level is reduced to about 5 % with Carreras.

QE improvement

The QE curves for both detectors were measured in Garching. The QE ratio is shown in Figure 3. Flats taken prior to the dismounting of Bruce from GIRAFFE

Mode	Read-out speed (kHz)	Dynamics* (Ke^-/pixel)	Conversion factor (e^-/ADU)	Read-out noise (e^-)	Read-out time (s)
1	50 kpx, 1 × 1, high	45	0.69 ± 0.1	2.2 ± 0.1	190
2	225 kpx, 1 × 1, low	142	2.35 ± 0.1	4.3 ± 0.1	43
3	625 kpx, 1 × 1, low	142	2.4 ± 0.1	5.2 ± 0.1	24

Table 1. Summary of performance of the scientific read-out modes.

* Limit of the 16 bit Analogue to Digital Converter (ADC).

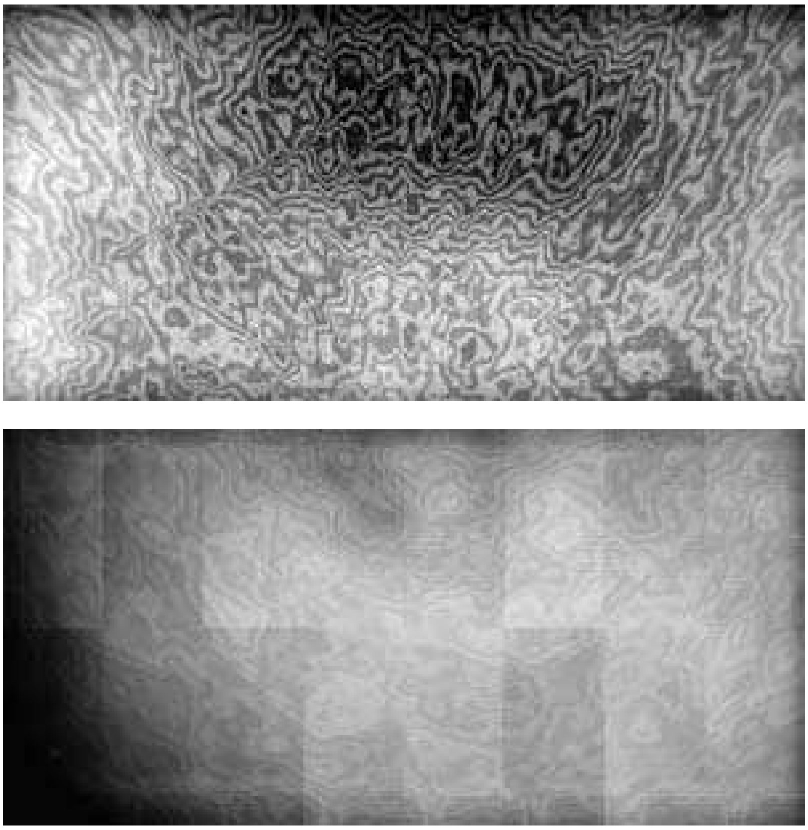

Figure 1. Comparison of flat-field images (~ 25 000 e^-) at wavelength 900 nm with 5 nm bandwidth. **Top:** Previous CCD Bruce. **Bottom:** New CCD Carreras. Carreras is a much thicker device (40 μm versus 16 μm) and thus has much less fringing.

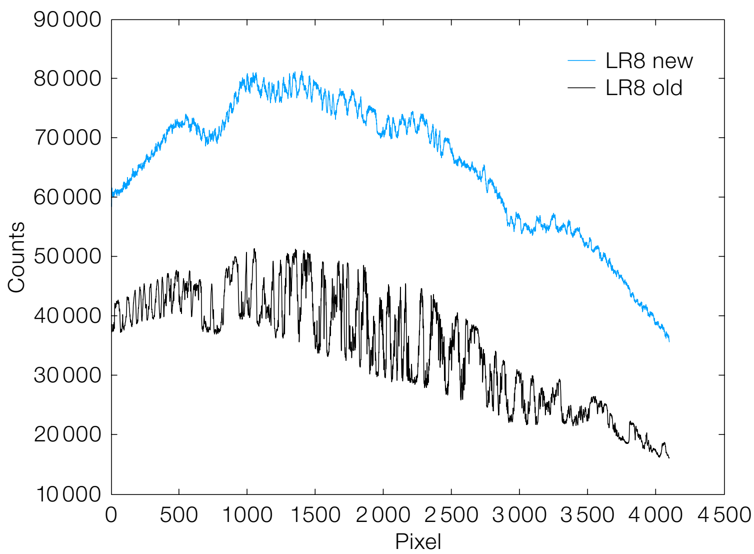

Figure 2. Extracted fibre flats for LR8 (881.7 nm) set-up taken with the same exposure time. Blue line is for the flat-field obtained with Carreras whereas the black line is the flat-field collected with Bruce.

were used to validate this curve. For the recent flats found in the ESO archive, the agreement of the observation with the lab prediction is very good in the red regime as shown in Figure 3, but slightly below the expectations for the blue settings.

Data reduction

During the commissioning, calibrations were taken for all set-ups in all five slit systems (two Medusa, two IFU and one Argus) in order to re-adjust the exposure times. These first flats and arcs allowed us to check whether the present default parameters are good enough to allow the pipeline to find and trace the fibres and compute the wavelength solution. We were happy to see that the pipeline with the default parameters could reduce all wavelength settings blueward of 650 nm.

A first trial was made to reduce a flat and an arc spectrum with the Geneva pipeline (Blecha et al., 2000; Royer et al., 2002).

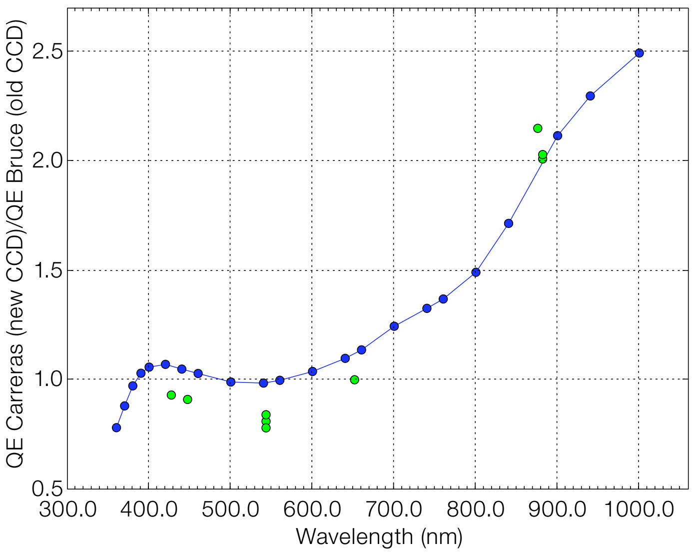

Figure 3. Quantum Efficiency ratio (Carreras/Bruce; new/old detector). The blue line shows the laboratory measurements. The green circles are the QE ratio measured using archive flat-field frames.

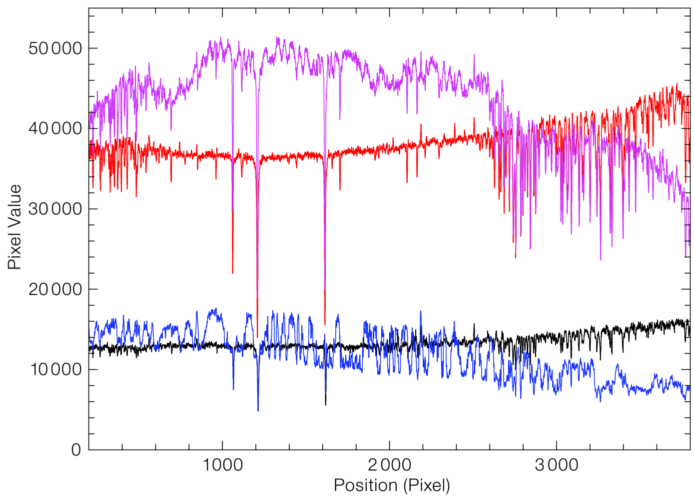

Figure 4. 10-min LR8 observations (low-resolution grating centred on 881.7 nm) for a V = 13.5 star in the globular cluster M15 (NGC 7078) observed with the old CCD Bruce (black and blue lines) and the new one Carreras (red and cyan lines). The blue (old observations) and the cyan (new observations) plots are the extracted spectra without flat-field correction, whereas the black (old observations) and the red (new observations) are spectra for which flat-field corrections were made.

The reduction took place without problems. This implies that those using this pipeline will probably be able to do so in the future. The static calibration database was prepared and installed at Paranal Observatory. A release of the new calibration database will be made public soon. Quality Control pages are available, fed by the QC parameters produced by the pipeline[1].

Science tests – Calcium triplet region

An important aspect for a full understanding of galactic evolution is the metallicity distribution function of the stellar population with time. There is an empirically developed, simply calibrated method available which allows an efficient estimate of metallicity ([Fe/H]) for individual red giant branch (RGB) stars using the strength of the Ca II triplet (CaT) lines at 849.8 nm, 854.2 nm and 866.2 nm. This method was pioneered for use on individual stars by Armandroff & da Costa (1991). It has the advantage that the lines are broad enough to be accurately measured with moderate spectral resolution (e.g. Cole et al., 2004). Since RGB stars are bright, this method can be successfully used to observe stars in other galaxies. As mentioned in section 1, the improvement of the QE and the drastic reduction of the fringing provided by Carreras are extremely interesting for studies using set-ups redder than 700 nm.

In Figure 4 we show 10-min LR8 set-up observations (low-resolution grating centred on 881.7 nm) for a V = 13.5 star in the globular cluster M15 (NGC 7078) observed with the old CCD (black and blue lines) and the new one (red and cyan lines). The blue (old observations) and the cyan (new observations) plots are the extracted spectra without flat-fielding whereas the black (old observations) and the red (new observations) are spectra for which flat-field correction was made.

From Figure 4 we can see that the difference in signal is almost a factor of three. The measured S/N ratios are 220 for the red spectrum and 60 for the black one, respectively. Even if the newer observations were taken in better seeing conditions (0.7 versus 1.1 arcsec) and after the M1 recoating, the impressive S/N improvement (higher than what was expected from photon noise only) is due to the QE enhancement and also (largely) to a much better fringing correction.

[1] Health Check pages can be accessed at *http://www.eso.org/observing/dfo/quality/GIRAFFE/reports/HEALTH/trend_report_BIAS_HC.html*.

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