New Power for the Danish 1.54-m Telescope

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Meeting New Challenges

After more than 15 years of intensive use, the Danish 1.54-m telescope on La Silla and its equipment are undergoing a major overhaul. The goal of this joint effort with ESO is to provide a more powerful research tool, updated to reflect changing scientific priorities. It will be armed with a couple of core instruments, permanently mounted and requiring a minimum of effort in operation and maintenance.

On January 20, 1995, we passed a major milestone in the upgrade project with the installation of several new features, chief of which is the new DFOSC (Danish Faint Object Spectrograph and Camera), patterned after ESO's very successful EFOSC instruments and equipped with a thinned Loral 2048 × 2048 CCD with exceptionally high quantum efficiency (QE). Also, a simple mirror cooling system was installed which will hopefully lead to an improved image quality. In this article, we briefly describe the DFOSC and its capabilities and our plans for the next steps.

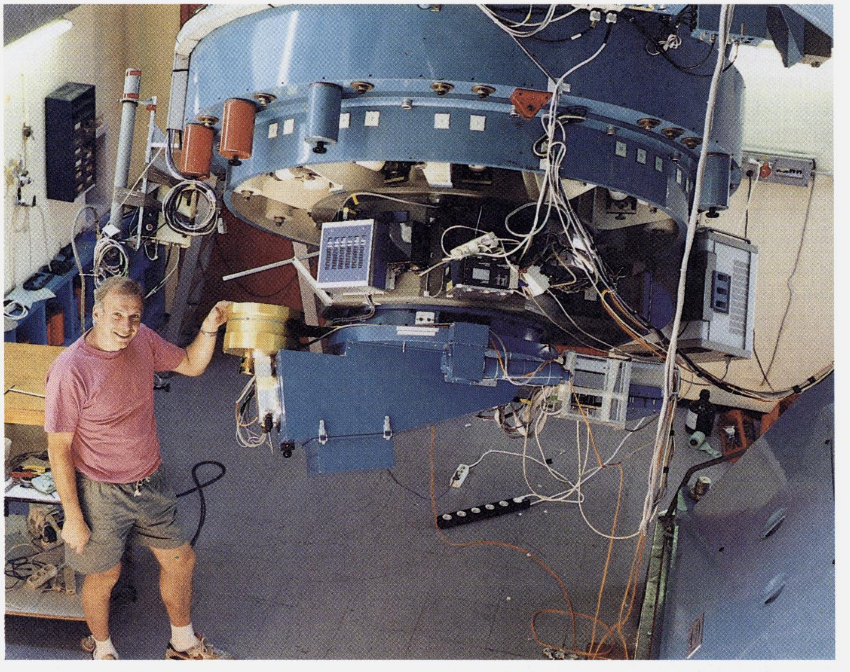

Figure 1: *DFOSC and the new CCD camera mounted on the telescope.*

The DFOSC

In choosing our new workhorse, scientific goals, the main strengths of the telescope, and the capabilities that do or will exist elsewhere on La Silla must all be considered. A future main class of research for a 1.5-m telescope on La Silla will be searches for and spectroscopy of faint objects, in stand-alone programmes or in preparation for studies with the VLT. Its wide-field Ritchey-Chrétien optics makes the 1.54-m particularly suited for such work. The EFOSC design (cf. *The Messenger* 38, 9) offers an elegant way to match a large optical field to available CCD detector formats, providing a maximum of observing modes with a minimum of operational effort. Therefore, and with the kind collaboration of Bernard Delabre of ESO, the DFOSC optical design is based on the EFOSCs, adapted to the 1.54-m environment.

With a single 2K × 2K CCD – as ambitious as our modest resources and the optical properties of the design were likely to allow – and an optimum final pixel size of 0.″4 (15 μm), the full field covered by the instrument is 13.′7 × 13.′7. Selecting a 30-mm collimated beam then fixes the main optical parameters. A prism with total internal reflection bends the light path almost parallel to the primary mirror, giving a compact instrument with minimal operational constraints (see Fig. 1).

Filters and grisms are introduced in the parallel beam via two wheels and are easily exchangeable from the bottom of the instrument. Thus, one can change from direct imaging in a variety of passbands to spectroscopy with a range of resolutions (Table 1) in a few seconds. In the telescope focal plane, aperture plates with long slits, multislits, or test patterns can be inserted in an aperture wheel; a small CNC machine allows quick fabrication of customized aperture plates for multi-object spectroscopy. The entire instrument rotates about the telescope optical axis so that long slits can be placed in the desired orientation, and it is operated from a workstation in the control room. The basic DFOSC was commissioned by ESO in November 1994.

In January 1995, the final CCD camera was added, and a new, user-friendly filter and shutter unit (FASU) was installed in front of the DFOSC. The 90-mm filters accommodated here cover the full field for applications, e.g. narrow-band interference filters, where filters mounted in the collimated beam (and tilted 6° to avoid ghost images) would introduce a significant field gradient in the passband.

The CCD Detector

As mentioned above, DFOSC is designed to use a 2K × 2K CCD with 15-μm

TABLE 1. DFOSC grisms data. RS is the resolution-slit product. Data for the echelle grisms are given for 13th (#9) and 3rd orders (#13).

Grism No.	Blaze (Å)	Dispersion (Å mm−1)	RS
3	385	179	640
4	495	220	700
5	670	220	870
6	385	110	990
7	515	110	1300
8	725	88	2200
9	520	26	4300
10	415	460	230
11	510	340	390
12	730	910	200
13	545	36	4200

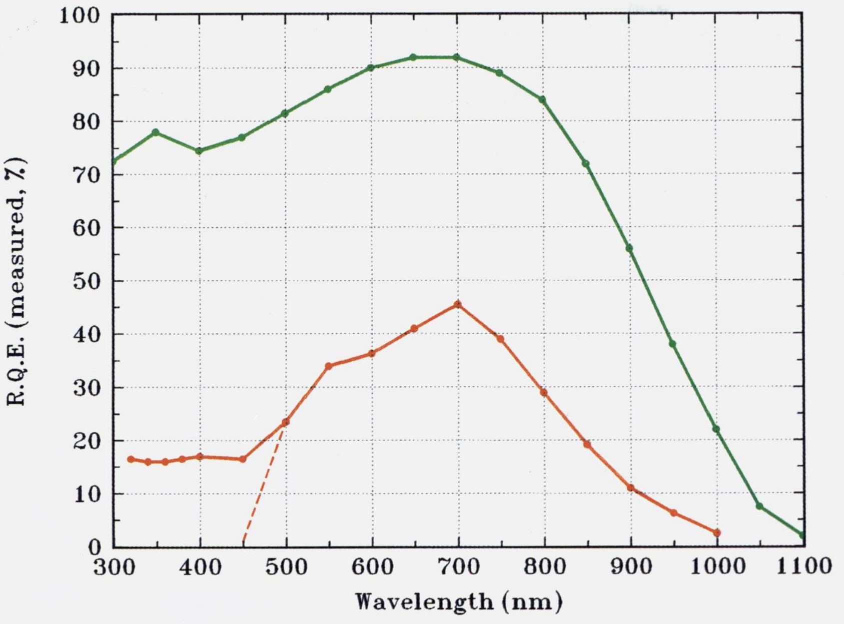

Figure 2: *Measured quantum efficiency of the thinned DFOSC CCD (green), compared to a typical thick Loral CCD (red; dashed: uncoated).*

pixels. The chip now mounted is the 3-side buttable version designed by John Geary (SAO) and fabricated by Loral Fairchild. In order to enhance sensitivity, especially in the blue, it was thinned by Michael Lesser (University of Arizona) and coated with a two-layer anti-reflection coating (HfO_2 + MgF_2). A simple UV flooding procedure is needed for optimum QE if the chip is warmed up to room temperature.

Figure 2 compares the actual, measured QE with that of a typical thick, coated Loral CCD. As will be seen, it is remarkable indeed. In fact, in the UV, the gain over the thick chip is quite comparable to that from a 3.6-m to one of the VLT 8.2-m unit telescopes!

As can be seen in Figure 1, a special shape of dewar is needed to avoid collisions with the telescope or pier when the telescope moves around and DFOSC is rotated about its axis. This special camera was constructed in our laboratory and equipped with a CCD controller and data acquisition system also developed there. Measured readout noise with the thinned Loral CCD is about 7 e^- rms, dark signal about 2 e^- $pixel^{-1}$ s^1 at –100 C (MPP mode), linearity very good up to near the saturation limit of about 85,000 e^- $pixel^{-1}$ (also in MPP mode). CTE and cosmetics are excellent, and crosstalk between the two amplifiers negligible. Pixel binning in X and Y and readout windows are easily selectable from exposure to exposure. Using both amplifiers, the full chip is read out and the data stored on the workstation disk in FITS format in 45 seconds, ready for processing.

Performance

During the nights January 20–26, 1995, a large number of tests were made of all operational aspects of the instrument. The detailed results will be given in a technical report when all the data have been properly reduced. To give readers a first impression of the new capabilities of the telescope, we show in Figure 3 a direct exposure of the 30 Doradus region in the Large Magellanic Cloud. In addition, Table 1 gives approximate count rates for grism spectroscopy; these numbers are subject to revision after the final data reduction.

In the cryostat window of the new CCD camera, doubling as the DFOSC field flattening lens, the original, slightly radioactive BK7 glass has been replaced by fused silica. The result is a tenfold reduction in cosmic-ray-event rate.

Future Plans

Our plans for the future have as one goal to integrate the new ESO Telescope Control System with the controls of the new adapter, the FASU, the DFOSC, and the CCD through one convenient user interface, so the observer can easily control all functions that are essential from his/her point of view (field to be observed, filters, exposure times; focus or calibration sequences, etc.), and the

Figure 3: *A 4-minute exposure of the 30 Doradus region in the Gunn r band, taken on January 20, 1995, with DFOSC and the new CCD camera.*

TABLE 2. Count rates (e⁻ s⁻¹ Å⁻¹) for monochromatic magnitude m_λ = 12.0.

λ (nm)	Grism #6	Grism #7
350	41	–
400	69	52
450	56	59
500	48	61
550	–	58
600	–	52
650	–	48

data are transferred seamlessly and with all necessary header information right into the observer's favorite image-processing system.

Another important goal is to add a direct CCD imaging option. Finer sampling is needed to yield the best spatial resolution on nights of good seeing (which will, we hope, be more frequent with the new mirror cooling system). Also, focal reducing optics are not always optimal for precision field photometry. Therefore, we plan to install, perhaps in early 1996, a direct CCD of the type described above in a stand-by position in the adapter, fed by a 45° mirror and with rapid tip/tilt correction for atmospheric image motion. At 0.″23 per pixel, this should be a valuable high-resolution imaging option, always readily available when good seeing occurs.

Moreover, a fiber-feed position is foreseen in the adapter, so an off-telescope instrument can be permanently connected, eliminating changeovers and improving instrument stability. Options under study include the radial-velocity scanner CORAVEL or (better) an optimized, bench-mounted échelle spectrograph.

Finally, much remains to be learned about the optimization (including UV flooding), testing, maintenance, and operation of high- performance CCD detectors. We look forward to continuing our pleasant cooperation with the ESO Optical Detector Group in this area, to the benefit of both sides – and our users.

Acknowledgement

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A New CCD Field Lens in EMMI Red Arm

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The ESO Multi-Mode Instrument EMMI was first installed at the NTT in the summer of 1990. At that time the red arm was equipped with a thick CCD with UV-blue sensitive coating because the originally planned thinned 2048² detector had not become available. At the beginning of 1994 (see *The Messenger* No. 76, p.15) a 2048² thinned SITe CCD was finally installed on the instrument with its dedicated camera. One last step was however still necessary to fully realize the planned optical quality of the instrument. The sensitive surface of the CCD delivered to ESO proved to be convex with a peak at its centre in the direction of the camera. The curvature is due to the CCD assembly process and it is well approximated by a paraboloid. The difference between centre and corners is approximately 200 μm and resulted in a higher dispersion around the average value of the image quality in the field of view, with a significant degradation in the corners. A new field lens, to serve also as window of the cryostat, was computed to compensate for this curvature and it has been installed and tested in three nights in January 1995.

Image quality has been determined through observations of several star fields (either outer regions of globular clusters, or open clusters) in order to determine the best centring position for the field lens. One important point to realize is that image quality can be really assessed only through astronomical observations performed in good seeing. NGC 2204 appeared to be the best choice in terms of uniform star distribution. After several iterations of fine-centring the lens, an image of 0.57″ was obtained (i.e. just above the critical sampling for the 0.27″ pixels of the camera). Although a 10 % variation was visible between centre and edges of the field of view, this demonstrated that the performance of the lens allows us to

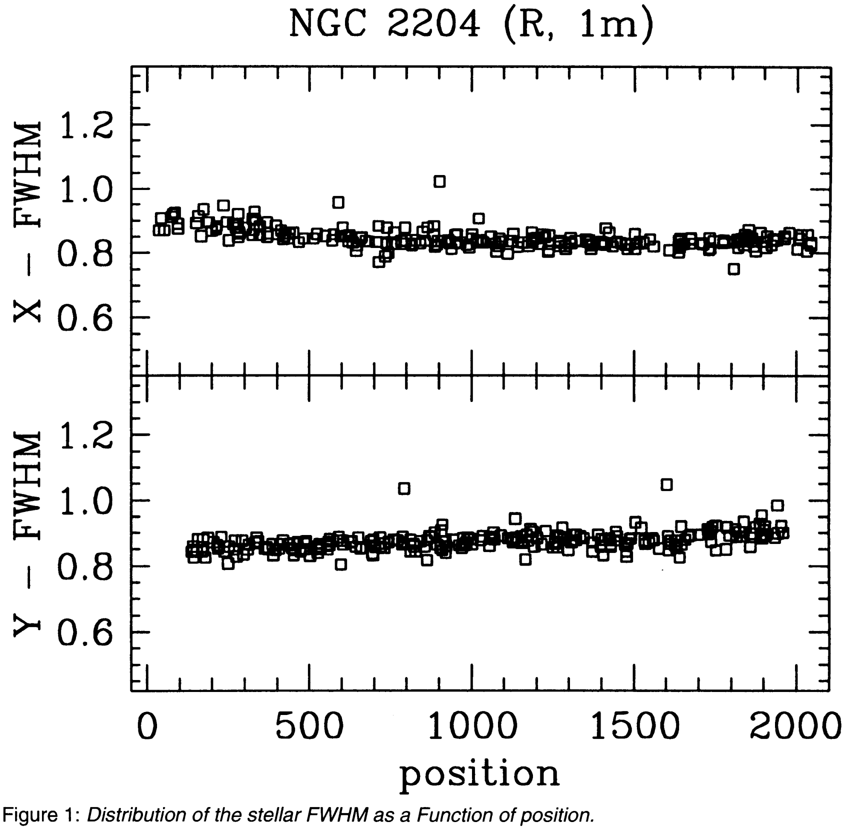

Figure 1: *Distribution of the stellar FWHM as a Function of position.*