A New 2048 × 2048 CCD for the CES Long Camera

L. PASQUINI[1], H. W. DUERBECK[1,2], S. DEIRIES[1], S. D'ODORICO[1] and R. REISS[1]

[1]European Southern Observatory; [2]Astronomisches Institut der Universität Münster, Germany

Introduction

The ESO CES spectrograph operates with the 1.4-m CAT telescope or it is fed by a fiber link from the Cassegrain focus of the 3.6-m. The spectrograph has two main configurations: a Short Camera used with the RCA CCD ESO # 9 and the Long Camera used with the same CCD or with a Reticon detector. In July 1992, a large-format CCD, a Ford Aerospace (now Loral) 2048 × 2048 CCD, ESO # 27, with a new ESO VME controller has been mounted and tested at the spectrograph and it is likely to replace the Reticon and CCD # 9 from now on. The characteristics of this device are summarized in Table 1. The main scientific, technical and operational drivers for this change are the following:

(1) The Reticon has so far been kept in operation for two main reasons: the absence of interference fringes which plague the RCA CCD at wavelengths longer than ~6000 Å, thus hampering very high S/N ratios in the observations and its length which, being almost the double of the RCA detector, allows a much broader wavelength coverage per frame. The new FORD CCD, a front-illuminated device, is much more uniform than the RCA CCD and is twice as long, giving the same spectral coverage per frame as the Reticon.

(2) The RCA CCD # 9 presents a rather high Read Out Noise (RON) level (33 e^-/pixel). When coupled with the Long Camera, the RON becomes the dominant source of noise for many of the applications. The Ford CCD has a RON of less than 10 e/pixel.

(3) By introducing a dedicated CCD detector for the Long Camera and retiring the Reticon, ESO expects to simplify the camera + detector changes at the spectrograph and to improve the reliability and performance of the systems.

The CCD belongs to a batch that ESO has procured from Ford Aerospace in 1991. This particular chip has subsequently been lumigen coated at EEV in order to enhance its blue response. The quantum efficiency curve is shown in Figure 1. The 15-μm pixel size is well matched to the spectral and spatial resolution given by the spectrograph.

Table 1. *FA 2048, UV-Coated ESO CCD # 27**

Pixel size	15 micron square
Active pixel number	2048 × 2048
QE	16 % (350 nm), 34 % (550 nm), 38 % (750 nm), 18 (850 nm)
Standard oper. temp.	~165° K
Standard conv. factor	2.9 e^- /ADU
Read-out noise	6 e^- RMS
Dark current	3 e^- /pixel/hour
Capacity	87000 e^- /pixel (3 % deviation from linearity)
CTE	≥ .99997
Bias value	~276
Defects	A number of warm and dark columns, but most of them outside the central 500 columns of the CCD
Cosmic ray event rate	1 event/min/cm^2

* Used at the CES with the Long Camera.

Results of the Tests

The test were performed during 5 nights in July 1992.

The first check was carried out on the spectral resolution. Measurements were performed on spectra from the Th-Ar calibration lamp taken at different wavelengths at a Resolving Power R = 100,000. The results were quite satisfactory: with the exception of the bluest ~150 pixels (see below) the FWHM of the measured lines was uniform within 0.1 pixel over the whole chip length and within 0.04 pixel in the central part. These values are typical for the Long Camera, compatible with the accuracy achievable with the focussing procedure used and prove that deviation from flatness in the CCD surface and the coating do not introduce significant degradation of the expected resolution.

Weather conditions were very poor during the test run, except for one photometric night which was used for absolute efficiency measurements. These were based on the observations of several standard stars (Hamuy et al. 1992). To have a direct comparison, the same central wavelengths as given in the CAT + CES Manual (Lindgren and Gilliotte 1989) were chosen. The result-

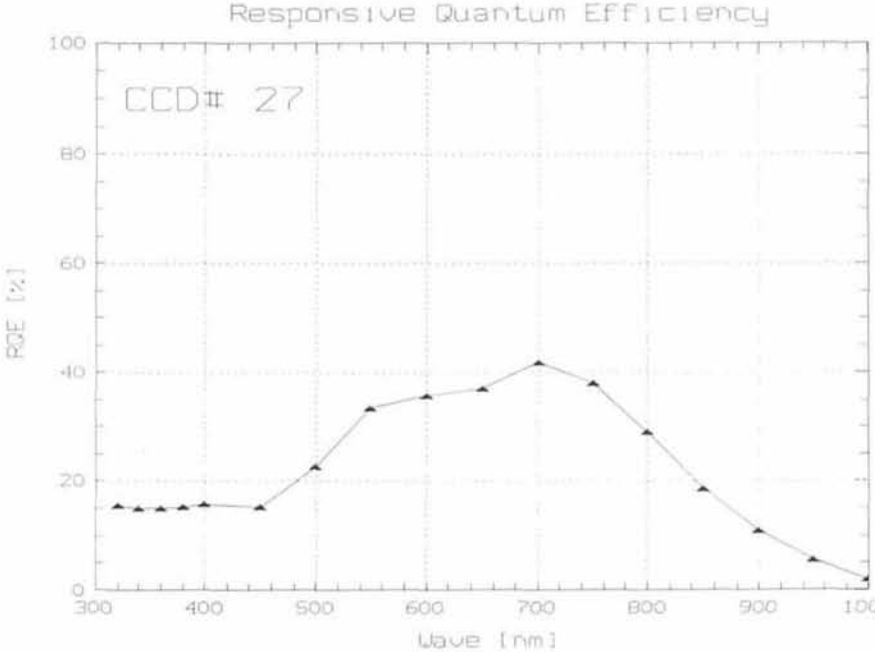

Figure 1: *Responsive quantum efficiency of the CCD # 27.*

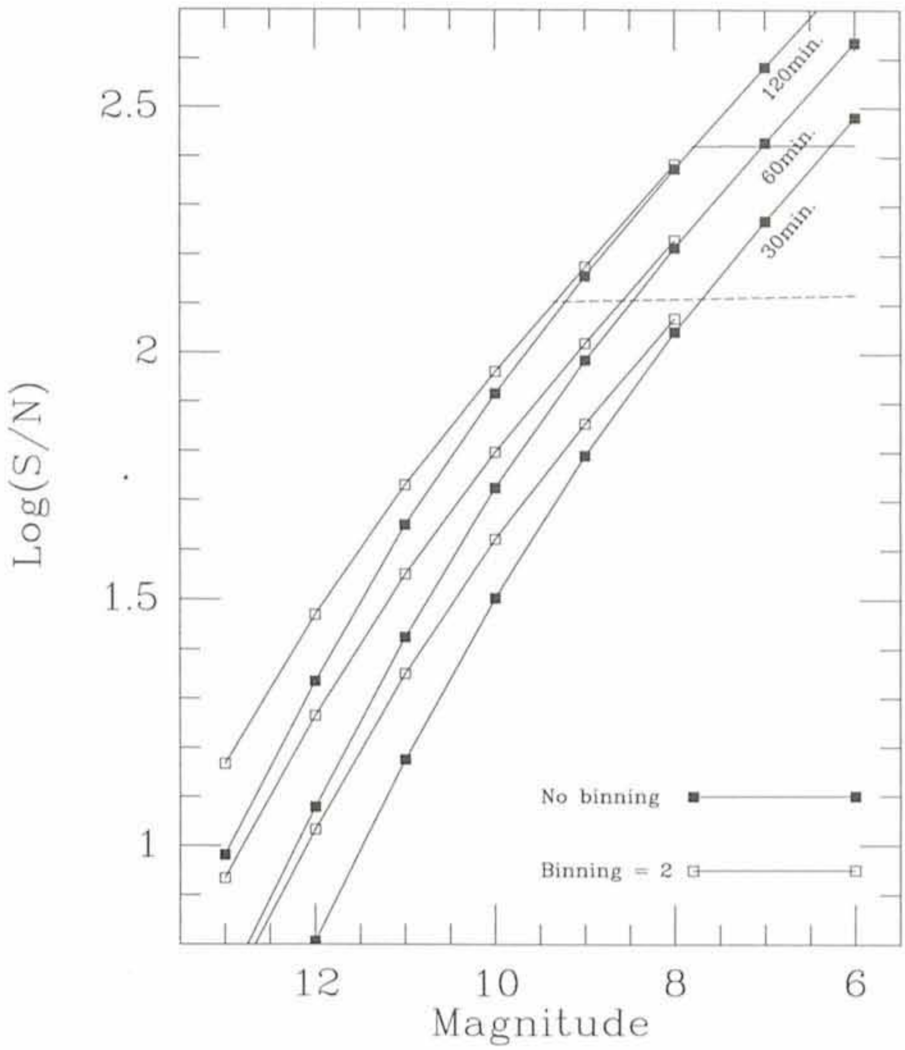

Figure 2: *Expected S/N ratios as a function of stellar magnitude and integration times. An efficiency of 4.6 % at 6450 Å is assumed. No slit losses were applied in the computation.*

ing efficiencies given in Table 2 are in very good agreement with what is expected from the ratio of the Ford and RCA CCD quantum efficiencies.

The new configuration has a lower overall efficiency but in order to evaluate the instrument performance, all the characteristics of the detector must be taken in account; in particular its RON and Dark Current level. This is particularly important in the CES Long Camera, where the spectrum is spread in the spatial direction over a considerable number of pixels (typically 9). With only 6 e^-/pix RON (compared with the 33 e^-/pix of the RCA) the advantage of using the Ford with respect to the RCA CCD becomes prominent, at least for all those observations requiring intermediate to high S/N ratios. Figure 2 shows the expected S/N ratios as a function of integration time and stellar magnitudes. To compute them the same formula used in the CES manual was adopted:

where N_o is the number of detected e^-/s/λbin for a star of magnitude m_o, T is the integration time in hours, W is the width of the spectrum in pixels, N_r is the RON, b the binning factor perpendicular to the dispersion, and D the dark current in e^-/pix/hour. The points in Figure 2 were computed assuming the Ford characteristics as given in Table 1 and an overall efficiency of 4.6 %. Although these numbers must be taken only as indicative (slit losses were not considered), a direct comparison with the performances of the CAT + CES and RCA CCD can be performed. The two almost constant lines in Figure 2 limit the loci of equal performances between the old and new configuration, both for unbinned (continuous line) and binned (dashed line) CCD's. For observations requiring S/N ratios lower than ~260 in unbinned mode and ~130 with a binning of 2, the use of the Ford is more convenient.

$$S/N = \frac{3600 \times N_0 T 10^{0.4(m_\lambda - m_o)}}{(3600 \times N_0 T 10^{0.4(m_\lambda - m_o)} + (W b^{-1} N_r)^2 + W^2 T D)^{0.5}}$$

Table 2. *Efficiency of the CAT + CES + Long Camera + CCD # 27*

Wavelength (Å)	Efficiency
5400	3.8 %
6450	4.6 %
8090	2.2 %

We expect that the advantages of using the Ford CCD will be even more conspicuous when the CES is coupled with the 3.6-m telescope fibre link (D'Odorico et al. 1989): in this case in fact the spectrum is spread over a much larger number of pixels (typically 220 with the 11 slice image slicer), therefore the lower RON of the Ford CCD becomes even more important.

The second advantage of this new configuration is the absence of fringes, even at very red wavelengths; in Figure 4, a five-minute normalized spectrum of the standard star HR 718 is shown in the region around 8092 Å. This spectrum has not been flat field corrected and the variations in the continuum are of the order of 0.9 % or less.

Last but not least, in evaluating the instrumental performances, we have to consider that almost the double of the spectral coverage is obtained in one frame; this feature is very important not only when the simultaneous observation of several lines is required, but also in those cases where broad lines are observed and a large coverage is essential to determine the continuum level.

As a scientific application, in Figure 3, a 1-hour Hα spectrum of the recurrent nova V745 Sco is shown. This object has a visual magnitude of 15.9 and an R magnitude of 13.8, as measured from absolute calibrated EFOSC spectra. The CES spectrum in Figure 3 shows that a S/N of ~ 5 is reached in the continuum close to the Hα line.

Considering all the previous points it may therefore be advisable to use the Long Camera and the Ford detector also for observations at red wavelengths and at lower resolution, for which the Short Camera is now used (i.e. R ~ 50000). On-chip binning and the absence of fringes will compensate in many types of observations the lower efficiencies of the Ford CCD and of the Long Camera.

Advice to the Users

Considering the results obtained from this test, ESO will normally offer from now on the Ford CCD on the Long Camera as a standard combination. This implies that the use of both the Reticon and the RCA # 9 at the same camera will be discontinued and that the RCA CCD will be permanently mounted on the CES Short Camera.

We regard this as an optimum compromise between scientific performances and the severe operational and maintenance constraints of the observatory.

Users must however be cautioned that this new configuration has not yet been extensively debugged. In the next months, their feedback on the astronomical performance and any general comments will be much appreciated.

Some problems have already been identified and are being investigated. Namely:

(1) Some vignetting is present at the blue edge of the spectra and this makes the first ~ 150 rows of little use. Vignetting was present at a lower level in the Reticon spectra: the larger format of the Ford shows this problem much more clearly.

(2) In order to reach the predicted performance of the new set-up, it is essential to operate the CCD in an optimal way, in particular with regard to the RON and the dark current. During the tests, the level of the dark current was somewhat higher than expected and the on-chip binning introduced variable patterns in the background at a level higher than the measured RON. Both of these problems have already been observed in the past with other CCDs, but they are transient in nature and hence not easily debugged. A careful monitoring of these CCD parameters by the scientific users is recommended and it will be useful to optimize the CCD performance.

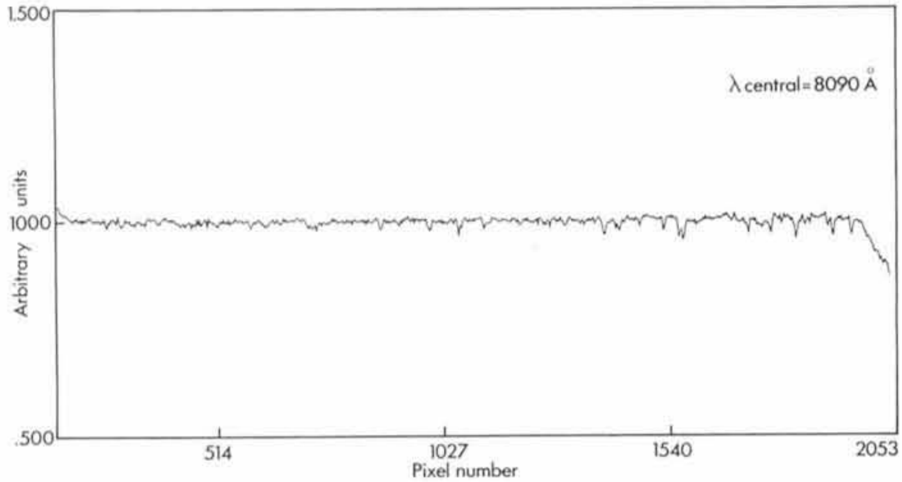

Figure 3: *A 5-minute, normalized spectrum of the standard star HR 718 centred at 8090 Å. No flat-field correction has been applied. Note the absence of interference fringes.*

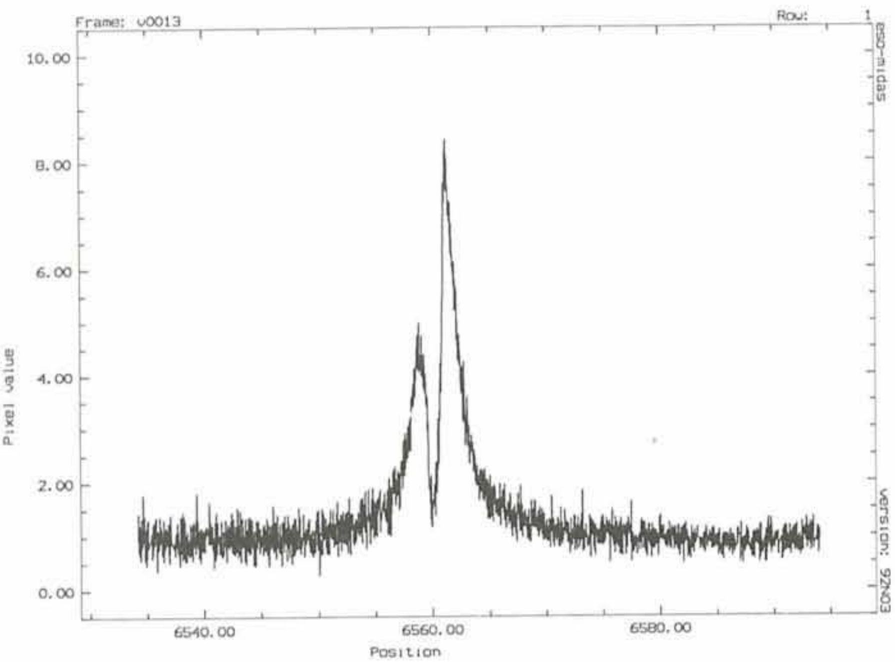

Figure 4: *A 1-hour Hα spectrum of the recurrent nova V745 Sco. The S/N is ~ 5 in the continuum.*

Acknowledgements

The mechanics and detector groups at La Silla worked hard and successfully to adapt the new CCD to the Long Camera. H.V. Winckel kindly provided some of the observations.

References

D'Odorico, S., Avila, G., Molaro, P. 1989: *The Messenger* **58**, 58.

Hamuy, M., et al. 1992: *A.J.*, in press.

Lindgren, H., Gilliotte, A. 1989: The Coudé Echelle Spectrometer – ESO Operating Manual No. 8.

New CCD Cryostat for EFOSC2

At the time of the transfer of EFOSC2 from the NTT to the 2.2-m telescope the instrument set-up had to be revised. The plan was to interface it to the 2.2-m rotator-adapter (DISCO) in order to profit from the existing calibration and guiding facilities.

The mounting extention with the large format CCD cryostat at the bottom of the instrument, however, restricted the declination drive freedom to 63° in the south. The intention was to replace the IR Lab cryostat with a shorter LN_2 container. But the hold time of such a small dewar presented a severe limitation.