EUROPEAN SOUTHERN OBSERVATORY

Organisation Européenne pour des Recherches Astronomiques dans l'Hémisphère Austral

Europäische Organisation für astronomische Forschung in der südlichen Hemisphäre

LA SILLA OBSERVATORY

Science Operations

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EFOSC2 USER'S MANUAL

Doc. No. LSO-MAN-ESO-36100-0004

Issue 3.1

Date 06/2008

Prepared . . . .
L. Monaco, C. Snodgrass   06/2008

                  Name   Date   Signature

Approved . . . .
I. Saviane   06/2008

                  Name   Date   Signature

Released . . . .
I. Saviane   06/2008

                  Name   Date   Signature

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Change Record

Issue/Rev.	Date	Section/Parag. affected	Reason/Initiation/Documents/Remarks
1.1	30/05/99	All	First Release
2.0	16/09/03	All	Major Rewrite
3.0	03/08	All	EFOSC2 to be relocated to NTT.
			User Requirements added.
			New Grisms and
			Quarter Wave Plate available.
3.1	06/08	All	EFOSC2 re-commissioned at NTT during April 2008;
			New instrument specifications implemented

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1 Introduction

1.1 Purpose

This manual describes the operation of the ESO Faint Object Spectrograph and Camera (EFOSC2) currently mounted at the New Technology Telescope (NTT). It is intended to be a general guide for the observer who is going to use EFOSC2, for both the proposal preparation and the observing run itself.

1.2 Scope

This is a revised version of the previous operating manuals. In particular, it collects the new features implemented with the relocation of EFOSC2 from the 3.6m telescope to the NTT as of April 2008. The present version of the manual includes the instrument specifications as measured and checked during the re-commissioning phase (April 2008).

First-time users are advised to read this manual carefully and to familiarize themselves with the optical system and the observing procedures, even if observation with P2PP makes it much simpler than it used to be.

For recent changes, updates and news related to EFOSC2, the WEB page
http://www.eso.org/sci/facilities/lasilla/instruments/efosc/
should be checked before an observing run. **The WEB page is updated constantly and may contain information not covered by this manual.**

The present EFOSC2 User's Manual is based on previous versions of the same manual by G. K. T. Hau and F. Patat.

<div align="right">Santiago, June 2008</div>

1.3 Reference documents

The following documents are referenced in this document:

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2. Augusteijn, T. & Storm, J., 1996 *Commissioning of new CCD#40 for EFOSC2*, ESO Memorandum

3. Filippenko, A.V., 1982, PASP, 94, 715

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5. McLean, I., 1997, *Electronic Imaging in Astronomy*, I. McLean, WILEY-PRAXIS Series in Astronomy and Astrophysics, John Wiley and Sons

6. Melnick, J, Dekker, H., D'Odorico, S., 1989, *EFOSC (ESO Faint Object Spectrograph and Camera)*, ESO Operating Manual n.4

7. Melnick, J., 1993, *EFOSC1 Update to the Operating Manual, Version n. 1*

8. Melnick, J., 1993, *EFOSC2 Operating Manual*, Version n. 2

9. Melnick, J. & Mendes de Oliveira, C., 1995, *EFOSC2 Operating Manual*, Version n. 2.1

10. Osterbrock, D.E. & Martel, A., 1992, PASP 104, 76

11. Savaglio, S., Benetti, S., Pasquini, L., 1996, *EFOSC1 Operating Manual*, Version n. 3

12. Storm, J. & Brewer, J., 1997, *Observing at the Danish 1.54m Telescope*, ESO Manual

13. Szeifert, T., 1998, *First Order Estimates of the systematic observation biases of FORS in polarimetric mode due to non Achromatism of the retarder plates*, VLT Instrument Consortium, Issue 1.3

14. Tyson, N.D., & Gal, R.R., 1993, AJ 105, 1206

15. Valdes, F., 1998, *Guide to the NOAO Mosaic Data Handling Software*, IRAF Package

1.4   Abbreviations and acronyms

The following abbreviations and acronyms are used in this document:

AG	Autoguider
BOB	Broker for Observation Blocks
EFOSC	ESO Faint Object Spectrograph & Camera
EMMI	ESO Multi Mode Instrument
FITS	Flexible Image Transport System
GUI	Graphical User Interface
HWP	Half Wave Plate
QWP	Quarter Wave Plate
ICS	Instrument Control Software
LSO	La Silla Observatory
MIDAS	Munich Image Data Analysis System
MOS	Multi Object Spectroscopy
NTT	New Technology Telescope
OS	Observation Software
P2PP	Phase 2 Proposal Preparation
RTD	Real Time Display
SA	Support Astronomer
TBC	To Be Checked
TBD	To Be Defined
TBV	To Be Verified
TCS	Telescope Control Software
TIO	Telescope & Instrument Operator
URL	Uniform Resource Locator
VLT	Very Large Telescope
VA	Visiting Astronomer

2 EFOSC2 Overview

2.1 History of EFOSC2

Late in 1987 it became clear that before the implementation of EMMI (the ESO Multi-Mode Instrument) on the NTT, an instrument with imaging and spectroscopic capabilities would be needed at the NTT both for the commissioning phase and for the first visitor programs. The obvious choice was to build a copy of EFOSC (later called EFOSC1) on the 3.6m telescope in view of its moderate size and above all the possibility of using the instrument later on the 2.2m telescope.

The original idea was to build an identical copy of the 3.6m telescope instrument, but it soon became clear that a different mechanical design would be needed to mount the instrument on the NTT and to accommodate a large format CCD. It was also clear from the experience with the 3.6m version that a number of improvements were desirable, in particular a better UV response, a lower sky background compensation and provisions for easier handling of the optical components.

In 1997 EFOSC1 was de-commissioned and EFOSC2 was finally moved to the 3.6m where it was offered until ESO period P80. As of April 2008, EFOSC2 is offered at the NTT together with the multimode infrared instrument SoFI.

2.2 General Description

Briefly, EFOSC2 is a focal reducer using multi–layer coated all–transmission optics. Figure 1 gives a general and schematic view of the optical and mechanical design of the instrument.

The EFOSC2 camera is opened to F/4.9 and its focal length is 200mm. The NTT Nasmyth stations work at $f/11$. The F/4.9 camera focuses the beam onto the CCD, whose pixel size is 15μ. This turns into a pixel scale of $0.''12$ px^{-1}.

The interchangeable optical elements (slits, filters, grisms, etc.) are mounted in three wheels which are referred to as: aperture wheel, filter wheel and grism wheel. The aperture wheel is located in the focal plane of the telescope, in front of the collimator, so that the projected scale for slits is the telescope scale ($5.''3$/mm.) The filter and grism wheels are located in the parallel beam, between the collimator and the camera. Thus, in principle, grisms and filters mounted on these wheels do not introduce focus offsets. In practice, however, some elements may have optical power, and it is recommended to check the focus during the instrument set–up phase.

Defocusing introduced by filters and grisms is negligible, so is secondary chromatic aberration which has been largely eliminated by using special glass (FK 54) for the optics. For all practical purposes, the EFOSC2 focus is stable and independent of temperature, wavelength, or mode of operation. It was therefore possible to build EFOSC2 without a remote focusing unit; the focus is checked during maintenance prior to a run and very accurately set. Thus, the observer only has to be concerned with focusing the telescope.

The optical transmission curve is shown in Fig. 2 where the transmission of EFOSC1 is also plotted for comparison. The rapid decrease of efficiency below 4000Å is due to intrinsic losses in optical cement and glass and increased glass/air interface losses.

2.3 EFOSC2 Modes

One of the most outstanding features of EFOSC2 is its flexibility in performing very different astronomical observations. In fact EFOSC2 offers seven different observing modes: three for **Imaging** and four for **Spectroscopy**. These modes are achieved using different combinations of the optical

EFOSC2

1. Calibr. Lamps
2. Aperture Wheel
3. Tel. F. Plane
4. Motor
5. Encoder
6. Collimator
7. Half Wave Plate
8. Filter Wheel
9. Grism Wheel
10. Shutter
11. Camera
12. Thermal Comp.
13. Focus Ring
14. CCD
15. Cryostat
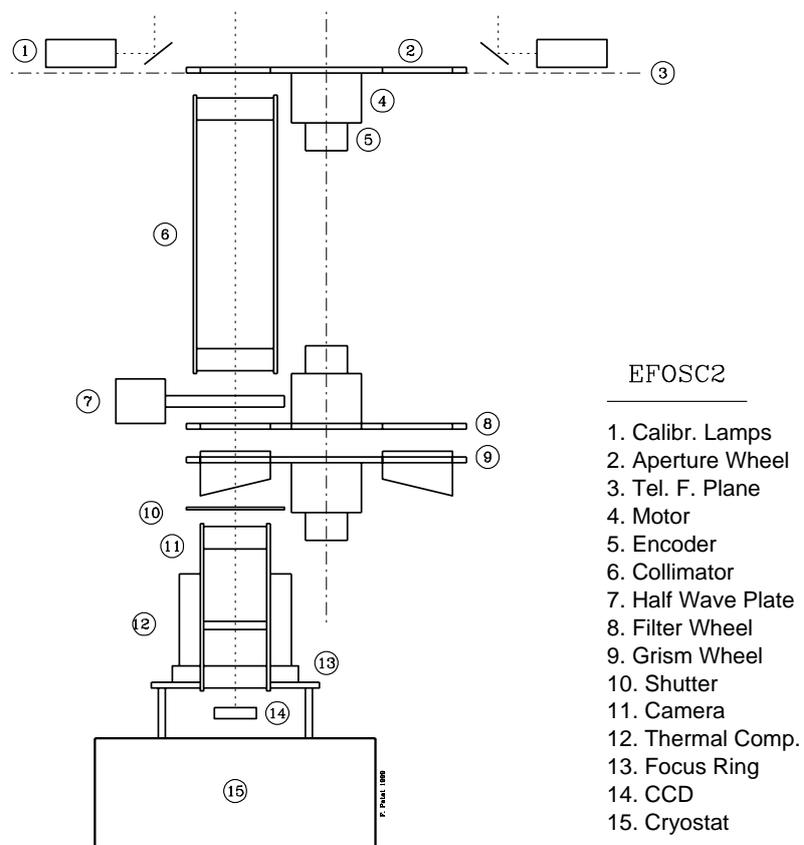
Figure 1: Schematic optical and mechanical layout of EFOSC2.
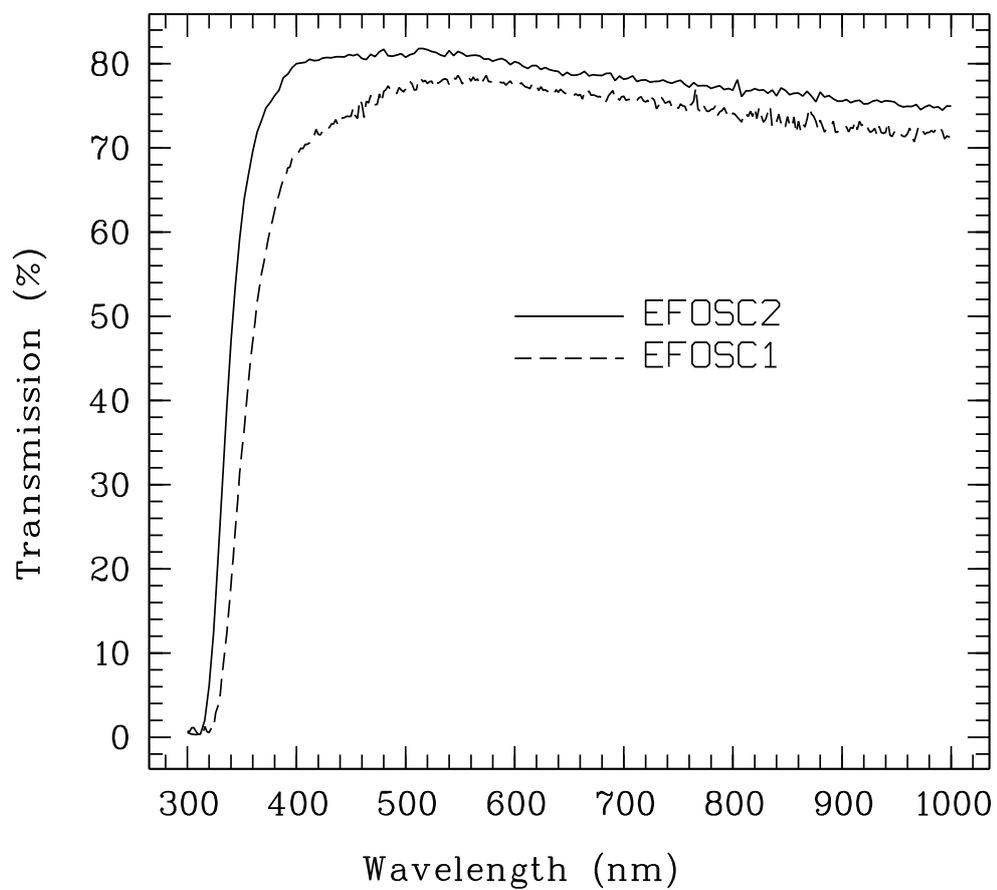
Figure 2: Overall transmission of the EFOSC2 optics compared to EFOSC1.

components which can be inserted in the instrument. All offered modes and their corresponding setups are presented in Table 1.

Mode	Aperture Wheel	Filter Wheel	Grism Wheel	HWP/QWP
Imaging	Free	Filter	Free	Out
Coronographic Imaging	Cor. Mask	Filter	Lyot Stop	Out
Polarimetric Imaging	Woll. Mask	Filter	Woll. Prism	In
Spectroscopy	Slit	Free	Grism	Out
Multi Object Spectroscopy	MOS Plate	Free	Grism	Out
Slitless Spectroscopy	Free	Free/Filt.	Grism/Prism	Out
Spectropolarimetry	Slit/Mask	Woll. Prism	Grism	In

Table 1: EFOSC2 Observing Modes.

Note that while all other modes are compatible among each other, Polarimetric Imaging and Spectropolarimetry Modes with the same Wollaston Prism **are not** simultaneously possible. In fact they require the Wollaston Prism to be mounted in two different wheels. The only possible configuration which allows both modes is to mount the 10″ Wollaston Prism in the filter wheel (for Spectropolarimetry) and the 20″ Wollaston Prism in the grism wheel (for Polarimetric Imaging).

2.4   Instrument Setup

Because of the many operation modes of EFOSC2, not all the available slits, filters and grisms can be permanently mounted. Please discuss your setup requirements with your Support Astronomer well in advance. In particular, at least one day before starting observations, the Visiting Astronomer must submit a setup request. This is done by filling a WEB form
http://www.eso.org/sci/facilities/lasilla/sciops/bin/efosc.cgi
(If the WEB form is offline, please send the request to ls-coord@eso.org.) Note that, while filters can be easily exchanged, changing slits and/or grisms is time consuming, since they require precise alignment. Hence last minute changes should be avoided as much as possible. The installation of the movable slit is particularly cumbersome, since the aperture wheel has to be dismounted and therefore all slit alignments are lost.

In total there are 8 free positions in the grism wheel, 11 in the filter wheel and 5–7 in the aperture/starplate wheel.

A form describing the current setup of the instrument can be provided upon request by the Day Operation crew at the beginning of the run and also after any changes.

In the next sections we will describe in detail all components which can be mounted on EFOSC2.

2.4.1   Slits

The terms Star-plates, slits and masks are used interchangeably - they all refer to elements which block light from some region of the field of view of EFOSC2. All these are mounted in the Aperture Wheel of EFOSC2.

The Slit wheel contains 10 positions of which

- 1 position should always be kept free

- 1 position is permanently occupied by the movable 1.5" slit

- 1 position is needed for the pinhole mask for aligning other optical elements (grisms)

- 1 position should be reserved for the 5" slit which is needed for spectrophotometric calibration.

- 1 position is occupied by the Holes Mask used for focusing the instrument during the set-up night.

Thus between 5 and 7 positions are available for user selected elements at any given time.

Fixed slits of widths $0''3, 0''5, 0''7, 1'', 1''0, 1''2, 1''5, 2''0, 5.0'', 10''0$, and $15''0$ are available for use with EFOSC2. The length of these slits is about $4'1$. Each time a fixed slit is mounted in the aperture wheel it rests in a slightly different position. The typical displacement in the Y position (i.e. along the dispersion direction) is of the order of a few pixels. This means that comparison spectra taken after two different setups might show small shifts.

In addition to the fixed slits, a $1''5$ movable slit has been manufactured at La Silla. This slit can be displaced in order to adjust the wavelength range covered by the grisms. This is a time consuming operation and **cannot be done during the night**. The slit can be displaced by ± 10mm with respect to the center position by means of an adjustment screw. A ruler with 0.5mm rulings placed under the slit is used for positioning. The relation between the slit displacement in mm (ΔY) and the wavelength shift of the spectrum ($\Delta \lambda$) in Å is,

$$\Delta Y = \frac{0.022}{D} \times \Delta \lambda$$

where D is the dispersion of the grism in Å/pix as given in Table 4. Moving the slit outwards in the wheel (turning the screw *clockwise*) corresponds to shifting the spectral lines towards the *blue* (the spectral coverage shifts to the *red*).

One should always check the shift by taking a He-Ar spectrum and visually determining the wavelength range. Observers should obtain all the required calibrations before a slit is dismounted from the wheel.

Additional to the standard slits, two sets of slits were made, with 15mm offsets in the dispersion direction (both to the blue and to the red), with respect to a central slit. These sets of offcentered slits may be of particular interest when used in combination with Grism#19 (the new blue volume-phase holographic grism, see §2.4.6).

2.4.2   MOS Plates

With EFOSC2 it is possible to perform simultaneous spectroscopy of a large number of objects through suitable slits produced on special metallic plates by a punching machine. Three punching heads are available, which produce slit-lets with the values specified in Table 2.

Punch. Head	Width	Length
5	$1''02$	$8''6$
7	$1''34$	$8''6$
3	$1''87$	$8''5$

Table 2: *Available Punching Heads.*

While the width of the slits is fixed by the punching head, the length can be increased to the required value by successive punchings. For this reason the values reported in Table 2 must be regarded as

minimum lengths. Typically, up to 25 and 15 slits can be produced with the shorter and longer punch heads, respectively. The field of view is the same as in the imaging mode (see §2.6).

Punch heads break from time to time due to wear and tear. The process of changing them is extremely delicate and requires a specialist (who may not be on the mountain) and may take up to a day. You are encouraged to use punch head no. 7 if possible.

Up to 5 MOS plates can be loaded simultaneously. They are punched off-line, so additional plates can be punched at any time. To create multi-slit masks, pre-imaging must be acquired using EFOSC-2 with the same position angle as for the actual observations. The La Silla Science Operations department will, on a best effort basis, obtain pre-imaging frames during technical/reserved time, for up to 20 min per night of spectroscopic observations allocated to the programme, provided that the list of coordinates, filters, exposure times and position angles are received at least 6 weeks before the observing run. The request should be sent to the La Silla Shift Leader `lasilla@eso.org`.

Important note: EFOSC2 shares the same program `xm` for the mask design as EMMI on the NTT. This is NOT the same as `FIMS` on the VLT. Especially important is that the image cannot be rotated nor shifted in the program. Hence it is vitally important that the correct coordinates and position angle is specified in the pre-imaging request.

Once the images are available, the visiting astronomer is responsible for preparing/designing the masks. Detailed instructions are available on
`http://www.eso.org/sci/facilities/lasilla/instruments/efosc/inst/ObsMOS.html`
for the various stages of preparation, from pre-imaging to defining and punching the masks, as well as calibrations and science observations. The observer should read these instructions. The observer should also read the MOS Operation Page
`http://www.eso.org/sci/facilities/lasilla/instruments/efosc/inst/MOSops.html`
maintained by the operations team.

Because the MOS design and punching process takes time, one should arrive two days before the scheduled night to allow enough time for the preparation. In fact, all the required procedures for the mask designation/preparation are local. As such, the observer must be at the LSO. The observer is warned against requesting installation of MOS plates during the night, since this is a time consuming operation and requires opening EFOSC2.

2.4.3   Filters

Filters are located in the filter wheel which lies in the parallel beam (after the collimator). Up to 11 filters may be mounted in the filter wheel, however if you are doing spectroscopy, you need to leave one position Free. As for EFOSC1, EFOSC2 filters are 60mm in diameter with a maximum thickness of 10mm. Since the filter and the grism wheels are located very close to each other there is very little possibility of squeezing in larger filters. Also, since the filter wheel is located at a relatively large distance from the focal plane, the quality of images obtained through filters mounted in this wheel is extremely sensitive to filter defects. These may appear in the form of image blurs or ghosts due to multiple reflections inside the filter. These ghosts can be a nuisance for observations of satellite features near bright objects.

Table 3 lists the EFOSC2 standard set of filters (the *basic-set*). Their laboratory transmission curves are plotted in Fig. 3 (note although the labels say SUSI, they are instrument independent). For a complete list of filters available on La Silla consult the online ESO La Silla Filters Catalogue
`http://filters.ls.eso.org/efs/index.htm`

or invoke the MIDAS context `filters (create/gui filters)` which provides utilities for searching for filters and extracting and plotting their transmission curves. The full characteristics of the basic set are also included in these references.
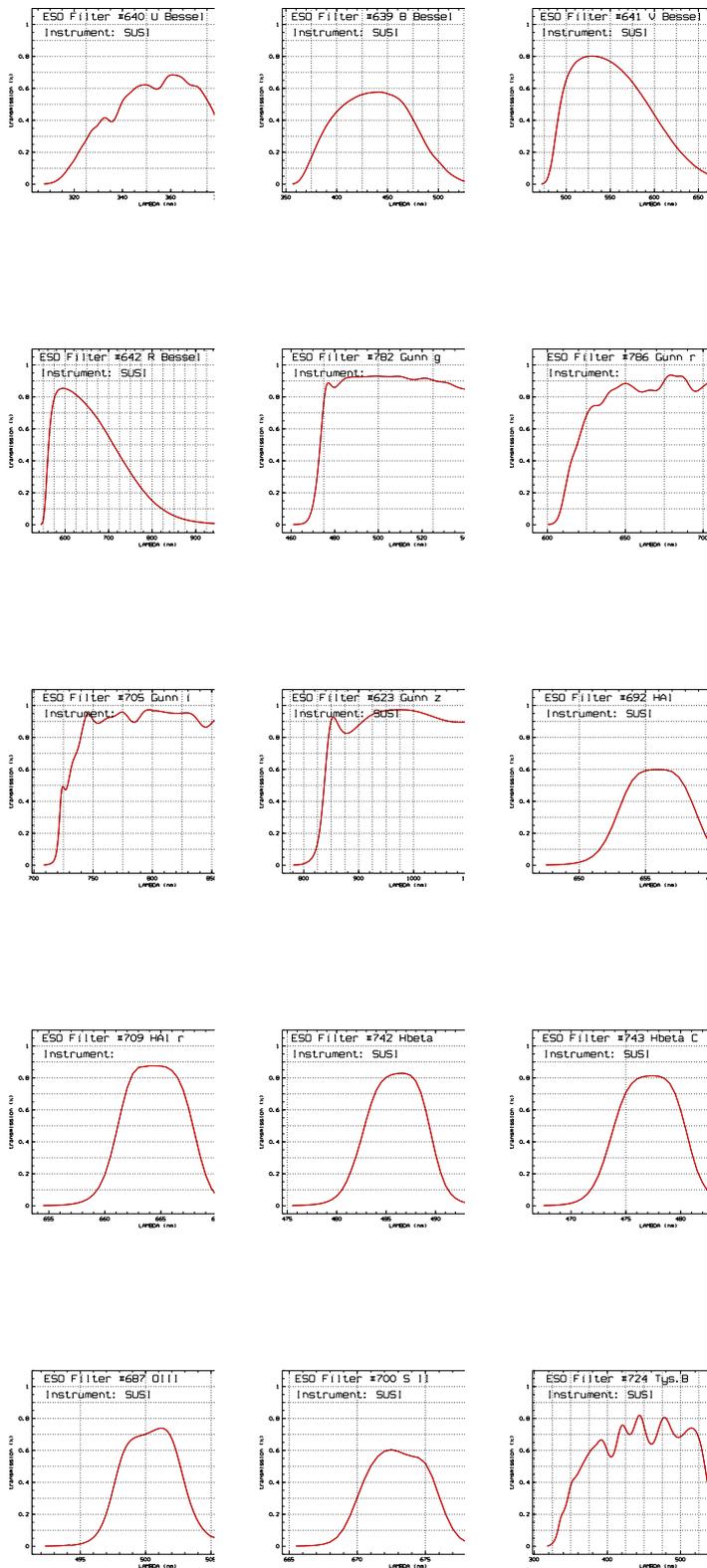
Figure 3: Laboratory transmission curves of the EFOSC2 standard set of filters. Note although they are labelled SUSI they are instrument independent.

ESO #	filter	λ_C (nm)	FWHM (nm)	Peak trans. (%)	Red leak information
640	U Bessel	354.5	53.8	68	<0.005%@1100nm
639	B Bessel	440.0	94.5	54	0.012%@1150nm
641	V Bessel	547.6	113.2	87	0.055%@1150nm
642	R Bessel	643.1	165.4	86	0.076%@1150nm
782	g Gunn	516.9	77.6	81	0.01%@1100nm
786	r Gunn	681.4	83.8	83	0.01%@1100nm
705	i Gunn	793.1	125.6	83	0.01%@1100nm
623	z Gunn	> 840	—	98	—
692	Hα	657.7	6.2	56	<0.01%
709	Hα/red	664.5	7.1	88	—
742	H Beta	486.1	7.2	83	—
743	Hbe Cont	477.1	7.2	81	—
687	[OIII]	500.3	5.3	74	—
700	[SII]	673.0	6.2	56	<0.01%
724	Tyson B	444.5	183.8	82	—

Table 3: *EFOSC2 filters: Basic set*

Since the filters are mounted in a parallel beam, the focus of the instrument in principle does not change when filters change. Some filters, however, have optical power (curvature) which introduces focus offsets. While this offset is less then 10 encoder units for the broad band filters (and thus is practically negligible), this is not true for Strömgren and interference filters.

Please note that since the filters are shared between telescopes, plenty of advance notice is required if a filter outside the standard EFOSC2 set is required. Observers who wish to bring their own filters are reminded of the image quality requirements.

2.4.4   Grisms and Prisms

Grisms are mounted in the grism wheel in the parallel beam of EFOSC2. There are at present 16 grisms available for EFOSC2. Table 4 summarizes their properties. The values given in the table correspond to CCD#40 with 15μ pixels. Efficiency curves are given in Appendix A for EFOSC2@3P6. Efficiency curves relative to EFOSC2@NTT will be added to this manual as soon as they will be available.

All grisms are mounted in such a way that red end will appear at the top of the Real Time Display (RTD), and in the FITS files. To facilitate data reduction, the dispersion is aligned to better than a few tenths of a pixel with the CCD columns. It takes 10-20 minutes to align the grism (and slits). So observers should not request grism/slit changes during the night.

The resolution of the spectra depends on the chosen slit width. If the slit width is doubled, the line FWHM will be doubled as well. One may have to change the CCD binning in order to give enough sampling for the line-width.

Contrary to grisms used in a converging beam, there are no wavelength dependent optical aberrations introduced by the EFOSC2 grisms. The spectral resolution therefore only depends on the slit width

| Grism # | Grating | | Wavelength range * | Dispersion * | Resolution * |
	gr/mm	λ_{Blaze}	(Å)	(Å/pixel)	FWHM (Å/1″)
1	100	4500	3185 – 10940	6.66	52
2	100	6700	5100 – 11000	6.60	53.69
3	400	3900	3050 – 6100	1.50	12.61
4	360	4700	4085 – 7520	1.68	13.65
5	300	6700	5200 – 9350	2.06	16.64
6	300	5000	3860 – 8070	2.06	16.77
7	600	3800	3270 – 5240	0.96	8.06
8	600	5300	4320 – 6360	0.99	8.06
18	600	5600	4700 – 6770	1.00	8.19
(+) 10	600	6500	6280 – 8200	0.95	7.67
11	300	4000	3380 – 7520	2.04	17.16
16	300	7900	6015 – 10320	2.12	17.29
13	236	4400	3685 – 9315	2.77	23.01
14	600	4000	3095 – 5085	0.93	7.54
17	600	8300	6895 – 8765	0.86	7.02
19	1557	4777	4441 – 5114	0.34	1.5
20	1070	6597	6047 – 7147	0.55	2.0
prism #1	-	-			
prism #2	-	-			

* Using Loral 2048^2 CCD with 15μ (0.″12) pixels (binning 1×1). (+) Gr#10 suffered a major damage and is no longer offered.

Table 4: EFOSC2 grisms. The quoted resolution are for a 1.″0 slit for all Grisms but Gr#19 and #20. For these latter Grisms the resolution was measured using a 0.″5 slit.

(or the seeing for slit-less spectroscopy) and the dispersion, and is constant along the spectrum.

Some of the grisms, introduce strong fringing redwards of about 7000Å. Sometimes afternoon dome flats do not always adequately remove all the fringing and this may be due to a small amount of telescope/instrument flexure. This is usually corrected by proper flat-fielding using internal flats taken at the position of the observed object. See § 2.6.5 for a discussion on fringing and ways to remove it.

Some grisms are also affected by second order contamination. Grisms for which 2nd order contamination was found are marked at:

http://www.eso.org/sci/facilities/lasilla/instruments/efosc/inst/Efosc2Grisms.html

and a report is available at:
http://www.eso.org/sci/facilities/lasilla/instruments/efosc/inst/2ndorder.pdf

The possibility of reducing the 2nd order contamination using order sorting filters is under investigation.

Figure 4 shows in schematic form the EFOSC2 grisms spectral coverage, dispersion, and wavelength
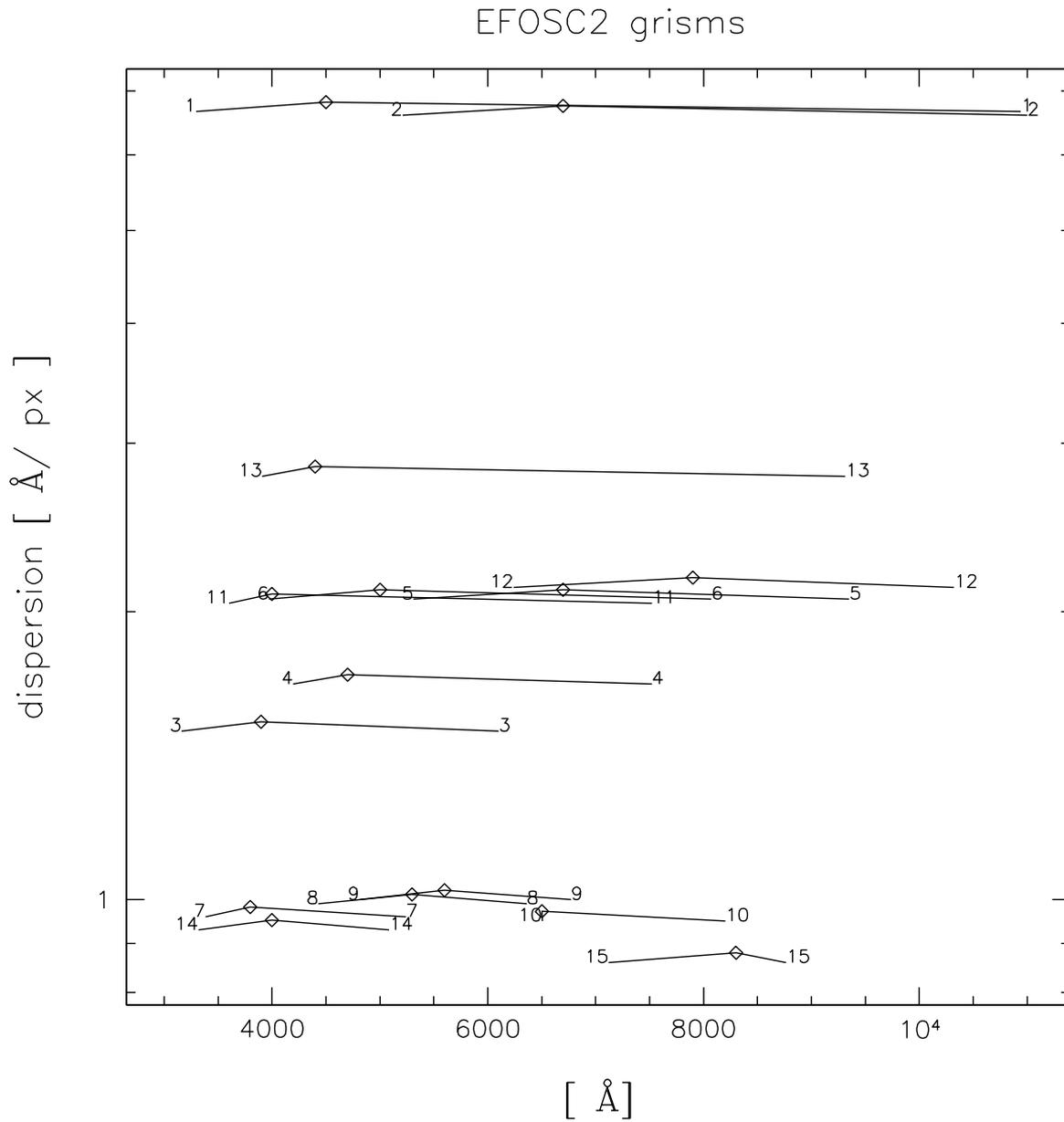
Figure 4: Schematic representation of EFOSC2 grisms
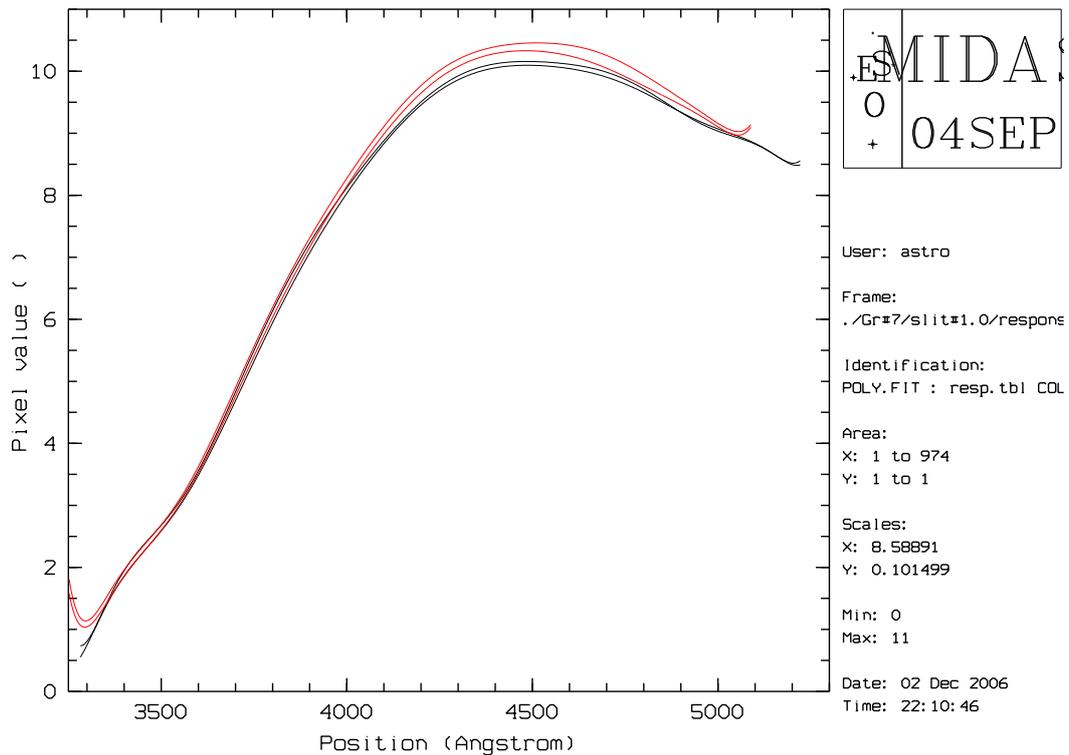
Figure 5: Response functions of grisms nr.7 (black) and 14 (red), on November 28, 2006. For each grism two standard stars have been used to define the response function (Hiltner 60 and LTT 2415).

of the peak efficiency. Grims #19 and 20 are not plotted in the figure and described in some detail below (see §2.4.6).

In addition to the grisms, 2 prisms are available. These low dispersion devices do not show zeroth order images and are therefore more useful than grisms for slit-less spectroscopy, in particular in combination with narrow-band interference filters. The resolution depends on the seeing.

2.4.5   Grisms nr.7 and 14

Grisms #7 and #14 have quite similar characteristics. To clarify the difference between them, on 2006/11/28 two standard stars were observed, with both grisms, and in photometric conditions. The response functions are shown in Fig. 5. The figure shows that Grism #14 is slightly more efficient near the maximum (2.6%), while Grism #7 extends a bit more to the red ($\sim$ 100 Å). A similar conclusion can be reached by looking at Fig. 6, where the instrumental spectra of the two standard are shown. The more extended spectral range of Grism #7 may allow to include some more arc lines for wavelength calibration. However, distortions are quite high at the extreme of the spectral range. As such, the few more lines added might not result in a more accurate wavelength calibration.
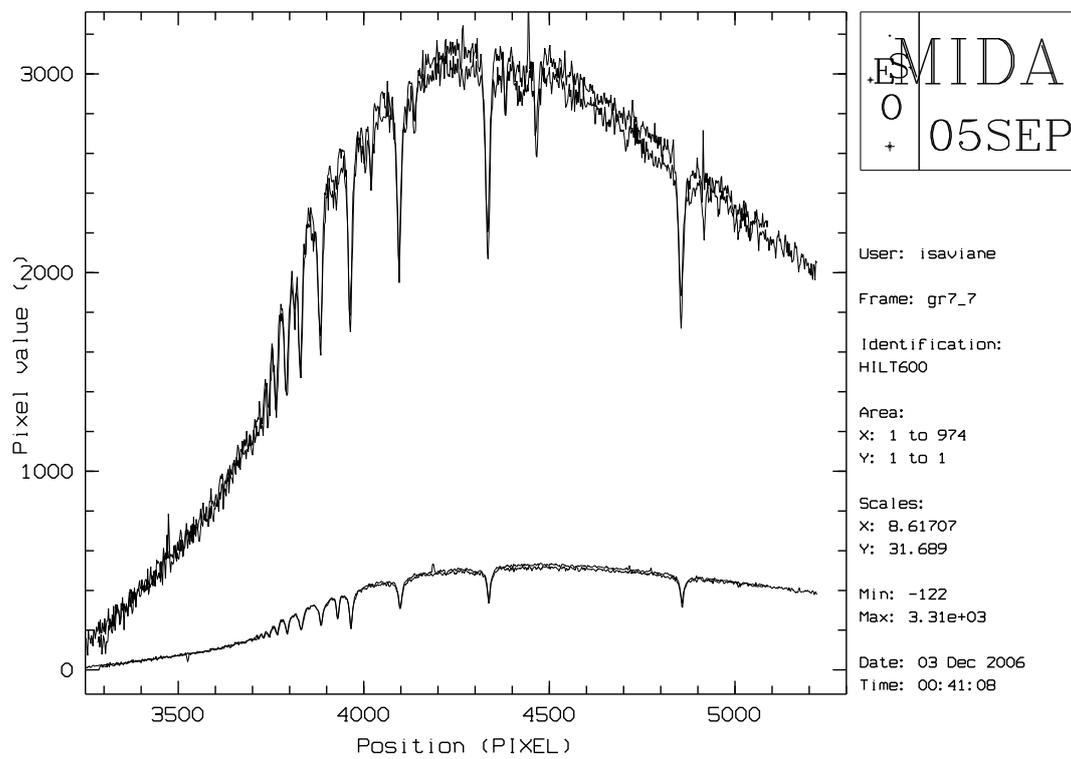
Figure 6: ADU sec^{-1} vs. wavelength for the two spectrophotometric standards Hiltner 600 (top spectrum) and LTT 2415. For each standard the two spectra have been taken with grisms nr.7 and 14.
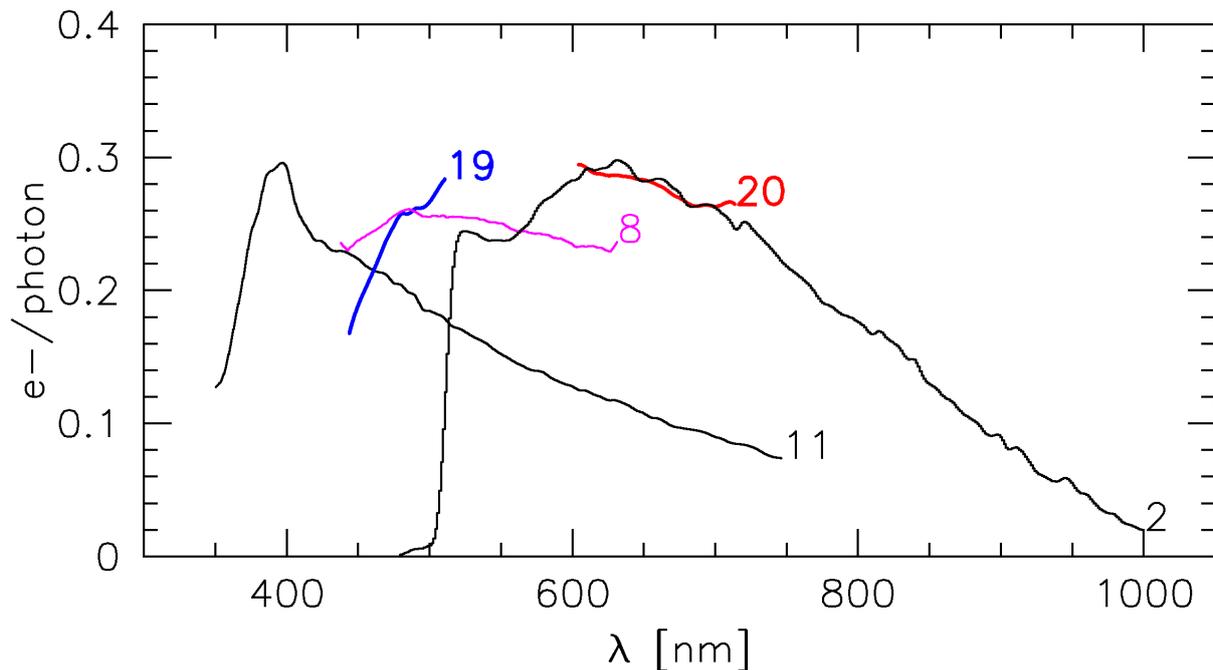
Figure 7:   System efficiency given by VPHGs #19 (blue curve) and #20 (red curve) compared to that of other EFOSC2 grisms.

2.4.6   New VPH Grisms offered as of P82

Starting with P81, two new volume-phase holographic grisms (VPHG) are offered. The blue grism (#19) covers the wavelength range from 440 nm to 510 nm, at a resolution of up to $\sim$3200 with a 0.5"slit, while the red grism (#20) covers the range 605 nm to 715 nm at a resolution of up to 3400 with the 0.5"slit. The grisms introduce a lateral shift of the beam, so the effective field-of-view is 3.1′and 2.8′for the blue and red VPHGs respectively (see Table 4).

The two Grisms were commissioned during February 2008 with EFOSC2@3P6 and a report is available at:

http://www.eso.org/sci/facilities/lasilla/instruments/efosc/doc/VPH/report.pdf

The system efficiencies of the VPHGs with EFOSC2 at the NTT are shown in Fig. 7, together with the efficiencies given by other grisms. The efficiency of the blue VPHG goes from 30% at the red end, down to 20% at the blue end. The red VPHG has a more constant response, with an efficiency around 30%. In general as Fig. 2 shows, the system efficiencies are comparable to those obtained with the existing EFOSC2 grisms.

To make the best use of these grisms, users must be aware of the following issues. The flat-fields of both grisms show gradients in the cross-dispersion direction.These gradients are also wavelength-dependent, which means that the response functions depend on the position along the slit. For point sources, an accurate flux-calibration then requires to obtain the spectrum of spectrophotometric standards in the same position as the targets. For extended sources the spectrophotometric standards should be placed in different positions across the CCD, or corrections to some fiducial response function should be obtained based on flat-fields. Second order contamination is apparent in the red grism for $\lambda > 6800\text{Å}$, so it is advisable to use order-sorting filters to cut the blue flux, if flux calibration is an issue for the science case. Note also that the spectral range of the blue grism does not reach the Mg triplet at 5200 Å or the G-band at 4300 Å. However, using the movable slit we verified

that the two features can be reached with a slit offset of 15mm in either direction (the displacement is 14.5 $\mathring{A}$/mm). Therefore, the two sets of offcentered slit (15mm to the blue or to the red) with respect to a central slit can be used to cover a more interesting blue spectral range, by merging two spectra (see also §2.4.1).

2.4.7   Focus Wedge Prism

At the NTT the telescope focus is done through an image analysis and applying a focus offset which is tabulated and proper to the different instruments. However, the telescopes focus can be checked quickly using a Focus Wedge prism which is permanently mounted in the EFOSC2 grism wheel. The prism covers only one half of the beam and hence it acts as a *transparent* Hartmann mask. Due to its geometry it also significantly enhances the distance between the baricenters of the two images produced by the two half beams, which would otherwise coincide in the case of a perfect focus. For this reason, the focus wedge produces two images for each of the sources in the field. Fig. 8 shows an example focus image. The prism is aligned in such a way that the displacement of the two images occurs along the columns and it gives a null vertical displacement (within the errors) when the telescope is in focus. Of course this requires an independent calibration, which is performed by the EFOSC support astronomers during technical nights.

2.4.8   Wollaston Prisms and Masks

The Wollaston prisms can be mounted both in the filter wheel or the grism wheel for Spectropolarimetry and Polarimetric imaging respectively. When introduced in the beam, the Wollaston prisms produce two images of each object with orthogonal polarizations, separated by fixed amounts. Two different Wollaston prisms for polarimetric imaging and spectro-polarimetry are currently available. In the imaging mode they are mounted in the grism wheel, while for spectropolarimetry they are mounted in the filter wheel. The corresponding separations of the ordinary and extraordinary beams are 10″ and 20″ for the two Wollaston prisms respectively. Both prisms produce a symmetric throw.

Caution: The 10″ Wollaston prism can be used for imaging ONLY, since its size does not allow it to be mounted in the filter wheel.

The orientation of the image separation can be changed by rotating the prisms in the wheels. At EFOSC2 the prisms are aligned to split the images either along the x- or the y-axis of the CCD. For polarimetric imaging, special masks are available. Their specifications are presented in Table 5. Corresponding to the two possible directions along which the prisms can split the image there are two types of Wollaston masks - parallel masks in which the strips are parallel to the x-axis and perpendicular masks in which the strips are perpendicular to the x-axis. Note the prisms must be oriented to split the images in a direction perpendicular to the long axis of the masking strips.

Woll. Mask	Length	Width	Inter-slit
20″ perp.	337″	19″7	22″5
20″ par.	224″	19″6	22″7
10″ par.	225″	9″9	16″8

Table 5: *Wollaston Masks for Polarimetry. The values reported in this table are relative to EFOSC2@3.6m. The actual values for EFOSC2@NTT will depend on the fabrication process.*

Spectropolarimetry is also possible, using the Wollaston Prism together with a grism. The required
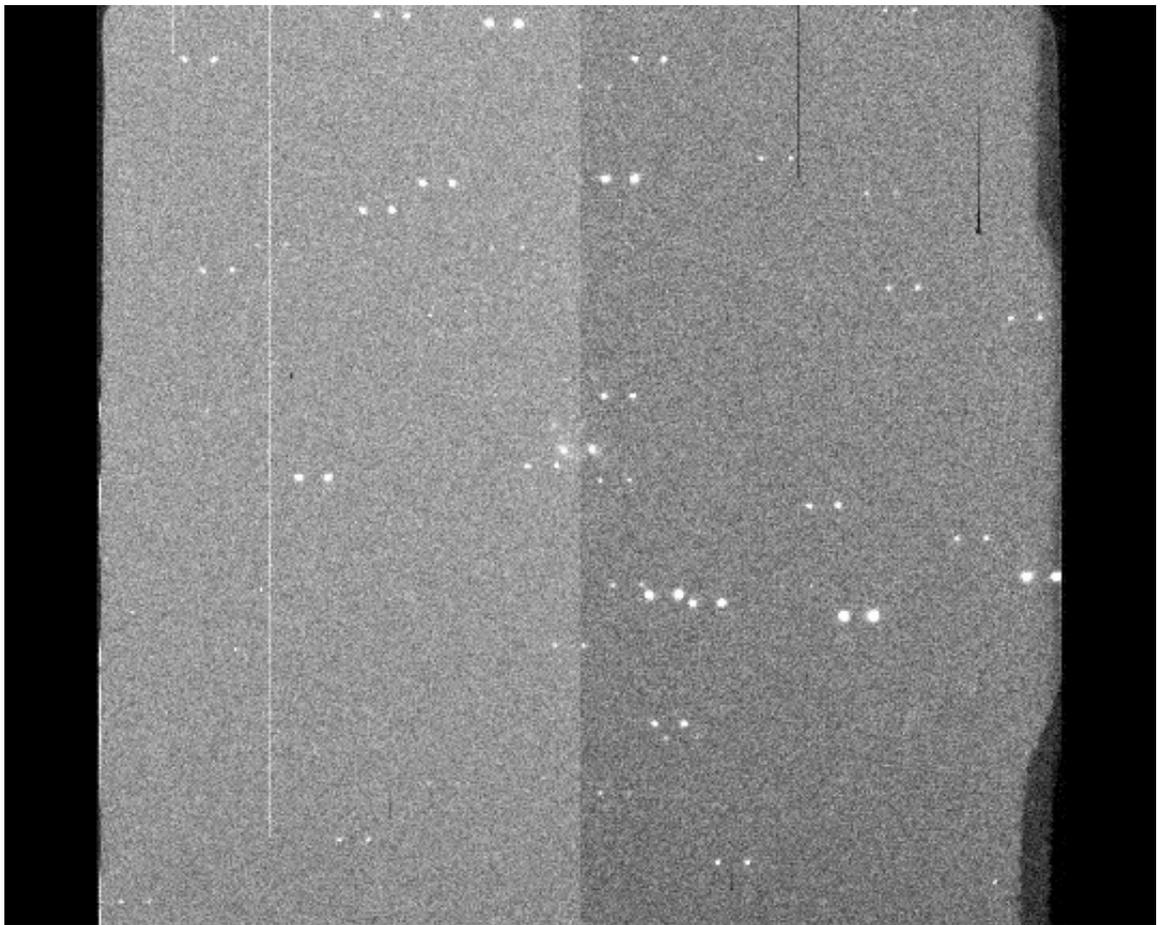
Figure 8: An image taken with the focus wedge. Each object is split into two. In this case the telescope is almost focused, since the split images are at nearly the same level with each other. Note that the fast readout using two amplifier gives the split appearance of the background.

slits are produced by mounting the suitable Wollaston mask on top of a normal slit. Since the dispersion axis of EFOSC2 is always along the y-axis of the CCD the two spectra must be split along the x-axis for spectropolarimetry. A possible alternative is represented by the punching of suitable slits on MOS plates (cfr. Sec. 2.4.2). This may be useful, for example, if 2 targets are located so that only one of them can be imaged at a time with the current set of masks.

2.4.9   Half/Quarter Wave Plate

Two rotating, super-achromatic Half and Quarter Wave Plate (HWP and QWP) have been added to EFOSC2 as the first element in the parallel beam after the collimator. The two plates share the same physical position and, therefore, they are mutually exclusive (see also Fig. 1). With such devices, it is possible to take either a full **linear** or **circular** polarization measurement without rotating the adapter. The usual practice is to obtain frames at 0°0, 22°5 45°0 and 67°5 with the HWP or at 45°0 and 135°0 with the QWP.

The HWP/QWP can be moved IN and OUT, set to a particular angle or to continuous rotation. The HWP/QWP, as seen from the CCD, rotates clockwise. It makes a complete turn in 2.3/4.0 seconds. This must be taken into account when selecting the exposure times for a good de-polarization. At least 20 seconds is recommended.

The image quality of the HWP is not exceptional. There seems to be a certain amount of internal reflection resulting in ghost images, especially of bright objects. Care must be taken to locate the object in the field such that the ghost image does not fall on the area of interest.

A description of the performance obtained with the QWP and EFOSC2@3P6 can be found in Saviane et al. 2007 (Msngr,129,14).

As is well known and discussed in the literature, the asymmetric reflection at M3 introduces instrument linear polarization, up to a few percent, with value and angle dependent on the elevation of the telescope (e.g. Li et al. 2006, Proc. of SPIE Vol. 6275, 62751H-1). This is of course a problem when trying to detect modest amounts of polarization.

During the re-commissioning phase, measurements of both polarised and unpolarised stars at many telescope positions were taken. Unfortunately, the commissioning period was mainly during bright time, and some of these stan- dards were taken relatively close to the Moon, introducing a polarised component in the sky from reflected Moonlight. The preliminary results are not encouraging. There seems to be a considerable instrument polarisation of 4%—5%. The polarization degree being nearly constant with hour angle and strongly dependant on the colour. Variations in the Q and U Stokes parameters seems important and not trivial to model. Also circular polarimetry shows some lower instrument polarisation, of the order of $\leq$0.4%. However, some still unclear systematic effects might be present. Further polarimetric standards will be measured in good dark conditions, in order to further assess these effects.

Users interested in using the EFOSC2 polarimetric modes are encouraged to include observations of unpolarized standard stars in their program, in order to remove the instrument polarization at the data reduction stage.

2.4.10   Coronograph

One coronograph is available for EFOSC2. It is called by the name `Cor_mask` in the P2PP templates. The sizes for the large and small spots are 8.0 and 4.0 arcsec respectively. Tests done using this unit on extremely bright stars give very little scattered light when the Lyot stop is in place and properly aligned. The layout and sizes of the coronographic spots are shown in Fig. 9.
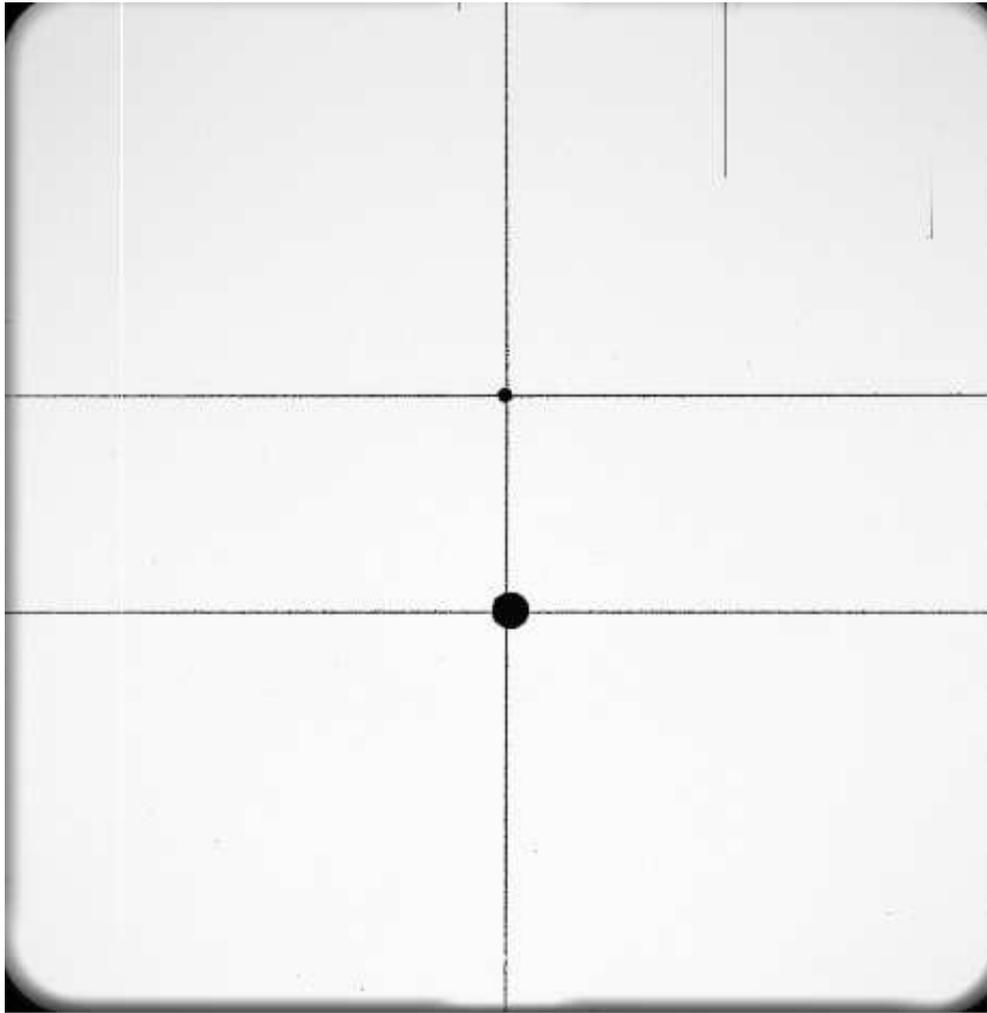
Figure 9: Size and position of the spots in the EFOSC2 Coronographic Mask.

The alignment of the Lyot stop must be done using bright stars. Therefore observers using the coronograph must allow 1-2 hours at the beginning of the first night to perform this alignment. Alternatively, you can inform `lasilla@eso.org` of your request well in advance and, depending on other tests that need to be made, the Lyot stop may possibly be aligned during technical/calibration nights. This is usually done by the opticians, but it may be checked using the following procedure.

- Point the telescope to a bright star ($V = 6 - 8$) and defocus it by about 500 encoder units

- Refocus guide probe and acquire a suitable guide star

- Obtain an exposure of the de-focused image. Typical exposure times should be close to 20s if a V filter is used

- Obtain a similar exposure with the Lyot stop in position

- Subtract the two images. If the Lyot stop is properly aligned, the difference image should be symmetrical and show the 4 quadrants of the telescope pupil not blocked by the Lyot stop. If this is not the case, please call the opticians as the alignment may require rotating the stop and offsetting the grism wheel.

We remind you here that to use this EFOSC2 mode, the coronograph must be mounted in the Aperture wheel while the Lyot stop has to be installed in the grism wheel.

The coronograph is very fragile. Plenty of advance notice is required to ensure the coronograph is mounted safely before the observations start.

2.5   Shutter

The shutter of EFOSC2 is mounted at the Camera entrance (see Fig. 1). Since the shutter is of the iris type, the effective exposure time in the central region is expected to be higher than in the outer region. Nevertheless, several tests have shown that the shutter delay is $+24ms \pm 5$ms across the entire CCD, with the position dependent time delay being smaller than 10ms. This means that after adding 24ms to the exposure time, a maximum position dependent error of ±5ms is left.

It is worth noting that neglecting the time delay correction at all ($\Delta t_{max} \simeq 30$ms) turns into a 3% error (0.03 mag) for a 1 second exposure; by taking the shutter delay into account, the position dependent error is less than 1%. Starting with an exposure time of 3 seconds the error becomes smaller than 1% (0.01 mag). For this reason, if the observer does not want to apply any shutter delay correction, avoid exposure times shorter than 3 seconds when accurate photometry is required.

The mechanism which keeps the shutter open absorbs about 3 Watts, causing a chimney effect inside EFOSC2. For long exposure times, this may cause a degradation of the focus stability, although so far this has not been noticeable.

2.6   EFOSC2 CCD

2.6.1   General specifications of CCD#40

The CCD presently mounted on EFOSC2 is ESO #40, a Loral/Lesser Thinned, AR coated, UV flooded, MPP 2048×2048 chip, with a pixel size of 15μm, corresponding to $0''.12$/pixel. The field of view is thus about $4.1' \times 4.1'$. The default CCD orientation is North to the top and East to the right of the RTD display (Fig. 10).

The spectral dispersion is aligned with the columns and the wavelength increases upwards.

N

↑

→E
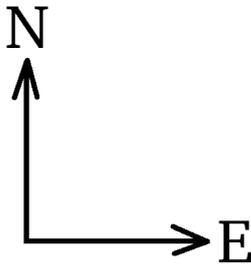
Figure 10: Default EFOSC2 CCD orientation.

The full specifications of CCD#40 are given in Table 6. The array has one serial register and two output ports; one port at each end of the register. This thinned CCD achieves its high quantum efficiency in the blue and UV through *UV flooding* of the backside. The quantum efficiency curve is plotted in Fig. 12.

Note that even though the CCD has 2048×2048 pixels, the image size is 2060×2060. In fact, during the read out process 12 rows and 12 columns are added (see Fig. 11). We remark that these additional pixels **cannot** be used as a real over-scan, since the region is too small and contaminated by the adjacent area during the charge transfer process. The observer should therefore take bias images at the beginning and/or end of the night.

The CCD is driven by the new ESO–FIERA controller. FIERA has two amplifiers (L and R) and offers 3 different read out speeds. Three modes are currently offered (*slow, normal* and *fast*). As it is shown in Table 6, there is not a big improvement in terms of R.O.N. using the *slow* mode. For this reason the *normal* mode should be used for the scientific images. The bias level for the three modes is ~ 220 ADUs.

The CCD system (CCD+FIERA controller) shows a linearity better than 0.4% over the full range of the 16 bit analog to digital converter (ADC). The system linearity has been explored in a range of 2000 e^- up to 83000 e^-. The electronics have been tuned so that the ADC will saturate before non-linearity is reached. Hence the full range ($\sim$200-65535) is usable for scientific purposes. Even in cases of strong saturation the residual effect is very small and it is completely removed by taking a few bias frames.

When a short read-out time is required (for instance during the acquisition phase) the *fast* mode can be used. Using 2×2 binning allows the CCD to be read in about 9 seconds, at an equivalent data transfer rate of 113 $kpx\ s^{-1}$. The user must be aware that this mode makes use of both amplifiers (L and R) and hence produces images with two different bias levels. During the target acquisition this is not a problem. However, the user can select the *normal* read-out mode also for the target acquisition images, in such a way that he/she can use them also for scientific purposes. Alternatively, the user can take flats, biases and standards in the `fast` mode for calibrating the data.

The web site:

http://www.eso.org/sci/facilities/lasilla/instruments/efosc/inst/Ccd40.html

gives more information about the CCD#40. Additionally, the user can have a look at the weekly
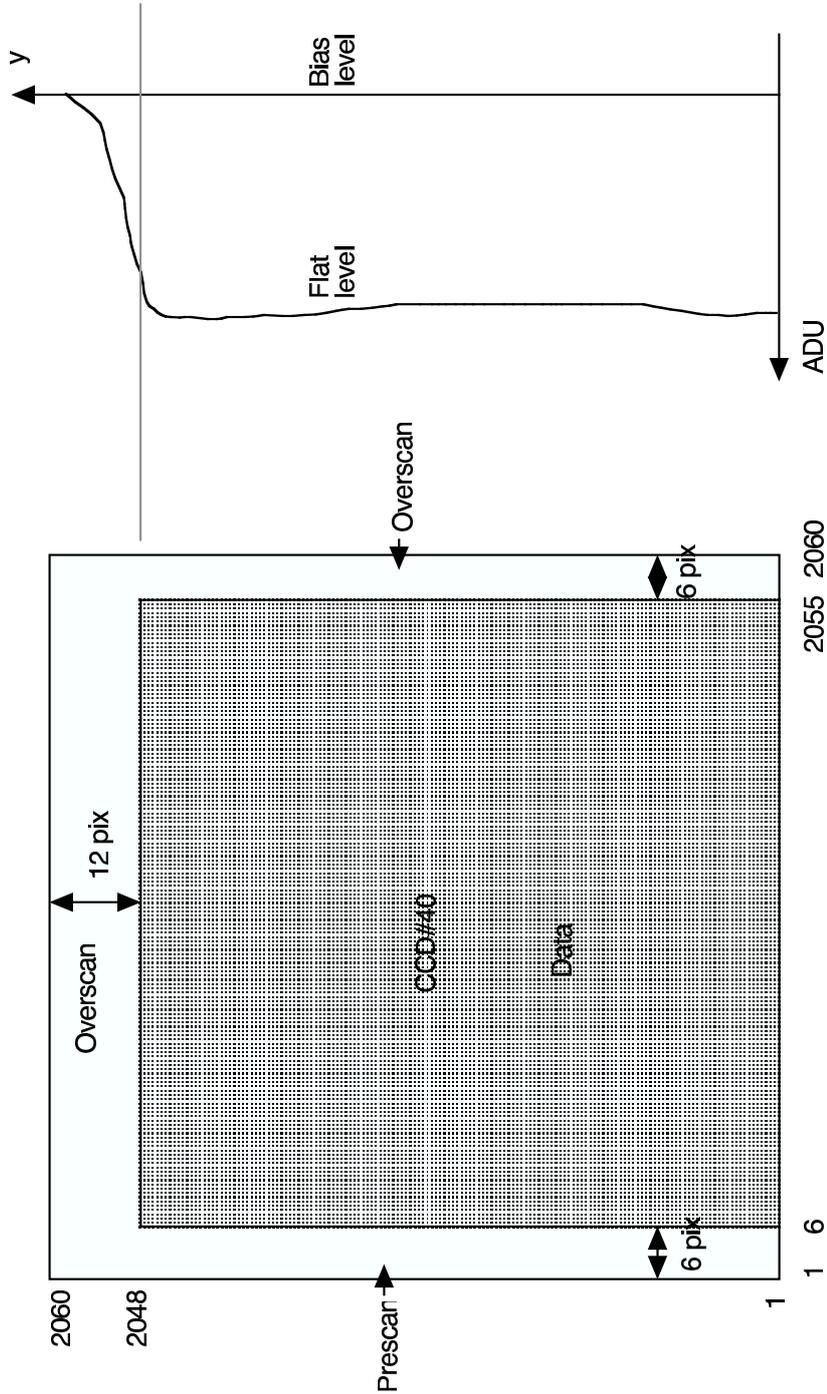
Figure 11: Location of the data section and the bias sections on the EFOSC2 CCD. The right diagram shows the "bleeding" effect when a flat is taken – the prescan and overscan sections are affected and do not give the correct bias value. The user should taken bias frames before and after the observations.
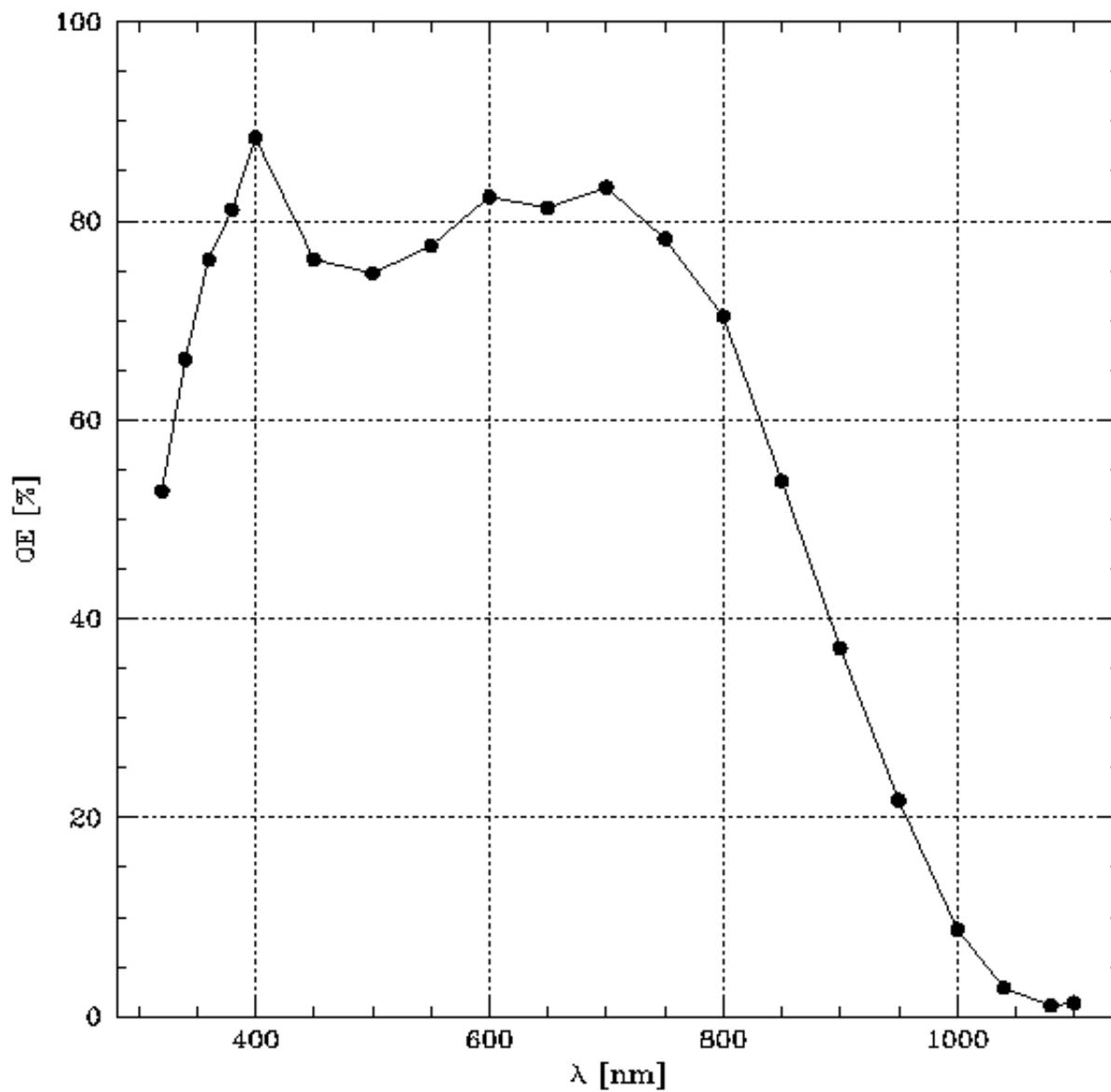
Figure 12: Quantum Efficiency of CCD#40.

Type	Loral/Lesser		
	Thinned, AR coated, UV flooded, MPP		
Image Size (px)	2060x2060		
Pixel Size (μ)	15 x 15		
Dark Current ($e^-\ px^{-1}\ hr^{-1}$)	≤ 3.5 at 140 °K		
Full Well Capacity ($e^-\ px^{-1}$)	104k		
Controller	ESO-FIERA		
Explored Range (e^-)	2000-83000		
Saturation (ADU)	65535		
Mode	Slow	Normal	Fast
Transf. Rate	27kpx s^{-1}	60kpx s^{-1}	178kpx s^{-1}
Bias (ADU)	$\sim$219	$\sim$219	$\sim$239
R.O.N. (e^- rms)	10.2$\pm$0.1	10.7$\pm$0.1	14.4$\pm$0.4
Linearity	$\pm$0.24%	$\pm$0.24%	$\pm$0.19%
Conv. Factor ($e^-\ ADU^{-1}$)	1.33$\pm$0.01	1.35$\pm$0.01	1.37$\pm$0.01
Full CCD R.O. Time (s)	160	70	24

Table 6: Specifications of CCD#40. All values correspond to a CCD binning 1x1.The Bias, R.O.N., Linearity and Conv Factor are average values from the first half of 2003. As the electronics may be changed or adjusted from time to time, please check the latest results of the CCD tests which can be found on http://www.eso.org/sci/facilities/lasilla/instruments/efosc/inst/Ccd40.html.

tests there to check the latest CCD performance.

2.6.2   Windowing and Binning

All three Read Out modes offer the possibility to window the CCD. This is selected during the preparation of the Observation Blocks, as described in Chapter 4. The position and size of the window are specified by entering the starting column and row, and the number of pixels in each direction.

Be aware that the dispersion direction is **along the columns** when defining the windowing for spectroscopy.

Officially, only two clock patterns are implemented for binning: 1×1 and 2×2. Under the median La Silla seeing of 0″8, a point source will cover 6.7 pixels FWHM, and 3.3 pixels with the 2×2 binning readout. Therefore we tend to over-sample the PSF. Higher binning ratios are currently under implementation (3x3 and 4x4 for imaging and 3x1, 3x2, 4x1, 4x2 modes for spectroscopy) to sample more efficiently the PSF and to cope with bad seeing situations. 2×1 binning also works but is not officially supported. This mode is useful when narrow slits are used for improved spectral resolution. Given the pixel size ($\sim$ 0″12 px^{-1}), the typical seeing (0″8 − 1″0) and the dispersions achieved with EFOSC2, most of the time it is worthwhile to bin the CCD 2×2. For spectroscopy, the rule of thumb is that for slits of widths 1″0 or wider, 2×2 binning is sufficient. For slits narrower than 1″0, 2×1 or 1×1 binning should be used to ensure sufficient sampling in the dispersion direction. For imaging, only when the seeing is exceptional or when observing very bright objects, would 1×1 binning be necessary. Note that 2×2 binning gives shorter readout times and smaller images ($\sim$2Mb instead of $\sim$8Mb). Finally, it allows a larger number of twilight sky flats to be taken, and improves

the signal to noise ratio.

Due to a problem in clock pattern, skipping pixels takes more time than reading them. The CCD is read from the left side. For this reason windowing saves time only if the starting row is close to the left part of the CCD. This should be taken into account when the observer wants to have the best time resolution for photometry. For example, if you want to use only the central part of the CCD, just take a window that starts from 1,1 and includes the central rectangle.

2.6.3   Bad Pixels and Columns

In Fig. 13 a bad-pixel map of CCD#40 is presented. There are a few bad columns, among which the one at X=986 is particularly bad and should be avoided. When placing a stellar object for spectroscopy, a position around 1100-1150 should be used. This strip is free from bad pixels.

The latest bad pixel map can be found on this webpage:
`http://www.eso.org/sci/facilities/lasilla/instruments/efosc/inst/BADPIXMASK/index.html`

The user can also construct their own bad pixel map by taking dome flat field images with high and low counts– the division of these 2 gives an indication on the linearity of the pixel.

2.6.4   Bias, Darks and Cosmic Ray Events

Several 0 seconds dark exposures can be taken and averaged to produce a frame which will be subtracted from the science images to take out the electronic bias (about 220 ADUs). CCD#40 has negligible "bias structure"; however it is not safe to assume the bias is always scalar and therefore it is recommended to take several bias exposures every day during the observation run. Even though the dark current of CCD#40 is low ($\sim 3.3~e^-~hour^{-1}~px^{-1}$), at least one long dark exposure is useful to monitor the CCD behavior and any exposure dependent features. Taking three dark exposures will allow cosmic rays, which are unavoidable in long exposures, to be removed. The cosmic ray event rate for CCD#40 measured with EFOSC2 mounted at the telescope, is about 940 ± 30 events hour^{-1} for the whole array. This corresponds to 0.03 events cm^{-2} s^{-1}. Typical cosmic ray hits affect several pixels, with average peak values of about 900 ADUs.

A pattern of probable electronic nature is found sporadically in Bias frames taken with binning 2x2. The pattern is different from frame to frame and it may be quite visible or almost absent. In the worst case the pattern can reach a level of ± 30 ADU peak-to-peak. However, the mean bias level and standard deviation are apparently not affected and stable.

2.6.5   Fringing

Fringing is caused by multiple reflections internal to the CCD substrate or between the silicon and the supporting substrate. For imaging, fringe patterns appear in R and especially I images. Their amplitude is of the order of 5% of the background intensity. Note that this effect appears only in the exposures taken during the night, due to the sky lines. In fact, fringing arises from the optical interference caused by near-monochromatic light and variations in the thickness of thinned CCDs. Therefore it is not possible to remove it using dome flats (the lamps have a black-body spectrum) or twilight flats (the solar continuum is dominating). The only way of correcting for this effect is the use of a *super-sky*, which is obtained by making a median of all the images taken during the night with the given filter (see also Sec. 3.2.13). Note that the effect of fringing is additive and the fringe pattern should be scaled and subtracted from the image. Fringing in imaging mode is further discussed in § 3.2.13.

For spectroscopy, fringes can be satisfactorily removed by taking internal flats at the position of
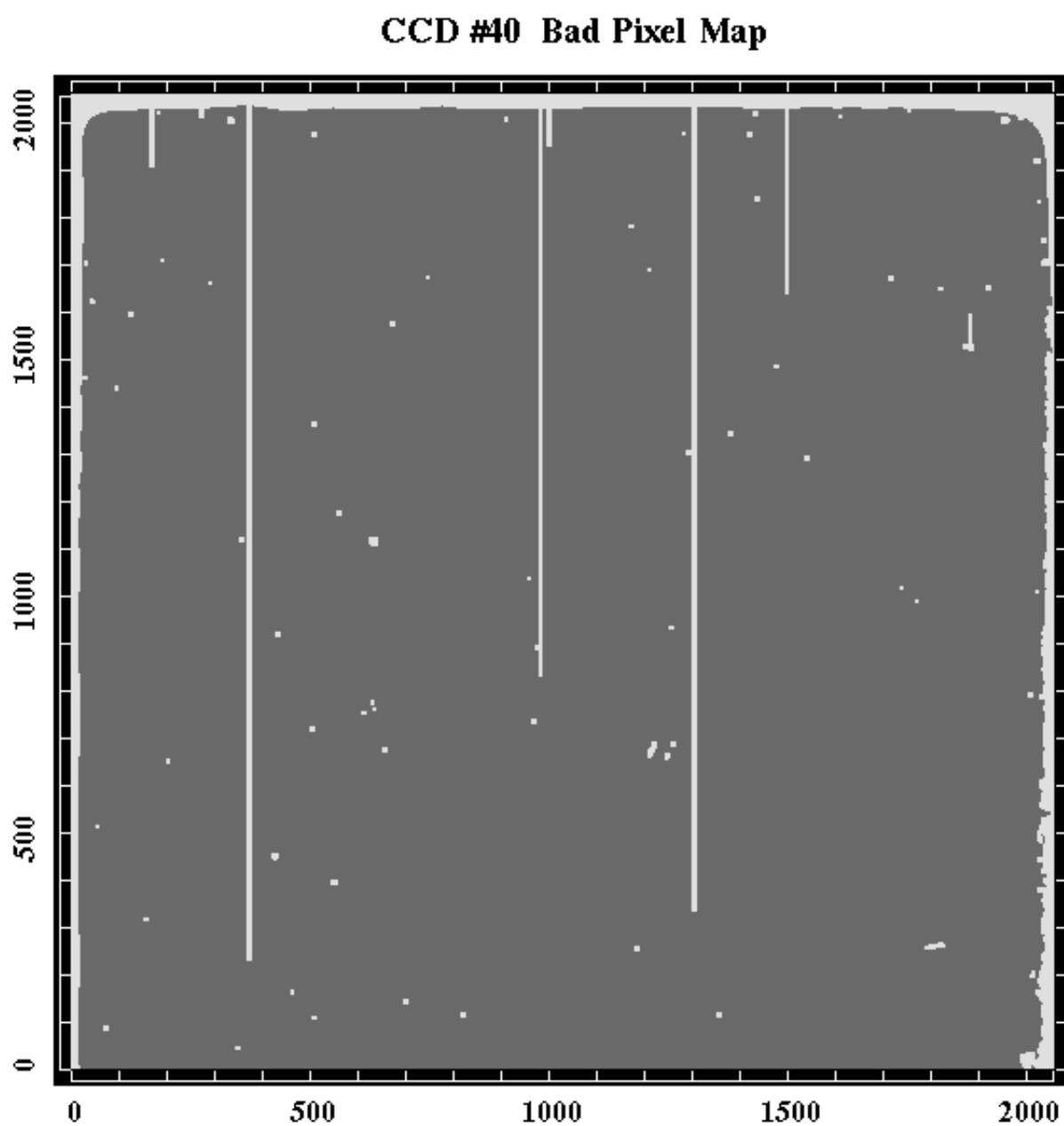
Figure 13: Bad pixel map of CCD#40. The latest bad pixel map can be found on the web.

the science observations, and using these to construct the normalized flat field image, to be divided from each frame. Dome flats taken during the day are not suitable due to flexure of the telescope/instrument. Fringing in spectroscopic mode is further discussed in § 3.5.7. It is also discussed on the EFOSC2 web page:

http://www.eso.org/sci/facilities/lasilla/sciops/team_only/efosc2/tests/Tests.html

2.7 Calibration Lamps

Note that EFOSC2 now makes use of the old EMMI Calibration lamps, which are available through the Calibration Unit associated with the adaptor/rotator. The main component of the calibration system is an integrating sphere mounted on the side of the adapter. Light from the output aperture of the integrating sphere passes through a lens and it is reflected onto the center of the focal plane by a 45° mirror which is moved into the optical axis. On the integrating sphere He, Ar, and ThAr lamps are mounted, while the light from flatfield or other spectral lamps that are mounted in a rack on the floor which is fed to the sphere through an optical fibre. The fiber induces some broad absorption features around $724\mu m$ and $880\mu m$. The angular size, location, and shape (including central obscuration) of the NTT exit pupil are approximately simulated. The illumination is homogeneous and unvignetted in a $3' \times 6'$ field and is still usable in a field of $5' \times 8'$ which covers the full EFOSC2 FOV.

Wavelength calibrations are normally achieved using Helium and Argon lamps only. The Quartz halogen lamp is meant to be used for internal spectroscopic flats, without the need of moving the telescope to the dome flat field screen. This is particularly useful if the observer wants to take flats soon after or before the target observations. This lamp can be used also to obtain images of the slits and the MOS plates. In this case the typical exposure times are of the order of 0.1s using the R filter.

For internal spectroscopic flats, the internal quartz lamp is too bright for certain slit and grism combination when the CCD is binned 2×2. In this case, flats with 1×1 binning can be taken and rebinned at the data-reduction stage.

For wavelength calibration, typical exposure times are reported in Table 13. Helium - Argon arc spectra often show a variety of unwanted features including extra lines which are often highly curved, big splotches of light, etc. These are illustrated in Fig. 14. All of these are due to a combination of reflections in the optics, the very bright emission lines in the arc lamp spectra and possible higher order spectra. At first glance these features look quite terrible as they are displayed on the Real Time Display (RTD) but in fact they are quite faint and the problem is with the display cuts automatically selected by the RTD. These have never been a problem during actual observing where the spectral lines are much fainter and such features are much fainter than the noise.

For dome flats, lamps of different power are available. They are controlled remotely via a panel on one of the displays (Fig. 15). Normally, the user does not have to set the lamp intensities, but specifies a desired mean level in ADUs in the dome flat field templates. The lamp intensities will be set by the telescope operator according to your setup.
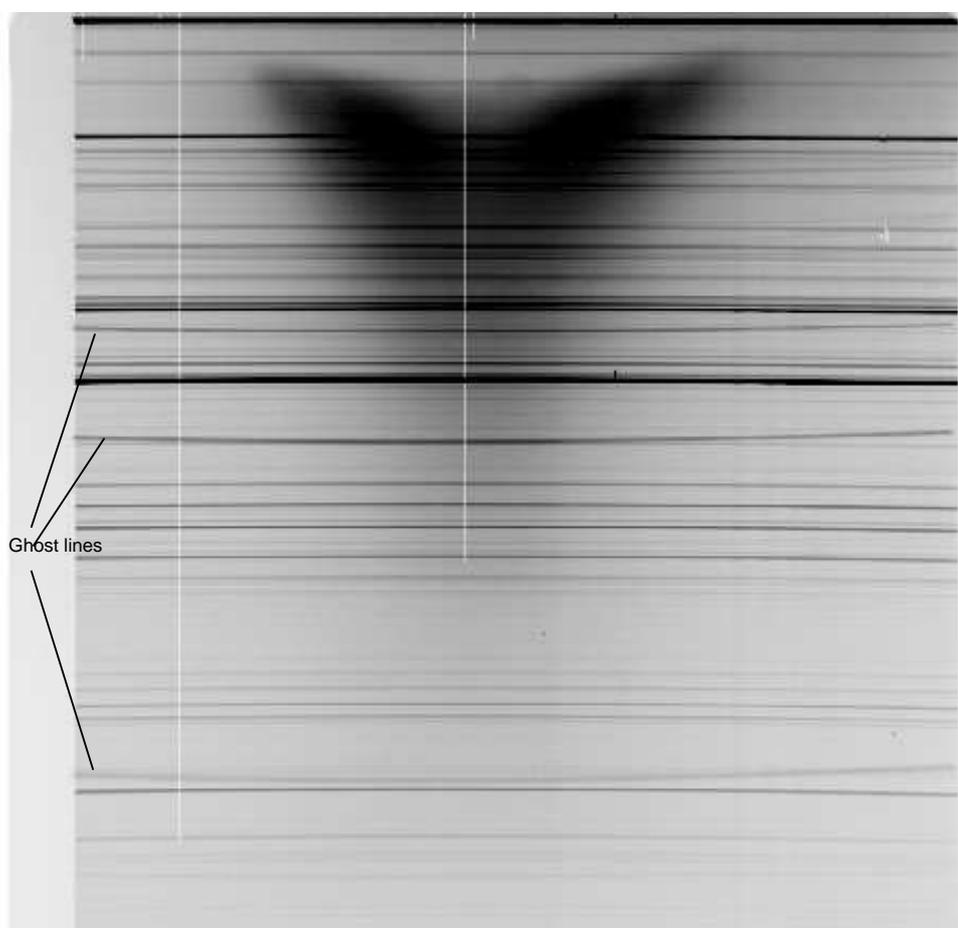
Figure 14: Artefacts in an Arc image. This is illustrated by an image of the He Ar arc lines for Grism 9. As well as the arc lines, there is reflected light from the Argon Lamp at the top of the frame. Very faint ghost lines resulted from reflection can also be seen in the image as lines which curve upwards. Both types of features do not affect the wavelength calibration as long as care is taken when identifying the lines. It must be emphasized that the ghost lines are faint.
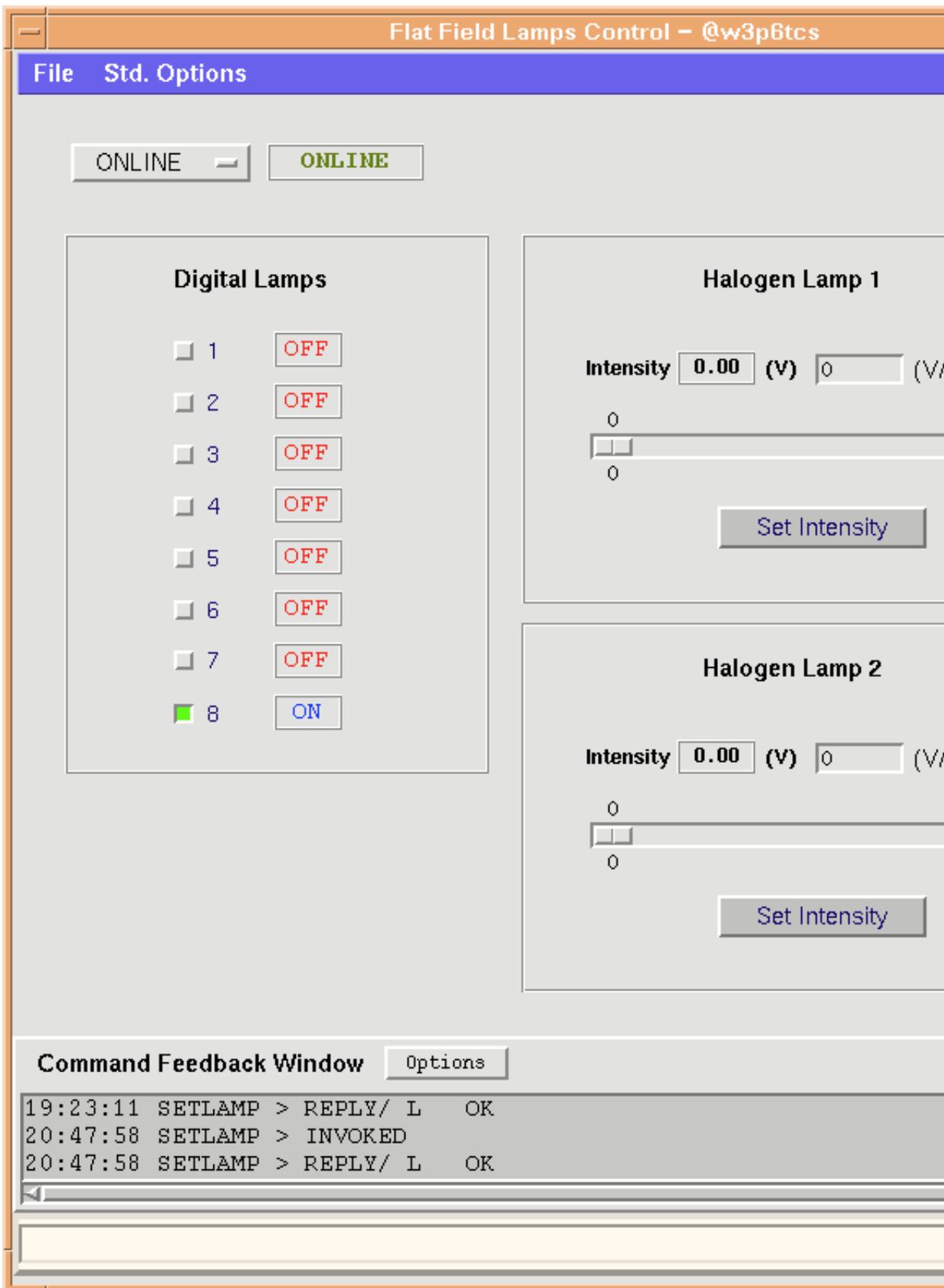
Figure 15:   The control panel for the dome flat lamps. This is usually controlled by the telescope operator. Different lamps of different wattages (some variable) can be selected. Such a figure refers to the 3.6m telescope. Different lamps are available at the NTT as well as a slightly different panel.

3   Observing with EFOSC2

3.1   The New Technology Telescope

Since April 2008 (ESO Period 81) EFOSC2 is mounted at the New Technology Telescope (NTT), where it is offered together with SoFI. The NTT has an alt-azimuth mounting, a 3.5m primary mirror diameter and a f/11 focal ratio. A description of the NTT can be found, for instance, at the following address:

http://www.eso.org/sci/facilities/lasilla/telescopes/ntt/index.html

or in the EMMI user manual:

http://www.eso.org/sci/facilities/lasilla/instruments/emmi/emmiManual.html

3.1.1   Telescope Focusing

As already introduced in §2.4.7, at the NTT the telescope focus is done through an image analysis and applying a focus offset which is tabulated and proper to the different instruments. However, the telescopes focus can be checked quickly using using the Focus Wedge. For this, a hard-coded procedure is implemented in all target acquisition templates (cf. Chap. 4) to allow focusing each time the telescope is preset to a new position. Following the needs of the observer, this step can be skipped.

A special template[1] (`EFOSC_img_cal_FocusWithWedge`) has been implemented in order to allow a Focus Wedge focusing outside of the target acquisition phase. This template, can be inserted in different points of an observation description to re-focus the telescope when staying for a long time on the same target[2]. When using the focus wedge, stars should be selected in the central region of the CCD, since the image quality is better there.

If the observer is not convinced yet a of the telescope focus obtained through the focus wedge a focus sequence may be also performed.

3.1.2   Pointing, Tracking and Guiding

Tracking of the NTT is quite accurate: without guiding, no degradation is seen with a seeing of 0".8 in 15 to 20-minute exposures not too close to zenith or horizon. Because the pointing model corrects for atmospheric refraction which is wavelength dependent, the central wavelength used in the scientific exposures can be set in the TCS (telescope control software) to achieve a very high precision. However, for most observations, using the default value of 650 nm is sufficient. Guiding the telescope during an exposure is usually done by setting one of the two guide probes located in the rotator/adapter on a star and using the autoguider. After each telescope preset, a list of suitable guide stars is displayed on the autoguider panel. The night assistant selects one of them and starts the guiding. Note that there is a region within the autoguider position range where the guide probe will cause vignetting in the images. This region is marked by a yellow box on the 'stella' display of the autoguider system, and the system will stop you selecting a guide star in this region. It is important to note that if you are performing a series of jittered exposures with the guiding on, you must take care that the offsets do not move the guide star into this region. If they do, the OB will give an error and guiding will have to be restarted, often causing the whole OB to be restarted. For this reason users should warn the telescope operator if they have any large offsets in their OBs, so

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[1]For more details on the *templates* and P2PP, see Sec. 4.

[2]This is possible because it is defined as a calibration template. P2PP only allows one acquisition template per Observing Block

that (s)he can select a guide star in a suitable region. The acquisition is done by a technical CCD, upgraded in November 2005, whose default orientation is North on the top and East to the left, with a field of view of 1.7′x 1.7′, and a scale of 0″.2/pix. The resolution of the guide probes is 0″.05. As the autoguider only corrects the altitude and azimuth motions, tracking inaccuracies of the rotator may induce image displacements. Note that in case of poor seeing or strong wind, autoguiding may make the images worse since the corrections always lag behind actual conditions. In such conditions, it is better to lower the frequency of the corrections to average the effects. It is also possible to observe moving targets with the NTT, but this is not implemented in the autoguider. Presently the best way is to use the tracking model, and to supply differential tracking rates, in arcsec/sec. The expected accuracy is the same as for simple tracking since the telescope is altazimutal, it doesn't care if the tracking is sidereal or not. Care should be taken in re-acquiring the moving object in the slit on average each 10m, depending on the telescope position and on the target speed. The NTT has an Altitude-Azimuthal mounting and, as a consequence, the singularity is in the Zenith and not in the pole. When observing very close to the Zenith, the telescope building and the rotator have to rotate very fast in order to track the object. The result will be a poor image quality, less accurate pointing and problems with the positioning of the object in the slit for spectroscopy. In the worst case scenario, if we point too close to the Zenith, the system can crash. A software interlock will trigger at telescope elevations of 89°and 10°respectively, while an hardware interlock will trigger at telescope elevations of 90°and 8.9°respectively. Users should be aware of the fact that, once the hardware interlock has been activated, a considerable amount of time will be needed to recover the telescope. In order to avoid such problem, it is advisable to respect the following limitations:

- Never, ever point within 5 degrees from Zenith (-32<dec<-26, HA < 00:10:00)

- Never, ever observe within 5 degrees from Zenith (-32<dec<-26, HA < 00:10:00)

- In the -32 to -27 range do NOT observe within 15 minute from the meridian.

- In the -50 to -10 range be aware that you may get bad surprises within 15 degrees from the meridian.

In all cases, AO should not be attempted at elevation < 40°and no optics adjustment must be done at elevation below 20°, not even M2 focus adjustment for temperature variations.

3.1.3   The Adapter

EFOSC2 is mounted horizontally at the NTT Nasmyth B focal station and connected to the telescope via an adaptor which contains some calibration units. It allows the instrument to rotate around its mechanical axis, with a resolution of 0°.1. Note, this movement is not fast, the time required to perform a complete rotation (360°) with this precision is about 5 minutes.

The adaptor orientation (and hence the slit orientation) definition used by ESO telescopes is "non-standard" in that it does not follow the usual Position Angle definition (positive angle subtended from north through east in the range 0 - 180 degrees).

The Rotator Offset Angle is the offset from the default Rotator Angle (0°). It is this offset which has to be defined in P2PP. With a Rotator Angle= 0° the CCD is oriented with North to the top and East to the right, as shown in Fig. 10.

The spectroscopic slit is always aligned along the x-axis of the CCD and the default slit orientation is East-West. So, if one wants a different orientation, usually for spectroscopy or MOS preimaging, one has to define a rotator offset angle in the Observing Block. As can be seen from fig. 16, an offset of PA-90° must be applied to position the slit along a given position angle. The slit can be aligned along the parallactic angle (calculated at the start of the OB) automatically (see Sec. 3.5.5).
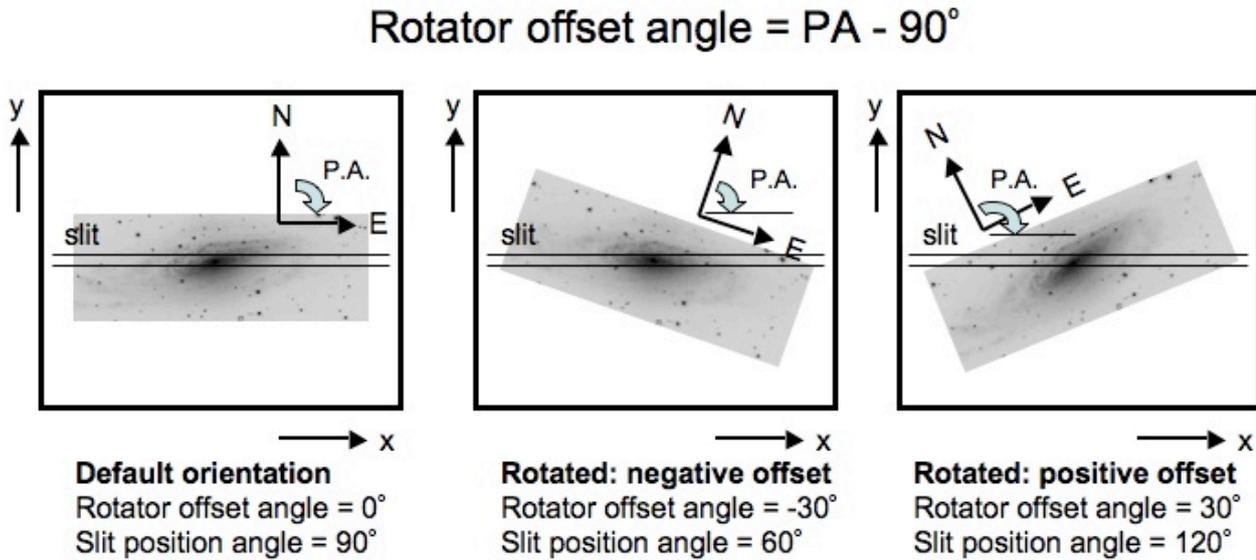
Figure 16: EFOSC2 slit orientation

3.2   Imaging

In this section the user will find some notes of specific interest when using EFOSC2 for Imaging. In this and the following sections we will often refer to the Templates and Observation Blocks (see Chap. 4).

3.2.1   World Coordinate System

The rotation centre is near the centre of CCD at pixel (1016,990). The orientation at zero rotator angle to be North up and East right (see 10), i.e. with the image reflected about the y-axis relative to the view on the sky. This information has been used to allow full World Coordinate System (WCS) information to be stored in the FITS headers of data taken with EFOSC2, which in test exposures of astrometric and standard star fields at various rotator angles to be accurate to within the typical pointing accuracy of the NTT (a few arcseconds). Note that the WCS information is correctly calculated for all binning modes.

3.2.2   Flat Fields

For an accurate flat field correction, both dome and evening/morning twilight exposures should be taken. These will allow the pixel to pixel and low frequency variations to be taken into account.

3.2.3   Dome Flats

As part of the start-up procedure, every afternoon the telescope can be left in the flat field position by Day Operations. The flat field screen can be illuminated using the quartz halogen lamps located in the dome, which are controlled remotely from the TIO's console.

The suitable template (`EFOSC_img_cal_Flats`) has been implemented in such a way that the observer needs only to specify the average exposure level (in ADUs) (s)he wants to reach in her/his frames. The correct exposure time will be estimated by the template itself via a test exposure.

To increase the signal to noise ratio it is a good idea to specify exposure levels around 40000 ADUs.

3.2.4   Sky Flats

A catalogue of *empty* fields is present in the TCS, so that the V.A. can request the Operator to preset the telescope to the one (s)he likes. The sky gradient can be reduced by pointing the telescope away from the Sun (i.e. east at dusk and west at dawn).

When in position, the suitable template (`EFOSC_img_cal_SkyFlats`) can be executed. Since we implemented the algorithm developed by Tyson & Gal, there is no need to specify any exposure time but only the average exposure level. After an initial test, if the computed exposure time is longer than 3 seconds, a series of frames (the number of which is specified by the user) is started. The procedure automatically extrapolates the exposure time for subsequent images and applies a user specified offset to the telescope. This offset allows the removal of stars present in the field during data-reduction.

Depending on the weather conditions, the algorithm gives equally exposed frames, with maximum differences of ∼3000 ADUs. When binning 2×2 it is possible to take 3 frames for each of the U, B, V, R and i broad band filters during a single twilight.

3.2.5   Sky Concentration

As with most focal reducers, EFOSC2 is affected by the so-called sky-concentration, a diffuse spot of light a few percent above the background in the center of the image. This effect is caused by light – from the sky background and from stars – reflected by the CCD back onto the camera and returned by some optical surfaces, with the main contribution from the field lens (see Fig. 17).

Sky concentration causes a distortion of the flat field, which will lead to an underestimation of the counts in the central part of the field. However this is comparable to the accuracy with which normal flat fields can be obtained. If higher accuracy is needed, a more sophisticated procedure has to be adopted. See for example Andersen et al. (1995) or Valdes (1998).

3.2.6   Image Quality

The excellent image quality of the NTT is the result of several factors: i) its "New Technology" enclosure which ensures a very good airflow through the telescope, ii) its active and passive temperature control, which guarantee that no heat source is near the optical path, and that the mirror is always cool, and iii) its revolutionary active optics (indeed, the NTT was the first telescope featuring a flexible, controlled mirror).

3.2.7   The active optics system

The good image quality of the NTT is in part due to the active control of the primary and the secondary mirror. The primary (M1) mirror is supported by 75 actuators and three fixed points, corresponding to actuators #7, #29 and #50. The force applied to each of the 75 actuators can be adjusted and thus the shape of M1 can be modified. The secondary mirror (M2) can be moved in X,Y,Z, where the X,Y motion of M2 is used to correct for decentring coma and the motion in Z controls the focus. The active supports are used to compensate for various deformation effects in the telescope structure and the mirrors, and for effects due to inhomogeneities of the air temperature in the dome. Some of these effects are elastic and can be empirically calibrated for each position. Others have inelastic components and are more difficult to predict. Confusion is sometimes found
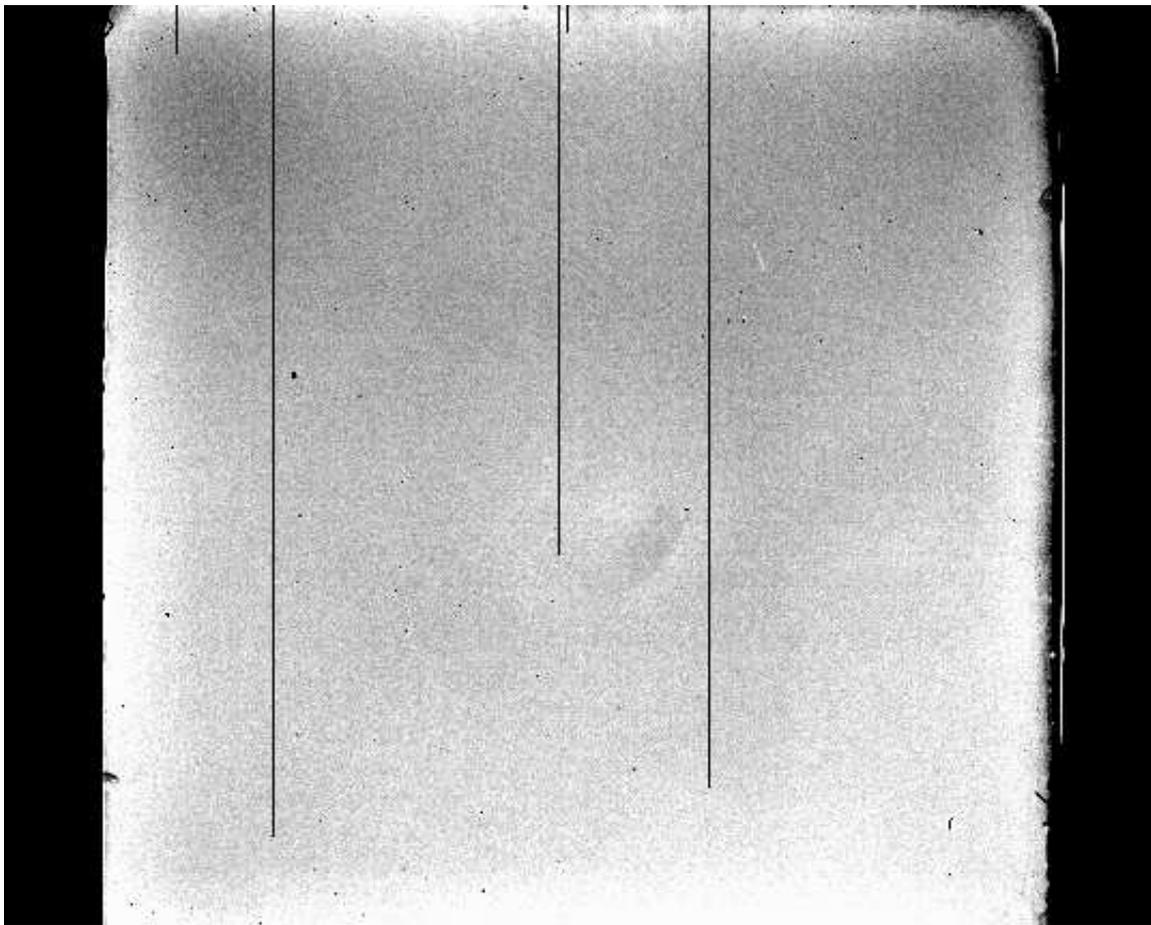
Figure 17:   Normalized R dome flat field (September 2003). The image cuts are 0.96,1.04. The scratches on the left side of the detector are due to the support of the Movable slit. The spot in the center is due to the Sky Concentration.

about the difference between active optics and adaptive optics. Adaptive optics can correct for turbulence in the atmosphere by means of very fast corrections to the optics, whereas active optics only corrects for much slower variations. Thus, whereas adaptive optics can reach the diffraction limit of the telescope, active optics (as on the NTT) only allows the telescope to reach the ambient seeing. There are two different procedures to set the NTT Active Optics System (AOS). The first is to use a default setting correcting for gravitationally induced deformations, using predefined look-up tables at different values of the telescope altitude. These tables include corrections for astigmatism and defocus, but not for higher-order effects. The second method is to do a full wavefront analysis, the so-called image analysis, and to calculate the mirror settings from this. The image-analysis systems (there is one at each Nasmyth station, located inside the instrument adapter/rotators) consist of a Shack-Hartmann grid and a CCD to record the image. The pupil image corresponding to a particular star is transformed by the grid into a regular pattern of dots. The position of each dot has been calibrated with an internal light source. The wavefront distortions can be obtained from the displacement of each dot from its calibrated position. From this, a software determines the telescope aberrations (Wilson et al. 1991, Journal of Modern Optics 38, 219): it solves for defocus $[r^2]$, spherical aberration $[r^4]$, coma $[r^3\cos(\phi)]$, astigmatism $[r^2\cos(2\phi)]$, triangular coma $[r^3\cos(3\phi)]$ and quadratic astigmatism $[r^4\cos(4\phi)]$, where r is the radial and ϕ the azimuth mirror coordinate. A low-order Zernike polynomial is fitted to the map of the displacement vectors. The accuracy or validity of the solution is estimated from the rms residual deviations with respect to this polynomial. If the rms is poor, the corrections are normally not applied to the mirror. The bad rms is usually caused by very bad seeing (in this case it's not really worth to perform the image analysis). The image-analysis system can be used in parallel mode, during the science exposures. In this mode, a dichroic is inserted in front of the guide probe which deflects most of the light of the guide star to the Shack-Hartmann grid. The corrections are calculated and applied between one exposure and the next one. The parallel mode requires a guide star brighter than 13th magnitude, which is not always available, and no jitter between one science exposure and the next. More information about the AOS can be found in:

LSO-MAN-ESO-40100-1001/1.0 — *The NTT Active Optics System Users Manual*, **Philippe Gitton**

3.2.8   Practical Considerations

The AOS is initialized every afternoon by the night assistant. A full image analysis will be done at the beginning of the night, when it has become sufficiently dark. This will generally be immediately after the taking of twilight sky flat fields and takes around 10 minutes. This analysis is done not only to improve your images, but also to monitor the telescope and detect possible problems. The observers may decide to shift these measurements to later in the night if they conflict with urgent observations, but the night assistants are instructed to do this test every night. During the night it is usually advisable to repeat the image analysis procedure. If the conditions improve noticeably, the mirror settings from the initial analysis are likely insufficiently accurate to make full use of this. A significant change may also be seen when moving to a different field, and it is necessary to redo the image analysis at this new position. To judge on the necessity, keep a careful eye on the image quality your frames. Images elongated by more than about 10% indicate residual astigmatism (in the presence of some defocus) which is generally the first indicator of imperfect settings. For the majority of NTT observations, whether imaging or spectroscopy, better seeing will give improved signal to noise. Under good conditions, the time spent on an extra image analysis will generally be a good investment. However, there are several conditions where little or no improvement can be expected from an image analysis. The first is when the seeing is poor (significantly above 1.0). In that case, the default setting is normally sufficient. Second, if windshake of the telescope is important (especially when observing into the wind at wind speeds of 10 m/s or more). Finally, if there is little

wind the solutions will not be good: this typically happens when the wind drops below 2—3 m/s. In the last case, either try doing an image analysis with the telescope pointing into the wind, or wait for the wind to pick up again. Problems may also occur when M1 is significantly warmer than the ambient temperature. This last problem is now reduced thanks to the fans that have been installed around M1 and a special M2 baffle to improve the air flow. The focus offset between the image analysis camera and EFOSC2 is calibrated and monitored. Therefore, the focus correction given by the active optics system should leave the instrument at the right focus. This is usually checked once at the beginning of night, then relied upon for the remaining of the night.

3.2.9   The EFOSC2 PSF and Image quality

The Focal Reducing optics of EFOSC2 considerably distort the PSF and this distortion varies across the CCD. The best (most circular) PSF occurs close to the centre of the CCD. NTT Nasmyth stations work at $f/11$ while the 3.6m Cassegrain focus works at $f/8$. Therefore, a better image quality is achieved at the NTT with respect to EFOSC2@3P6.

The PSF distortion as a function of position on the CCD was measured to reach 10% beyond approximately $2'$ from the centre. The elongation of stars in an image taken in good conditions is shown as a function of position on the CCD and of the radial distance from the center in fig 18 and fig 19, respectively. In fig 18 the length of the segments is proportional to the star elongation: $(1.37A/B)^{10}$.

It must be noted that this represents the minimum distortion that one should expect, which is "intrinsic" to the instrument/CCD combination. The image quality on any single image could be worse due to improper focus, telescope tracking effects, telescope optics distortion (due to stresses in primary and secondary mirrors) etc..

3.2.10   EFOSC Vignetting

The pixel scale of EFOSC2@NTT is $0''12$ px^{-1}. The maximum field of view (i.e. free of vignetting) is set by the field lens just before the detector, and it is a circle of radius 18 mm. The current detector has 2048 pixels of 15μm, so its size is 30.7×30.7 mm^2. Therefore $\approx 8\%$ of the detector area will be vignetted at the edges (beyond a radius of $2'.4$ from the field centre), as is graphically illustrated in Fig. 20 and visible in the accompanying flat field image. Variation in the flat field illumination with rotator angle are negligible (see Fig. 21).

3.2.11   Target Acquisition

Two different templates have been implemented for pointing the telescope in the imaging mode, according to the positioning accuracy needed by the observer.

The first (`EFOSC_img_acq_Preset`) performs a blind preset of the telescope, without taking any acquisition image. This template should be used, for example, for photometric standards or in all cases where an accurate positioning is not required.

If the observer wants to place the object in an exact position on the CCD (i.e. to avoid bad columns), the template to be used is `EFOSC_img_acq_MoveToPixel`, which allows a positioning accuracy of the order of one pixel. Unless differently specified in the template, the acquisition images are taken in the *fast* mode with binning 2×2 to reduce overheads.
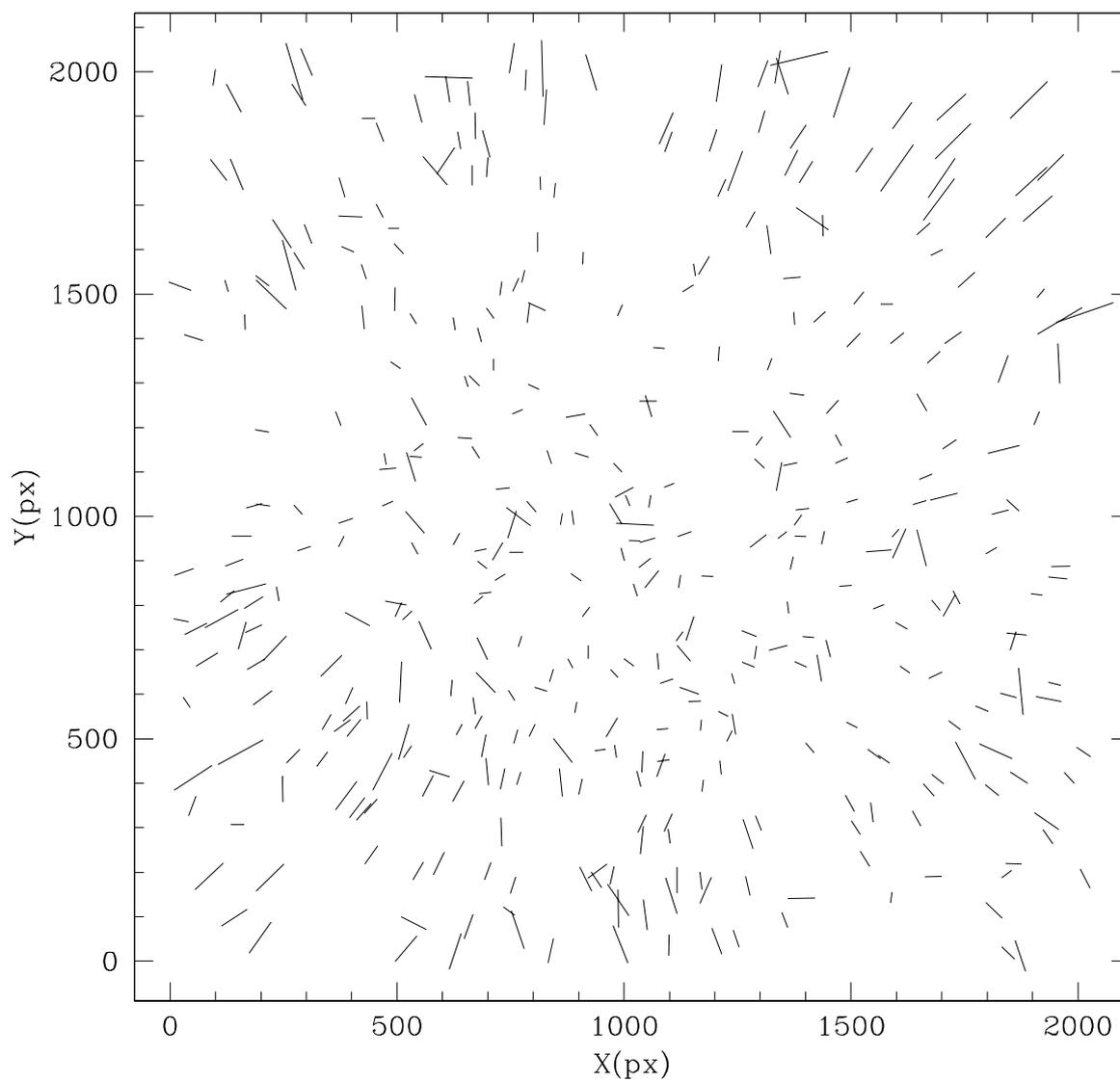
Figure 18:   The PSF shape variation across the CCD. It is measured by determining the PSF ellipticities in an image of the loose globular cluster Pyxis stellar fields taken under good seeing (< 0.75 arcsec) conditions. The vectors indicate the orientation and magnitude of the PSF ellipse at that CCD location.
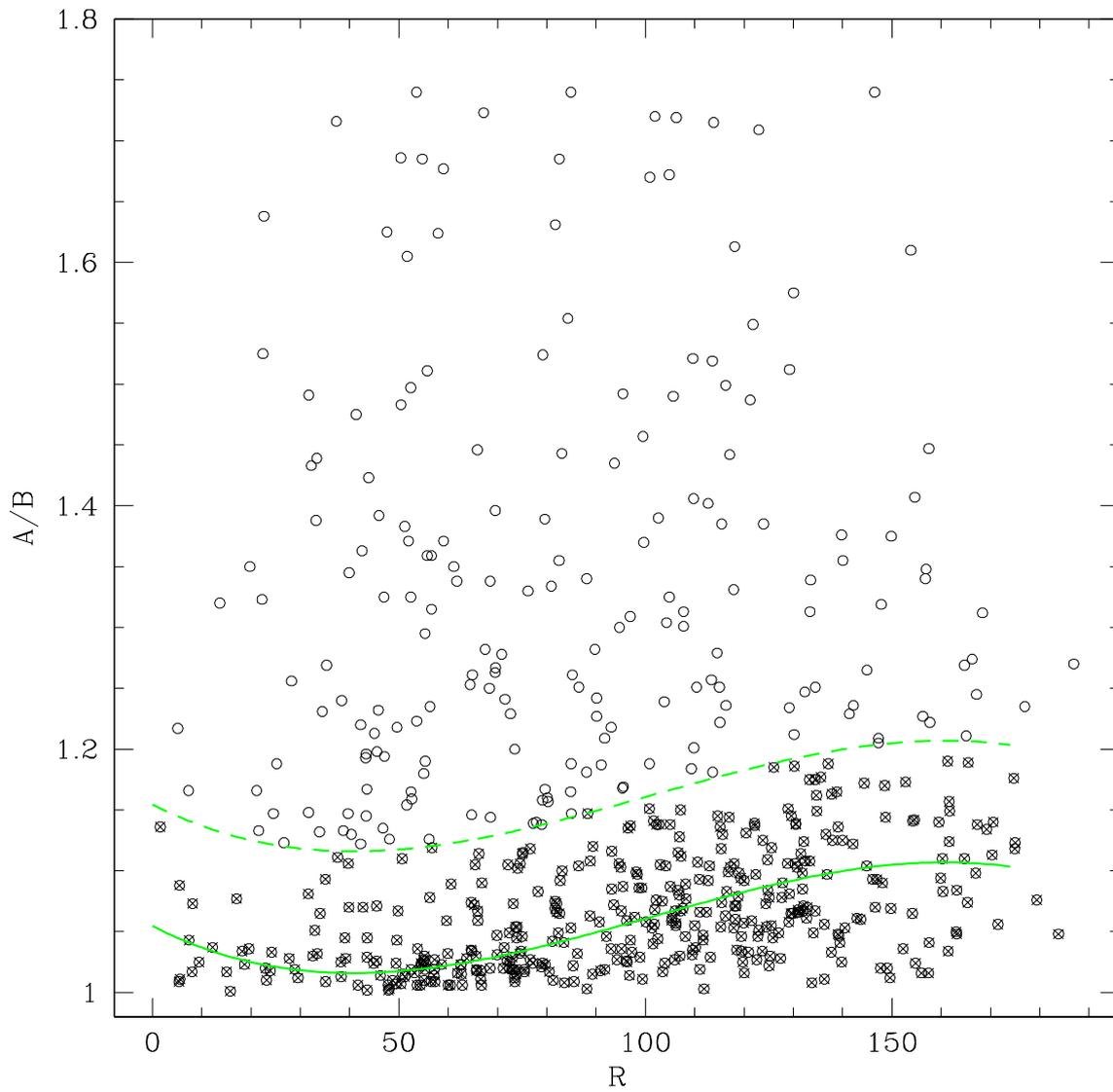
Figure 19: The ellipticity of stars measured in the same stellar field as the previous figure is plotted as a function of the radial distance from the CCD center. Only stars below the dashed curve were plotted in the previous figure.
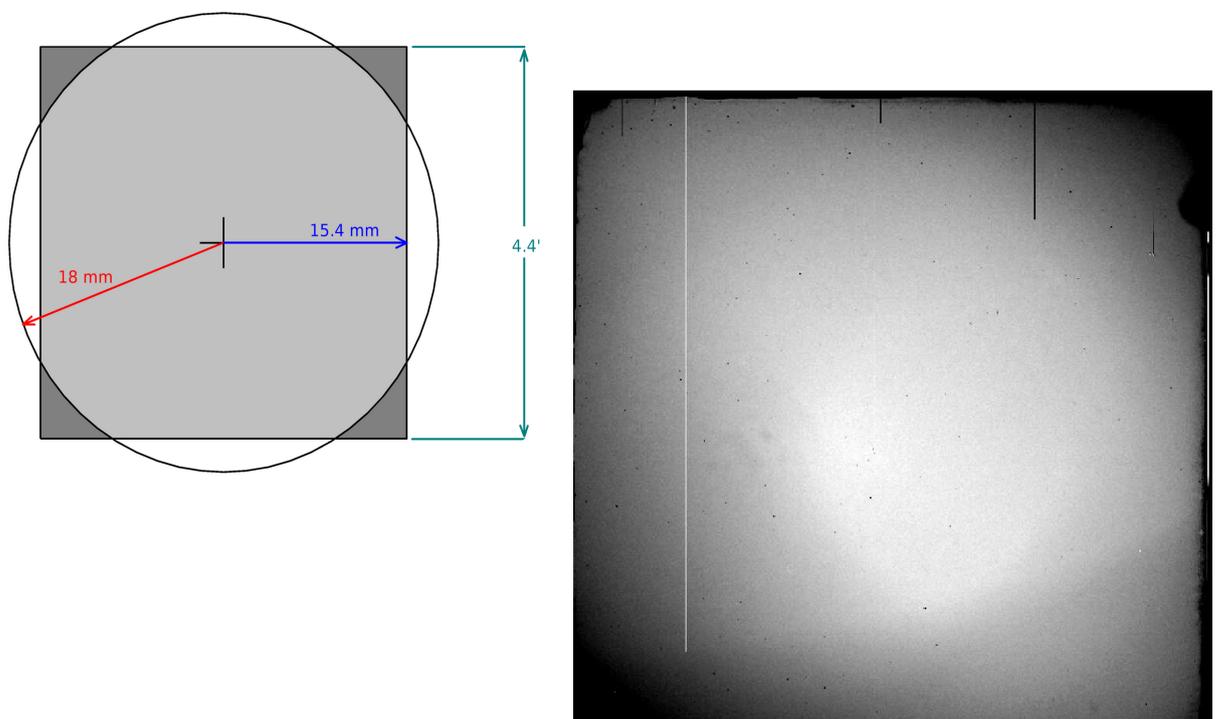
Figure 20: *Left*: The dark shaded area shows the regions of the detector that will be affected by some degree of vignetting, after changing to the slower $f/11$ ratio of the NTT. It corresponds to $\approx 8\%$ of the active field of view. *Right*: a blue dome flat field after the installation of EFOSC2 at the NTT.

Figure 21: Ratio of dome flat fields taken at different rotator angle. The px-to-px differences are less than 1% .

3.2.12   Science Exposures

Imaging can be performed by two different templates. `EFOSC_img_obs_Image`, allows one or more exposures to be taken without offsetting the telescope. `EFOSC_img_obs_ImageJit` allows for small telescope offsets between exposures, according to a user-defined offset pattern. The latter is particularly suitable for accurate photometry or in cases when a deconvolution-coaddition technique is to be applied in the data reduction phase. It is also useful for fringe-removal for i band (and also R band) exposures.

The colour equations, the efficiency of the whole system and other relevant informations are given in Appendix A.

3.2.13   Fringing

As discussed in Sec. 2.6.5, long R and especially I exposure images are affected by fringing which can significantly undermine accurate photometry. An example of fringing in the I band is shown in the left panel of Fig. 22, while a cross cut of an I superflat obtained combining 14 exposures of 480s each is shown in the right panel of the same Figure. In this case the maximum amplitude of the fringes is of the order of 3%.

Caution: It must be noted that this effect is *additive* and cannot be removed by a simple flat-fielding. Therefore the user must be aware that if one really wants to remove the fringe pattern, one has to create a so called *super-flat*, which is usually built using all the frames taken in the specific passband. This works only if the fields are not strongly crowded and if there are no extended objects. Otherwise it is necessary to obtain dithered images of some *blank* fields during the night.

Once the super-flat has been obtained, fringe removal can be performed by the *adaptive modal filtering* (see, for instance, McLean 1997). Basically this method allows the fringe frame to be built and then subtracted from the image to be corrected. Since generally one has only one fringe pattern per night and the sky background is changing with time, it is necessary to apply a *trial-and-error* iterative technique.

The measured fringing patterns are available at:

http://www.eso.org/sci/facilities/lasilla/instruments/efosc/inst/fringing.html

3.3   Polarimetric Imaging

As already mentioned (see Sec. 2.4.8) the Wollaston prism produces two images of the same object (usually called ordinary and extraordinary) with perpendicular polarization on the output CCD image (the separation of the two beams depends on the specific prism).

In order to avoid confusion and increased sky, it is a common technique to insert in the aperture wheel a special mask with alternating transparent and opaque parallel strips with a width corresponding to the splitting. Naturally, this mask masks out half the viewing area. Therefore a polarization image of the whole field at one position angle requires two sets of exposures with the telescope moved by an amount equal to the beam split, in order to recover the part of the field occulted by the mask. Of course, in case the object of interest is well contained in one strip, one exposure for each position angle will be sufficient.
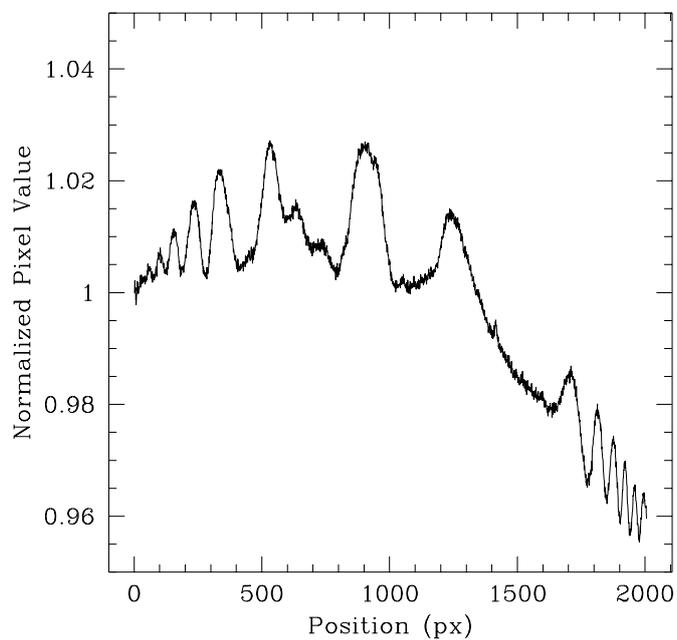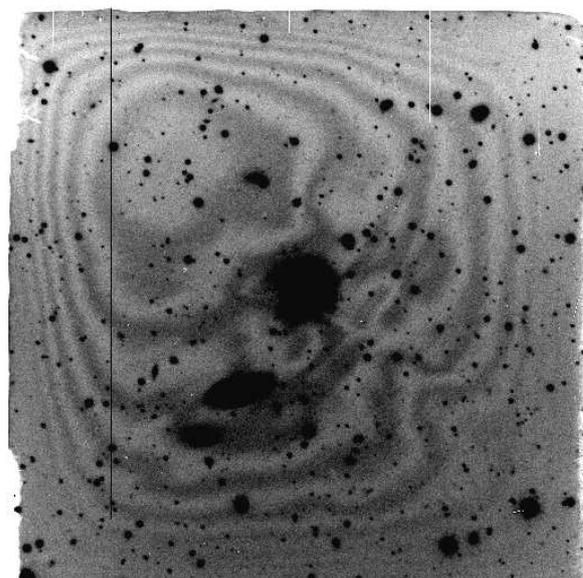
Figure 22: Upper panel: Fringe pattern on a 10 minutes exposure in the I band (CCD#40). Lower Panel: A mesh of the central 100 columns from an I superflat obtained combining 14 exposures of 480s each (courtesy of A. Iovino).
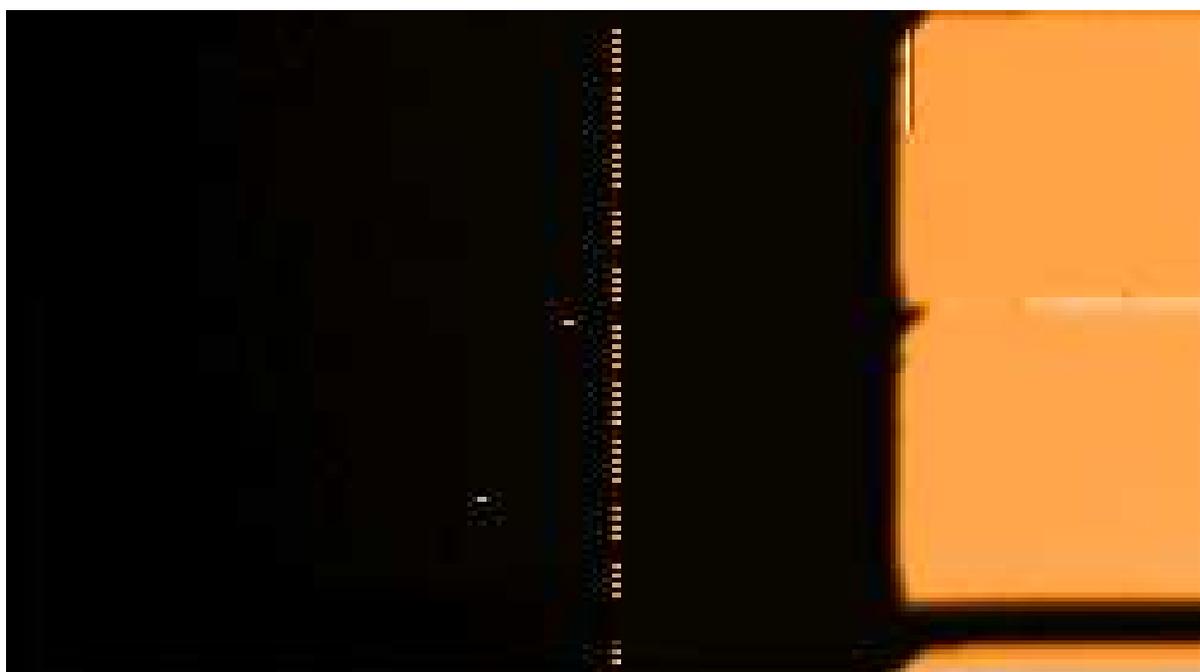
ESO   **test_vfastL_win_1_1_500_280_wollmask.fits**

isaviane/Skycat   **Mar 05, 2006 at 00:41:31**

Figure 23: A window to reduce read-out time for polarimetry; the source must be centered at pixel (427, 157); not that the RTD does not have the full FITS header, so this px will correspond to another position in the RTD

Figure 24: Comparison of a two-beam image without (left) and with (right) Moon

3.3.1 Fast Polarimetry

If you have a single point-source, you can reduce the read-out time by taking a CCD window of dimensions 500x280 (and starting at 1,1, see Fig. 23). The read-out time of this sub-frame is 3.07 sec in vfastL mode (not offered) and 3.28 sec in fastL (aka normal). When including all overheads (transfer to ws, etc.) the total time is 12sec for the fastL/normal mode. So basically, this is the fastest time offered for polarimetry. For plain imaging of one object an even smaller window can be used, is appropriate.

For comparison, reading out the full frame in vfastLR mode (aka fast) takes 9.71sec, and to this overheads must be added.

3.3.2 Observing close to the Moon

When observing close to the Moon, the scattered and polarized light from the sky increases, inducing the effect shown in Fig. 24. The background of the ordinary and extraordinary beams are very different, but this is not an instrumental problem.

3.3.3 Linear Polarization

In order to determine the Stokes parameters, and therefore the degree of linear polarization (P) and the angle of polarization (θ), at least four images rotated by 22°5 with respect to each other must be obtained. This is usually done at 0°0, 22°5, 45°0 and 67°5.

If β_i is the HWP rotator angle ($\beta_i = 22°.5 \times (i-1)$ with $i = 1, 2, 3, 4$) and $f^o(\beta_i)$ and $f^e(\beta_i)$ are the fluxes measured for the ordinary and the extraordinary channels, the normalized flux differences $F(\beta_i)$ are:

$$F(\beta_i) = \frac{f^o(\beta_i) - f^e(\beta_i)}{f^o(\beta_i) + f^e(\beta_i)} \tag{1}$$

Then the Stokes parameters are simply given by[3]:

$$Q = \frac{F(\beta_1) - F(\beta_3)}{2} \tag{2}$$

$$U = \frac{F(\beta_2) - F(\beta_4)}{2} \tag{3}$$

With these definitions, the polarization degree is given by:

$$P = \sqrt{Q^2 + U^2} \tag{4}$$

while the polarization angle is given by the following set of equations:

$$\theta = \begin{cases} \frac{1}{2}atan(\frac{U}{Q}) & U > 0, Q > 0 \\ 90° + \frac{1}{2}atan(\frac{U}{Q}) & U < 0, Q > 0 \\ 90° + \frac{1}{2}atan(\frac{U}{Q}) & U < 0, Q < 0 \\ 180° + \frac{1}{2}atan(\frac{U}{Q}) & U > 0, Q < 0 \end{cases} \tag{5}$$

For more details see Szeifert (1998) or Lamy & Hutsemekers (1999).

Note also that the asymmetric reflection at M3 seems to introduce a significant amount of instrumental linear polarization (up to ~5%, see 2.4.9).

3.3.4 Circular Polarization

The amount of circular polarization V[4] can be determined, observing with the quarter wave retarder plate at two retarder plate angles of $= \pm 45$ (i.e. a phase difference of $90°$), by the equation:

$$V = \frac{1}{2}[(\frac{f^o - f^e}{f^o + f^e})_{\beta=45} - (\frac{f^o - f^e}{f^o + f^e})_{\beta=-45}] \tag{6}$$

(f^o, f^e being the ordinary and extraordinary beam of the object measured for a given retarder plate angle β) One could determine the circular polarization observing at one retarder plate position, but two observations are required to eliminate the strongest observing biases in the first order approximation:

- the improper flat field correction FF

- the color dependent offset to the nominal retarder plate zero angle

- the incomplete and color dependent retardation of $90 + \epsilon_\phi(\lambda)$ degree of the quarter wave plate

---

[3]These Q and U are normalized parameters, sometimes indicated in the literature as Q/I and U/I.

[4]As for the case of linear polarization, V is normalized parameters, sometimes indicated in the literature as V/I.

Observations at only one retarder plate angle would cause hardly correctable Stokes parameter cross talks in the case of objects with non-negligible linear polarization. The color dependence of the retarder angle ϵ_β would cause an additional polarization of $\Delta V = -2\epsilon_\beta U$ and the incomplete retardation ϵ_ϕ ($\phi \neq 90$ degree, quarter wave) would cause the additional polarization of $\Delta V = -2\epsilon_\phi Q$ (ϵ_ϕ & ϵ_β in radians, UVQ being the Stokes parameters). One would get

$$(\frac{f^o - f^e}{f^o + f^e})_{\beta=45} = V + \epsilon_{FF} + (-2\epsilon_\beta U - \epsilon_\phi Q) \tag{7}$$

$$(\frac{f^o - f^e}{f^o + f^e})_{\beta=-45} = -V + \epsilon_{FF} + (-2\epsilon_\beta U - \epsilon_\phi Q) \tag{8}$$

The difference between the two observations yields V while the small deviations have the same sign in the two equations and are therefore eliminated for small angles ϵ_ϕ & ϵ_β. See also the FORS1+2 User's Manual:

http://www.eso.org/instruments/fors1/doc/

Note also, that an instrumental circular polarization up to $\sim$0.4% seems to present (see 2.4.9).

3.3.5   Flats and Other Calibrations

The procedure to obtain polarimetric flats (dome and sky) is similar to the one described for normal Imaging. The only relevant difference is that in this case the exposures are taken with the Wollaston mask, Wollaston prism and HWP/QWP in the beam. Note that to achieve a complete de-polarization of the incoming light, the HWP/QWP is automatically set to a continuous rotation. Since the rotation time is 2.3/4 seconds, the templates `EFOSC_img_cal_PolarFlats` and `EFOSC_img_cal_PolarSkyFlats` (and the equivalent for the QWP) do not allow exposure times shorter than 10^s.

Note that in addition to the usual bias, dark and flat-field, other additional forms of calibration are needed for polarimetry:

- To determine the instrumental reference angle, a known polarized star should be measured. Note, however, that the only reliable polarimetric standards available are all very bright.

- These stars can also be used to determine the instrumental polarimetric efficiency.

- To determine the intrinsic instrumental polarization, one ore more known unpolarized standard stars should be measured.

- The cross talk between linear and circular polarization is known to be small (below 0.05%, see Saviane et al. 2007, Msngr, 129, 14). However, the observer interested in measuring circular polarization may want to take highly linearly polarized standard to take into account during the data reduction phase the possible residual cross talk between the two type of polarization.

- As already mentioned in §2.4.9, the asymmetric reflection at M3 seems to introduce instrument linear polarization, with value and angle dependent on the elevation of the telescope (e.g. Li et al. 2006, Proc. of SPIE Vol. 6275, 62751H-1). Therefore, the users are encouraged to include observations of unpolarized standard stars in their program, in order to remove the instrument polarization at the data reduction stage.

We finally remark that the zero point offset of the polarization angle is somewhat wavelength dependent because of the chromatism of the Q/HWP. Therefore all calibrations have to be taken in the different pass-bands that will be used in the science exposures.

Note that there is also the possibility of inserting a Polaroid filter on top of a pinhole mounted in the aperture wheel. The user may want to take advantage of this to perform some additional tests on a nearly 100% polarized source.

A list of highly polarized standard stars for imaging polarimetry can be found online at:
http://www.eso.org/instruments/fors/tools/FORS_Std/FORS1_Std.html

3.3.6   Target Acquisition

To allow for a proper positioning of the target under one of the transparent strips of the Wollaston mask, it is necessary to measure the position of the transparent strip. The template `EFOSC_img_obs_Image` can be used for this purpose, while pointing the telescope towards the flat field screen. Note that some tuning of the dome flat field lamp may be necessary to obtain the correct exposure level.

Alternatively `EFOSC_img_cal_IntImage` may be used, with the advantage that there is no need to move the telescope. It might be necessary to insert a narrow band filter (i.e. $H\alpha$) to avoid saturation.

Once such image has been produced, the coordinates of the suitable position must be measured (X and Y pixel coordinates in 1×1 binning) and noted down, since it will serve as an input for the acquisition template `EFOSC_img_acq_Polarimetry`.

Caution: The images of the mask have to be taken **without** the Wollaston Prism.

3.3.7   Science Exposures

The template `EFOSC_img_obs_Polarimetry` allows one or more sequences of images to be obtained. The default sequence takes four images at $0°.0, 22°.5, 45°.0$ and $67°.5$ respectively for linear polarization and two images at $45°$ and $135°$ respectively, for circular polarization. For more details refer to Chap. 4 and check the web for additional information.

3.4   Coronographic Imaging

3.4.1   Flats

For the coronography flat fields the discussion concerning Imaging flats applies. Remember that the flats (both dome and sky) have to be taken with the Coronographic mask and the Lyot stop in the beam. Failure to do this will lead to dust and imperfections on the plate not being properly flat-fielded out.

We remind the observer that the Lyot stop must be aligned before starting the observations, using a bright star (see also Sec. 2.4.10). This is usually done at the beginning of the first night of a Coronographic run.

3.4.2   Target Acquisition

To allow for a proper positioning of the target behind one of the spots of the coronographic mask, it is necessary to measure accurately their centers. This is usually achieved by obtaining an image of the coronographic mask during the afternoon in 1×1 binning. Proceed in the same way described in the previous section.

It is worth noting that, especially when using the smaller spots, it is important to use the **same filter** which will be used during the target acquisition phase to avoid possible offsets. Since the objects to be masked are usually very bright, most likely the acquisition will be done with a narrow band filter.

To have a *clean* image of the spots, we suggest that in both cases you divide a frame taken with the coronographic plate by one taken without it.

Once a good image of the Coronographic mask has been produced, the centre of the spots must be measured accurately (X and Y pixel coordinates in 1×1 binning) and noted down, since it will serve as input for the acquisition template `EFOSC_img_acq_MoveToPixel`.

3.4.3   Science Exposures

The template to be used in this mode is `EFOSC_img_obs_Coronography`, which is essentially identical to `EFOSC_img_obs_Image`. The only difference is that the Lyot stop and the Coronographic mask are automatically selected for the grism and Aperture wheels respectively, without any intervention from the user.

3.5   Spectroscopy

3.5.1   Dome and Sky Spectroscopic Flats

Spectroscopic flats should be taken with the same slit and grism as the scientific exposures. Spectroscopic flat fields can be obtained using the dome flat field screen or the twilight sky, using the template `EFOSC_spec_cal_Flats` for both cases. In this template, the user specifies a desired peak exposure level in ADUs. A 1 second test exposure is taken to calculate the optimum exposure time with which subsequent exposures are taken. To reach a good signal-to-noise ratio, an exposure level of about 40000 ADUs is recommended. When taking sky flats using this template, the user should specify a high level during evening twilight since the sky is dimming, whereas a low level should be specified during morning twilight since the sky is brightening.

There are different uses for the dome and sky spectroscopic flats. Dome flats are obtained with a quartz lamp, which produces a black-body spectrum free of emission lines. A continuum can be fitted and divided from the flat to produce a normalized flat-field image, which can be used to flat-field the scientific data. Note that with some grisms, however, the counts in the blue end are of the order of 10% of the peak counts. This may turn into somewhat noisy normalized flats in the extreme regions of the spectral range. The effect can be reduced by taking a large number of flats.

Sky flats (aka solar spectrum) are obtained with the sky, and the twilight spectrum is much bluer (due to the Rayleigh scattering) than dome flats and therefore provides significantly more photons in the blue region, where the quartz lamp is faint. The problem is that these flats are dominated by strong lines, making them unsuitable for flat-fielding in the spectral direction. Sky flats are useful for constructing the so called *slit function*, which traces the variations of the slit illumination in the spatial direction. This is needed if one is doing spectroscopy on an extended object and very accurate sky-subtraction is needed.

3.5.2   Internal Spectroscopic flats

Internal flats can be taken during the night at the same telescope position as the science target, at the expense of increased overheads of about 40 seconds per flat-field image. This can be achieved by means of the template `EFOSC_spec_cal_IntFlats`, which makes use of the internal quartz lamp. We remark that this requires the calibration screen to be inserted in the beam and this means that the autoguider is automatically switched off. This may turn into a drift of the object out of the slit. Nevertheless, internal flats are normally done before moving the telescope to another position.

Internal flats taken at the position of the science object are useful for removing fringes in the near-

infrared part of the spectrum ($\lambda > 7200\mathring{A}$). Due to telescope flexure, there might be a spatial shift between the fringes in the dome flat-field exposure and the fringes in the science exposure. Since the fringe pattern is strong ($\sim 15\%$ of the continuum in a raw spectrum), this shift (up to a few pixels) is enough to give ripples of about 2% or more of the continuum level in the flat-fielded spectrum if the dome flat is used. If instead of dividing by the normalized dome flat field, the science spectrum is divided by the normalized internal flat field taken at the same position as the science object, then the residual becomes negligible. Thus, internal flat fields are recommended for observers who need good flat-fielding in the near-infrared part of the spectrum.

There are several points to note. Firstly, as opposed to the fringes in the images which are additive, fringes in the spectroscopic exposures seem to be multiplicative and can be satisfactorily removed by dividing the scientific exposure with the normalized internal flat. Secondly, the internal quartz lamp is rather red in colour which means the blue part of the spectrum is not well flat-fielded, unless a large number of flats are taken during the night at the expense of increased overheads. Even in this case the result is not satisfactory since there seems to be a fair amount of internal reflection which is more pronounced in the blue than in the red. Thus, internal flats may be used for the red part of the spectrum whereas dome flats should be used for the blue part of the spectrum. Thirdly, there is a software limit of 1 second for the exposure time, as short exposures will result in an uneven illumination of the slit. For certain slit and grism combinations, the calculated exposure times for a 2×2 CCD binning is shorter than 1 second, and the template will exit with a warning message. In this case, the observer should specify a 1×1 CCD binning and rebin the flat-field image during data-reduction.

Fringing in spectroscopic mode is further described in § 3.5.7.

3.5.3   Wavelength Calibration

The Helium and Argon lamps used for wavelength calibration of slit spectra are obtained by means of the template `EFOSC_spec_cal_Arcs`. Exposures can be taken with one or both of the lamps. In the former case, just specify a non-zero exposure time only for the lamp to be used and set the other to zero. The recommended exposure times are shown in Table 13, and on

http://www.eso.org/sci/facilities/lasilla/instruments/efosc/inst/Perf_HeAr.html

These values avoid line saturation, however, the observer may consider increasing the exposure times to obtain a better signal to noise ratio for the weaker lines. Alternatively there is the possibility of taking several frames to be combined later on. Note that for some grisms, the strong red lines of Argon produce ring-like ghosts in the blue part of the spectrum. To reduce this effect the template automatically inserts a diaphragm in the beam. This component is permanently mounted in the filter wheel.

An atlas of the He-Ar lines can be found in Appendix G.

There are 2 features of the wavelength calibration which should be noted (see Fig. 14). Firstly, for several grisms the Argon lamp has a very bright reflection in the red part of the spectrum, which may seem alarming on first sight. However, this reflection has a broad profile and as long as the superimposed individual arc lines are not saturated, a satisfactory wavelength calibration can be obtained. Secondly, the instrument suffers from internal reflection and this produces very faint but visible ghost images of very bright lines. These ghost lines are not second order lines, since in the two-dimensional spectrum they have a curvature different to the first order lines. Care must be taken when performing wavelength calibration that these ghosts lines are not misidentified as faint lines in the arc spectrum.

The instrument suffers from considerably large flexures. Arcs with grism 20 were taken at several rotator positions. The spectrum taken with rotator angle 174.9 (corresponding to 0 position angle on sky) was cross-correlated with other spectra at 20 degrees step. The spectra were taken with grism #20, i.e. the red VPHG, to have a large dispersion. Figure 25 shows the shift of the spectra in the dispersion direction, which is the y-coordinate on the CCD. Efforts are being made to reduce these flexures, but it is recommended to users looking to measure radial velocities that they take arc lamp exposures after each science frame.

Note that the telescope flexures cause a rigid shift of the wavelength scale. Therefore, it is always a good idea to check the wavelength calibration using the night sky lines and get the average shift, which can be as big as several Angstroms. Correcting for this shift usually gives good wavelength calibration. An atlas of the brightest night sky lines can be found in Osterbrock & Martel (1992).

3.5.4 Target Acquisition

Two templates are available for placing a target on the slit, namely EFOSC_img_acq_Move ToSlit and EFOSC_img_acq_RotateToSlit. The former is to be used when the user wants to place a single object whose orientation is known *a priori* into the slit, or to orient the slit at the parallactic angle (see below). The latter is for placing two objects in the slit, or to align the slit itself along a direction to be measured interactively from the acquisition image.

The exact y pixel positions of the slits on the chip are measured by Day Operations and stored in a database. For this reason the user **must** specify the name of the slit to be used in the acquisition template, since this information is fundamental for retrieving the relevant value from the database. It must be noted that the position of the slit is measured by Day Operations from an image taken with the R filter. For this reason the acquisition should be done, in principle, with the same filter. In practice, the displacements in slit position introduced by the other broad band filters with respect to the R filter are less than one pixel. Since the accuracy of guiding and target centering is of the same order, all broad band filters can be used for centering the object.

The user can optionally check the slit position using the same procedure as described in Sec. 3.4.2.

Both acquisition templates allow the user to focus the telescope before starting the acquisition. The focus image is then used for a first approximate centering. At this stage it is not important to give a very precise position and thus it is not necessary to see the object to be centered. It is sufficient to give the template a tentative position using the cursor instead of the Gaussian centering algorithm if the object is too faint. When this is done the real acquisition image will be taken and the iterative centering process will commence. Note that by default, the acquisition images are taken in *fast* mode and binning 2×2, to reduce the overheads. If one wants to use the acquisition frames for scientific purposes, one may consider using the same CCD parameters as used for the science frames, or to take the necessary calibrations with the CCD in fast mode with 2×2 binning.

The default slit orientation is East-West, so an offset of PA+90° must be applied to position the slit along a given position angle (see 16). Therefore, users wishing to use the EFOSC_img_acq_Move ToSlit procedure along with a specific position angle are advised to add 90° to the supplied rotator offset angle.

3.5.5 Parallactic Angle

Since differential refraction occurs in a direction perpendicular to the horizon, it is strongly recommend to align the slit along the so called parallactic angle to avoid significant flux losses, especially when observing at large airmass es. For instance, when the airmass is 1.5, the differential refraction at 3500Å is about 1″3 with respect to a wavelength of 5000Å (a more detailed description of the
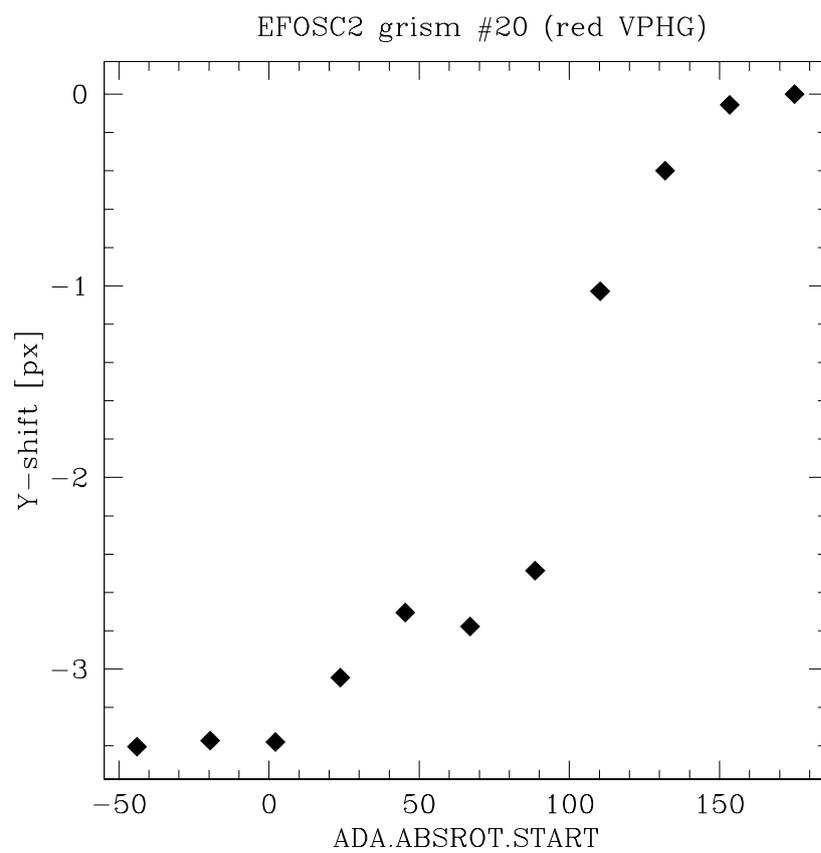
Figure 25: The shift in dispersion direction of spectra taken at different rotator angles.

effect can be found in Filippenko, 1982). This would turn into strong flux losses in the blue. Note that when observing at the meridian, the parallactic angle is 180°, i.e. the slit should lie along the N-S direction, i.e. perpendicular to the usual E-W orientation.

For acquisition templates which allow the user to specify the Rotator Offset Angle, if a value of -9999 is specified, the rotator will be preset to the parallactic angle at the start of the exposure.

When taking spectra of spectrophotometric standard stars, instead of aligning the slit to the parallactic angle, the user can choose to observe with a wide slit ($5''$, $10''$) in order to minimize the flux losses. This of course will reduce the resolution, which generally is not a problem for measuring the response curve[5]. If one is interested in correcting for the atmospheric absorption bands redder than 6500Å, one may instead want to observe the standards with the same spectral resolution as the target frames.

3.5.6   Science Exposures

The template to be used is `EFOSC_spec_obs_Spectrum`, which allows one or more frames to be taken at the same position. It is recommended that the user re-acquire the object every couple of hours if the object is near the meridian, and every hour if the object is at large hour angles or close to the zenith.

The overall efficiency in spectroscopic mode is discussed in Appendix A.

3.5.7   Fringing

There is significant fringing for grisms which cover the near-infrared part of the spectrum, above about 7200 Å. For example, the left panel of Fig. 26 shows a normalized flat field obtained with grism#12, one of the grisms most affected by fringing. A cross-cut along the central column of this image shows that the amplitude of the fringes can be as much as 10% of the continuum level (right panel).

Due to the instrument plus telescope flexure, there may be a slight positional mismatch between the fringes in the dome flats and the science frame, causing an imperfect flat-fielding. Fig. 27 illustrates this effect using a normalized and sky-subtracted spectrum of an astronomical object observed with grism#10. The left panel shows the spectrum flat-fielded using a dome flat. Residual ripples of about 2% of the continuum level can be seen in the continuum. However, if an internal flat is taken at the same telescope position as the object and used to flat-field the spectrum, the residuals become negligible (right panel). Hence if fringing is an issue, it is highly recommended to take internal flat fields at the position of the targets as well as dome flats.

A fringe pattern may also be generated from a series of science exposures with the telescoped "nodded" between exposures so that the spectrum does not fall on the same x position all the time. However, currently there is no P2PP template implemented for this mode of observation.

3.6   Multi Object Spectroscopy

Multi object spectroscopy is actually very similar to normal Spectroscopy described in the previous section. The only relevant difference is that special MOS plates are used instead of the long slits (cfr.

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[5]Note however that the Helium Argon arc spectra will be pretty useless for wavelength calibration at these resolutions. Since usually the y positions of the slits do not differ by a few pixels, and the response function is a slowly variation function with wavelength, one may chose to take Helium Argon arcs with narrower slits and used them for the wavelength calibration.
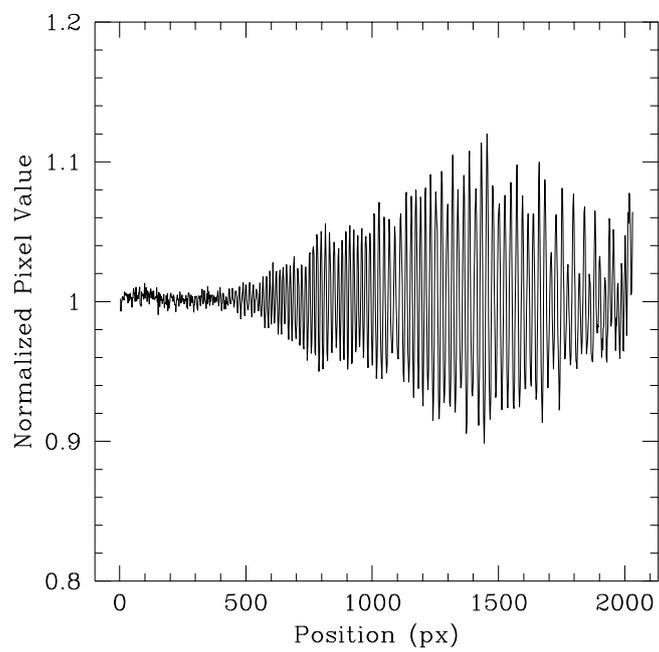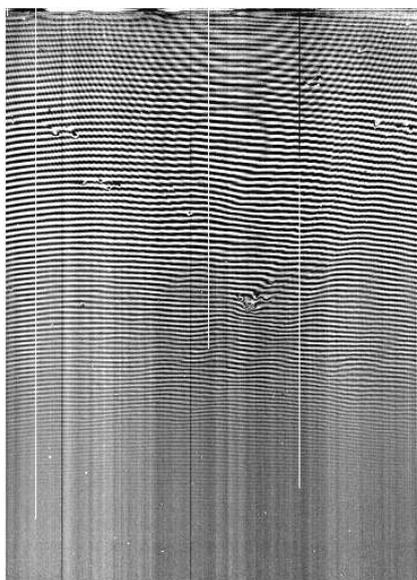
Figure 26:   Upper panel: normalized flat field taken with grism#12 and CCD#40. Lower panel: cross cut along the central column of the same frame.
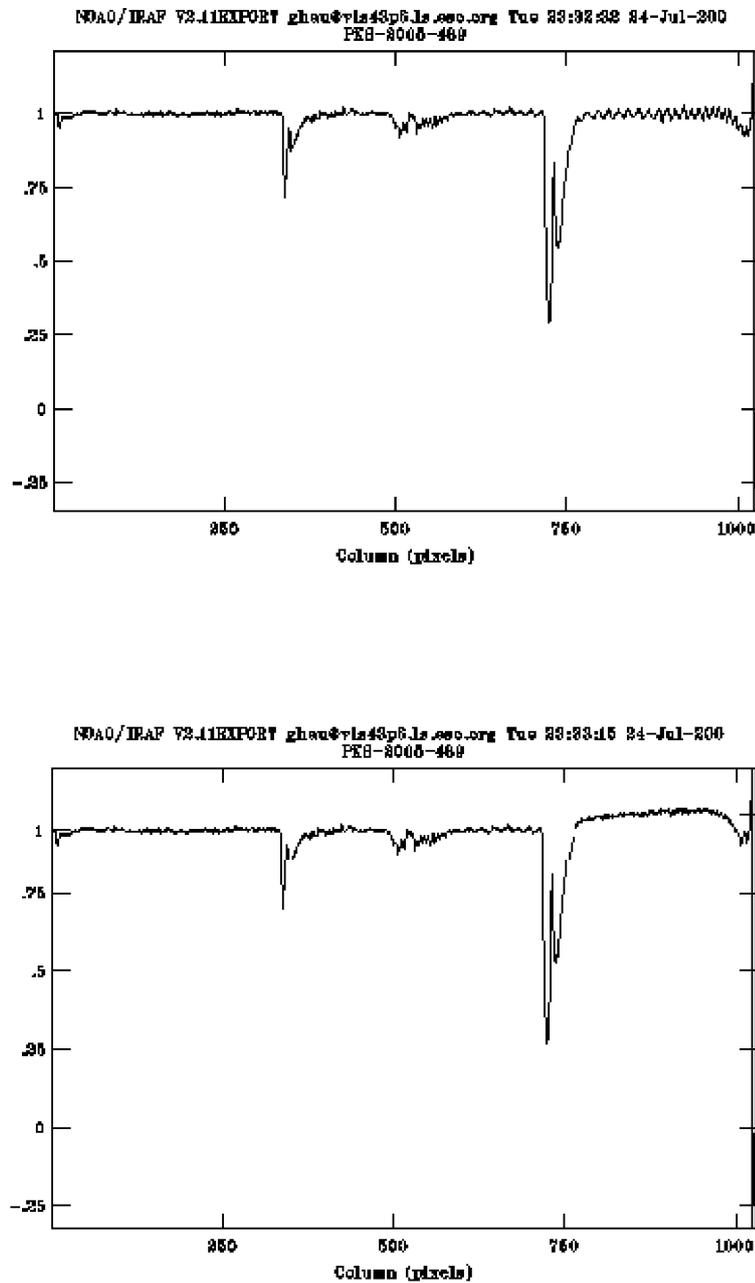
Figure 27: Upper panel: normalized and sky-subtracted spectrum of an astronomical object taken with grism#10, 1".0 slit and CCD#40. The spectrum has been flat-fielded by a spectroscopic dome flat taken in the afternoon. Residual ripples of about 2% of the continuum level can be seen in the continuum, especially towards the red. Pixel 1 and 2048 correspond to wavelengths of 6285 and 8210 Å respectively. Note that the 2 prominent absorption features are caused by the atmosphere and not fringing. Lower panel: the same spectrum but flat-fielded by an internal flat taken at the target position instead of a dome flat. The ripples in the continuum are not at a significant level.

Sec. 2.4.2). For the preparation of the MOS plates please read the detailed online guide at
http://www.eso.org/sci/facilities/lasilla/instruments/efosc/inst/ObsMOS.html

Here some of the issues are briefly discussed.

The images to be used for preparing the MOS plates **must** be taken with EFOSC2 (see Sec. 2.4.2 for
the possibility of observing some fields in advance). The instrument orientation **must** be specified
in advance and cannot be changed by software in the design stage (like in FIMS for FORS on the
VLT).

To speed up the centering procedure and to make it more reliable, the users are strongly recommended
to include at least three relatively bright stellar objects (even near the border of the plate) in each
field. When defining the MOS mask, it is very important that these objects are placed **exactly** in
the X center of the slit-lets. Failure to do this will lead to misalignment during the centering phase.

MOS design is done by a program `xm` and the observer will be taught how to do it during the
introduction. Once the slits are defined, masks are punched using a special punch machine.

Observers are reminded that preparing a MOS plate, including running the mask-design software
and punching, may require up to 30-45 minutes. Therefore, the preparation of the MOS plates for
the first night should be done the day before. For the next night, mask definition and punching can
be done during the observations. Delays in delivering the MOS plates to Day Operations may result
in insufficient time to run all the required calibrations in the afternoon.

As soon as the MOS plates are mounted, an image of the mask (without the grism) should be taken
to check the position of the slits. This image will also be required later in the target acquisition stage
for centering the 3 alignment stars with their corresponding slits.

The observer is reminded that if for some reason the MOS plates are removed from the Aperture
Wheel and re-mounted again, flat-fielding and wavelength calibration **must** be performed again.

3.6.1   Flats

The discussion concerning flat-fielding for normal spectroscopy applies to MOS as well. In this case
the procedure is not completely automatic, and the Telescope Operator must select manually on the
display a suitable region to be used to compute the correct exposure time.

Helium Argon arc exposures are also required for MOS (as in normal spectroscopy), as well as an
image of the mask illuminated by the internal lamp (used to center the mask).

3.6.2   Target Acquisition

Target acquisition for Multi Object Spectroscopy is a particularly delicate procedure and is achieved
by means of the template `EFOSC_img_acq_MOS`. After the telescope and the rotator are preset, the
template proceeds with focusing (if required by the astronomer). Then the same focus image (or the
first acquisition image) is used to perform the first approximate offset, which is meant only to center
the field. Then the real iterative acquisition process commences.

The template will prompt the astronomer for the name of the mask image taken in the afternoon, and
ask to select 3 slits. Immediately afterwards, the astronomer will have to identify in the acquisition
image the 3 alignment stars into which the 3 selected slits should fall. An offset angle is calculated
and the instrument rotated. This process is iterated until the user is happy with the orientation.
Next the telescope offset is calculated by the displacement of the 3 stars and the process repeated
until the user is satisfied with the slit alignment. Note, however, that if the 3 stars are centred in
the 3 slits, no further improvement in the alignment is possible.

From experience, if the images have been taken during the same EFOSC2 run at the same nominal rotator angle, rotation corrections are of the order of $0°.1$, which is the resolution of the rotator adapter. For this reason in most cases no adaptor rotation is necessary.

The typical time needed for focusing and accurate centering is about 10 minutes.

3.6.3   Science Exposures

Once the acquisition phase is over, the spectrum can be taken using the `EFOSC_spec_obs_Spectrum` template, by specifying the desired mask and grism. However, some observers find it useful to take a through slit image at this point to check that indeed all the objects are visible through the slits, by inserting the same template with the same mask but without the grism (i.e. using template `EFOSC_img_obs_Image` with Grism `Free`). This may be worthwhile for long exposures of faint objects. It is also worthwhile to take a through slit image between long exposures to check the alignment.

Due to autoguider drifts and telescope flexures (cfr. Sec. 3.1.2), it is always a good idea to re-acquire the field from time to time, especially when observing at large hour angles or close to the zenith (see also Sec. 3.5.6). It may also be worthwhile to re-acquire the field if the seeing has improved substantially. It takes only a few minutes.

Caution: The visiting astronomer is reminded that from time to time it may not be possible to have all the targets perfectly centered in the slit-lets after the acquisition, especially when using the narrowest Punch Head. This problem seems to be related to MOS plate bending, both during the punching process, and during the mounting in the Aperture Wheel. Unfortunately, if the bright reference objects are well centered, there is no way to correct the centering in order to bring the other objects into the slit-lets.

3.7   Slitless Spectroscopy

This mode of operation should be useful in a variety of survey programs, due to the large number of available grisms and the overall efficiency. The use of filters in combination with a grism can be useful to isolate the spectral region of interest and to reduce crowding and sky background intensity. Note that the spectral coverage depends on the position of the objects.

3.7.1   Target Acquisition

Since here there is no need to place the objects in the slit, the templates `EFOSC_img_acq_Preset` or `EFOSC_img_acq_MoveToPixel` can be used.

3.7.2   Science Exposures

The scientific frames are obtained with `EFOSC_spec_obs_Spectrum`, the same template used for normal spectroscopy. The only difference is that the user must set the Aperture wheel to FREE and insert the desired grism and filter.

3.8   Spectropolarimetry

Spectropolarimetry can be performed by inserting the Wollaston Prism into the filter wheel to work in combination with a grism. The Wollaston Prism splits the incoming radiation into two perpendicularly polarized beams separated by a small angle which depends on the selected prism. Therefore, for each object in the slit two spectra are projected onto the CCD and the intensity ratio between these

two spectra gives the component of the Stokes vector for linear/circular polarization in the direction of the split. The components in other directions can be obtained by rotating the HWP/QWP as for polarimetric imaging. Refer to Sec. 3.3 for more details on the calculation of the polarization degree and the polarization angle.

In order to avoid overlapping object and sky spectra, the slit is transparent only in slots which are as long as the separation produced by the Wollaston prism, and separated by opaque masks of equal length. Therefore one obtains spectra only for half the sky area covered by the slit. One of the sections may contain the object of interest, the others are devoted to the sky, and possibly to a field star, which, if unpolarized, can be used to check the instrumental polarization. This configuration is well suited to objects which are not extended more than 20 arcsec. For larger objects only sections can be observed in a single set of spectra. As for all prisms, the Wollaston has dispersive power and so acts as a cross-disperser. When using low-dispersion grisms (#1, #2), this is especially visible as a slight inclination and curvature of the spectrum. This affects one of the two spectra (the extraordinary beam).

The same discussion about additional calibration for polarimetric imaging applies equally here.

A list of highly polarized standard stars for spectropolarimetry can be found online at:
http://www.eso.org/instruments/fors/tools/FORS_Std/FORS1_Std.html

3.8.1   Flats

The template to be used is `EFOSC_spec_cal_PolarFlats`, which allows sky/dome flat fields to be taken with the HWP/QWP continuously rotating to act as a de-polarizer. The exposure times must be longer than 10 seconds.

3.8.2   Target Acquisition

Refer to Sec. 3.3.6.

3.8.3   Science Exposures

The template `EFOSC_spec_obs_Polarimetry` allows one or more sequences of spectra to be obtained. The default sequence takes four images at $0°.0, 22°.5, 45°.0$ and $67°.5$ respectively for linear polarization and two images at $45°$ and $135°$ respectively, for circular polarization. For more details refer to Chap. 4.

4   The EFOSC2 Observing Templates

4.1   Observing with P2PP

All the instructions for a given observation are specified in a so called Observation Block (OB), which is produced by the astronomer using the Phase 2 Proposal Preparation facility (P2PP). This can be done at the astronomer's institute or at La Silla. If the OBs are created at the home institute of the astronomer, they must be exported from P2PP and the resulting ascii files brought to La Silla with the astronomer. A comprehensive description of P2PP including the latest user manual can be found online at

http://www.eso.org/observing/p2pp/

There are 2 categories of OBs. **ObsBlocks** are the **Science OBs** which require the target position to be specified in an Acquisition template. **CalBlocks** are the **Calibration OBs**, which do not require an Acquisition template and have no provision for defining a target[6]. The former is designed for observations of an astronomical target, while the latter is used to acquire reference data which do not require the observation of an astronomical object. The two are catalogued separately and cannot be changed from one type to another.

The core of an OB is composed of a number of instrument-specific **Templates**. Practically, all calibration and observing procedures possible with EFOSC2 have been coded into the templates, and these allow the observer to perform a certain type of observation following a pre-defined path. For example, there is a specific template to take images, which sets automatically the grism wheel in the free position. When using this template, the user can choose the filter or the exposure time, but (s)he is not allowed to insert a grism, since the procedure is specifically designed for Imaging.

Very briefly, a template is an entity containing a sequence of commands, dealing with the setup and execution of one or more exposures. It also contains a set of parameters, whose specific values determine the exact behavior of its execution (i.e. exposure time, CCD binning, filter, etc). The values of these parameters are mostly set by the observer using P2PP, while other non-user service-able parameters are hard-coded within the templates themselves. For more details on the EFOSC2 templates refer to Sec. 4.3.

The templates that a typical science OB contains are:

- An **Acquisition template**, describing how the target acquisition is to be performed: for example which filter or slit is to be used in the (acquisition) observation, which exposure time the acquisition image should have, which position angle on the sky the slit should have...

- One or more **Science templates** describing the instrument setup and the exposure parameters: for example, which mask should be loaded in a MOS observation, which grism should be used, which jitter pattern should be followed, what exposure time should each exposure have.

- In some cases the OB may end with an **attached calibration template**. For example, if precise wavelength calibration is required, an arc lamp exposure can be taken immediately after the last scientific exposure with the instrument in the same configuration.

The set of science and possibly attached calibration templates in a given OB compose the **Observation Description (OD)**. This represents the core of an Observation Block. Once an OD has been defined, it can be associated with different targets to create different OBs.

In addition to the templates, a science OB contains other important, instrument-independent information:

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[6]The terminology is unfortunately a bit confusing since they both generate what is called an OB or observing block which is what is used to execute the observations
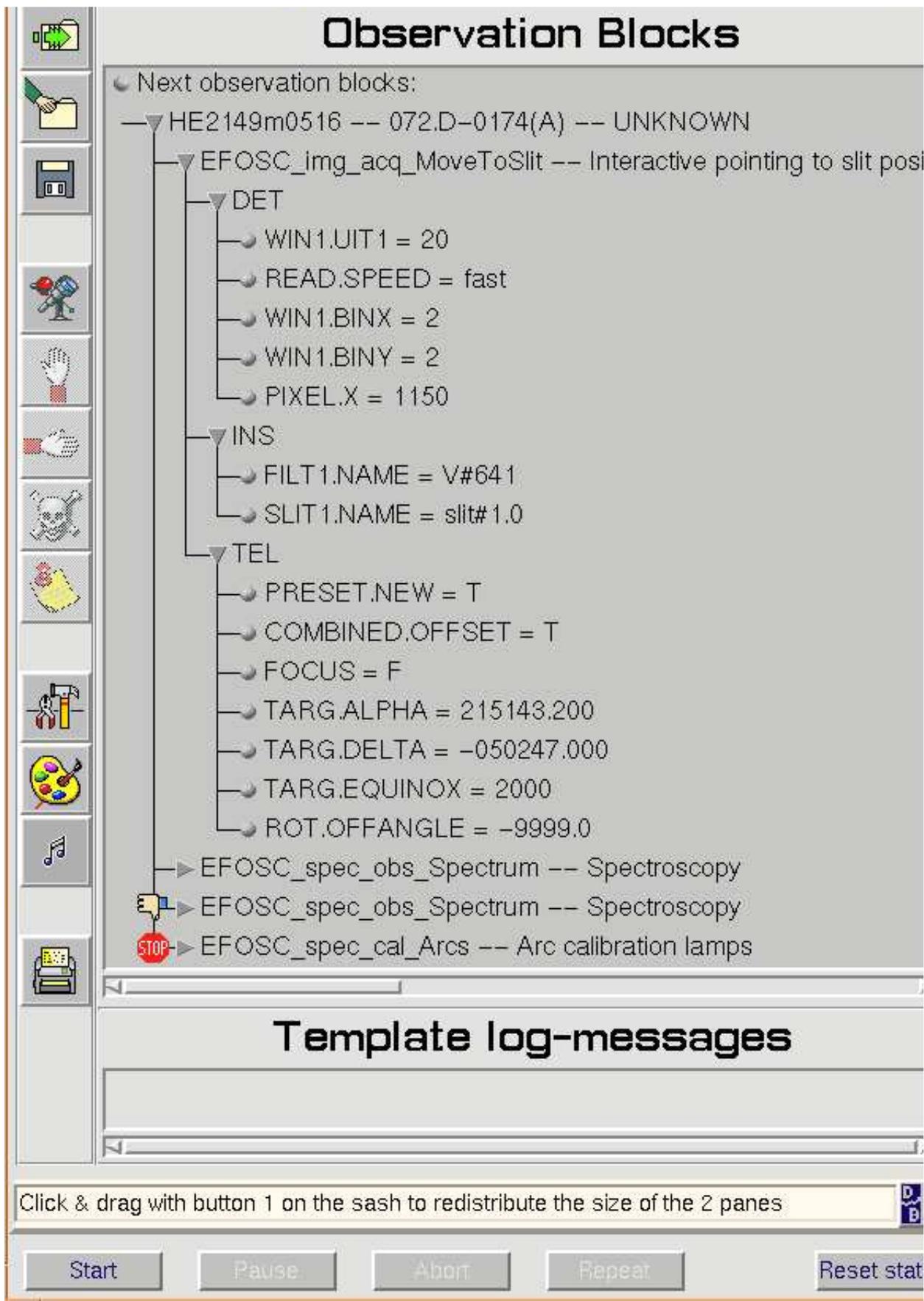
Figure 28: The Broker for Observation Blocks (BOB) panel. In this example an OB has been fetched from the visitor's P2PP session. The OB consists of 4 templates. The first template (acquisition) is expanded and being examined, and its parameters can be changed. Two flags have been introduced by the TIO: a skip flag for the 3rd template, and a pause flag at the last template. The observations will be started when the TIO clicks on the start button on the lower left.

- **Target information** including coordinates, epoch, proper motion, and differential motion.

- The **Constraint Set**, to be used in service mode only, specifying under which external conditions (airmass, seeing, transparency, lunar illumination...) the OB should be executed.

- The time interval information, also to be used in Service Mode only, specifying the time windows when the OB can be executed.

- The **Calibration Requirements** information, a free text field where comments can be given to the Service Mode observer or where the Visitor Mode observer can include a reminder on the calibrations needed.

Obviously, none of these last 4 fields is present in a Calibration OB.

Although the bulk of OBs are prepared in day time, it is possible to prepare and/or modify them at night while observing. A P2PP session is always running on one of the computers in the control room and preparing an OB requires little time (once you've done a few for practice). New OBs can be prepared while an exposure is still running.

New users will be introduced to the use of P2PP by the Support Astronomer. For this reason successful PIs (or their delegated observers) are warmly invited to arrive at La Silla **two** days before starting the observations. More details on P2PP can be found at the following URL:
http://www.eso.org/observing/p2pp/P2PP-tool.html

4.2   What happens at the telescope?

The Visiting Astronomer (VA) is assisted at the beginning of his run by the Support Astronomer (in the afternoon) and always by the Telescope & Instrument Operator (TIO) during the night. The TIO is in charge of operating both the telescope and the instrument. The VA interacts with the system through P2PP, where (s)he can build, modify and finally select the Observation Block to be executed. Once this is done, the TIO fetches the OB from P2PP to the Broker for Observation Blocks (BOB), where a final check can be performed before the OB is executed. An example of BOB is shown in Fig. 28.

An OD may be composed of several Templates, which are executed in the order specified by the astronomer. Sometimes, the astronomer may want to skip or pause the execution of a template within the OB, for instance to check the signal-to-noise ratio before executing the next template. This is possible by simply instructing the TIO, who can introduce the suitable flags (skip or pause) using the BOB panel. As long as the template has not started, the parameters in it can be changed. Once a template is executing, however, there is no way of changing the parameters except via the EFOSC2 Control Panel (the OS Panel). Note that not all parameters can be changed in this way, however it is possible to change the exposure time of the observation. Once an OB is executed, it may be reset and re-executed, with the option of changing some of the parameters beforehand.

The possibility of preparing the observations in advance has the obvious advantage of reducing the chance of making a mistake under stress or due to tiredness. Moreover, this forces the observer to think about the observing strategy well in advance. This reduces the time lost during the night and maximizes the efficiency of the observations. Another advantage is that the VA does not need to know how to physically operate the telescope and the instrument, since all these operations are executed by the software and supervised by the TIO. Of course there are a series of status panels that can be accessed by the VA to check what is going on. For example, there is a status panel that displays the information which is usually of interest to the astronomer (see Fig. 29).
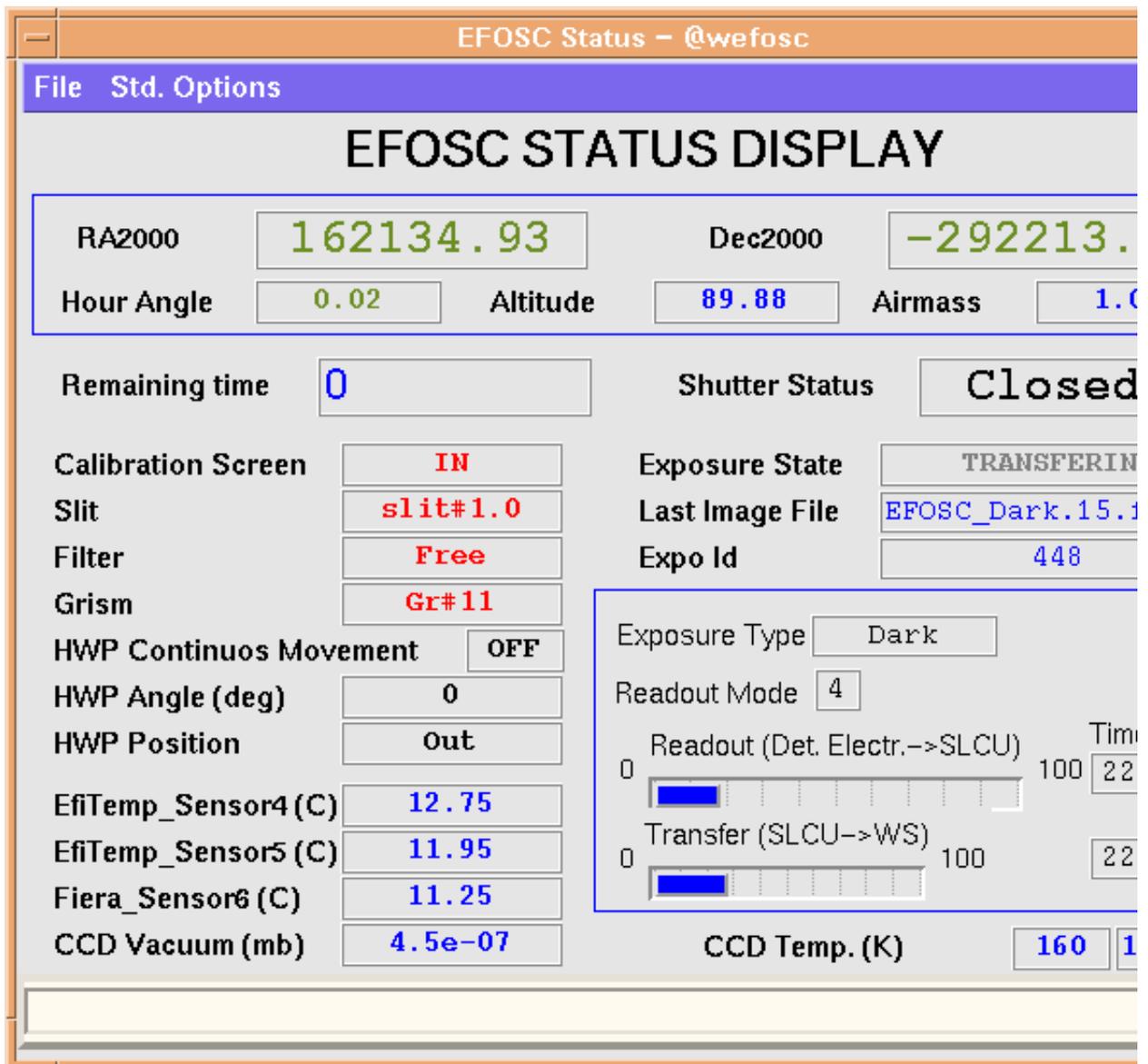
Figure 29: The EFOSC2 Status Panel.

4.2.1 Abort, Stop, Pause, Continue and Change Exp. Time

It is possible to Abort, Stop, Pause and Continue an exposure by asking the TIO. One can also change the exposure time of an observation once the template has started running in this manner. These commands and changes are entered on the EFOSC2 Control Panel (also known as the OS Panel).

4.2.2 Telescope logs, location of data, data-reduction and backup

A log of all the data files taken by EFOSC2 is automatically displayed on a screen of wg5off. This displays the filename, the object name, the start U.T., the object position, and other instrument-related parameters. An example of the telescope log is displayed in Fig. 34 in the Appendix. Note that the data is saved at the telescope under the convention `EFOSC_X.fits` where X denotes the type of observation. Thus, the first long-slit spectrum of the day will be named `EFOSC_Spectrum.fits` and the second will be `EFOSC_Spectrum.1.fits`. An important point to note is that this filename convention is restricted to the data at the telescope only. Once the file is transferred to the archive, it will be named under the standard ESO convention `EFOSC.YYYY-MM-DDTHH:MM:SS.SSS.fits`.

Once the file is read from the instrument, it is distributed by the Data Subscriber program whose task is, among others, to deliver a copy of the data to the offline data-reduction machines wg5off and to the ESO data archive. On wg5off, the data is put into a directory `/data/raw/YYYY-MM-DD/` where YYYY-MM-DD denotes the date of the observation. For example, data collected from midday of today to midday of tomorrow will go into today's directory. Each day a new directory will be created automatically. The telescope log corresponding to the day can also be found in the directory.

Data reduction can be performed on the offline data-reduction machine wg5off, where IRAF and MIDAS are installed as part of the `scisoft` package. There is also a quick-look tool for long-slit spectroscopy; the software and detailed descriptions can be found at
http://www.eso.org/sci/facilities/lasilla/instruments/efosc/tools/qlook/index.html.

On wg5off, data shouldn't be reduced where the raw files are (`/data/raw/YYYY-MM-DD/`, but in a directory under `/data/reduced/`.

Note that we do not keep backups of the user OBs, and any OBs left in the system will be erased during regular software upgrades. If the user would like to keep their OBs, for example to be used in a future observing run, then he/she should export the OBs from the P2PP panel and make a backup. Note however that the observing templates are modified from time to time for bug fixes or improvements, hence it is recommended to make fresh OBs for each observing run, using the latest version of P2PP and Instrument Package, to ensure compatibility.

4.3 EFOSC2 Templates: a Reference Guide

This section provides summaries of the currently supported EFOSC2 templates. Table 7 contains a quick reference to the templates currently implemented and supported.

There are three types of templates for EFOSC2 that concern the observer: Observation Templates (`obs`) for science observations, Calibration Templates (`cal`) for calibration exposures, and Acquisition Templates (`acq`) for target acquisition. The names of the templates have been set according to the ESO official Data Interface specifications. All the template names start with the word `EFOSC` followed by `img` or `spec` according to the type of observation (imaging or spectroscopy). Then comes the template type (`acq`, `obs`, `cal` for acquisition, observation and calibration respectively). Finally, the template name ends with a meaningful string (like MoveToPixel or MoveToSlit), which permits a quick understanding of the purpose of the template itself. When P2PP is running, a list of the

Procedure	Template to use
ACQUISITION TEMPLATES	
Preset telescope and centre objects in slits for MOS	`EFOSC_img_acq_MOS`
Preset telescope and move object onto a pixel	`EFOSC_img_acq_MoveToPixel`
Preset telescope and centre an object in slit	`EFOSC_img_acq_MoveToSlit`
Preset telescope and position an object for polarimetry	`EFOSC_img_acq_Polarimetry`
Simple telescope preset without focus	`EFOSC_img_acq_Preset`
Preset telescope and centre an object in slit with rotation	`EFOSC_img_acq_RotateToSlit`
IMAGING TEMPLATES	
Coronographic Imaging	`EFOSC_img_obs_Coronography`
Imaging without Jitter	`EFOSC_img_obs_Image`
Imaging in Jittering mode	`EFOSC_img_obs_ImageJit`
Polarimetric Imaging	`EFOSC_img_obs_Polarimetry`
SPECTROSCOPY TEMPLATES	
Spectropolarimetry	`EFOSC_spec_obs_Polarimetry`
Long-slit Spectroscopy	`EFOSC_spec_obs_Spectrum`
MOS Spectroscopy	`EFOSC_spec_obs_MOS`
CALIBRATION TEMPLATES	
Darks	`EFOSC_img_cal_Darks`
Imaging Dome Flat Fields	`EFOSC_img_cal_Flats`
Telescope Focus using Focus Sequence	`EFOSC_img_cal_FocusSequence`
Telescope Focus using Focus Prism	`EFOSC_img_cal_FocusWithPrism`
Telescope Focus using Focus Wedge	`EFOSC_img_cal_FocusWithWedge`
Internal Lamp Imaging (slits, Cor. Masks, MOS plates)	`EFOSC_img_cal_IntImage`
Polarimetric Imaging Dome Flat Fields	`EFOSC_img_cal_PolarFlats`
Polarimetric Imaging Sky Flat Fields	`EFOSC_img_cal_PolarSkyFlats`
Imaging Sky Flat Fields	`EFOSC_img_cal_SkyFlats`
Arcs (spectroscopy)	`EFOSC_spec_cal_Arcs`
Spectroscopy Dome/Sky Flat Fields	`EFOSC_spec_cal_Flats`
Spectroscopy Internal lamp Flat Fields	`EFOSC_spec_cal_IntFlats`
Spectropolarimetry Dome/Sky Flat Fields	`EFOSC_spec_cal_PolarFlats`
Spectroscopy Arcs and Dome Flat Fields	`EFOSC_spec_cal_ArcFF`

Table 7: EFOSC2 Templates Quick Reference.

available templates will be presented in the View OB window, therefore the user does not need to remember these names by heart.

When using the EFOSC2 templates in P2PP, the user will automatically get the default values for the parameters, unless (s)he actively changes them. However, some parameters have NODEFAULT as their default values. These parameters must always be changed to something else or P2PP will report an error.

In the following sections we give the names of the files produced by the templates, and descriptions of the user serviceable parameters that will appear in the part of the View OB window dedicated to the Observation Description (see *P2PP user's manual*). An example of the main P2PP panel and the View OB panel is displayed in Fig. 30.

Note, that the software system is unable to distinguish between the Half and Quarter Wave Plate as they are mounted on the same physical location. Therefore, all the polarimetric templates can be used indifferently for linear or circular polarimetry. However, polarimetric templates are present in two flavors. Templates meant to be used for circular polarimetry having the same name as the linear polarimetry ones but for the two letters "QW" added to the name. The slightly different name of the template (e.g. "QWPolarimetry", which will appear in the fits header) might then be used as a signature that the Quarter Wave Plate was used.
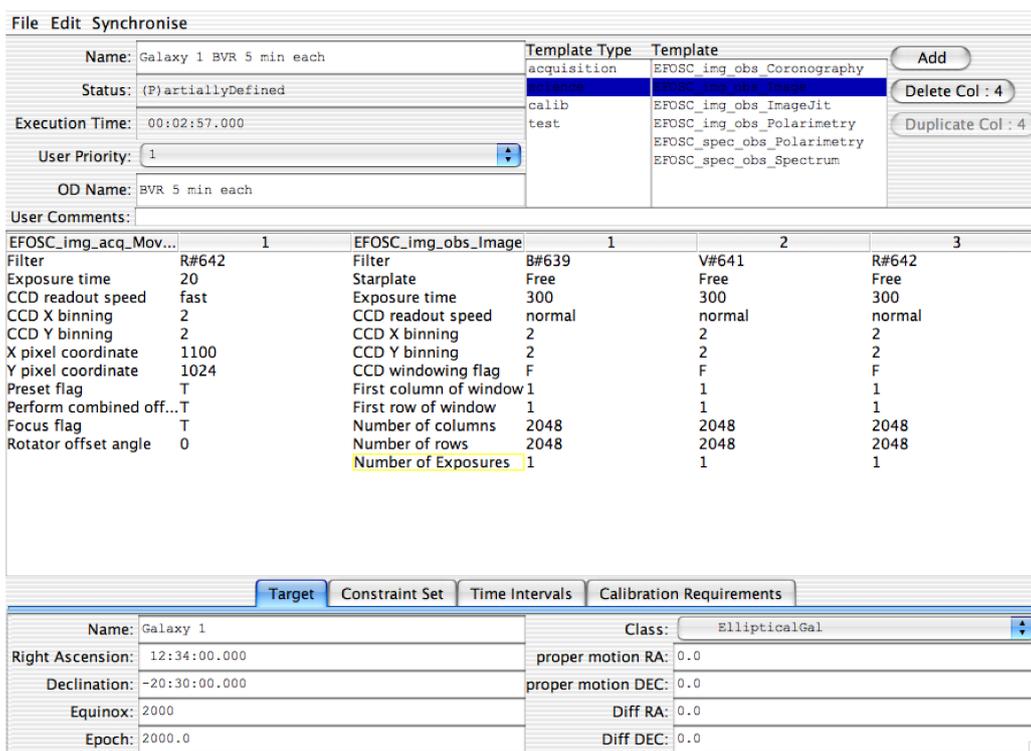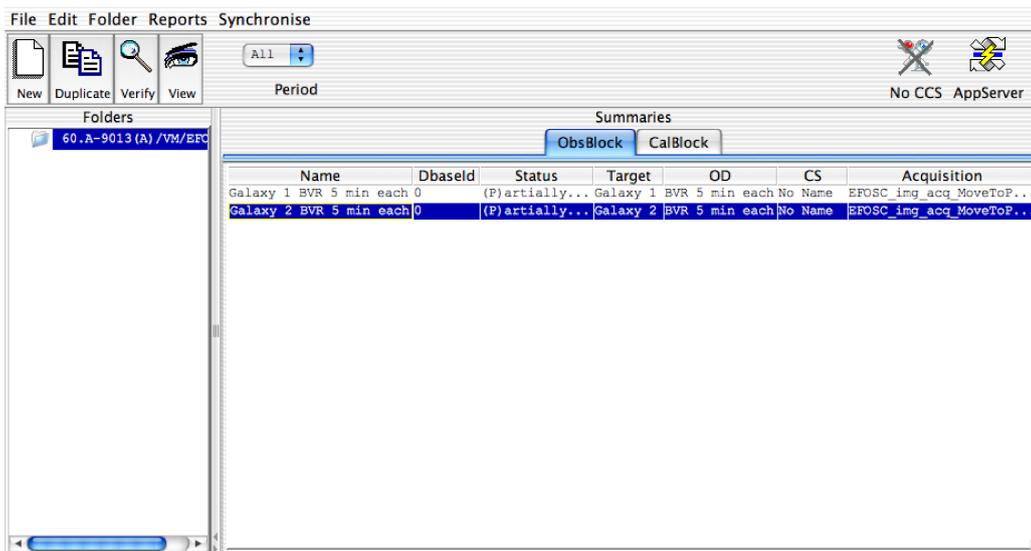
Figure 30: Top: An example of the main P2PP panel. In this case there are 2 Science OBs prepared. They both have the same Observing Description and only the targets are different. Bottom: An example of the View OB panel. The top left area defines the name of the OB and OD. The OD consists of an acquisition template followed by 3 exposures of 5 minutes each using the B, V and R filters. The bottom section defines the Target properties such as the name and position. The top right section shows the available templates for EFOSC2.

4.3.1   Files Produced By The Templates

All the Templates (except `EFOSC_img_acq_ Preset`) produce one or more fits files. These files are named indicating which Template created it.

On `wg5off` the images are stored in
`/data/raw/<imagename>.<seqnumber>.fits`
where `<imagename>` is the name given by the Template and `<seqnumber>` is a sequential number given by the OS. An example of name produced by the template `EFOSC_img_obs_Image` is `EFOSC_Image.12.fits`. The names are given in such a way to allow an easy search in the storage directory, according to the different image types, as shown in the following table.

The templates automatically update an observation log file each time an exposure is terminated. See Appendix C for an example.

Image type	Image names
Acquisition	`EFOSC_Acq*.fits`
Imaging	`EFOSC_Ima*.fits`
Spectroscopy	`EFOSC_Spec*.fits`
Darks	`EFOSC_Dark*.fits`
Flats	`EFOSC_Flat*.fits`
Arcs	`EFOSC_spec_HeAr*.fits`
Focus	`EFOSC_Foc*.fits`

The names of fits files produced by each template are given in Table 8.

4.3.2   EFOSC2 Acquisition Templates

Acquisition Templates (`acq`) determine how a target field is acquired by the telescope. They are inserted to the Observation Blocks during the OB building process. Telescope presets can **only** be performed using acquisition templates, since observation templates can only offset the telescope. Also adapter rotations are achieved within the acquisition templates only.

Note that in almost all Acquisition templates the grism and slit are automatically set to `Free` and the CCD parameters are set to hard-coded values. The observer has no control over them. This is to avoid possible mistakes while preparing OBs with P2PP and consequent time losses during the observations.

Note that all acquisition templates (with the only exception of `EFOSC_img_acq_Preset`) have a special logical `Preset Flag`. If this flag is set to `T`, the telescope (and the rotator) will preset to the required position, if it is set to `F`, the template will be executed with the telescope and rotator presets **skipped**. This is particularly useful, for instance, when the telescope and rotator adapter are already at the desired position and the observer wants only to perform a combined offset to re-center the object in the slit.

With the exception of `EFOSC_img_acq_Preset`, all Acquisition Templates gives the user an option to focus the telescope after the telescope preset and before the combined offset (for fine positioning the telescope). If the `Focus Flag` is set to `Y`, the telescope will be focused with the Focus Wedge.

When working with P2PP, the observer must remember that **all Science OBs must have an acquisition template attached, and it must be the first template in the sequence. Only one Acquisition Template is allowed for each OB.** The only exception are the OBs created

Template	`<imagename>`

ACQUISITION TEMPLATES

EFOSC_img_acq_MOS	EFOSC_AcqMOS
EFOSC_img_acq_MoveToPixel	EFOSC_AcqPix
EFOSC_img_acq_MoveToSlit	EFOSC_AcqSlit
EFOSC_img_acq_Polarimetry	EFOSC_AcqPol
EFOSC_img_acq_Preset	NONE
EFOSC_img_acq_RotateToSlit	EFOSC_AcqRotSlit

OBSERVATION TEMPLATES (IMAGING)

EFOSC_img_obs_Coronography	EFOSC_ImaCor
EFOSC_img_obs_Image	EFOSC_Image
EFOSC_img_obs_ImageJit	EFOSC_ImaJit
EFOSC_img_obs_Polarimetry	EFOSC_ImaPol

OBSERVATION TEMPLATES (SPECTROSCOPY)

EFOSC_spec_obs_Polarimetry	EFOSC_SpecPol
EFOSC_spec_obs_Spectrum	EFOSC_Spectrum
EFOSC_spec_obs_MOS	EFOSC_Spectrum

CALIBRATION TEMPLATES

EFOSC_img_cal_Darks	EFOSC_Dark
EFOSC_img_cal_Flats	EFOSC_FlatIma
EFOSC_img_cal_FocusSequence	EFOSC_FocSeq
EFOSC_img_cal_FocusWithWedge	EFOSC_FocWedge
EFOSC_img_cal_FocusWithPrism	EFOSC_FocPrism
EFOSC_img_cal_IntImage	EFOSC_ImaInt
EFOSC_img_cal_PolarFlats	EFOSC_FlatPolIma
EFOSC_img_cal_PolarSkyFlats	EFOSC_FlatSkyPolIma
EFOSC_img_cal_SkyFlats	EFOSC_FlatSkyIma
EFOSC_spec_cal_Arcs	EFOSC_spec_HeAr
EFOSC_spec_cal_Flats	EFOSC_FlatSpec
EFOSC_spec_cal_IntFlats	EFOSC_FlatIntSpec
EFOSC_spec_cal_PolarFlats	EFOSC_FlatPolSpec

Table 8: File names produced by EFOSC2 Templates.

explicitly for calibrations. If an acquisition template is not included in an OB, the error will be indicated by a colored dot next to the OB name in the main P2PP panel. For more details refer to the *P2PP User's Manual.*

4.3.3   `EFOSC_img_acq_Preset`

This acquisition template presets the telescope to the coordinates of the target associated with this Observation Block. At the end of the execution the operator is requested to find a guide star and to activate the autoguider. There is no further operator intervention. No CCD frame is produced by this template, which is meant to be used to quickly preset the telescope to targets which do not require an accurate centering. Its use, restricted to imaging only, is limited by the pointing accuracy of the telescope ($\sim 5\rlap{.}''$).

This template also allows the user to preset the `Rotator Offset Angle` to the desired value. Note that if it set to -9999, the Rotator Angle will be set to the parallactic angle corresponding to the start of the exposure.

Parameter	Default	Description
Rotator Offset Angle	0	Rotator Offset Angle (deg), see definition in § 3.1.3.

4.3.4   `EFOSC_img_acq_MoveToPixel`

This template performs an interactive presetting to a specific pixel position for imaging. It has three parts. First, it presets the telescope to the coordinates of the Target associated with the Observation Block and it rotates the Adaptor to the requested Rotator Offset Angle. It then inserts the filter, and takes a short image through the Focus Wedge, to focus the telescope before the fine positioning. After the iterative focus process is terminated, the last focus image is used by the operator to perform the first approximate pointing to the desired object. Note that the exposure time for the focus image in all acquisition templates is hard-coded to 20 seconds, because no matter what the field is, with this exposure time it is always possible to find suitable stars for focusing. Note that it is possible to skip the focusing by setting the `Focus flag` to `F`.

When this is completed, the template takes an exposure of `Exposure time` seconds, which is displayed in a `MIDAS` window for inspection by the operator. He/she can then perform a combined offset so that the desired object (e.g. as marked on a finding chart) is placed on the CCD pixel coordinates specified by `X pixel coordinate` and `Y pixel coordinate`. It is important to note that these coordinates are in the 1×1 binning system. This process can be iterated until the desired pointing accuracy is achieved. The `Perform combined offset` flag should be set to `T` if the telescope is to be positioned accurately by offsetting the guide probe in this iterative process. Note that if the `Rotator Offset Angle` is set to -9999, the Rotator Angle will be set to the parallactic angle corresponding to the start of the exposure.

If this acquisition template is used during service observing, a finding chart **must** be supplied by the user. By default the acquisition images are taken in `fast` mode and binning 2×2. If the observer wants to use these images for scientific purpose, he/she may want to change these parameters.

When this template is used to put an object under one of the dark spots of the coronographic mask, the user must take an image of the mask (using the template `EFOSC_img_obs_IntImage`) before performing the acquisition, in order to measure the pixel center coordinates (in the 1×1 binning system) of the spot. Alternatively, the user can use `EFOSC_img_acq_Polarimetry` to reach the same goal in a slightly different way.

Parameter	Default	Description
Filter	R#642	User specified filter
Exposure time	20	Exposure time for the acquisition image (sec)
CCD readout speed	fast	Read Out Mode for the acquisition image
CCD X binning	2	CCD binning factor in X direction
CCD Y binning	2	CCD binning factor in Y direction
X pixel coordinate	1100	User specified X coordinate
Y pixel coordinate	1024	User specified Y coordinate
Preset flag	T	Preset the telescope?
Perform combined offset	T	Perform accurate offset using the guide probe?
Focus flag	T	Focus flag
Rotator offset angle	0	Rotator Offset Angle (deg), see definition in § 3.1.3.

4.3.5 `EFOSC_img_acq_MoveToSlit`

This acquisition template is used for grism spectroscopy where the position angle of the object is known (or is the parallactic angle). It has three parts. First, it presets the telescope to the coordinates of the Target associated with this Observation Block and rotates the Adapter to the requested Rotator Offset Angle. It then inserts a filter, and takes a short image through the Focus Wedge, to focus the telescope before acquiring the target into the slit. After the iterative focus process is terminated, the last focus image is used by the operator to perform the first approximate pointing to the desired object. Note that the exposure time for the focus image in all acquisition templates is hard-coded to 20 seconds, because no matter what the field is, with this exposure time it is always possible to find suitable stars for focusing. Note that it is possible to skip the focusing by setting the `Focus flag` to `F`.

When these steps are done, the template takes an exposure of `Exposure time` seconds, which is displayed in a `MIDAS` window for inspection by the operator. He/she can then perform a combined offset so that the desired object (e.g. as marked on a finding chart) is placed on the slit position specified by `X pixel coordinate` (in the 1×1 binning system). The Y position of the slit is automatically selected from an internal database according to the `Slit for reference`, and is updated by Operations when a new instrument set-up is performed. Since this parameter depends on the slit used, the astronomer **must** supply its name. The `Perform combined offset` flag should be set to `T` if the telescope is to be positioned accurately by offsetting the guide probe in this iterative process. Note that if the `Rotator Offset Angle` is set to -9999, the Rotator Angle will be set to the parallactic angle at the start of the exposure.

If this acquisition template is used during service observing, a finding chart **must** be supplied by the user. By default the acquisition images are taken in *fast* mode and binning 2×2. If the observer wants to use these images for scientific purpose, he/she may want to change these parameters.

Note also that if a particular position angle is required, the a rotator offset angle equal to PA+90° must be supplied (see §3.1.3 and fig. 16).

Parameter	Default	Description
Filter	R#642	User specified filter
Slit for reference	NODEFAULT	User specified slit
Exposure time	20	Exposure time for acquisition image (sec)
CCD readout speed	fast	Read Out Mode for the acquisition image
CCD X binning	2	CCD binning factor in X direction
CCD Y binning	2	CCD binning factor in Y direction
X pixel coordinate	1100	User specified X coordinate
Preset flag	T	Preset the telescope?
Perform combined offset	T	Perform accurate offset using guide probe?
Focus flag	T	Focus flag
Rotator offset angle	0	Rotator Offset Angle (deg), see § 3.1.3.

4.3.6 | EFOSC_img_acq_RotateToSlit |

This acquisition template is used for grism spectroscopy, for interactively putting 2 objects into the slit when the position angle is not well known in advance. It has three parts. First, it presets the telescope to the coordinates of the Target associated with the Observation Block and it rotates the Adaptor to the initial Rotator Offset Angle. It then inserts a filter, and takes a short image through the Focus Wedge to focus the telescope before acquiring the targets into the slit. After the iterative focus process is finished, the last focus image is used by the operator to perform the first approximate rotation to align the slit with the 2 objects. The exposure time for the focus image is hardcoded to 20 seconds, and it is possible to skip focusing by setting the `Focus flag` to `F`.

After completing these steps, the template takes an exposure of `Exposure time` seconds, which is displayed in a `MIDAS` window for inspection by the operator. He/she can then supply two user specified objects or points to be aligned with the `Slit for Reference`. When this is done, the adapter is rotated to a new position angle and an acquisition image is taken and loaded in the `MIDAS` display. This process iterated until the desired rotation accuracy is achieved. Next, the operator can perform a combined offset so that one of the 2 objects (or a point in the sky) is placed in the slit position specified by the `X pixel coordinate` (in 1×1 binning system). The Y position is automatically selected according to the `Slit for Reference` supplied by the user. The offset can be iterated until the desired pointing accuracy is achieved.

When observing 2 objects with wide separations, a common mistake is to forget to change the `X pixel coordinate` to be closer to the edges so that when one object is placed at this coordinate, the other is not out of the frame.

Note that this template does not accept -9999 for the `Initial Rotator Offset Angle`, because it is supposed to be used to align the slit along a precise direction (for instance defined by two objects) rather than using the parallactic angle, which is time and telescope coordinates dependent. If a value of -9999 is entered, *P2PP* shall complain and display the value in red.

If this acquisition template is used during service observing, a finding chart **must** be supplied by the user, indicating the two points that must fall within the slit, and the object (or point in the sky) to be placed at the reference pixel. By default the acquisition images are taken in *fast* mode and binning 2×2. If the observer wants to use these images for scientific purpose, he/she may change the parameters.

Parameter	Default	Description
Filter	R#642	User specified filter
Slit for Reference	NODEFAULT	User specified slit
Exposure time	20	Exposure time (sec) for the acquisition image
CCD readout speed	fast	Read Out Mode for the acquisition image
CCD X binning	2	CCD binning factor in X direction
CCD Y binning	2	CCD binning factor in Y direction
X pixel coordinate	1100	X coordinate in 1×1 binning of one of the objects
Preset flag	T	Preset the telescope?
Focus flag	T	Focus flag
Initial Rotator angle	0	Initial Rotator Offset angle (deg)

4.3.7 EFOSC_img_acq_Polarimetry

This template is used to place an object inside a Wollaston Mask for Polarimetric Imaging. It has two parts. First, it presets the telescope to the coordinates of the Target associated with the Observation Block. It then takes a short exposure (it can a be a focus wedge image, if the Focus flag is set to T) which is displayed in a MIDAS window for inspection by the operator. He/she can then offset the telescope so that the target is placed in a suitable position within the Wollaston Mask. The X and Y PIXEL coordinates (in 1×1 binning system) will be prompted from the user at this stage. This means that he/she has to measure them from an image of the Wollaston Mask taken beforehand (usually in the afternoon) using the template EFOSC_img_cal_IntImage.

The Insert HWP flag allows the Half Wave Plate to be inserted (T) or removed (F) before the acquisition is started.

Note that this template can also be used to place an object under one of the spots of the Coronographic Mask. The pixel position of the spot has to be measured in advance, as in the case of the Wollaston Mask. An identical template is available for circular polarimetry (EFOSC_img_acq_QWPolarimetry).

Parameter	Default	Description
Filter	R#642	User specified filter
Insert HWP (T/F)	T	Insert Half Wave Plate (T/F)
Exposure time	20	Exposure time (sec) for the acquisition image.
CCD X binning	2	CCD binning factor in X direction
CCD Y binning	2	CCD binning factor in Y direction
CCD readout speed	fast	Read Out Mode for the acquisition image
Preset flag	T	Preset the telescope?
Focus flag	T	Focus flag
Rotator offset angle	0	Rotator Offset Angle (deg), see definition in § 3.1.3.

4.3.8   EFOSC_img_acq_MOS

This template is used to align objects in an astronomical field with slits on a MOS plate for Multi Object Spectroscopy. During its execution, and in order to align the 3 slits with the 3 reference stars, the user will be prompted for the filename of image of the mask. This means that the observer has to take an image of the MOS plate (usually in the afternoon) before running this Acquisition Template by means of EFOSC_img_cal_IntImage. This image has to be left in the default directory $INS_ROOT/SYSTEM/DETDATA/, otherwise EFOSC_img_acq_MOS will not be able to find it.

This template has three parts: 1) telescope and rotator preset; 2) focus, rotator offset and approximate telescope offset; 3) final telescope offset.

First, the template presets the telescope to the coordinates of the Target associated with the Observation Block and rotates the Adaptor to the requested Rotator Offset Angle. It then inserts a filter, and takes a short exposure (it can be a focus wedge image, if the Focus flag is set to T) which is displayed in a MIDAS window for inspection by the operator. Following this, an iterative acquisition loop is started to put the instrument into the correct orientation. The user will be prompted for the name of the file containing the image of the slits. He/she will then be prompted to identify the 3 slits for the alignment from this image. Afterwards, an image of the sky is taken and displayed, and the user is asked to identify the 3 stars corresponding to the 3 slits. This process can be iterated until the desired rotator accuracy is reached. When this is done, the operator will be requested to find a guide star and to activate the autoguider. An iterative acquisition loop is then started to refine the alignment. In this loop, a short image is taken and sent to the MIDAS display. The operator selects the 3 alignment stars and a telescope offset is calculated and performed. This process can be iterated until the desired positional accuracy is reached.

If the Focus flag is set to T, after the rotator offset and before the alignment procedures, an iterative focusing procedure using the focus wedge is initiated. The last image produced during the focusing procedure will the be used to make the first approximate offset to center the field. If the Focus flag is set to F, the focusing is simply skipped.

Note that if the observer does not need to rotate the adapter, the second step can be skipped. The operator is requested to make this choice just after the telescope terminates presetting.

Parameter	Default	Description
Filter	R#642	User specified filter
MOS Plate	NODEFAULT	User specified MOS plate
Exposure time	20	Exposure time (sec) for the acquisition image
Preset flag	T	Preset the telescope?
Focus flag	T	Focus flag
Rotator offset angle	0	Rotator Offset Angle (deg) (§ 3.1.3)

4.3.9   EFOSC2 Observation Templates

Observation Templates are used to perform the actual scientific observations. They allow full control of the CCD parameters and optical components required for each kind of observation. Some of them are hard-coded within the templates so that the observer cannot select them by mistake. For instance, the grism is always set to `Free` when taking Images. When executed, all templates make an automatic check to assess if there are undesired components in the light path. For example, the Calibration Unit and the Half Wave Plate positions are always checked; if they are in the way they will be removed.

The various observing modes and associated templates are described in detail under the section Observing Modes in the EFOSC2 main web page
http://www.eso.org/sci/facilities/lasilla/instruments/efosc/

where examples for typical uses are given.

4.3.10   `EFOSC_img_obs_Image`

This template is used for the Simple imaging mode, and takes `Number of exposures` normal images through a `Filter` with a duration of `Exposure time` seconds each. The CCD readout, binning and windowing can be controlled.

Note that it is possible to insert a slit, even if this is usually (and by default) set to `Free`. This option is used when an image of a field through a slit, a MOS plate or the Coronographic Mask is needed. When executed, the template warns the user that the slit is in the beam.

Parameter	Default	Description
Filter	NODEFAULT	User specified filter
Starplate	Free	User specified slit
Exposure time	NODEFAULT	Exposure time (sec)
CCD readout speed	normal	CCD read-out speed
CCD X binning	2	CCD binning factor in X direction
CCD Y binning	2	CCD binning factor in Y direction
CCD windowing flag	F	F=no CCD window, T=CCD windowed
First column of window	1	If ST=T, first column of window
First row of window	1	If ST=T, first row of window
Number of columns	2048	Number of CCD columns in window
Number of rows	2048	Number of CCD rows in window
Number of exposures	1	Number of exposures

4.3.11 `EFOSC_img_obs_ImageJit`

This template is for the Jittered Imaging mode and takes `Number of Exposures` normal images through `Filter` according to a `List of Exposure times`. Between exposures the telescope is offset in RA and DEC by user specified amounts (in arcseconds). These are relative offsets, not absolute offsets from the original position. Note that the first image will not be taken at the initial position unless the first value in the list is set to 0. If the offset list is shorter than the number of exposures, the offset pattern is cycled until the end of the image sequence is reached. The user can specify if he/she wants to put the telescope back to the original position at the end of the sequence (`Return to origin`) and if accurate offsets by combining the guideprobe and the telescope offsets should be performed (`Perform combined offset`). The slit is automatically set to Free. The CCD readout, binning and windowing can be controlled.

Note that if the `List of Exposure times` has more than one entry, and they are separated by spaces, it is interpreted as its namesake. If the `List of Exposure times` is shorter than the number of exposures, then the list is cycled until the image sequence is reached. Of course the exposure time list is effective only if `Number of exposures` is bigger than 1.

Parameter	Default	Description
Filter	NODEFAULT	User specified filter
List of Exposure times	NODEFAULT	Space-separated list of exposure times (sec)
CCD readout speed	normal	CCD read-out speed
CCD X binning	2	CCD binning factor in X direction
CCD Y binning	2	CCD binning factor in Y direction
CCD windowing flag	F	F=no CCD window, T=CCD windowed
First column of window	1	If ST=T, first column of window
First row of window	1	If ST=T, first row of window
Number of columns	2048	Number of CCD columns in window
Number of rows	2048	Number of CCD rows in window
List of telescope RA offsets	5	Space-separated RA offset list (arcsec)
List of telescope DEC offsets	5	Space-separated DEC offset list (arcsec)
Return to origin	T	Return to origin (T/F)
Perform combined offset	T	Perform combined offset (T/F)
Number of Exposures	3	Number of exposures

4.3.12   `EFOSC_img_obs_Polarimetry`

This template is for the Polarimetric Imaging Mode and takes `Number of Exposures` images for Polarimetry through a `Filter` with a duration of `Exposure time` seconds for each of the positions in the `List of HWP rotator positions` specified by the user. If you ask for N exposures, the template does N cycles where all HWP angles are repeated. So the N exposures of angle, say, 22.5, are separated by those of the other three angles. In algorithm:

- for every exposure
    - for every angle
        * take frame

The `Starplate` is not free but contains a `Wollaston Mask`, while the `Grism wheel` contains the corresponding `Wollaston Grism`. The `Move HWP IN` flag should be set to `T`. The `Continuous rotation of HWP` should be set to: `T` to get depolarized radiation (note in this case there has to be 1 and only 1 value (any is fine) entered against the `List of HWP rotator positions`); and to `F` to have polarized radiation at fixed angles (note in this case there has to be at least 1 value entered against the `List of HWP rotator positions`).

The CCD readout, binning and windowing can be controlled.

An identical template is available for circular polarimetry (`EFOSC_img_obs_QWPolarimetry`).

Parameter	Default	Description
Filter	NODEFAULT	User specified filter
Starplate	NODEFAULT	User specified Wollaston Mask
Grism	NODEFAULT	User specified Wollaston Prism
Move HWP IN	T	Insert the HWP (T/F)
Continuous rotation of HWP	F	Continuous rotation of HWP (T/F)
List of HWP rotator positions	0 22.5 45.0 67.5	Space-separated HWP positions (deg)
Exposure time	NODEFAULT	Exposure time (sec)
CCD readout speed	normal	CCD read-out speed
CCD X binning	2	CCD binning factor in X direction
CCD Y binning	2	CCD binning factor in Y direction
CCD windowing flag	F	F=no CCD window, T=CCD windowed
First column of window	1	If ST=T, first column of window
First row of window	1	If ST=T, first row of window
Number of columns	2048	Number of CCD columns in window
Number of rows	2048	Number of CCD rows in window
Number of Exposures	1	Number of exposures

4.3.13   `EFOSC_img_obs_Coronography`

The Coronographic mode is very similar to the Simple Imaging Mode already described, except that its template lacks the Starplate option. Since coronographic imaging always requires the use of a coronographic mask (in the Starplate wheel) and a Lyot stop (in the grism wheel), the template automatically sets the aperture wheel to COR_MASK and the grism wheel to LYOT. The template takes `Number of Exposures` coronographic images with a duration of `Exposure time` seconds each through a `Filter`. The CCD readout, binning and windowing can be controlled.

For acquisition, one has to use the `EFOSC_img_acq_MoveToPixel` template since the object has to be accurately placed behind the coronographic mask. Note that the mask is not in place during the acquisition. Obviously, the pixel specified in the Move To Pixel template should be at the centre of the coronographic mask. Hence it must be measured before the observations are started, and entered in `EFOSC_img_acq_MoveToPixel`.

Note that typically Coronographic targets are extremely bright stars and hence one should use very small integration times in the acquisition template. The bright targets and the consequent saturation may result in small deviation from the ideal position. In such cases one may have to position the telescope using trial-and-error offsets. We recommend the following procedure:

Include in the OB a very short duration Coronographic Imaging template between the acquisition template and the programme Coronographic imaging templates. Execute the OB and terminate it after the acquisition template - this will position the star close to the centre of the coronographic mask. Execute the OB again but skip the acquisition template and go directly to the very short exposure template. If the star looks properly positioned in this short exposure continue with the programme templates. If not, terminate the OB, ask the telescope operator to apply the desired telescope offset using the telescope control panel and repeat the OB (after skipping the acquisition).

Parameter	Default	Description
Filter	NODEFAULT	User specified filter
Exposure time	NODEFAULT	Exposure time (sec)
CCD readout speed	normal	CCD read-out speed
CCD X binning	2	CCD binning factor in X direction
CCD Y binning	2	CCD binning factor in Y direction
First column of window	1	If ST=T, first column of window
First row of window	1	If ST=T, first row of window
CCD windowing flag	F	F=no CCD window, T=CCD windowed
Number of columns	2048	Number of CCD columns in window
Number of rows	2048	Number of CCD rows in window
Number of Exposures	1	Number of exposures

4.3.14   `EFOSC_spec_obs_Spectrum`

This template is designed for long-slit spectroscopy and MOS spectroscopy, and acquires `Number of Exposures` spectroscopic images of duration `Exposure time` with a user specified `Starplate` and `Grism`. It is possible to insert a filter, even if it is usually (and by default) set to Free. This option may be used for slitless grism/prism spectroscopy for example.

The CCD readout, binning and windowing can be controlled. Although 2×2 and 1×1 binning are officially supported (Note: it takes 4 times as long to readout the chip in 1×1 mode than in 2×2 mode), 2×1 and 1×2 binning also work. The user may consider the former if high spectroscopic resolution is required, for example when working with slit widths which are less than 1".0. A binning in X of 1 is almost always unnecessary, since the seeing is never good enough to warrant it. The observer uses these unsupported readout modes at their own risk, and should be aware that the electronics are not optimized for these modes.

With this template one can obtain 1 or more spectra of 1 or more objects through 1 or more grisms. However, it is essential that all templates in an OB use the same slit, as each slit falls at a different y-pixel value and there is no provision for recentering the object from one exposure to another.

The acquisition templates `EFOSC_img_acq_MoveToSlit`, `EFOSC_img_acq_RotateToSlit` and `EFOSC_img_acq_MOS` may be used in conjunction with this template, depending on the nature of the target. If the grism used covers the near-IR part of the spectrum, fringing may become an issue and the user may consider taking internal-flats on source; see § 3.5.7 for details. If the user also wants very accurate wavelength calibration (remind that the instrument suffers at the moment by significant flexures, see fig. 25) then one may also consider taking Helium and Argon arc lamps on source. These calibration templates can be added to the end of the science OB or executed independently.

Parameter	Default	Description
Filter	Free	user specified filter
Starplate	NODEFAULT	User specified slit or MOS plate
Grism	NODEFAULT	User specified grism
Exposure time	NODEFAULT	Exposure time (sec)
CCD readout speed	normal	CCD read-out speed
CCD X binning	2	CCD binning factor in X direction
CCD Y binning	2	CCD binning factor in Y direction
CCD windowing flag	F	F=no CCD window, T=CCD windowed
First column of window	1	If ST=T, first column of window
First row of window	1	If ST=T, first row of window
Number of columns	2048	Number of CCD columns in window
Number of rows	2048	Number of CCD rows in window
Number of Exposures	1	Number of exposures

4.3.15   EFOSC_spec_obs_MOS

This template is new for P82. For the user it is identical to EFOSC_spec_obs_Spectrum, but it should be used for MOS observations. Internally, it will store the slitlet positions in the FITS headers in the output file, which are required for pipeline processing of the data and may also be of use to users in their own reductions.

4.3.16 `EFOSC_spec_obs_Polarimetry`

The SpectroPolarimetry mode is very similar to the Long Slit Spectroscopy mode except that the `20" Wollaston prism` has to be chosen for the filter wheel (the template helpfully labels the field `Wollaston Prism` instead of Filter). The 10" prism cannot be used since the parallel Wollaston Mask (`WollMask=`) should be chosen for `Starplate`. Typically, the half wave plate should be moved in and set to fixed values (continuous rotation `F` and a list of HWP rotator positions).

This template acquires `Number of Exposures` spectropolarimetric images for each of the positions specified in `List of HWP rotator positions`, using `Wollaston Mask=`, a `Grism` and the `Wollaston Prism`. The CCD readout, binning and windowing can be controlled.

The template `EFOSC_img_acq_MoveToPixel` template should be used, with the parallel Wollaston Mask (`WollMask=`) chosen for `Starplate`. Note the choice of x pixel positions is limited by the locations of the transparent sections of the SpectroPolarimetric Wollaston mask/slit. Any one of the 2 available SpectroPolarimetric Masks/Slits may be mounted in the aperture wheel but the name in P2PP will be the same. The Wollaston Prism in the grism wheel must be aligned in a manner appropriate for a parallel mask.

For a detailed description of the SpectroPolarimetry mode plus examples, please see
http://www.eso.org/sci/facilities/lasilla/instruments/efosc/inst/ObsSciSpec.html

An identical template is available for circular polarimetry (`EFOSC_spec_obs_QWPolarimetry`).

Parameter	Default	Description
Wollaston Prism	NODEFAULT	Desired Wollaston Prism (in filter wheel)
Starplate	NODEFAULT	User specified Wollaston Mask
Grism	NODEFAULT	User specified grism
Move HWP IN	T	Insert the HWP (T/F)
Continuous rotation of HWP	F	Continuous rotation of the HWP (T/F)
List of HWP rotator positions	0 22.5 45.0 67.5	Space-separated HWP position list (deg)
Exposure time	NODEFAULT	Exposure time (sec)
CCD readout speed	normal	CCD read-out speed
CCD X binning	2	CCD binning factor in X direction
CCD Y binning	2	CCD binning factor in Y direction
CCD windowing flag	F	F=no CCD window, T=CCD windowed
First column of window	1	If ST=T, first column of window
First row of window	1	If ST=T, first row of window
Number of columns	2048	Number of CCD columns in window
Number of rows	2048	Number of CCD rows in window
Number of Exposures	1	Number of exposures

4.3.17   Calibration Templates

Calibration Templates are used to perform standard calibrations. They permit full control of the CCD parameters and the optical components, allowing the instrument setup for the science observations to be duplicated. Some of the parameters are actually hard-coded within the templates, in such a way that the observer cannot select them by mistake. For instance, the `Grism` is always set to `Free` when taking imaging flat fields.

Calibration OBs can be defined in the P2PP main panel under either the ObsBlock category, or the CalBlock category.

OBs under the CalBlock category do not require an acquisition template and are usually carried out when the telescope is parked at the zenith or at the Flat-field position (e.g. darks, internal lamp flats, dome flats and comparison lamps). Note that automatic preset to the Flat Field Screen is NOT YET implemented. This means that the operator has to issue the command from the TCS panel before the calibrations are carried out.

Calibration template(s) may also form part of an OB under the ObsBlock category. These calibrations are done usually with the telescope pointing to the sky (e.g. Sky flats), and often for on-source calibration of science data (e.g. Helium Argon arc lamp, internal flat field), and for focusing. These OBs usually include an acquisition template as well as the science and calibration templates. For example, when the observer wants to take sky flats on a particular region of the sky (e.g. empty field), he/she should attach an acquisition template to preset the telescope to the desired position. Since no accurate position is needed, `EFOSC_img_acq_Preset` will serve the purpose. Alternatively (and this is the way that is usually done) one can ask the TIO to preset the telescope to one of the empty fields selected from the catalog on the TCS machine, and then execute an OB which contains just the Sky Flat field template.

4.3.18　　`EFOSC_img_cal_Darks`

This Template acquires bias or dark exposures specified by `Number of exposures`. Bias frames are acquired if the `Exposure time` is set to `0`. Conversely, dark frames are acquired if the `Exposure time` is non–zero. The CCD configuration can be changed, such as the binning, readout speed, and windowing.

The operator must make sure that all the lights in the dome are OFF. To prevent possible light leaks, the Calibration Unit is automatically moved IN at the beginning of the execution. It is then removed at the end of the exposure sequence.

Biases frames are needed for every combination of Binning and Readout Speed used during observations. The best time to take dark current frames is at the end of the night after the telescope has been parked, the dome closed, and all lights have been switched off. One can leave the OB running, but make sure that the exposure sequence will terminate before 8.00 AM local time as the staff start working on the telescope after that.

Parameter	Default	Description
Exposure time	0	Exposure time (sec)
CCD readout speed	normal	CCD read-out speed
CCD X binning	2	CCD binning factor in X direction
CCD Y binning	2	CCD binning factor in Y direction
CCD windowing flag	F	F=no CCD window, T=CCD windowed
First column of window	1	If ST=T, first column of window
First row of window	1	If ST=T, first row of window
Number of columns	2048	Number of CCD columns in window
Number of rows	2048	Number of CCD rows in window
Number of exposures	5	Number of exposures

4.3.19   `EFOSC_img_cal_Flats`

This calibration template acquires `Number of exposures` imaging dome flat fields with levels approximately the `Requested intensity level` through a desired `Filter`. The slit and grism wheels are automatically set to `Free`. The HWP and Calibration Unit positions are checked, and if they are in the light path, these components are automatically removed. The Guide probe is sent to park position to avoid possible vignetting. The operator is requested to preset the Telescope and the Dome to the proper positions and to switch ON the Flat Field lamps in the dome.

The exposure time is computed automatically as follows:

- The average bias level is retrieved from a database;

- A windowed flat with exposure time 1 sec is acquired;

- The bias level is subtracted from the windowed flat and the mean intensity is computed.

- The exposure time needed to reach the `Requested intensity level` is calculated, and adopted for subsequent exposures.

Note that if the computed exposure time is less than 3 sec or greater than 5 min, the template will be aborted automatically.

Currently the lamp intensity is manually controlled using the Flat Field Lamp Control Panel. This means that some tuning may be required when observing with very different pass-bands. The most up to date settings of the lamp intensities for each filter can be found in the EFOSC2 web page.

Parameter	Default	Description
Filter	NODEFAULT	User specified filter
Requested intensity level	40000	Requested intensity level in ADUs
CCD readout speed	normal	CCD read-out speed
CCD X binning	2	CCD binning factor in X direction
CCD Y binning	2	CCD binning factor in Y direction
CCD windowing flag	F	F=no CCD window, T=CCD windowed
First column of window	1	If ST=T, first column of window
First row of window	1	If ST=T, first row of window
Number of columns	2048	Number of CCD columns in window
Number of rows	2048	Number of CCD rows in window
Number of exposures	5	Number of exposures

4.3.20   EFOSC_img_cal_SkyFlats

Before this template is executed, the telescope must already be preset to an empty field, either by an acquisition template, or manually by the TIO.

This calibration template acquires `Number of exposures` sky (twilight) flats for normal imaging, with an intensity of approximately the `Requested intensity level`, through the specified `Filter`. Before the start of each each exposure, the telescope position is offset by `Telescope RA offset` and `Telescope DEC offset`. The HWP and Calibration Unit positions are checked. If they are in the light path, these components are automatically removed. The Guide probe is parked to avoid possible vignetting. The exposure time is computed automatically as follows:

- The average bias level is retrieved from a database;

- A windowed flat field with exposure time 3 sec is acquired;

- The bias level is subtracted from the windowed flat and the mean intensity is computed.

- Based on the mean intensity and the requested intensity, an exposure time sequence is computed automatically using the Tyson & Gal algorithm.

The sequence is started only if the exposure time of the first frame is greater than 3 sec. The sequence terminates when the desired number of exposures have been taken, or when the exposure time exceeds 300 sec. The template also checks the exposure level, which can range from 1200 to 60000 ADUs. The exposure levels obtained by this template are within a few thousand ADUs from the one specified by the user. This is due to seasonal effects and sky conditions.

Note that in evening twilight, flats should be taken for the most insensitive passbands first (U, B), whereas during morning twilight the reverse is true.

In this template, it is also possible to specify a `Grism` but the `Slit for Reference` parameter does not cause an insertion of the slit into the lightpath, hence the template is not usable for spectroscopic sky flats. They are usually done using the **EFOSC_spec_cal_Flats** template.

Parameter	Default	Description
Slit for reference	NODEFAULT	User specified slit for reference
Filter	NODEFAULT	User specified filter
Grism	Free	User specified grism
Requested intensity level	40000	Requested intensity level in ADUs
CCD readout speed	normal	CCD read-out speed
CCD X binning	2	CCD binning factor in X direction
CCD Y binning	2	CCD binning factor in Y direction
CCD windowing flag	F	F=no CCD window, T=CCD windowed
First column of window	1	If ST=T, first column of window
First row of window	1	If ST=T, first row of window
Number of columns	2048	Number of CCD columns in window
Number of rows	2048	Number of CCD rows in window
Telescope RA offset	6	Telescope offset in R.A. (arcsec)
Telescope DEC offset	4	Telescope offset in DEC. (arcsec)
Number of exposures	5	Number of exposures

4.3.21   `EFOSC_img_cal_PolarFlats`

This calibration template acquires `Number of Exposures` dome flat fields with HWP inserted and in continuous rotation. These flat fields, suitable for reducing polarimetric imaging data, are taken at an intensity level of approximately the `requested intensity level` through a desired `Filter` and `Wollaston Mask` . During the execution, the position of the calibration Unit is checked. If necessary this component is automatically removed from the light path. The Guide probe is parked to avoid possible vignetting. The operator is requested to preset the Telescope and the Dome to the proper positions and to switch ON the Flat Field lamps in the dome. The exposure time is computed automatically as follows:

- The average bias level is retrieved from a database;

- A windowed flat with exposure time 1 sec is acquired;

- The bias level is subtracted from the windowed flat and the mean intensity is computed.

- From this intensity the exposure time needed to reach the `requested intensity level` is calculated.

Currently the lamp intensity is manually controlled using the Flat Field Lamp Control Panel. Note that if the computed exposure time is less than 3 sec or greater than 5 min, the template will be aborted automatically.

An identical template is available for circular polarimetry (`EFOSC_img_cal_QWPolarFlats`)

Parameter	Default	Description
Filter	NODEFAULT	User specified Filter
Starplate	NODEFAULT	User specified Wollaston Mask in Starplate Wheel
Grism	NODEFAULT	User specified Wollaston Prism in Grism Wheel
Requested intensity level	40000	Requested intensity level in ADUs
CCD readout speed	normal	CCD read-out speed
CCD X binning	2	CCD binning factor in X direction
CCD Y binning	2	CCD binning factor in Y direction
CCD windowing flag	F	F=no CCD window, T=CCD windowed
First column of window	1	If ST=T, first column of window
First row of window	1	If ST=T, first row of window
Number of columns	2048	Number of CCD columns in window
Number of rows	2048	Number of CCD rows in window
Number of Exposures	5	Number of exposures

4.3.22   `EFOSC_img_cal_PolarSkyFlats`

Before this template is executed, the telescope must already be preset to an empty field, either by an acquisition template, or manually by the TIO.

This calibration template acquires `Number of exposures` sky (twilight) flats with an intensity of approximately the `Requested intensity level` through a desired `Filter`, with the Half Wave Plate inserted and in continuous rotation. The user can insert the desired `Wollaston Mask` and `Wollaston Prism` into the `Starplate` and `Grism` wheel positions respectively.

Before the start of each exposure, the telescope position is offset by `Telescope RA offset` and `Telescope DEC offset`. The Calibration Unit position is checked. If it is in the light path, this component is automatically removed. The Guide probe is parked to avoid possible vignetting. The exposure time is computed automatically as follows:

- The average bias level is retrieved from a database;

- A windowed flat field with exposure time 1 sec is acquired;

- The bias level is subtracted from the windowed flat and the mean intensity is computed.

- Based on the mean intensity and the requested intensity, an exposure time sequence is computed automatically using the Tyson & Gal algorithm.

The sequence is started only if the exposure time of the first frame is greater than 10 sec, to allow for a complete de-polarization of the incoming light by the rotating HWP.

The sequence terminates when `Number of exposures` frames have been acquired, or when the exposure time exceeds 300 sec. The template also checks the exposure level, which can range from 1200 to 60000 ADUs. The exposure levels obtained by this template are within a few thousand ADUs from the one specified by the user. This is due to seasonal effects and sky conditions.

Note that in evening twilight, flats should be taken for the most insensitive passbands first, whereas during morning twilight the reverse is true. Also, a polarimetric imaging sky flat requires an exposure twice as long as an equivalent simple Imaging sky flat. Therefore one can take only 2 or 3 sets of flats during twilight.

An identical template is available for circular polarimetry (`EFOSC_img_cal_QWPolarSkyFlats`).

Parameter	Default	Description
Filter	NODEFAULT	User specified filter
Starplate	NODEFAULT	User specified Wollaston Mask
Grism	NODEFAULT	User specified Wollaston Prism
Requested intensity level	40000	Requested intensity level in ADUs
CCD readout speed	normal	CCD read-out speed
CCD X binning	2	CCD binning factor in X direction
CCD Y binning	2	CCD binning factor in Y direction
CCD windowing flag	F	F=no CCD window, T=CCD windowed
First column of window	1	If ST=T, first column of window
First row of windows	1	If ST=T, first row of window
Number of columns	2048	Number of CCD columns in window
Number of rows	2048	Number of CCD rows in window
Telescope RA offset	10	Telescope offset in R.A.
Telescope DEC offset	4	Telescope offset in DEC.
Number of exposures	5	Number of exposures

4.3.23   `EFOSC_img_cal_IntImage`

This template is mainly used for 2 purposes: for taking an internal image of a slit or MOS mask, and for taking an internal image of a coronographic mask. This template means that the telescope does not need to be moved to the flat field screen.

This template takes `Number of exposures` images with the desired `Internal lamp` through the `Filter` and `Slit`, with a desired `Exposure time`. The CCD configuration may be controlled. The Calibration Unit is automatically moved IN and OUT of the light path at the beginning and at the end of the execution respectively.

Currently, `Ne`, `Ar`, `He` and `Quartz` lamps are available. The mask images can be taken with any of the lamps.

The acquisition template for MOS spectroscopy `EFOSC_img_acq_MOS` requires the output from this template, for identifying the 3 slits for alignment. It will list only the files produced by `EFOSC_img_cal_IntImage` when requesting the MOS plate image. Therefore the observer **must** always use `EFOSC_img_cal_IntImage` when preparing the MOS plate images, and these must be left in the default directory `$INS_ROOT/SYSTEM/DETDATA/` (the user should take a note of the name of each file and which MOS mask it corresponds to in the afternoon). Since all the files are moved in the morning into a subdirectory, it may be necessary to copy them back to `$INS_ROOT/SYSTEM/DETDATA/` before starting any acquisition.

Parameter	Default	Description
Filter	NODEFAULT	User specified filter
Slit	Free	User specified slit
Internal lamp name	Ar	User specified internal lamp
Exposure time	1.0	Exposure time (sec)
CCD readout speed	fast	CCD read-out speed
CCD X binning	2	CCD binning factor in X direction
CCD Y binning	2	CCD binning factor in Y direction
CCD windowing flag	F	F=no CCD window, T=CCD windowed
First column of window	1	If ST=T, first column of window
First row of window	1	If ST=T, first row of window
Number of columns	2048	Number of CCD columns in window
Number of rows	2048	Number of CCD rows in window
Number of exposures	1	Number of exposures

4.3.24   `EFOSC_spec_cal_Flats`

This template is designed for taking both Dome and Sky Flat Fields in spectroscopic mode, and does not use the Tyson & Gal algorithm. The operator is requested to preset the Telescope and the Dome to the proper positions and to switch ON the Flat Field lamps in the dome (for dome FF only!). There are several lamps available, and their intensity levels can be adjusted remotely by a graphical control panel by the operator.

This calibration template acquires `Number of exposures` dome/sky flat fields for spectroscopy with a level approximately the `Requested intensity level` through the desired `Slit` and `Grism`. Although the `Filter` position is by default set to `Free`, a filter can be inserted when performing grism/prism slitless spectroscopy. Before the exposure, the HWP and Calibration Unit positions are checked, and they are automatically removed if they are in the light path. The exposure time is automatically computed as follows:

- The average bias level is retrieved from a database;

- A windowed flat with exposure time 1 sec is acquired;

- The bias level is subtracted from the windowed flat and the peak intensity is computed from the spectrum. This is done by performing a mesh of the central 50 columns and applying a heavy median filtering

- From this intensity the exposure time needed to reach the `Requested intensity level` is calculated.

Note that since this template is designed for a stable light source, the computed exposure time is fixed and hence when taking sky flats the levels will change in successive exposures due to darkening or brightening of the sky. For evening sky flats, the `Requested intensity level` should be set to about `40000`, whereas for morning sky flats, it should be set to about `10000`. Note also that as a lot of light is required for these flats, they should be taken when the sky is bright. i.e. before imaging sky flats in the evening, and after imaging sky flats in the morning.

Occasionally when taking flats for MOS, the template calculates a wrong exposure time. This may be caused by the window of the test-spectrum falling onto regions between slit-lets, by overlapping slits, or by a mismatch between the regions of the spectrum sampled by the test-spectrum and the rest of the slitlets. If this happens, the user can either experiment with the `Requested intensity level`, or take the spectrum using `EFOSC_spec_obs_Spectrum` setting the exposure time by hand.

Parameter	Default	Description
Filter	Free	User specified filter
Slit	NODEFAULT	User specified slit
Grism	NODEFAULT	User specified grism
Requested intensity level	40000	Requested intensity level in ADUs
CCD readout speed	normal	CCD read-out speed
CCD X binning	2	CCD binning factor in X direction
CCD Y binning	2	CCD binning factor in Y direction
CCD windowing flag	F	F=no CCD window, T=CCD windowed
First column of window	1	If ST=T, first column of window
First row of window	1	If ST=T, first row of window
Number of columns	2048	Number of CCD columns in window
Number of rows	2048	Number of CCD rows in window
Number of exposures	5	Number of exposures

4.3.25 `EFOSC_spec_cal_IntFlats`

This calibration template is mainly used for taking internal spectroscopic flats, usually on-source, since the telescope does not need to be moved to the flat field screen. Currently, `Ne`, `Ar`, `He` and `Quartz` lamps are available, but internal spectroscopic flats should only be taken with the `Quartz` lamp.

This template acquires `Number of exposures` internal flats taken with a lamp specified by the `Internal lamp name`, with a level approximately the `Requested intensity level`, through a desired `Slit` and `Grism`. The Calibration Unit is automatically moved IN and OUT at the beginning and at the end of the execution respectively. The exposure time is automatically computed as follows:

- The average bias level is retrieved from a database;

- A windowed flat with exposure time 1 sec is acquired;

- The bias level is subtracted from the windowed flat and the mean intensity of the spectrum is computed.

- From this intensity the exposure time needed to reach the `Requested intensity level` is calculated.

Note that the quartz lamp is rather bright and for certain slit and grism combinations (especially a wide slit with a low resolution grism) the calculated exposure time is less than 1 second for a CCD binning of 2×2, resulting in a non-uniform illumination of the slit. If this happens, the program exits with a warning, and no spectrum is taken. A possible solution is specify a binning of 1×1 and rebin the data at data-reduction stage. Note also that the quartz lamp is rather red and the internal flats have low counts in the blue. Furthermore there seems to be some internal reflection in the blue part of the spectrum. The user may also want to take normal dome flats for reducing separately the blue part of the spectrum.

Parameter	Default	Description
Slit	NODEFAULT	User specified slit
Grism	NODEFAULT	User specified grism
Internal lamp name	Quartz	User specified internal lamp
Requested intensity level	40000	Requested intensity level in ADUs
CCD readout speed	normal	CCD read-out speed
CCD X binning	2	CCD binning factor in X direction
CCD Y binning	2	CCD binning factor in Y direction
CCD windowing flag	F	F=no CCD window, T=CCD windowed
First column of window	1	If ST=T, first column of window
First row of window	1	If ST=T, first row of window
Number of columns	2048	Number of CCD columns in window
Number of rows	2048	Number of CCD rows in window
Number of exposures	5	Number of exposures

4.3.26   `EFOSC_spec_cal_PolarFlats`

This template is designed for taking both Dome and Sky Flat Fields in spectropolarimetric mode, and does not use the Tyson & Gal algorithm. The operator is requested to preset the Telescope and the Dome to the proper positions and to switch ON the Flat Field lamps (for dome FF only!). There are several lamps available, and their intensity levels can be adjusted remotely by the operator.

This calibration template acquires `Number of exposures` dome/sky flat fields with a level approximately the `Requested intensity level`, with the HWP inserted and in continuous rotation, with a `Wollaston Prism` mounted on the filter wheel, and with the desired `Starplate` and `Grism`. Before the exposure, the Calibration Unit position is checked, and it is automatically removed if it is in the light path. The exposure time is automatically computed as follows:

- The average bias level is retrieved from a database;

- A windowed flat with exposure time 1 sec is acquired;

- The bias level is subtracted from the windowed flat and the mean intensity is computed from the spectrum.

- From this intensity the exposure time needed to reach the `Requested intensity level` is calculated.

Note that since this template is designed for a stable light source, the computed exposure time is fixed. Hence when taking sky flats the levels will change in successive exposures due to darkening or brightening of the sky. For evening sky flats, the `Requested intensity level` should be set to about `40000`, whereas for morning sky flats, it should be set to about `10000`.

An identical template is available for circular polarimetry (`EFOSC_spec_cal_QWPolarFlats`).

Parameter	Default	Description
Wollaston Prism	NODEFAULT	User specified Wollaston Prism
Starplate	NODEFAULT	User specified slit
Grism	NODEFAULT	User specified grism
Requested intensity level	40000	Requested intensity level in ADUs
CCD readout speed	normal	CCD read-out speed
CCD X binning	2	CCD binning factor in X direction
CCD Y binning	2	CCD binning factor in Y direction
CCD windowing flag	F	F=no CCD window, T=CCD windowed
First column of window	1	If ST=T, first column of window
First row of window	1	If ST=T, first row of window
Number of columns	2048	Number of CCD columns in window
Number of rows	2048	Number of CCD rows in window
Number of Exposures	5	Number of exposures

4.3.27   `EFOSC_spec_cal_Arcs`

This template is used for taking arc line spectra for wavelength calibration in spectroscopy. Helium (LAMP1) and Argon (LAMP 2) lamps are available. It acquires arc line spectra through the desired `Filter` (usually Free), `Starplate` and `Grism`. The user can control the exposure time of the 2 lamps independently. The Calibration Unit is automatically moved IN and OUT at the beginning and at the end of the execution respectively. Once the Calibration Unit is moved in, the lamps are turned on sequentially, and the shutter is opened for the desired duration for each of the lamp. There is a lamp preheating of a few seconds before each exposure. The CCD configuration can be changed, such as the binning, readout speed, and windowing.

For a discussion of wavelength calibration issues, please see § 3.5.3. A table of the recommended exposure times are available online at
http://www.eso.org/sci/facilities/lasilla/instruments/efosc/inst/Perf_HeAr.html

These values may change from time to time due to aging of the lamps. The user may want to experiment with the exposure times during afternoon calibration to optimize the line intensities.

Parameter	Default	Description
Filter	Free	User specified filter
Starplate	NODEFAULT	User specified slit
Grism	NODEFAULT	User specified grism
He lamp exposure time	NODEFAULT	Exposure time for He lamp (sec)
Ar lamp exposure time	NODEFAULT	Exposure time for Ar lamp (sec)
CCD readout speed	normal	CCD read-out speed
CCD X binning	2	CCD binning factor in X direction
CCD Y binning	2	CCD binning factor in Y direction
CCD windowing flag	F	F=no CCD window, T=CCD windowed
First column of window	1	If ST=T, first column of window
First row of window	1	If ST=T, first row of window
Number of columns	2048	Number of CCD columns in window
Number of rows	2048	Number of CCD rows in window
Number of exposures	1	Number of exposures

4.3.28   EFOSC_spec_cal_ArcFF

This template takes *internal* arc lamp exposures, followed by *external* dome flat field exposures. It is intended to be used as part of the automatic calibrations generated by the 'CALOB' program, to be run in the morning following observations. It will be executed when necessary by the day time TIOs, and is not intended for our users: visiting astronomers should use separate arc and flat field templates.

4.3.29   `EFOSC_img_cal_FocusWithWedge`

This calibration template acquires an image with a specified `Exposure time` through the Focus Wedge and a `Filter`. The Focus Wedge splits each star image into 2 horizontally. It is set up in such a way that the two images are level with each other when the telescope is focused, but are tilted if the focus is off. The telescope operator will be prompted to identify the stars in the image, and the program will work out the tilt angle and hence the offset in focus. The operator will be given the option to offset the focus or not. The process may be repeated until the operator is satisfied with the focus.

When the template is executed, the Grism, HWP and Calibration Unit positions are first checked. If they are in the light path, these components are automatically removed. The CCD parameters are hard-coded in the software and are set to fast readout with 2×2 binning.

Parameter	Default	Description
INS.FILT1.NAME	R#642	User specified filter
DET.WIN1.UIT1	20	Exposure time

4.3.30 | `EFOSC_img_cal_FocusSequence` |

This calibration template acquires a *through focus* frame. It takes `Number of subexposures` frames of `Exposure time` seconds through a `Filter` and optionally a `Grism`. If the `Number of subexposures` is EVEN, then `Number of subexposures +1` exposures are taken. Before each subexposure, the telescope is offset by `Telescope offset` arcseconds in the specified `Direction of telescope offset` (`ALPHA` or `DELTA`). The telescope focus will start from `Telescope focus offset`×(`Number of subexposures` −1)/2 below the original value, and will increase by `Telescope focus offset` encoder units until all the subexposures are taken. Between subexposures the shutter is closed. At the end of the sequence the CCD is read out and the telescope is sent back to the original position. The operator will be prompted to identify from the image all the positions of ONE star in the focus sequence, sticking to the order of the sequence. A MIDAS routine will measure the Point Spread Function at each focus position, and the result will be plotted in a graphics window, where the operator can inspect the trend. A best focus will be calculated and the operator can chose to apply the focus offset or not.

Note that a `Grism` can be inserted, however, for normal focus sequences this has to be set to `Free`. The `Focus Wedge` prism (Focw) is selected only for calibration purposes. Note also that only positive `telescope focus offsets` are allowed.

Since this procedure takes several minutes, it is recommended to avoid using it for normal focusing, which should be performed by means of the Focus Wedge. This procedure is also not useful in very crowded fields.

Parameter	Default	Description
Filter	R#642	User specified filter
Grism	Free	User specified grism
Exposure time	20	Exposure time
Telescope focus offset	10	Focus step (encoder units)
Telescope offset	10	Telescope offset (arcseconds)
Direction of telescope offset	DELTA	Direction of telescope offset
Number of subexposures	9	Number of requested exposures

4.3.31   `EFOSC_img_cal_FocusWithPrism`

This calibration template acquires an image with a specified `Exposure time` and `Filter` using the Focus Prism/Pyramid. This is a new addition to the focusing capabilities of EFOSC2.

When the template is executed, the Grism, HWP and Calibration Unit positions are first checked. If they are in the light path, these components are automatically removed. The CCD parameters are hard-coded in the software. Note that `Slit for Reference` should always be set to free.

The Focus Pyramid splits each star into 5 in a cross shape. The Pyramid is setup in such a way that the axes of the "cross" will be aligned with the X and Y axes of the CCD when the image is focused, but the "cross" will be rotated if the focus is off. The telescope operator will be prompted to identify the centers of each cross in the image, and the program will work out the angle of offset of each "cross" and hence the offset in focus. The operator will be given the option to offset the focus or not.

This focusing procedure gives roughly the same performance as the Focus Sequence and the Focus Wedge. A comparison of their performances can be found online at
http://www.eso.org/sci/facilities/lasilla/sciops/team_only/efosc2/tests/Tests.html

This template is likely to fail in crowded fields. Note that since this template is not frequently used, please notify the astronomer or operations staff beforehand if you want to use it, to ensure that the system is calibrated.

Parameter	Default	Description
Slit for Reference	Free	Slit for reference
Filter	R#642	User specified filter
Exposure time	20	Exposure time

A   EFOSC2 Efficiency

A.1   Imaging

A.1.1   Colour Equations

The photometric performance of EFOSC with the principle broad band filters is constantly monitored. Usually during setup nights photometric standards are taken and a full photometric solution is obtained, according to the following equations:

$$U - u = ZP_U + CT_U \times (U - B) - \kappa_U \times z \tag{9}$$

$$B - b = ZP_B + CT_B \times (U - B) - \kappa_B \times z \tag{10}$$

$$V - v = ZP_V + CT_V \times (B - V) - \kappa_V \times z \tag{11}$$

$$R - r = ZP_R + CT_R \times (V - R) - \kappa_R \times z \tag{12}$$

$$I - i = ZP_I + CT_I \times (R - I) - \kappa_I \times z \tag{13}$$

In these equations, U, B, V, R and I are the catalogue magnitudes of the standard stars, and u, b, v, r, i are their instrumental magnitudes ($= -2.5 \times \log f_{\mathrm{ADU}}$) computed from the counts f_{ADU} in ADUs per second. z is the airmass. The quantities ZP, CT and κ are the instrumental zeropoint, colour term, the atmospheric extinction coefficient respectively, and their values are obtained by solving the above equations for a number of stars with different magnitudes and colour at different airmasses. `Normal` readout is used for the CCD. Notice that on EFOSC2 a Gunn i filter is used instead of the Bessel I, and equation 13 shows how the I magnitude can be obtained from i.

Filter	ZP	κ	CT
	mag	mag	
U	24.39	0.53	0.04
B	26.16	0.25	0.03
V	26.28	0.17	0.04
R	26.36	0.11	0.01
I	25.48	0.05	-0.01

Table 9: The instrumental zero points, atmospheric extinction and colour terms ZP, κ and CT for different filters. These values were obtained using data data from photometric nights obtained during the re-commissioning of EFOSC2@NTT (April 2008).

The mean values for ZP, CT and κ for different filters measured during the re-commissioning of EFOSC2@NTT (April 2008) are listed in table 9. Up-to-date values will be posted at:
http://www.eso.org/sci/facilities/lasilla/instruments/efosc/inst/zp/index.html

In obtaining table 9, only data from photometric nights have been used.

A comparison of the UBVRI zero-points for EFOSC2@NTT and EFOSC2@3P6 is shown in Fig. 31. Clearly, the sensitivity is improved across all wavelengths.

Equations 9 to 13 and table 9 can be used for on-line magnitude determinations or to compute expected count rates, exposure times and signal to noise ratio.

Note that the overall efficiency of the system changes with time, due to factors such as changes in the electronics, and washing of the M1 mirror. The extinction coefficients can change due to site conditions (volcano eruptions for example). Hence the values in table 9 are for reference only, and *users should obtain their own photometric solutions for calibrating their science data.*
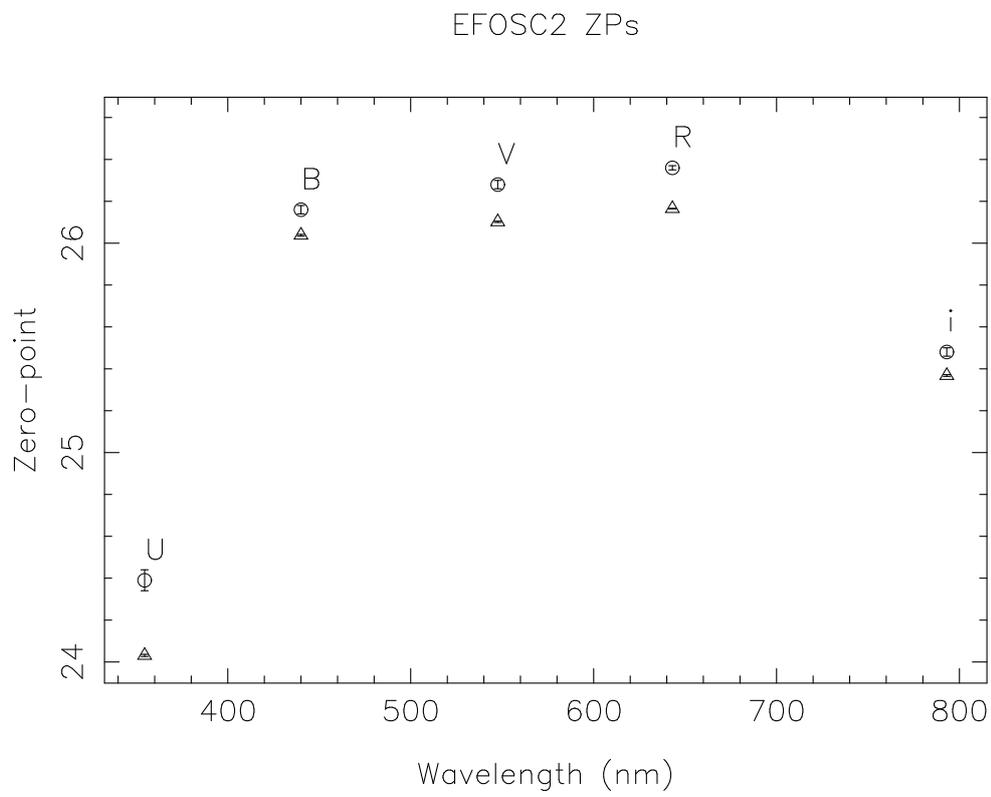
Figure 31: Zero points for the UBVRi broad-band filters (circles) compared with the mean values for the same filters at the 3.6m (triangles)

Older reference values for the extinction coefficients are $\kappa_U = 0.55$, $\kappa_B = 0.25$, $\kappa_V = 0.14$, $\kappa_R = 0.11$ and $\kappa_I = 0.09$ mag.

A.1.2   Expected Count Rates

Using the colour equations given in Sec. A.1.1 it is possible to compute the expected count rate for a star of given magnitude and colour.

For sake of simplicity, in the following we will neglect the colour dependence and any atmospheric extinction. If m_0 is the zero point and m_* is the magnitude of the star in a given band, then the expected count rate (in ADU per second) is simply given by:

$$F_* = 10^{0.4 \times (m_0 - m_*)} \text{ ADU s}^{-1} \tag{14}$$

If g is the gain (e$^-$ ADU^{-1}) the expected count rate in electrons per second is simply $F_{e^-} = g \times F_*$. The expected count rates (in both ADU s^{-1} and e$^-$ s^{-1}) for a star of magnitude $U = B = V = R = i = 15$ are reported in Table 10.

Filter	Count Rate (ADU s^{-1})	Count Rate (e$^-$ s^{-1})	I_0 (ADU s^{-1} px^{-1})
U	5.0 10^3	5.7 10^3	38
B	2.5 10^4	2.9 10^4	193
V	2.9 10^4	3.3 10^4	219
R	3.0 10^4	3.5 10^4	233
I	1.3 10^4	1.5 10^4	100

Table 10: Expected count rates for a star of $U = B = V = R = i = 15$. The peak intensity (I_0) was calculated by assuming a seeing with $FWHM = 1\rlap{.}''5$ and binning 1×1.

These count rates refer to the global flux integrated over the entire Point Spread Function (PSF), which distributes the star light over many pixels. Assuming that the PSF is a Gaussian (where the seeing $FWHM = 2.35 \times \sigma$) and that all the flux is contained within a circle with a radius 3σ, the total number of pixels is given by:

$$n \simeq 350.0 \left\{ \frac{FWHM}{b} \right\}^2 \tag{15}$$

where is $b = 1$ for binning 1×1 and $b = 2$ for binning 2×2. With a seeing of $1\rlap{.}''5$ this implies that the star light is distributed over about 790 pixels (using a binning 1×1). Of course, under the same assumptions, one can compute also the expected central intensity I_0. After expressing σ as a function of the $FWHM$ (converted to pixels) we obtain:

$$I_0 \simeq 1.72 \times 10^{-2} \, b^2 \, \frac{F_*}{FWHM^2} \text{ADUs}^{-1} \tag{16}$$

The last column of Table 10 reports the expected peak intensities for a seeing of $1\rlap{.}''5$ and binning 1×1, according to Eq. 16. This formula can be used to estimate the time needed to reach a given peak intensity. In particular, it is useful to compute the maximum allowed exposure time to avoid saturation of bright stars. If I_{max} is the maximum permitted intensity, we have:

$$t_{max} \simeq \frac{58}{b^2} \, FWHM^2 \, I_{max} \, 10^{-0.4 \times (m_0 - m_*)} \text{ s} \tag{17}$$

As an example, for a star with $V = 11.0$ mag and $(B - V) = 0.0$, $FWHM = 1''5$, $I_{max} = 65000$ and $b = 2$ we get $t_{max} \simeq 6.6$s. Such result has to be kept in mind while trying to obtain images of photometric standards brighter than $V \sim 11.0$ mag, since this may require a de-focusing of the telescope or binning in 1×1 in order to avoid saturation without reducing too much the exposure times (cfr. also Sec. 2.5).

A.1.3 Overall Efficiency

The figures derived in the following subsections are still relative to EFOSC2@3P6. In particular, the pixel size (0.12 instead of 0.158), the telescope clear collecting area and the zero points were changed by moving EFOSC2 to the NTT. However, the basic concepts do applies to EFOSC2@NTT too and the aforementioned quantities were only mildly changed.

Old EFOSC2 zero points are available in EFOSC2@3P6 user manual at:

http://www.eso.org/sci/facilities/lasilla/instruments/efosc-3p6/manual/EFOSC2manual_v2.0.ps.gz

In planning their observing strategy users can refers to the EFOSC2 exposure time calculator available at:

http://www.eso.org/observing/etc/bin/gen/form?INS.NAME=EFOSC2+INS.MODE=imaging

Using the zero points from the photometry, it is possible to compute the overall efficiency $\epsilon(\lambda)$ of the whole system (3.6m telescope+EFOSC2+CCD), according to the following formula:

$$2.5\log(\epsilon) = m_0 - 2.5 \left\{ \frac{\lambda_c \ \Delta\lambda \ A_{tel} \ F_\lambda(0)}{\text{h c}} \right\} \tag{18}$$

where λ_c and $\Delta\lambda$ are the central wavelength and the width of the bandpass respectively, A_{tel} is the clear collecting area of the telescope, $F_\lambda(0)$ is the flux from a 0th magnitude standard star and h and c have their usual meanings. In Table 11 we report the results calculated from Eq. 18 and the relevant adopted values. $A_{tel} = 88564.3 \ cm^2$ was used.

filter	λ_c (μm)	$\Delta\lambda$ (μm)	$F_\lambda(0)$ ($10^{-12} \ W \ cm^{-2} \ \mu m^{-1}$)	Efficiency %
U	0.35	0.05	4.35	21.5
B	0.44	0.09	7.20	26.0
V	0.55	0.11	3.92	33.0
R	0.64	0.17	1.76	45.7
I	0.79	0.13	1.20	32.7

Table 11: Overall computed efficiency for 3.6m+EFOSC2+CCD#40.

Clearly the system reaches its maximum efficiency in the R band. Note that these are crude estimates, since we assume here that the filters have a *box-car* profile and the standard star spectrum is flat across the pass-band.

A different approach can be used to estimate the overall efficiency, i.e. by directly using the transmission, reflectance and quantum efficiency factors in the optical configuration.

When used in Imaging mode the system is made up of 2 mirrors (M1, M2), 5 lenses (2 in the Collimator and 3 in the Camera), 1 filter and the CCD. Typical values for mirror reflectance and lens transmission are 0.95 and 0.90 respectively. The peak transmission for the V filter is 0.87

and the quantum efficiency of CCD#40 at this wavelength is 0.80. Using these numbers we have $\epsilon(V) \simeq (0.95)^2 \times (0.90)^5 \times 0.87 \times 0.80$, i.e. $\epsilon(V) \simeq 37\%$, which is in good agreement with the value reported in Table 11.

A.1.4   Signal to Noise ratio and Detection Limits

The expected count rate per square arcsecond and per unit time for the sky background is given by the following formula:

$$s_{\text{sky}} = 10^{0.4 \times (m_0 - m_{\text{sky}})} \quad \text{ADU s}^{-1} \text{ arcsec}^{-2} \tag{19}$$

where m_0 is the zero point and m_{sky} is the sky brightness in the given band (expressed in mag arcsec^{-2}). This value depends of course on the Moon phase, as shown in Table 12, where the expected count rates for the sky background have also been reported.

Days from	m_{sky} (mag arcsec^{-2})					s_{sky} (ADU s^{-1} arcsec^{-2})				
new Moon	U	B	V	R	I	U	B	V	R	I
0	22.0	22.7	21.8	20.9	19.9	8	20	47	121	141
3	21.5	22.4	21.7	20.8	19.9	13	26	52	133	141
7	19.9	21.6	21.4	20.6	19.7	57	54	69	160	169
10	18.5	20.7	20.7	20.3	19.5	207	124	131	211	203
14	17.0	19.5	20.0	19.9	19.2	824	373	249	305	268

Table 12: Sky surface brightness and expected background count rates (Walker 1987, NOAO Newsletter).

It is very useful to estimate the integrated signal coming from the sky background in the area covered by the PSF. This is simply given by:

$$F_{\text{sky}} = 5.12 \, FWHM^2 \, s_{\text{sky}} \quad \text{ADU s}^{-1} \tag{20}$$

while the expected background count rate in a single pixel is expressed by the following formula:

$$f_{\text{sky}} = 2.6 \times 10^{-2} \, b^2 \, s_{\text{sky}} \quad \text{ADU s}^{-1} \text{ px}^{-1} \tag{21}$$

Now, the main sources of noise in CCD images are the Photon Shot Noise of the source (PSN), the background noise (σ_{sky}) and the Read Out Noise (RON). Nevertheless, most of the time the dominating source is the sky background. In fact, if g is the *gain* (in e$^-$ ADU^{-1}), we have $\sigma_{sky} \geq RON$ when:

$$t \geq \frac{RON^2}{g \times f_{sky}} \tag{22}$$

Inserting the proper values for g and RON in Eq. 22 we have that during the new Moon the noise starts to be sky dominated after about 40 seconds in V and already after 16 seconds in R. For this reason we will neglect the RON contribution in the following Signal to Noise Ratio (SNR) calculations. With this assumption, the expected SNR averaged over the entire PSF area is given by:

$$SNR \simeq \frac{F_*}{\sqrt{F_* + F_{sky}}} \sqrt{g \times t} \tag{23}$$

Eq. 23 can be inverted to compute the time required to achieve a given SNR:

$$t = \frac{F_* + F_{sky}}{g \times F_*^2} \, SNR^2 \tag{24}$$

For example, with a seeing of $1''\!.5$ and during the new Moon, to reach a $SNR = 100$ with a star of $V = 20.0$ an exposure time of about 90 seconds is required.

If the objects are very faint, the PSN from the sources is also negligible with respect to the noise generated by the sky background. In this regime, if we assume that the detection limit is given by a $SNR = 5$, we can easily compute the limiting magnitude of an image with an exposure time of t seconds:

$$m_{lim} \simeq m_0 - 2.40 - 2.5 \, log FWHM - 1.25 \, log \frac{s_{sky}}{t} \tag{25}$$

The limiting magnitude with a seeing of $1''\!.5$ in a V exposure of 1800 seconds taken during the new Moon is $V_{lim} \simeq 25.1$. If we assume the limiting $SNR = 3$ the correspondent limiting magnitude increases by 0.56 mag. Note that the integrated SNR for a point source does not depend on the binning factor b, while the SNR in a single pixel scales directly as b.

In the case of extended sources (i.e. when the angular size of the object is much larger than the seeing) it is more convenient to treat each pixel separately instead of computing an integrated SNR. If the surface brightness of the source is m_* mag arcsec^{-2}, the expected SNR is:

$$SNR_{\mathrm{ext}} \simeq 0.16 \, b \, \frac{s_*}{\sqrt{s_* + s_{sky}}} \, \sqrt{g \times t} \tag{26}$$

where $s_* = 10^{0.4 \times (m_0 - m_*)}$.

An imaging exposure time calculator for EFOSC2, developed by J. Brewer, can be found online at: http://www.eso.org/observing/etc/bin/gen/form?INS.NAME=EFOSC2+INS.MODE=imaging.

A.2   Spectroscopy

In planning their observing strategy users can refers to the EFOSC2 exposure time calculator available at:

http://www.eso.org/observing/etc/bin/gen/form?INS.NAME=EFOSC2+INS.MODE=spectro

A.2.1   Relative Grism sensitivities

The relative Grism throughputs/sensitivities are displayed in Fig. 32. These are all measured relative to Grism 1, which is the EFOSC2 grism with the widest spectral range. For their measurements, spectra were taken with all the grisms with an internal lamp with fixed intensity. With the spectrum for Grism 1 normalized to have a value of 1 everywhere, the throughputs of different grisms relative to Grism 1 are calculated.

Fig. 32 is useful for finding the most efficient grism at the spectral range that you want. For example, at 8000Å Grism 2 is the most efficient.

Beware that in Fig. 32 for some Grisms there seems to be an upturn or bump in the blue extreme of the curve. This is due to reflected light in the instrument and not due to a real improvement in sensitivity. As the sensitivity in UV drops dramatically, and the internal lamp is rather red, the spectrum of the internal lamp is quite faint in the blue. Thus a small amount of reflected light contamination gives a bump in the blue extremes of some of the curves.
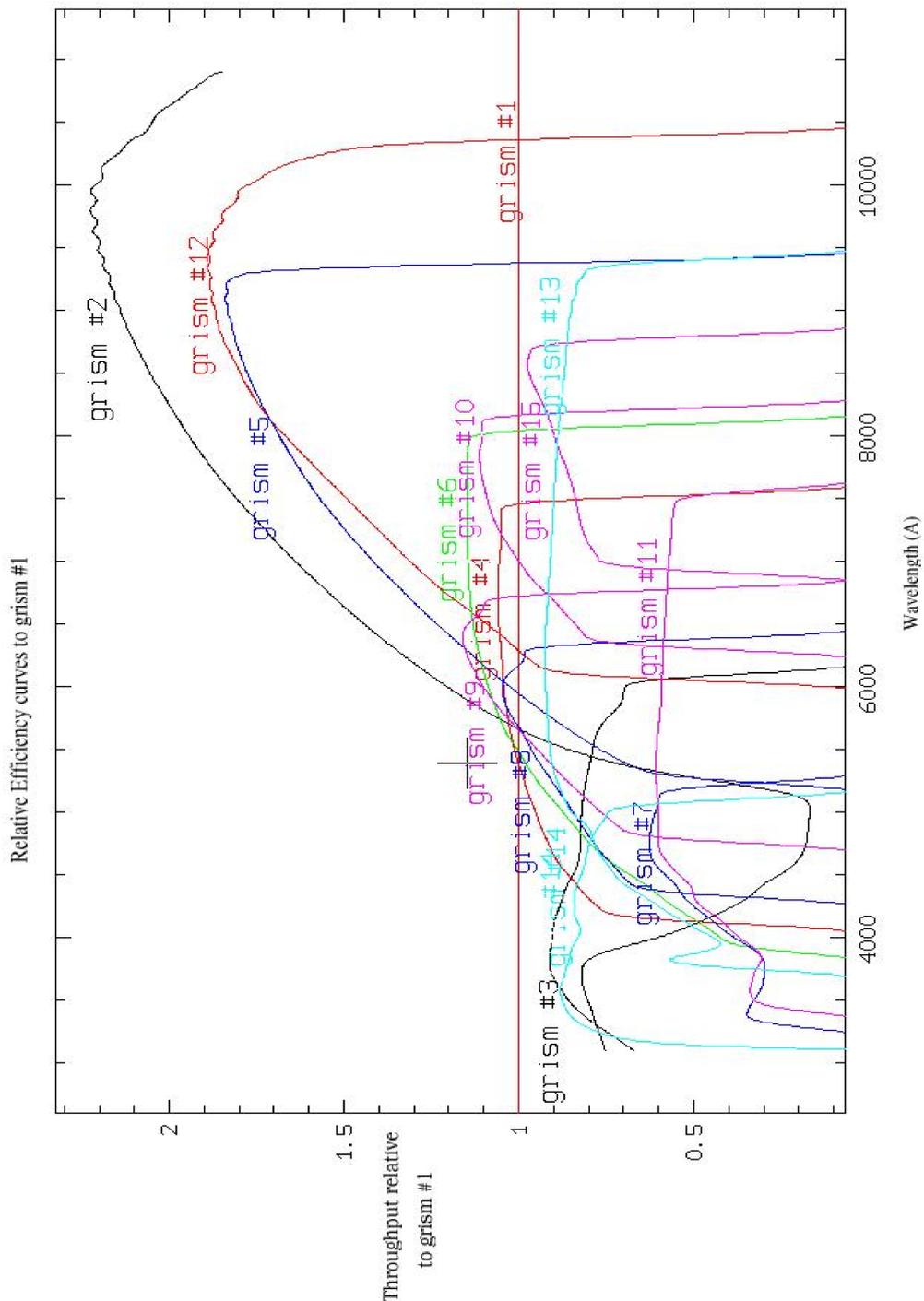
Figure 32: Relative Grism sensitivities. These are all relative to Grism 1, which is set to have a value of 1 everywhere. The upturn in blue for some grisms is due to reflected light within the instrument rather than a real increase in sensitivity.

A.2.2   Grism throughputs

The overall efficiencies of the whole system (Telescope+EFOSC2+CCD) at different wavelengths for different grisms can be measured directly by the instrument throughput of a spectroscopic standard star. In Fig. 33 the throughputs for several of EFOSC2's grisms are plotted. The throughputs of the missing grisms can be calculated by using Fig. 32 and 33. These have been calculated from observations of a number of spectrophotometric standard stars, with the throughputs normalized for a 15th magnitude star at all wavelengths.

Such throughputs are still relative to EFOSC2@3P6. The EFOSC2@NTT throughputs will be posted to this manual and on the EFOSC2 web page as soon as they will be available. Therefore, the following sub-sections are still relative to EFOSC2@3P6.

A.2.3   Signal to Noise ratio and Expected Count Rates

Using the throughput values, one can calculate the expected flux and hence the signal-to-noise ratio for a spectrum. The example below demonstrates the cases for a point source and for an extended source.

A.2.4   Point Source

As an example, one wants to take a spectrum of a star which is 20th magnitude at 5000Å. The observer wants to know how much time is needed to achieve a SNR ratio of 5 per Angstrom at 5000Åusing Grism 8 and the $1''\!\!.0$ slit.

From Fig. 33, a 15th magnitude star at 5000Å observed with Grism 8 gives 26.0 e$^-$ Å^{-1} s^{-1}, hence a 20th mag star will give 0.260 e$^-$ Å^{-1} s^{-1}. Only a fraction of this flux arrives at the detector. As the star image is smeared out spatially by the seeing, some of the flux is obscured by the slit. For example, assume the seeing FWHM is $1''\!\!.20$ and the slit is $1''\!\!.00$ wide. Assuming that the atmospheric scattering is not correlated in directions perpendicular and parallel to the slit, the probability of a photon falling into the slit will be given by a one-dimensional normal distribution. The seeing σ is $1''\!\!.2/2.35 = 0''\!\!.51$, and the slit width is therefore $1''\!\!.0/0''\!\!.51 = 1.96\sigma$. Reading off from a table of standard normal distribution gives 67.2% probability. Thus the flux at the detector will be $0.260 \times 0.672 = 0.175$ e$^-$ Å^{-1} s^{-1}. In the spatial direction, the flux will be spread out with a profile equivalent to the seeing convolved with the object profile (a delta function for a star). In this case the profile has a FWHM the same as the seeing. For ease of calculation, let's assume that we can extract all the flux from the profile to make the 1-dimensional spectrum. In this case the flux per Angstrom of the final one-dimensional star spectrum will be just 0.175 e$^-$ Å^{-1} s^{-1} ($= O$ for below).

To estimate the readout noise, assume that for extracting the 1-d spectrum, a summation/collapse over a spatial region corresponding to the seeing FWHM ($1''\!\!.20$) is required. We want to estimate the SNR which corresponds to a $1\mathring{A}$ bin at $5000\mathring{A}$. Hence the area under consideration is $1''\!\!.20 \times 1\mathring{A}$. For a CCD binning of 2×2 and Grism#8, the area covered by a pixel is $0''\!\!.314 \times 1.98\mathring{A}$. Hence our area of consideration is 1.93 times that of an image pixel. The Read Out Noise for one image pixel is about 10 e^{-1}, thus the Read Out Noise for the area under consideration is $10 \times \sqrt{1.93} = 13.9$ e^{-1} ($= R$ for below). This is the Read Out Noise contribution to a 1 Angstrom region in the final 1-dimensional star spectrum. Note that if the exposures are to be split into n sub-exposures, R should be multiplied by $\sqrt{n}$.

To estimate the flux from the sky, we assume that the sky brightness at 5000Åis 22.1 mag per arcsec^2 for a 3 day moon. Using the throughput value from Fig. 33 gives a sky surface brightness of 0.038 e$^-$ Å^{-1} s^{-1} arcsec^{-2}. Since the slit width is $1''\!\!.0$ and the spectrum is extracted over a region of $1''\!\!.2$, the sky contribution to a 1 Angstrom region in the final 1-dimensional star spectrum will be
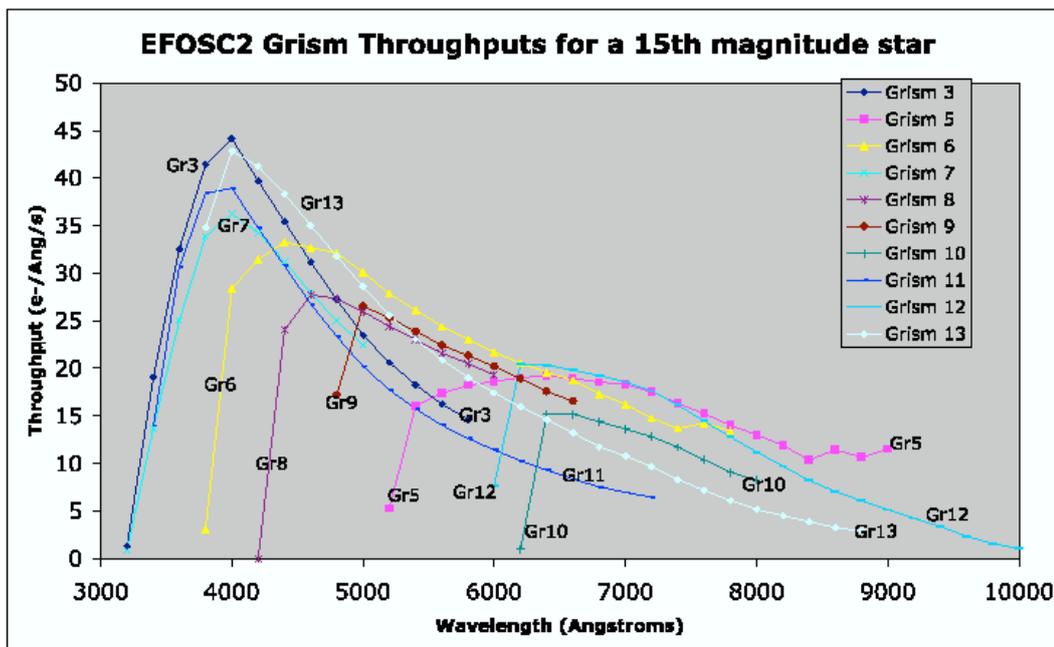
Figure 33: EFOSC2 Grism Throughputs (in electrons per Angstrom per second) for a 15th magnitude star. These represent the averaged values of different observations of many spectrophotometric standard stars, normalized to 15th magnitude at all wavelengths.

$1\rlap{.}''0 \times 1\rlap{.}''2 \times 0.038 = 0.045$ e$^-$ Å^{-1} s^{-1} ($= S$ for below).

Assuming Poisson shot noise from the star and from the sky, the final SNR per Angstrom can be expressed as:

$$SNR = \frac{O \times t}{\sqrt{O \times t + S \times t + R^2}} \tag{27}$$

where O and S denote the flux per Angstroms per second of the Star and Sky respectively, R is the readout noise, and t is the exposure time in seconds. Plug in the relevant numbers calculated above, we see that at $5000\mathring{A}$, to achieve $SNR = 5$ per Angstrom in the final extracted 1-dimensional spectrum, an exposure time of 500 seconds is required.

A.2.5   Extended source

The calculation for an extended source is similar to the case for a point source. The difference is that we work with surface brightness.

As an example, one wants to take a spectrum of a large galaxy at 5000 Å(for example, to make different spatial extractions to obtain a rotation curve), using Grism#8, 2×2 binning, and the $1\rlap{.}''0$ slit. Your requirement is that you need to achieve a SNR of 20 per Angstrom per arcsec out to a surface brightness of 20 mag arcsec^{-2}, and so you want to know how much time is needed.

(For a small galaxy, one may want to convolve a typical seeing with the galaxy light profile to estimate the surface brightness at which the SNR is calculated. For really small galaxies the point source example should be followed.)

From Fig. 33, a 15th magnitude star at $5000\mathring{A}$ observed with Grism#8 gives 26.0 e$^-$Å^{-1}s^{-1}, hence a surface brightness of 20 mag arcsec $^{-2}$ will give 0.260 e$^-$ Å^{-1}s^{-1}arcsec^{-2} at the slit. Since the slit is $1\rlap{.}''0$ wide, the flux arriving at the detector for every $1\rlap{.}''0$ along the slit is 0.260 e$^-$ Å^{-1}s^{-1}arcsec^{-1} ($= O$ for equation 27).

We want to estimate the readout noise which corresponds to a $1\rlap{.}''0 \times 1\mathring{A}$ bin at $5000\mathring{A}$. For a CCD binning of 2×2 and Grism#8, the area covered by a pixel is $0\rlap{.}''314 \times 1.98\mathring{A}$. Hence our area of consideration is 1.61 times that of an image pixel. The Read Out Noise for one image pixel is about 10 e^{-1}, thus the Read Out Noise for the area under consideration is $10 \times \sqrt{1.61} = 12.7$ e^{-1} ($= R$ for equation 27). Note that if the exposures are to be split into n sub-exposures, R should be multiplied by $\sqrt{n}$.

To estimate the flux from the sky, we assume that the sky brightness at 5000 Angstroms is 22.1 mag per arcsec^2 for a 3 day moon. Using the throughput value from Fig. 33 gives a sky surface brightness of 0.038 e$^-$Å^{-1}s^{-1}arcsec^{-2}. Since the slit width is $1\rlap{.}''0$ and the spectrum is extracted over a region of $1\rlap{.}''0$ along the slit, the sky contribution to a 1 Angstrom region in the 1-dimensional spectrum will be 0.038 e$^-$Å^{-1}s^{-1} ($= S$ for equation 27).

Plugging in the values for O, R and S in equation 27, it follows that to get a SNR of 20 per Angstrom per arcsec along the slit, an exposure time of 2200 seconds is required.

B   He-Ar Exposure Times

Table13 reports the typical exposure times for the He and Ar comparison lamps. The values have been obtained using a CCD binning of 2×2 and a slit of $1''0$, and should be changed according to the setup used. For example, the exposure times should be halved for a $2''0$ slit and doubled for a $0''5$ slit. The exposure time should be multiplied by 4 for 1×1 binning.

These values might change with time, since the arc lamps usually loose their efficiency with time. For this reason it is recommended to check the exposure level at the telescope, to make sure that they are high enough to allow a good wavelength calibration. For this reason, the numbers reported in Table 13 should be considered as minimum values. An up-to-date list of the recommended exposure times can also be found online at the EFOSC2 web page:

http://www.eso.org/sci/facilities/lasilla/instruments/efosc/inst/Perf_HeAr.html

Grism	He	Ar	Grism	He	Ar	Grism	He	Ar
#1	1.0	0.25	#7	15.0	30	#13	2.5	0.6
#2	1.0	0.07	#8	2.0	30	#14	30.0	30.0
#3	2.0	10.0	#18	2.5	60	#17	3.0	0.3
#4	1.25	1.75	#10	2.0	0.4	#19	15	30
#5	0.8	0.2	#11	3.0	3.0	#20	0.1	30
#6	2.0	0.3	#16	3.0	0.3			

Table 13: He-Ar comparison lamps exposure times (in sec.). The values are suitable for CCD binning 2×2 and a slit of $1''0$. Grism #10 is decommissioned. Grisms #9, 12, 15 were replaced by Grisms #18, 16, 17, respectively.

```
              ESO 3.6m EFOSC OBSERVING LOG Thu Sep 25 19:52:47 UTC 2003

--------------------------------------------------------------------------------------
File          Ident     UTStart    RA         DEC       Exp  Slit      Filter  Gris      BIN CCDSpeed  Prog ID
--------------------------------------------------------------------------------------
Dark          BIAS      19:52:22 00:00:00 +00:00:00 0.0  Free      Free    Free      2x2 normal 60.A-9013(A)
Dark.1        BIAS      20:13:36 00:00:00 +00:00:00 0.0  Free      Free    Free      1x1  fast  60.A-9013(A)
Dark.2        BIAS      20:14:12 00:00:00 +00:00:00 0.0  Free      Free    Free      1x1  fast  60.A-9013(A)
Dark.3        BIAS      20:14:48 00:00:00 +00:00:00 0.0  Free      Free    Free      1x1  fast  60.A-9013(A)
Dark.4        BIAS      20:15:23 00:00:00 +00:00:00 0.0  Free      Free    Free      1x1  fast  60.A-9013(A)
Dark.5        BIAS      20:15:58 00:00:00 +00:00:00 0.0  Free      Free    Free      1x1  fast  60.A-9013(A)
Dark.6        BIAS      20:16:34 00:00:00 +00:00:00 0.0  Free      Free    Free      1x1  fast  60.A-9013(A)
Dark.7        BIAS      20:17:09 00:00:00 +00:00:00 0.0  Free      Free    Free      1x1  fast  60.A-9013(A)
Dark.8        BIAS      20:17:45 00:00:00 +00:00:00 0.0  Free      Free    Free      1x1  fast  60.A-9013(A)
Dark.9        BIAS      20:18:20 00:00:00 +00:00:00 0.0  Free      Free    Free      1x1  fast  60.A-9013(A)
Dark.10       BIAS      20:18:56 00:00:00 +00:00:00 0.0  Free      Free    Free      1x1  fast  60.A-9013(A)
spec_HeAr     HeAr_spe  22:36:19 18:10:20 -29:22:43 2.5  slit#1.0  Free    Gr#4      2x2 normal 60.A-9013(A)
spec_HeAr.1   HeAr_spe  22:40:10 18:14:11 -29:22:44 2.0  slit#1.0  Free    Gr#8      2x2 normal 60.A-9013(A)
FlatTest      FLAT      23:10:24 19:04:11 -37:16:48 1.0  Free      g#782   Free      2x2 normal 60.A-9013(A)
FlatSkyIma    SKYFLAT   23:11:01 19:04:11 -37:16:48 16.2 Free      g#782   Free      2x2 normal 60.A-9013(A)
FlatSkyIma.1  SKYFLAT   23:11:53 19:04:11 -37:16:47 19.7 Free      g#782   Free      2x2 normal 60.A-9013(A)
FlatSkyIma.2  SKYFLAT   23:12:48 19:04:12 -37:16:41 24.2 Free      g#782   Free      2x2 normal 60.A-9013(A)
AcqSlit       Pointing  00:33:10 18:36:26 -44:18:33 20.0 Free      R#642   Free      2x2  fast  60.A-9013(A)
AcqSlit.1     Pointing  00:39:28 18:36:27 -44:18:27 20.0 Free      R#642   Free      2x2  fast  60.A-9013(A)
Spectrum      LTT7379   00:42:46 18:36:27 -44:18:28 30.0 slit#5.0  Free    Gr#4      2x2 normal 60.A-9013(A)
Spectrum.1    LTT7379   00:43:57 18:36:27 -44:18:28 30.0 slit#5.0  Free    Gr#6      2x2 normal 60.A-9013(A)
Spectrum.2    LTT7379   00:45:08 18:36:27 -44:18:28 30.0 slit#5.0  Free    Gr#7      2x2 normal 60.A-9013(A)
Spectrum.3    LTT7379   00:46:18 18:36:27 -44:18:28 30.0 slit#5.0  Free    Gr#8      2x2 normal 60.A-9013(A)
Spectrum.4    LTT7379   00:47:29 18:36:27 -44:18:28 30.0 slit#5.0  Free    Gr#9      2x2 normal 60.A-9013(A)
Spectrum.5    LTT7379   00:48:42 18:36:27 -44:18:28 30.0 slit#5.0  Free    Gr#10     2x2 normal 60.A-9013(A)
Spectrum.6    LTT7379   00:49:56 18:36:27 -44:18:29 30.0 slit#5.0  Free    Gr#11     2x2 normal 60.A-9013(A)
Spectrum.7    LTT7379   00:51:07 18:36:27 -44:18:29 30.0 slit#5.0  Free    Gr#14     2x2 normal 60.A-9013(A)
FocWedge.8    Focus     01:44:56 22:16:26 -00:21:44 20.0 Free      R#642   Foc_Wedg  2x2  fast  60.A-9013(A)
FocWedge.9    Focus     01:46:53 22:16:26 -00:21:44 20.0 Free      R#642   Foc_Wedg  2x2  fast  60.A-9013(A)
AcqPix        Pointing  01:49:41 22:16:26 -00:21:43 20.0 Free      R#642   Free      2x2  fast  60.A-9013(A)
ImaJit        PG2213-0  01:51:09 22:16:27 -00:21:38 45.0 Free      U#640   Free      2x2 normal 60.A-9013(A)
ImaJit.1      PG2213-0  01:52:34 22:16:27 -00:21:33 15.0 Free      U#640   Free      2x2 normal 60.A-9013(A)
ImaJit.2      PG2213-0  01:53:36 22:16:27 -00:21:38 30.0 Free      B#639   Free      2x2 normal 60.A-9013(A)
```

Figure 34: Example of automatic EFOSC2 logfile.

C   Observing Log

An *ASCII* log-file of all your observations is automatically updated each time a new image is produced. Its name is `EFOSC_YYYY-MM-DD.log`, where `YYYY-MM-DD` is the date of the observations. This file can be found under `/data/raw` on `wg5off`. We suggest that the VA saves a copy of this log file. A useful command for printing is

`a2ps -c132 -2 -f7 --land EFOSC_YYYY-MM-DD.log`

As well as this automatic log file, the VA is encouraged to make his or her own handwritten log file, especially for noting down comments which are relevant for the observations.

An example of the automatically generated file is given in the following. A report containing the night weather conditions and details of the performed observations is issued by the TIO at the end of every night using the NightLog 2.0 tool. Such a report can also be e-mailed to the VA.

D   Standard *FITS* Header

The images produced by *FIERA* have the standard VLT *FITS* header.

IRAF users may encounter some problems when dealing with these headers as they are in the standard ESO Hierarchical Format. To convert them to standard FITS headers, the user can use the command `hierarch28` which comes with the standard `Scisoft` distribution.

```
SIMPLE  =                     T          / Standard FITS format (NOST-100.0)
BITPIX  =                    16          / # of bits storing pix values
NAXIS   =                     2          / # of axes in frame
NAXIS1  =                  1030          / # pixels/axis
NAXIS2  =                  1030          / # pixels/axis
ORIGIN  = 'ESO     '                     / European Southern Observatory
DATE    = '2003-09-29T22:55:19.961'      / UT date when this file was written
CRVAL1  =                   1.0          / value of ref pixel
CRPIX1  =                   1.0          / Ref. pixel of center of rotation
CDELT1  =                   2.0          / Binning factor
CTYPE1  = 'PIXEL   '                     / Pixel coordinate system
CRVAL2  =                   1.0          / value of ref pixel
CRPIX2  =                   1.0          / Ref. pixel of center of rotation
CDELT2  =                   2.0          / Binning factor
CTYPE2  = 'PIXEL   '                     / Pixel coordinate system
BSCALE  =                   1.0          / pixel=FITS*BSCALE+BZERO
BZERO   =               32768.0          / pixel=FITS*BSCALE+BZERO
MJD-OBS =          52911.95496435        / MJD start (2003-09-29T22:55:08.920)
DATE-OBS= '2003-09-29T22:55:08.920'      / Date of observation
EXPTIME =                9.9993          / Total integration time
EXTEND  =                     F          / Extension may be present
OBJECT  = 'Sky-Flat-Gr11'                / Original target
INSTRUME= 'EFOSC/2.4'                    / Instrument used
OBSERVER= 'UNKNOWN '                     / Name of observer
PI-COI  = 'UNKNOWN '                     / Name(s) of proposer(s)
TELESCOP= 'ESO-3P6 '                     / ESO Telescope Name
RA      =            286.045114          / 19:04:10.8 RA (J2000) pointing (deg)
DEC     =            -37.28004           / -37:16:48.1 DEC (J2000) pointing (deg)
EQUINOX =                 2000.          / Standard FK5 (years)
RADECSYS= 'FK5     '                     / Coordinate reference frame
LST     =             67512.831          / 18:45:12.831 LST at start (sec)
UTC     =             82501.000          / 22:55:01.000 UTC at start (sec)
HIERARCH ESO OBS DID        = 'ESO-VLT-DIC.OBS-1.7' / OBS Dictionary
HIERARCH ESO OBS OBSERVER   = 'UNKNOWN '   / Observer Name
HIERARCH ESO OBS EXECTIME   =         179 / Expected execution time
HIERARCH ESO OBS PI-COI NAME = 'UNKNOWN '  / PI-COI name
HIERARCH ESO OBS PI-COI ID  =        2400 / ESO internal PI-COI ID
HIERARCH ESO OBS GRP        = '0       '   / linked blocks
HIERARCH ESO OBS NAME       = 'LS7_UM133' / OB name
HIERARCH ESO OBS ID         =   100155087 / Observation block ID
HIERARCH ESO OBS PROG ID    = '71.B-0032(B)' / ESO program identification
HIERARCH ESO OBS START      = '2003-09-29T22:54:50' / OB start time
HIERARCH ESO OBS TPLNO      =           2 / Template number within OB
HIERARCH ESO OBS TARG NAME  = 'Sky-Flat-Gr11' / OB target name
HIERARCH ESO TPL DID        = 'ESO-VLT-DIC.TPL-1.4' / Data dictionary for TPL
HIERARCH ESO TPL ID         = 'EFOSC_spec_obs_Spectrum' / Template signature ID
HIERARCH ESO TPL NAME       = 'Spectroscopy' / Template name
HIERARCH ESO TPL PRESEQ     = 'EFOSC_spec_obs_Spectrum.seq' / Sequencer script
HIERARCH ESO TPL START      = '2003-09-29T22:54:50' / TPL start time
HIERARCH ESO TPL VERSION    = '1.0     '   / Version of the template
HIERARCH ESO TPL NEXP       =           3 / Number of exposures within templat
HIERARCH ESO TPL EXPNO      =           1 / Exposure number within template
HIERARCH ESO DPR CATG       = 'SCIENCE '   / Observation category
HIERARCH ESO DPR TECH       = 'SPECTRUM'   / Observation technique
```

```
HIERARCH ESO TEL DID        = 'ESO-VLT-DIC.TCS' / Data dictionary for TEL
HIERARCH ESO TEL ID         = 'v 5.37 '    / TCS version number
HIERARCH ESO TEL DATE       = 'not set '   / TCS installation date
HIERARCH ESO TEL ALT        =        81.035 / Alt angle at start (deg)
HIERARCH ESO TEL AZ         =       334.696 / Az angle at start (deg) S=0,W=90
HIERARCH ESO TEL GEOELEV    =         2400. / Elevation above sea level (m)
HIERARCH ESO TEL GEOLAT     =      -29.2584 / Tel geo latitute (+=North) (deg)
HIERARCH ESO TEL GEOLON     =      -70.7345 / Tel geo longitude (+=East) (deg)
HIERARCH ESO TEL OPER       = 'I, Condor'  / Telescope Operator
HIERARCH ESO TEL FOCU ID    = 'CA      '    / Telescope focus station ID
HIERARCH ESO TEL FOCU LEN   =       108.827 / Focal length (m)
HIERARCH ESO TEL FOCU SCALE =         1.894 / Focal scale (arcsec/mm)
HIERARCH ESO TEL FOCU VALUE =        19.500 / M2 setting (mm)
HIERARCH ESO TEL PARANG START=      -27.937 / Parallactic angle at start (deg)
HIERARCH ESO TEL AIRM START =         1.012 / Airmass at start
HIERARCH ESO TEL AMBI FWHM START=     -1.00 / Observatory Seeing queried from AS
HIERARCH ESO TEL AMBI PRES START=    773.50 / Observatory ambient air pressure q
HIERARCH ESO TEL AMBI WINDSP =         0.55 / Observatory ambient wind speed que
HIERARCH ESO TEL AMBI WINDDIR=         346. / Observatory ambient wind directio
HIERARCH ESO TEL AMBI RHUM  =           38. / Observatory ambient relative humi
HIERARCH ESO TEL AMBI TEMP  =         14.40 / Observatory ambient temperature qu
HIERARCH ESO TEL MOON RA    =    235.692618 / 15:42:46.2 RA (J2000) (deg)
HIERARCH ESO TEL MOON DEC   =     -20.29768 / -20:17:51.6 DEC (J2000) (deg)
HIERARCH ESO TEL TH M1 TEMP =         -1.00 / M1 superficial temperature
HIERARCH ESO TEL TRAK STATUS = 'NORMAL '   / Tracking status
HIERARCH ESO TEL DOME STATUS = 'FULLY-OPEN' / Dome status
HIERARCH ESO TEL CHOP ST    =             F / True when chopping is active
HIERARCH ESO TEL TARG ALPHA =    190048.000 / Alpha coordinate for the target
HIERARCH ESO TEL TARG DELTA =   -372118.000 / Delta coordinate for the target
HIERARCH ESO TEL TARG EPOCH =      1950.000 / Epoch
HIERARCH ESO TEL TARG EPOCHSYSTEM= 'J      ' / Epoch system (default J=Julian)
HIERARCH ESO TEL TARG EQUINOX=     1950.000 / Equinox
HIERARCH ESO TEL TARG PMA   =      0.000000 / Proper Motion Alpha
HIERARCH ESO TEL TARG PMD   =      0.000000 / Proper motion Delta
HIERARCH ESO TEL TARG RADVEL =        0.000 / Radial velocity
HIERARCH ESO TEL TARG PARALLAX=       0.000 / Parallax
HIERARCH ESO TEL TARG COORDTYPE= 'M       ' / Coordinate type (M=mean A=apparent
HIERARCH ESO TEL PARANG END =       -27.513 / Parallactic angle at end (deg)
HIERARCH ESO TEL AIRM END   =         1.012 / Airmass at end
HIERARCH ESO TEL AMBI FWHM END=       -1.00 / Observatory Seeing queried from AS
HIERARCH ESO TEL AMBI PRES END=      773.40 / Observatory ambient air pressure q
HIERARCH ESO ADA ABSROT START=    270.02238 / Abs rot angle at exp start (deg)
HIERARCH ESO ADA POSANG     =       0.00000 / Position angle at start
HIERARCH ESO ADA GUID STATUS = 'OFF     '  / Status of autoguider
HIERARCH ESO ADA ABSROT END =     270.02238 / Abs rot angle at exp end (deg)
HIERARCH ESO INS SWSIM      = 'NORMAL '    / Software simulation
HIERARCH ESO INS ID         = 'EFOSC/2.4'  / Instrument ID
HIERARCH ESO INS GRIS1 ID   = '9       '    / GRIS1 unique ID
HIERARCH ESO INS GRIS1 NAME = 'Gr#11  '    / GRIS1 name
HIERARCH ESO INS GRIS1 NO   =             9 / GRIS1 slot number
HIERARCH ESO INS FILT1 ID   = '1       '    / FILT1 unique ID
HIERARCH ESO INS FILT1 NAME = 'Free   '    / FILT1 name
HIERARCH ESO INS FILT1 NO   =             1 / FILT1 slot number
HIERARCH ESO INS SLIT1 ID   = '5       '    / SLIT1 unique ID
HIERARCH ESO INS SLIT1 NAME = 'slit#1.0'   / SLIT1 name
HIERARCH ESO INS SLIT1 NO   =             5 / SLIT1 slot number
HIERARCH ESO INS OPTI1 ID   = 'HWP     '    / OPTI1 unique ID
HIERARCH ESO INS OPTI1 NAME = 'hwp motor'  / OPTI1 name
HIERARCH ESO INS OPTI1 ST   =             F / Status.
HIERARCH ESO INS OPTI2 ST   =             F / depolarizer on/off (T/F).
HIERARCH ESO INS OPTI2 POS  =         0.089 / Position angle in [deg].
HIERARCH ESO DET ID         = 'CCD FIERA - Rev 2.87' / Detector system Id
HIERARCH ESO DET NAME       = 'efosc - ccdefosc' / Name of detector system
```

```
HIERARCH ESO DET DATE      = '30-08-2000' / Installation date
HIERARCH ESO DET DID       = 'ESO-VLT-DIC.CCDDCS,ESO-VLT-DIC.FCDDCS' / Diction
HIERARCH ESO DET BITS       =              16 / Bits per pixel readout
HIERARCH ESO DET RA         =      0.00000000 / Apparent 00:00:00.0 RA at start
HIERARCH ESO DET DEC        =      0.00000000 / Apparent 00:00:00.0 DEC at start
HIERARCH ESO DET SOFW MODE  = 'Normal  '   / CCD sw operational mode
HIERARCH ESO DET CHIPS      =               1 / # of chips in detector array
HIERARCH ESO DET CHIP1 ID   = 'ccd40   '   / Detector chip identification
HIERARCH ESO DET CHIP1 NAME = 'LORAL   '   / Detector chip name
HIERARCH ESO DET CHIP1 DATE = '30-08-2000' / Date of installation [YYYY-MM-DD]
HIERARCH ESO DET CHIP1 X    =               1 / X location in array
HIERARCH ESO DET CHIP1 Y    =               1 / Y location in array
HIERARCH ESO DET CHIP1 NX   =            2048 / # of pixels along X
HIERARCH ESO DET CHIP1 NY   =            2048 / # of pixels along Y
HIERARCH ESO DET CHIP1 PSZX =            15.0 / Size of pixel in X
HIERARCH ESO DET CHIP1 PSZY =            15.0 / Size of pixel in Y
HIERARCH ESO DET EXP NO     =            1061 / Unique exposure ID number
HIERARCH ESO DET EXP TYPE   = 'Normal  '   / Exposure type
HIERARCH ESO DET EXP DUMDIT =               0 / # of dummy readouts
HIERARCH ESO DET EXP RDTTIME =        22.381 / image readout time
HIERARCH ESO DET EXP XFERTIM =        22.751 / image transfer time
HIERARCH ESO DET READ MODE  = 'normal  '   / Readout method
HIERARCH ESO DET READ SPEED = 'fast    '   / Readout speed
HIERARCH ESO DET READ CLOCK = 'read R port Fas' / Readout clock pattern used
HIERARCH ESO DET OUTPUTS    =               1 / # of outputs
HIERARCH ESO DET OUTREF     =               0 / reference output
HIERARCH ESO DET OUT2 ID    = 'R       '   / Output ID as from manufacturer
HIERARCH ESO DET OUT2 NAME  = 'R       '   / Description of output
HIERARCH ESO DET OUT2 CHIP  =               1 / Chip to which the output belongs
HIERARCH ESO DET OUT2 X     =               1 / X location of output
HIERARCH ESO DET OUT2 Y     =               1 / Y location of output
HIERARCH ESO DET OUT2 NX    =            1024 / valid pixels along X
HIERARCH ESO DET OUT2 NY    =            1024 / valid pixels along Y
HIERARCH ESO DET OUT2 PRSCX =               6 / Prescan region in X
HIERARCH ESO DET OUT2 OVSCX =               0 / Overscan region in X
HIERARCH ESO DET OUT2 CONAD =            1.30 / Conversion from ADUs to electrons
HIERARCH ESO DET OUT2 RON   =            0.00 / Readout noise per output (e-)
HIERARCH ESO DET OUT2 GAIN  =            0.77 / Conversion from electrons to ADU
HIERARCH ESO DET FRAM ID    =               1 / Image sequencial number
HIERARCH ESO DET FRAM TYPE  = 'Normal  '   / Type of frame
HIERARCH ESO DET WINDOWS    =               1 / # of windows readout
HIERARCH ESO DET WIN1 STRX  =               1 / Lower left pixel in X
HIERARCH ESO DET WIN1 STRY  =               1 / Lower left pixel in Y
HIERARCH ESO DET WIN1 NX    =            1030 / # of pixels along X
HIERARCH ESO DET WIN1 NY    =            1030 / # of pixels along Y
HIERARCH ESO DET WIN1 BINX  =               2 / Binning factor along X
HIERARCH ESO DET WIN1 BINY  =               2 / Binning factor along Y
HIERARCH ESO DET WIN1 NDIT  =               1 / # of subintegrations
HIERARCH ESO DET WIN1 UIT1  =       10.000000 / user defined subintegration time
HIERARCH ESO DET WIN1 DIT1  =        9.999325 / actual subintegration time
HIERARCH ESO DET WIN1 DKTM  =         10.0244 / Dark current time
HIERARCH ESO DET SHUT TYPE  = 'Slit    '   / type of shutter
HIERARCH ESO DET SHUT ID    = 'ccd shutter' / Shutter unique identifier
HIERARCH ESO DET SHUT TMOPEN =           0.028 / Time taken to open shutter
HIERARCH ESO DET SHUT TMCLOS =           0.027 / Time taken to close shutter
```

E Sidereal Time and Sun Tables

In the following table the Local Sidereal Time at midnight (LST) is reported together with the relevant times concerning the Sun for La Silla. LST at evening and morning twilights are also tabulated to have a quick idea of the range of R.A. accessible during the night. All times are CST/CDT.

Date	LST midnight	Sun set	twilight	twilight	rise	LST evening tw.	morning tw.
Jan 01	05:02	20:46	22:20	5:13	6:48	03:23	10:16
Jan 15	05:57	20:46	22:19	5:27	6:59	04:16	11:25
Feb 01	07:04	20:40	22:08	5:46	7:13	05:12	12:51
Feb 15	07:59	20:30	21:54	6:01	7:25	05:53	14:01
Mar 01	08:54	20:16	21:37	6:14	7:35	06:32	15:10
Mar 15	10:50	19:00	20:20	5:24	6:44	07:09	16:15
Apr 01	11:57	18:40	19:59	5:35	6:54	07:56	17:33
Apr 15	12:52	18:24	19:44	5:42	7:02	08:36	18:36
May 01	13:55	18:09	19:30	5:51	7:11	09:25	19:47
May 15	14:50	17:59	19:21	5:57	7:20	10:11	20:49
Jun 01	15:57	17:52	19:16	6:05	7:29	11:13	22:04
Jun 15	16:53	17:52	19:17	6:10	7:35	12:09	23:04
Jul 01	17:56	17:56	19:20	6:13	7:38	13:16	00:10
Jul 15	18:51	18:02	19:26	6:12	7:35	14:16	01:04
Aug 01	19:58	18:11	19:33	6:05	7:27	15:31	02:04
Aug 15	20:53	18:19	19:40	5:55	7:15	16:32	02:49
Sep 01	22:00	18:28	19:47	5:38	6:57	17:47	03:39
Sep 15	22:55	18:35	19:54	5:21	6:40	18:49	04:18
Oct 01	23:58	18:44	20:04	5:01	6:21	20:02	05:01
Oct 15	23:53	19:52	21:14	5:43	7:05	21:07	05:38
Nov 01	01:00	20:04	21:29	5:23	6:49	22:30	06:25
Nov 15	01:56	20:15	21:44	5:11	6:40	23:40	07:08
Dec 01	02:59	20:28	22:01	5:03	6:36	01:00	08:03
Dec 15	03:54	20:38	22:13	5:03	6:38	02:07	08:58

Table 14: Sidereal Time and Sun Tables for La Silla.

F   General Instructions For Visiting Astronomers

There are detailed instructions available online at the EFOSC2 web pages. Below we briefly list a few instructions.

- Successful EFOSC2 applicants should book their trip to Chile in such a way to reach La Silla two days before starting the observations, to get the proper introduction to P2PP and prepare their Observing Blocks.

- Upon arrival in La Silla, they should contact as soon as possible their Support Astronomer. This is done through the La Silla paging system. Dial 93 and then wait for a tone. Then dial 04 and wait for a series of beeps. When it stops, repeat at least three times the extension of the phone from which you are calling. You will be called back.

- The Visiting Astronomer should discuss the EFOSC2 setup he/she needs with the Support Astronomer. The online instrument setup form (available from the EFOSC2 homepage) should be filled in and sent to the telescope team at least the night before the start of the run, and earlier if a non-standard setup is required.

- Visiting Astronomers will have car number 97 from the first day of their observing run. Note that the same car is used by the Team between 08:00 and 16:00.

- Access to the NTT telescope and the RITZ (Common Control Room) is restricted. Any visit to the telescope **must be authorized** by the Team Coordinator (beeper 13). The telescope is available for calibrations from 16:00 onwards.

- The data will be delivered to the V.A. by the Data Handling Administrator on turno together with an observing log. The standard data format is FITS, saved on USB disks.

- In case of Multi Object Spectroscopy, successful applicants can ask the SciOps Team `ls-sciops@eso.org` to obtain images of some of their fields (up to a total exposure time of 20 minutes per allocated observing night) during the setup night. In this case the request must be submitted **at least two months before** the observing run. Clear finding charts (scale, orientation) must be provided, together with all precise coordinates and any other relevant detail (centering, position angle, exp. time, filters, etc.).

G   Helium Argon Atlas

The following He–Ar lines are recommended for on–line wavelength calibrations. Particularly bright lines are marked in bold face. Line identification charts are provided for all grisms in the next pages. Lines identified in the arcs for the new VPH Grisms (#19 and #20) are reported in the commissioning report at the following address:

http://www.eso.org/sci/facilities/lasilla/instruments/efosc/doc/VPH/report.pdf

λ (Å)	Ion	λ (Å)	Ion	λ (Å)	Ion
3888.646	He I	6172.278	Ar II	8014.786	Ar I
3948.979	Ar I	**6678.151**	He II	8115.311	Ar I
3964.729	He I	6752.833	Ar I	8264.522	Ar I
4044.420	Ar I	6871.289	Ar I	8408.210	Ar I
4158.590	Ar I	6965.430	Ar I	8424.647	Ar I
4200.674	Ar I	7030.25	Ar I	8521.442	Ar I
4300.101	Ar I	**7065.190**	He I	8667.944	Ar I
4333.561	Ar I	7147.04	Ar I	**9122.967**	Ar I
4471.479	He I	7272.93	Ar I	9194.638	Ar I
4510.733	Ar I	7383.980	Ar I	9224.499	Ar I
4713.146	He I	7503.869	Ar I	9354.22	He I
4921.931	Ar II	7514.65	Ar I	9657.78	He I
5015.680	He I	7635.106	Ar I	9784.50	He I
5875.621	He I	7723.984	Ar I	10830.30	He I
6114.923	Ar II	7948.176	Ar I		

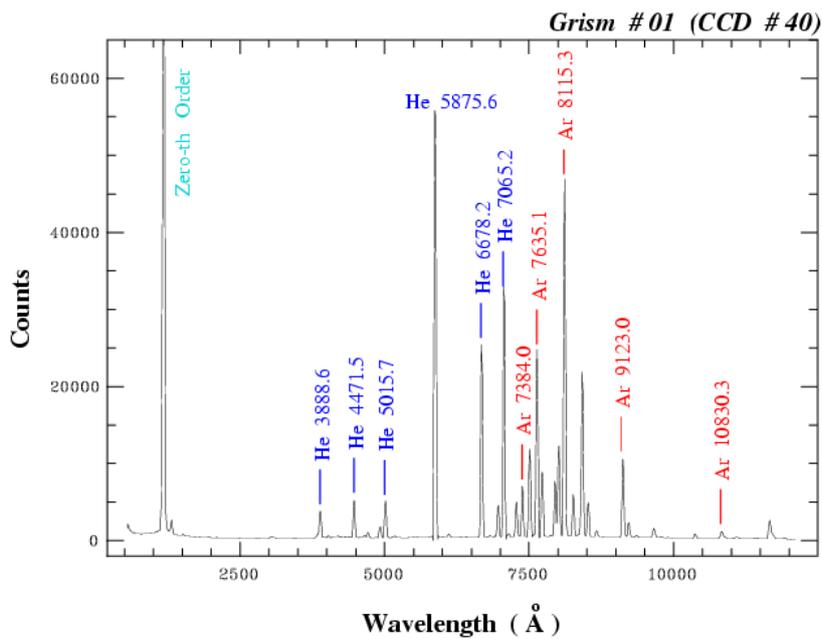Table 15: Recommended He–Ar Lines for wavelength calibration.
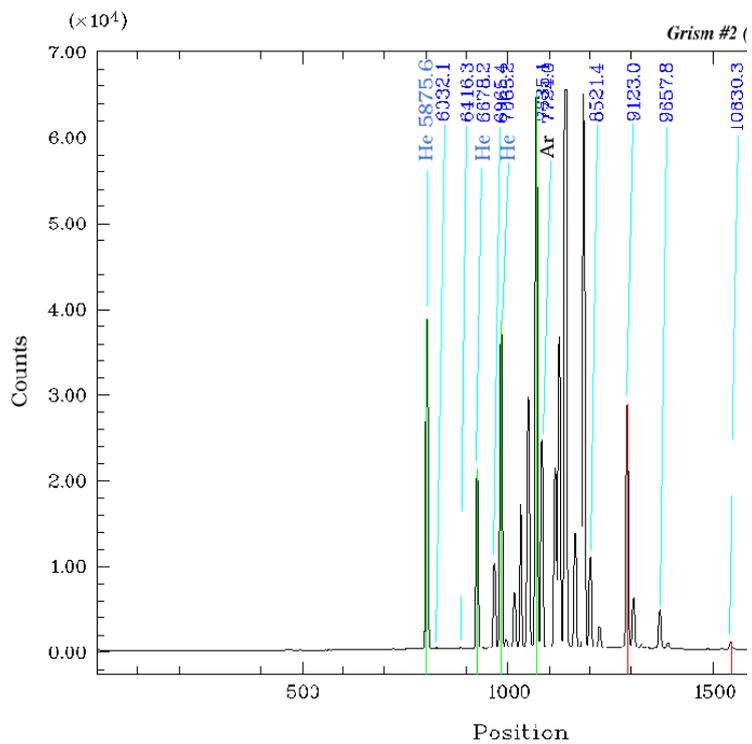
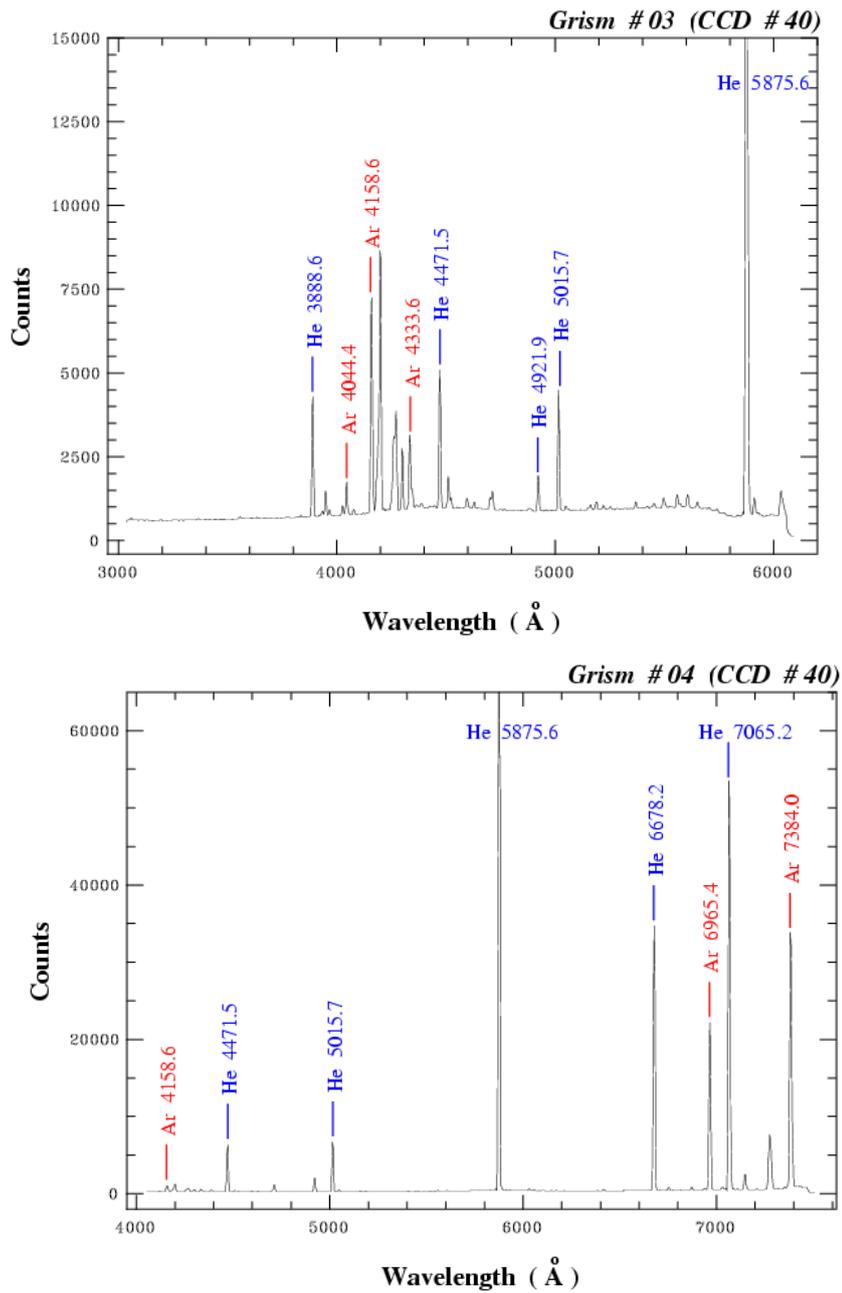Figure 35: Helium-Argon Atlas for grisms #1 and #2.

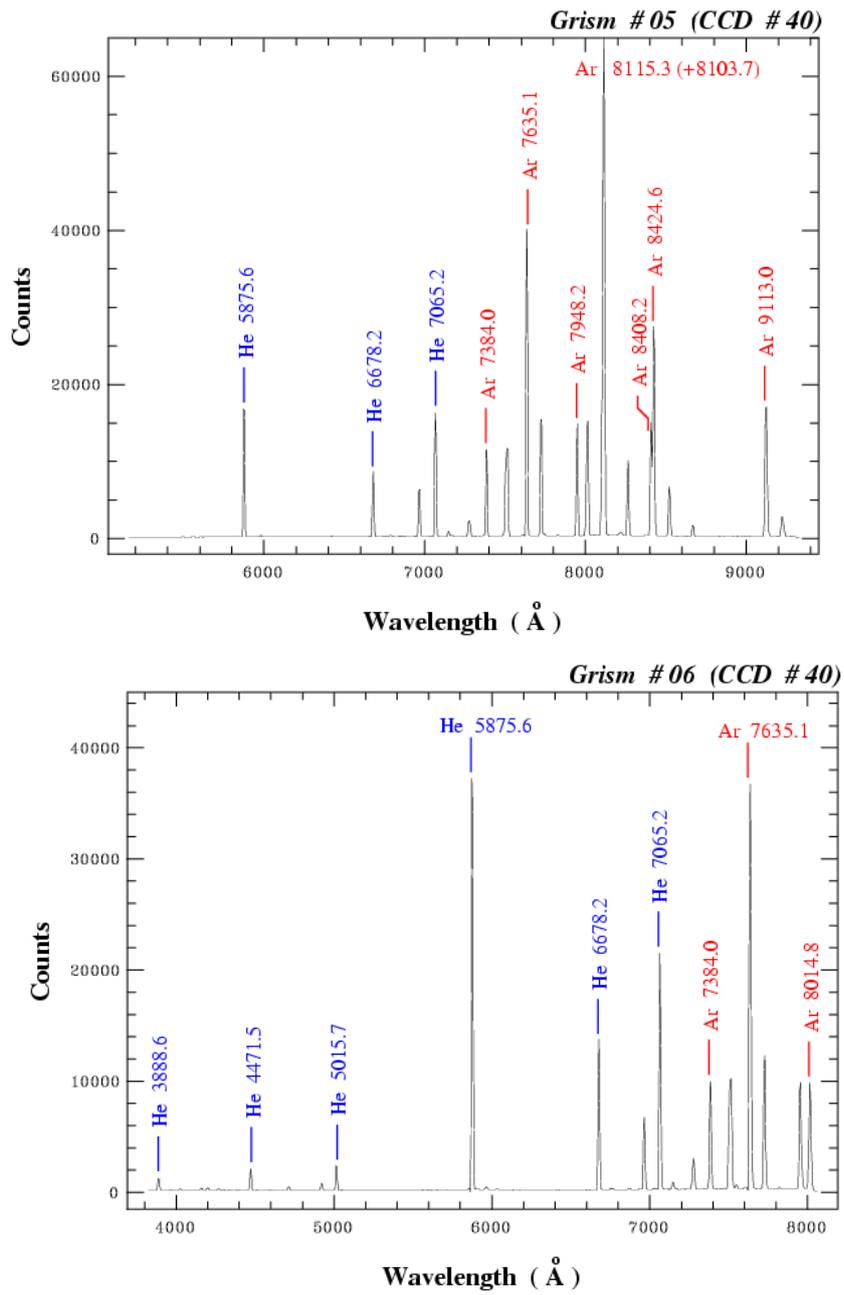Figure 36: Helium-Argon Atlas for grisms #3 and #4.

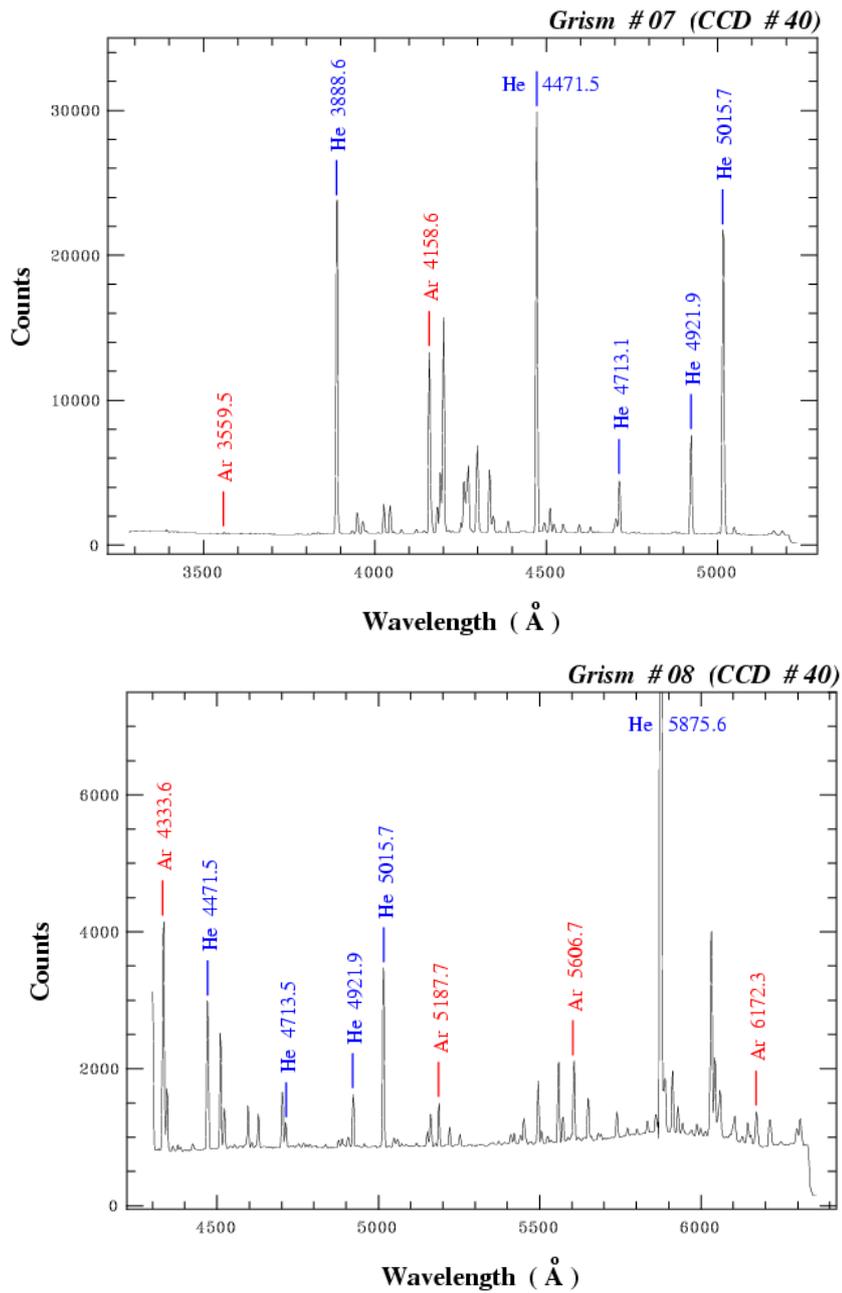Figure 37: Helium-Argon Atlas for grisms #5 and #6.

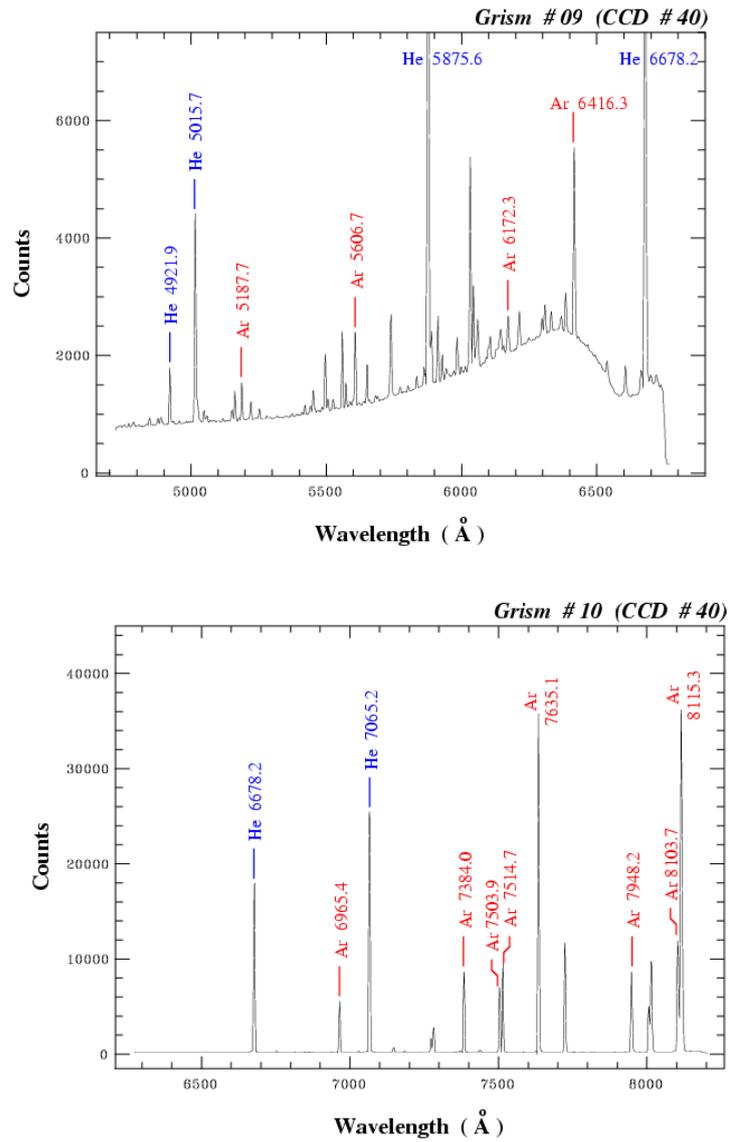Figure 38: Helium-Argon Atlas for grisms #7 and #8.

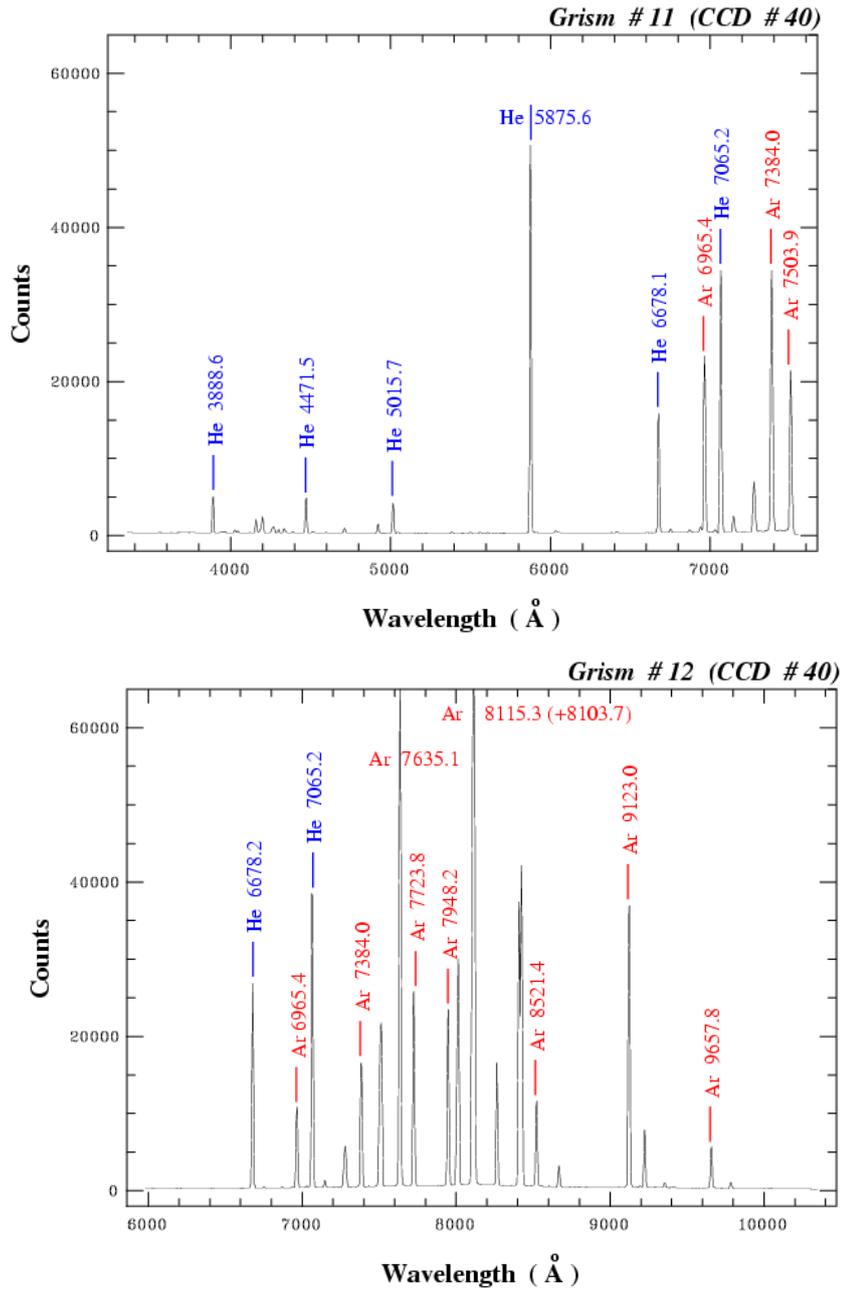Figure 39: Helium-Argon Atlas for grisms #9 (replaced by grims #16) and #10 (decommissioned).

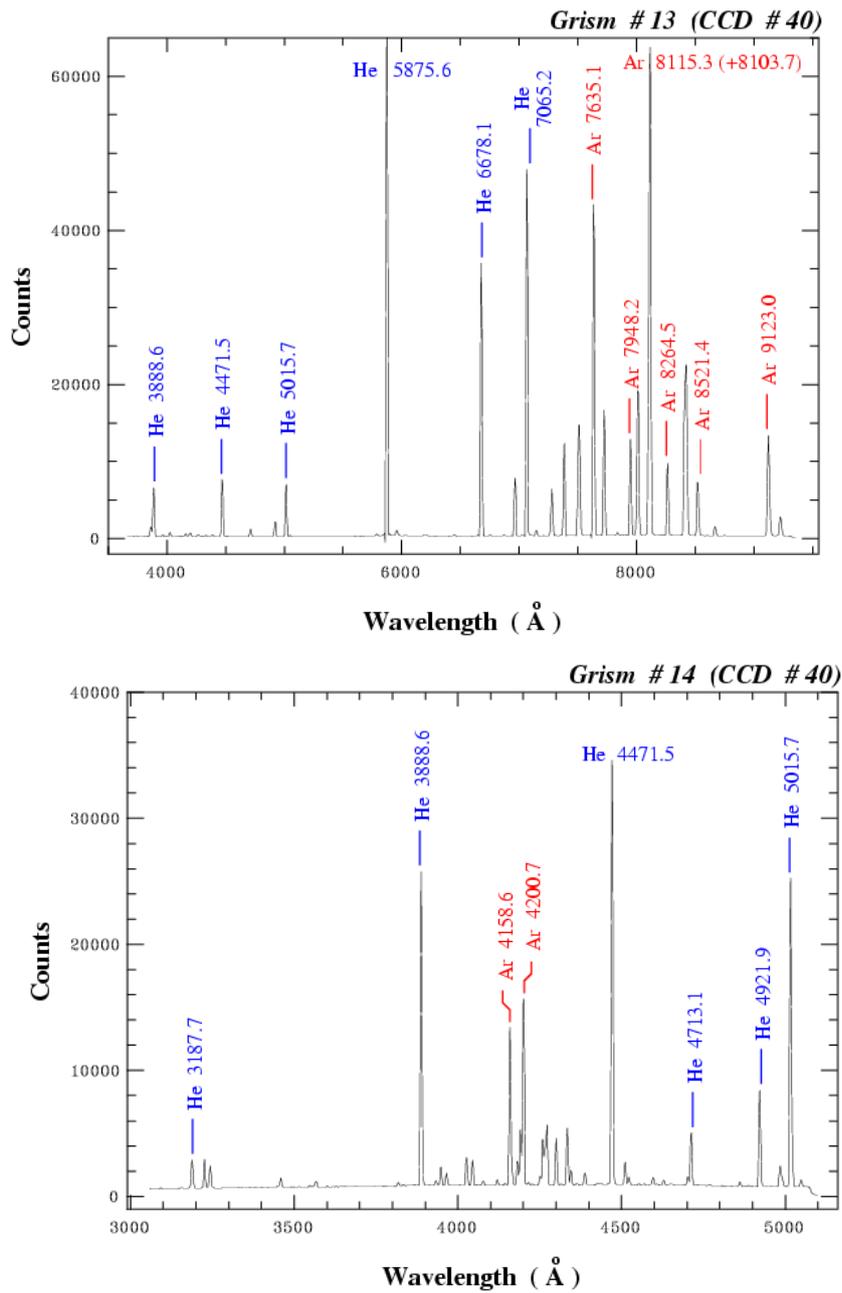Figure 40: Helium-Argon Atlas for grisms #11 and #12 (replaced by grims #16).
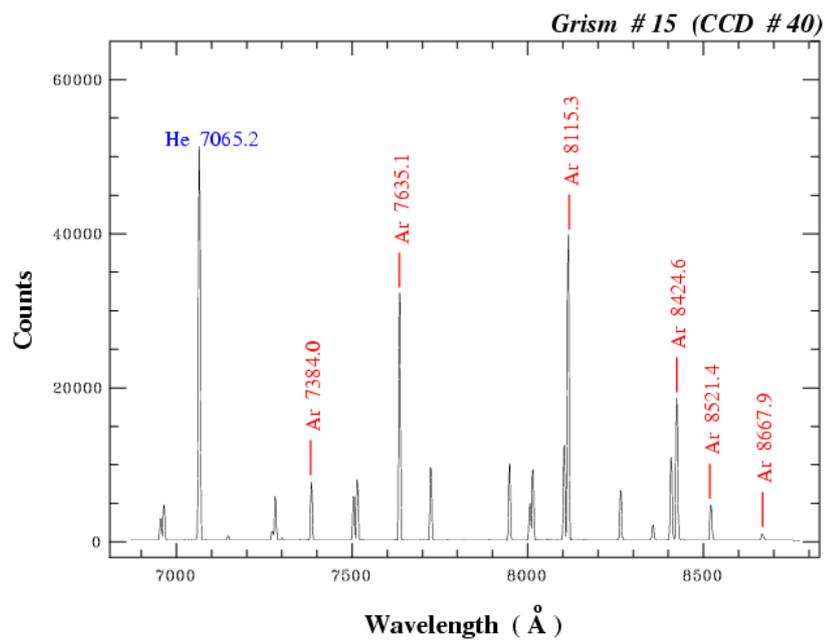
Figure 41: Helium-Argon Atlas for grisms #13 and #14.

Figure 42: Helium-Argon Atlas for grisms #15 (replaced by grims #17).