EFOSC2

Operating Manual

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Introduction

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 programmes. The obvious choice was to build a copy of EFOSC 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 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 an improved UV response, a lower sky background compensation, and provisions for easier handling of the optical components.

These notes describe in detail the main characteristics of the second ESO Faint Object Spectrograph and Camera (EFOSC2) including the properties of the optical components and the operation of the instrument on the 2.2m telescope. The present notes are sufficient to operate the instrument, and to help astronomers with previous knowledge of the EFOSC principles to prepare observing proposals.

A full description of the principles of the EFOSC instruments is given in the EFOSC(1) manual (ESO Operating Manual #4).

Chapter 2

Instrument configuration

2.1 Optics

A full description of the optical layout of EFOSC is given in ESO Operating Manual #4. Of course, the optical components of EFOSC2 differ from those of EFOSC1, but the optical layouts of the two instruments are the same. Briefly, the EFOSC instruments are focal reducers using multi-layer coated all transmission optics. The EFOSC2 camera opened to F/4.9 as compared to F/2.5 for EFOSC1. The focal length of the EFOSC2 camera is 200mm. The 2.2m plate scale is $11.67''$/mm and therefore the focal plane scale of EFOSC2 is $(8/4.9) \times 11.67 = 19.05''$/mm since the telescope is F/8. The interchangeable optical elements (slits, filters, grisms, etc.) are mounted on 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 the projected scale for slits is the telescope scale ($11.67''$/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.

The optical transmission of EFOSC2 is presented in Figure 2.1 where the transmission of EFOSC1 is also plotted for comparison.

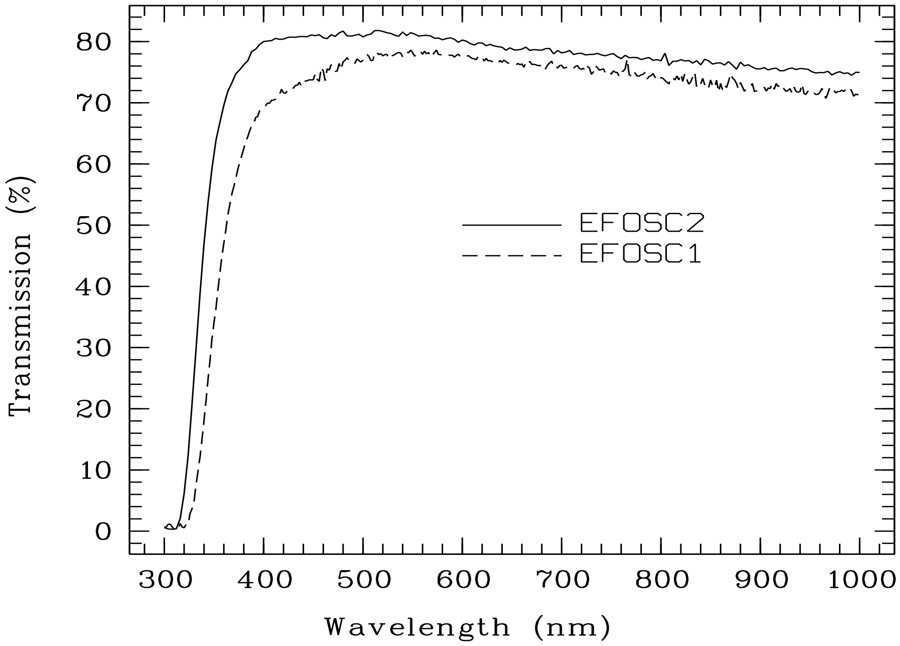

Figure 2.1: *Optical transmission of EFOSC2 compared to EFOSC1.*

2.1.1 Slits

Fixed slits of widths $0.75'', 1'', 1.5'', 2'', 5''$, and $10''$ are available for use with EFOSC2. In addition, a special set of movable slits of the same widths has been manufactured at La Silla for both EFOSC instruments. These slits can be displaced in order to adjust the wavelength range covered by the grisms. Only one of these movable slits can be mounted on a special position of the slit wheel. This is a time consuming operation and cannot be done during the night.

The slits can be displaced by ± 10mm with respect to the center position by means of an Allen 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 nm is,

$$\Delta Y = \frac{0.031}{D} \times \Delta\lambda$$

where D is the dispersion of the grism in nm/pix as given in Table 2.2. Moving the slit outwards in the wheel (turning the screw in the *clockwise* direction) corresponds to shifting the spectral lines towards the *blue* (the spectral coverage shifts to the *red*).

Fine tuning may be done considering that one full turn of the Allen screw shifts the projected slit by 25 pixels on the CCD ($25 \times D$ Å). Moving the slit in the negative Y direction (i.e. turning the screw clockwise) shifts the spectral lines towards the blue.

The fixed and the movable EFOSC2 slits are $5.7'$ long.

2.1.2 Filters

Up to 11 filters may be mounted in the filter wheel. As for EFOSC1, EFOSC2 filters are 60mm in diameter with a maximum thickness of 10mm. Because the filters are mounted at a relatively large distance from the focal plane, the quality of the images is very sensitive to filter defects. These may appear in the form of image blurs or ghosts due to multiple reflections inside the filters. Observers who wish to bring their own filters are reminded of the image quality requirements as described in the ESO Image Quality Filters Catalogue (A. Gilliotte, 1991).

Table 2.1 lists the EFOSC2 standard set of filters (the "basic-set"). For a complete list of filters available on La Silla consult the ESO Image Quality Filters Catalogue, or invoke the MIDAS context `FILTERS (create/gui FILTERS)` which provides utilities for searching for filters and extracting and plotting the transmission curves. The full characteristics of the basic set are also included in these references.

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. Table 2.1 gives an incomplete set of values. Values for other filters, however, are very easy to measure using a pin-hole in the aperture wheel and the MIDAS batch `FOCUS` *after the focus wedge has been calibrated.*

2.1.3 Grisms

There are at present 10 grisms available for EFOSC2. These are off the shelf units of characteristics similar to the grisms used with EFOSC1. The longer focal length of the EFOSC2 camera, however, results in higher resolving powers for the EFOSC2 grisms. The equivalent of the B300 and R300 grisms in EFOSC1 are not available in EFOSC2. It expected to purchase new units approaching these highly demanded grisms in the near future. In addition to the grisms, 2 prisms are available. These low dispersion devices do not show zero-th order images and are therefore more useful than grisms for slitless spectroscopy, in particular in combination with narrow band interference filters. Notice that only one set of prisms is available for both EFOSCs; EFOSC1 has priority in case of coincident requests.

Table 2.2 summarizes the properties of the EFOSC2 set of grisms. The values given in the table correspond to the Thomson 1024^2 CCD with 19μm pixels. Efficiency curves are given in Chapter 6.

Notice that the full spectral resolution of EFOSC2 can only be realized using narrow slits.

Table 2.1: *EFOSC2 Filters: basic set*

ESO #	**Filter**	λ_C (nm)	**FWHM** (nm)	**Peak trans.** (%)	**Red leak information**	Focus offset
631	U Bessel	354.5	53.8	68	< 0.005%@1100nm	
583	B Bessel	440.0	94.5	54	0.012%@1150nm	
584	V Bessel	547.6	113,2	87	0.055%@1150nm	0
585	R Bessel	643.1	165.4	86	0.076%@1150nm	+7
616	g Gunn	516.9	77.6	81	0.01%@1100nm	
617	r Gunn	681.4	83.8	83	0.01%@1100nm	
618	i Gunn	793.1	125.6	83	0.01%@1100nm	
619	z Gunn	> 840	—	98	—	-3
689	[OIII]	500.4	5.6	74	—	
694	H_α	657.7	6.2	56	< 0.01%	
698	H_α red.	665.9	6.1	54	< 0.01%	
702	[SII]	673.0	6.2	56	< 0.01%	

2.1.4 Wollaston prism

EFOSC2 can be used with the Wollaston prisms from EFOSC1 for imaging and spectro-polarimetry. (See the EFOSC1 manual for details about this options.) Of course, the separation of the two orthogonally polarized beams at EFOSC2 is different from the EFOSC1 values. At EFOSC2 the corresponding separations are 17.6$''$ and 35$''$ for the two Wollaston prisms. For imaging polarimetry, special masks similar to the ones used with EFOSC1 are available for EFOSC2.

Special masks may also be required for spectro-polarimetry of extended objects. At EFOSC1 these masks may be prepared using the PUMA machine. The width of the PUMA masks, however, is 3.5$''$ at the 2.2m making them unsuitable for most applications.

Please contact the La Silla staff concerning the possibility of manufacturing special spectro-polarimetry masks for EFOSC2.

2.1.5 Coronograph

One of the two coronographs available for EFOSC1 is very well suited for EFOSC2 and the spare of the EFOSC1 unit is now dedicated to EFOSC2. Tests done using this unit on extremely bright stars give very little scattered light when the Lyot stop is in place and

Table 2.2: *EFOSC2 Grisms*

GRISM #	Grating gr/mm	λ_{Blaze}	Wavelength range * (nm)	Resolution * (nm/pixel)
1	100	450	340 – 920	0.84
2	100	670	540 – 1050	0.84
3	400	390	352 – 547	0.19
4	360	470	465 – 680	0.22
5	300	670	580 – 840	0.25
6	300	500	460 – 720	0.27
7	600	380	358 – 484	0.12
8	600	530	464 – 595	0.13
9	600	650	587.5 – 702	0.11
10	600	650	660 – 782	0.12
prism #1	-	-	500 – 800	101 nm/mm @525nm 187 nm/mm @610nm
prism #2	-	-	350 – 550	99 nm/mm @350nm 188 nm/mm @525nm

* Using Thomson 1024^2 CCD with 19μm ($0.33''$) pixels

properly aligned. The layout and sizes of the coronographic spots are shown in Figure 2.2.

The alignment of the Lyot stop must be done using bright stars so observers using the coronograph must allow 1-2 hours at the beginning of the first night to perform this alignment. This is usually done by the opticians, but may be checked using the following procedure.

- Point telescope to a bright star (V=6 – 8) and defocus the telescope by about 500 encoder units
- Refocus guide probe and acquire a suitable guide star
- Obtain an exposure of the defocused image. Typical exposure time 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.

2.2 EFOSC2 CCD

The CCD presently used on EFOSC2 is ESO #19, a Thomson THX31156 1024^2 chip (ESO#19) with 19μm pixels corresponding to $0.362''$ on the sky. The measured scale, however, is $0.336 \pm 0.04''$/pixel. The difference is probably due to the fact that in the new ESO dewars the CCD sits further from the field lens than in the old ones. The field of view is thus $5.7' \times 5.7'$ and the orientation in the default position angle (PA=90° is North on top East to the right of the monitor.

The full characteristics of CCD#19 are described in the ESO CCD catalog. Briefly, CCD#19 is a thick, front illuminated, UV coated chip with excellent cosmetic and charge transfer characteristics. A radial pattern caused by the spin-coating treatment of the CCD is visible in narrow band and grism exposures. This pattern is also present at low levels in science exposures taken through broad band filters, probably due to airglow emission. When used in slow readout, the normal conversion factor is close to $2e^-$/ADU and the readout noise is less than $5e^-$. These values are measured every time the instrument is mounted on the telescope and are written on the set-up forms which are kept in a special folder in the 2.2m control room. The CCD linearity has been tested up to about half of the full well capacity. Thus, up to 60,000 electrons the CCD is linear to better than 0.2%. The possibility of using the full 16-bits of the AD converter has been implemented recently and linearity tests up to full well capacity are in progress, Please check with the introducing astronomer. The dark current is about 2 e^-/pix/hr.

The major drawbacks of the Thomson CCDs are low quantum efficiency and strong remanence after saturation. The quantum efficiency curve for CCD#19 is shown in Figure 2.3. Remanence appears if the CCD is saturated (i.e. exposed to levels above the physical saturation level of about $10^5 e^-$/pix). This remanence lasts minutes to hours depending on the level of saturation. At a level of the physical well capacity, remanence may last for a few minutes while for exposures of 4 times the physical saturation, the remanence may last several hours to full days. In these cases saturation may be eliminated by warming up the CCD. This may lead to significant loss of observing time. Therefore whenever possible AVOID SATURATING the CCD. Thus, special care should be taken during flat field and wavelength calibrations.

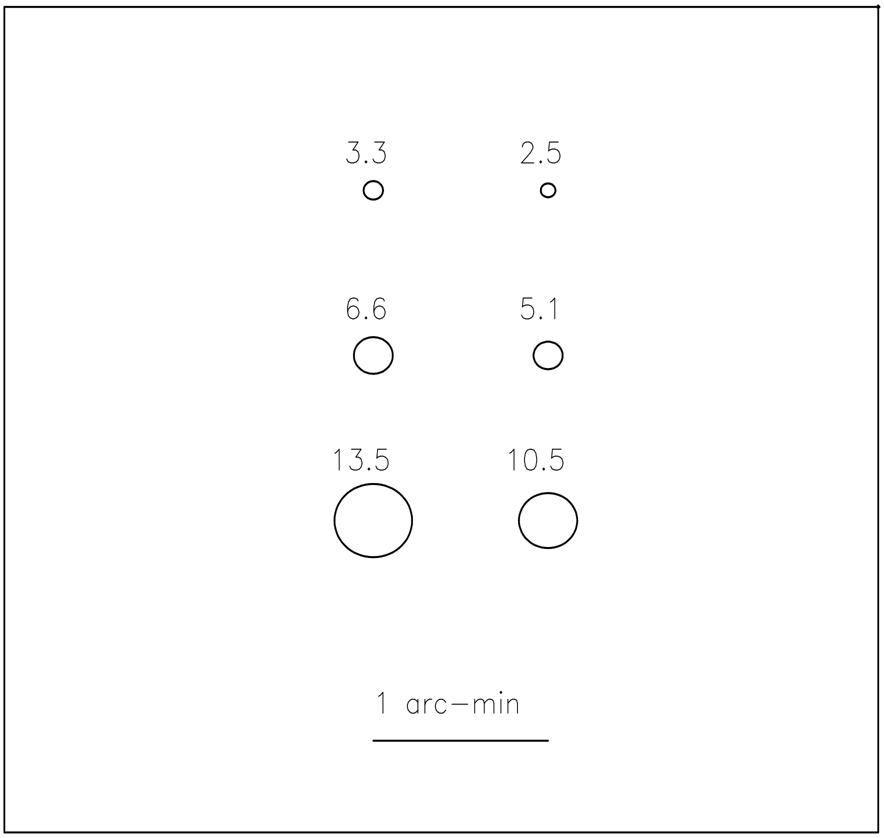

Figure 2.2: *Layout of the EFOSC2 coronograph. Spot sizes are in arc-seconds. The separation between spots is about 1′. The drawing is not made to scale.*

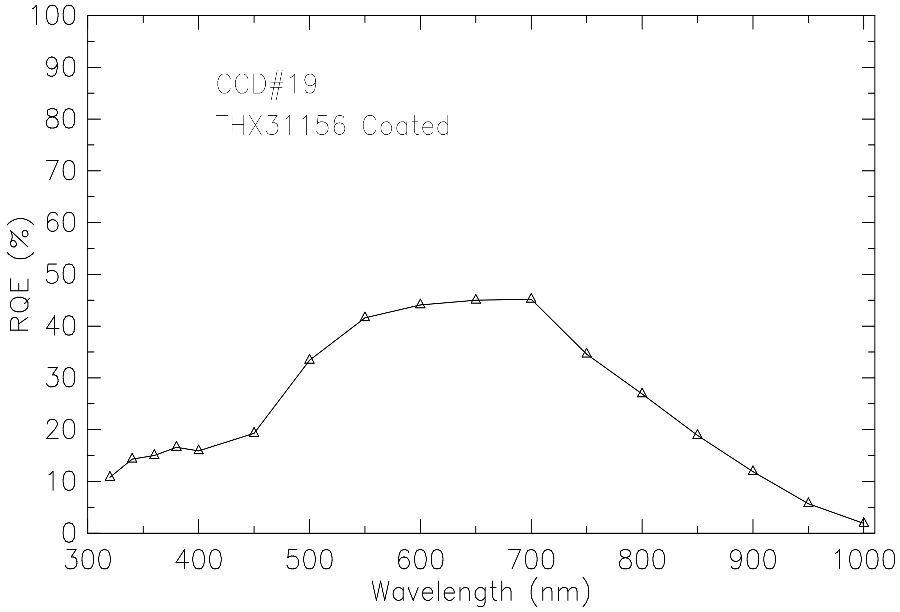

Figure 2.3: *Quantum efficiency curve for CCD#19*

Chapter 3

Observing with EFOSC2

3.1 The DISCO adapter

EFOSC2 is mounted on the so-called DISCO adapter (see e.g. The Messenger **48**, p. 51) without the image motion compensation system. DISCO provides the calibration lamps and the offset guider which consists of a TV camera mounted on an XYZ table. Light from the telescope is diverted to the offset guider by means of a diagonal mirror with a hole in the center. Therefore, when using EFOSC2 it is not possible to see the center of the field which can only be viewed by taking a direct exposure with the instrument. A FAST readout mode for the CCD is implemented for this purpose.

The field of view of the guide probe is $1.6' \times 2.2'$ and the orientation (with the slit at PA=90°) is North to the right and East to the bottom of the screen.

DISCO is operated from a separate console to the instrument HP1000 computer. The operation is very simple and makes use of soft-keys in two menus. The main menu of DISCO contains 3 principal softkeys: `Cal. lamp handling` which is used to manually turn on/off one or more calibration lamps in the adaptor, `GUIDEPROBE` that leads to a menu that allows moving and focusing the guide probe, and `Manual comb. offset` which is used to offset the telescope by a given value in RA and DEC and the guideprobe by the corresponding X and Y values in order to maintain the guide star in the autoguider box. A form appears on the screen where the values of the offset in RA and DEC, and the angle of the instrument rotator must be entered.

The `GUIDEPROBE` menu contains the following softkeys:

- `Move guideprobe ±X` and `Move guideprobe ±Y` to move the guide probe in the X and Y directions, and,
- `Move guideprobe ±Z` used for focusing the guide probe.

Once one of these keys is pressed, the guide probe keeps moving until the key is pressed again. During the motion the position of the changing coordinate is displayed on the DISCO console.

The key `Toggle to FAST(SLOW)` is used to toggle the X,Y,Z motions from fast to slow and viceversa. The label of this key changes according to whether the `FAST` or `SLOW` mode is selected. The scale of the guide probe is $0.128''$/step in X and $0.256''$/step in Y. The full field of view is $2' \times 3'$; the orientation is North on top, East to the right when the instrument rotator angle is $90°$ (slit oriented E-W).

The guideprobe can also be moved by typing the command `MOVE` on the DISCO keyboard. Thus, the commands

```
MOVE REL 1 x.xx
MOVE REL 2 y.yy
MOVE REL 3 z.zz
```

may be used to offset the guide probe from its current position by x.xx encoder steps in X, y.yy steps in Y, or z.zz steps in Z. The command `MOVE ABS 1(2,3) x(y,z)` may be used to send the probe to an absolute encoder value. The message `** Cannot move motor beyond software limit **` will appear if you try to move the guide probe too far. If this happens, move it back so further operations (like pointing for example) are not hampered by the guide probe running to its limits.

To start the DISCO program, simply logon as `DISCO` on the console next to the instrument one, and follow the instructions that will appear on the screen.

3.2 Using the autoguider

Make sure that the correct instrument has been specified to the TCS control program. To do this, hit the `MAIN MENU` soft-key in the TCS console and then the `instrument spec` key. A form will appear on the screen where the instrument specified should be EFOSC, the rotation angle should be 90 degrees, and the orientation flag (autoguider orientation) should be 0. Do not change any of the other parameters in this form.

Note

Do not forget to change the rotator angle in this form every time you rotate the instrument (as described below). The orientation flag should be 0 for angles 0°-180°, 3 for 181°-269°, and 6 for 270°-359°.

The autoguider cross hair should appear in the guideprobe console. Otherwise, turn it `ON` in the crosshair generator box. The size of the cross-hair box can be adjusted using special buttons on this unit, or using the softkeys in the `AUTOGUIDER` menu of the TCS. Four buttons on the telescope console located below the α and δ displays allow you to move the autoguider box, The menu `cross motion rate` allows to give a tracking rate (in $''/sec$) to the autoguider cross and thus to track solar system objects. Make sure it is set to 0.00, 0.00 for normal observations.

The autoguider is enabled/disabled using softkeys in the `AUTOGUIDER` menu. The key `autoguid ON w relx` turns the autoguider on *with relaxation.* This means that the cross-hair is moved to center the star before autoguiding starts. The key `autog. ON w/o relx` turns the autoguider on *without relaxation* meaning that the *telescope* is moved until the star is centered on the box and then autoguiding starts. The difference between these two options is very important for the operation of EFOSC. Normally, autoguiding is started with relaxation; the telescope position does not change. If, for any reason (e.g. clouds), an exposure is interrupted and you want to return exactly to the position you were before, autoguiding must be resumed *without* relaxation. Offset pointing with EFOSC is defined by the guideprobe position and, therefore, after combined offsetting autoguiding must be started *without* relaxation.

3.3 Rotating the slit

DISCO is mounted on the manual turntable of the 2.2m telescope. This table has an accurate Vernier scale engraved on the side which is unfortunately partially covered by the DISCO enclosure. Therefore, reading the scale is not easy. You will need a ladder and a pocket lamp to illuminate the scale. Even then the fiducial mark is difficult to see at some positions and you may need to use a secondary mark to set your angle. The scale reads Position Angle and the instrument is normally mounted at a position angle of 90° (i.e. slit oriented E-W). To rotate the instrument you must first release the clamp and then use the handle to move the instrument. This may also be done by simply pushing or pulling on the instrument itself. Please be careful not to pull any cables during this operation. The clamp has lock pins at right angles, so it will fall into lock at 90, 180, 270, etc.

Remember that the field orientation with the instrument at the default position angle (PA=90°) is North on top and East to the right.

3.4 The EFOSC2 control programme

The control programme of EFOSC2 is basically identical to the EFOSC1 programme described in the EFOSC manual. Only the position of some of the soft-keys differ, but the functions and the names are the same. To start the programme, logon as `EFOSC` in the instrument console (located next to the Ramtek display) and follow the instructions that will appear on the screen. Notice, however, that the softkey `Combined offset` only works when the IHAP batch `EFPOINT` is used.

3.4.1 CCD windowing and binning

It may convenient for your observing program to change the size of the readout window of the CCD (e.g. to save readout and storage time), or to bin the CCD pixels (e.g. for spectroscopy using slits wider than 1″). To do this go to the CCD menu on the instrument console. Press `previous menu` under the OBSERVING menu, then `TERMINATE`, `CCD`, and `CCD frame/binning`. A form will appear where you may specify the size of the readout window and the pixel binning in X and in Y. The readout window may be enabled/disabled by entering 1 or 0 on top of the field. This can also be done from the OBSERVATION menu using the commands `WIND,ON` and `WIND,OFF`.

3.5 Focusing the telescope with EFOSC

As EFOSC1, EFOSC2 incorporates a focus wedge that allows the telescope to be focused quickly and accurately. The focus wedge is normally mounted in position 8 of the grism wheel. The wedge divides the pupil into the upper and lower halves and separates the two by about 20 pixels along the CCD columns (X). When the telescope is perfectly in focus, the two images are round and should be aligned to better than a fraction of a pixel in Y. The vertical (Y) separation between the two images is a function of telescope focus which is linear for small amounts of defocusing. Therefore, by measuring the ΔY between the two images and iterating once, the focus can be accurately determined. The MIDAS procedure `FOCUS` (IHAP batch `EFOCUS`) are available to analyze focus wedge exposures.

The focus wedge is normally calibrated every time the instrument is mounted on the telescope. The calibration is obtained in two steps: firstly, the internal focus of the instrument is adjusted using the Hartmann screens. These are generally mounted in positions 3 and 5 of the grism wheel. You may easily run the Hartmann test yourself by using the `Def Hartm foc exp` softkey in the `-- ETC --` menu of the EFOSC main menu. The IHAP batch `SFOCS` (normally specified in the form) gives you the shift between the two Hartmann images at the edges and center of the slit. Should this shift be more than 0.1 pixels call Operations. The focus wedge alignment is checked by taking a direct image of a pinhole mask mounted in the slit wheel with the focus wedge. Typically a one second exposure with the Ar lamp and no filter should give a good exposure. Run the MIDAS procedure `FOCUS` (IHAP batch `EFOCUS`) on this image. The resulting telescope focus correction should be close to zero. If it differs significantly from zero (i.e. more than 5 units) call Operations. This procedure may be used with different filters to determine filter offsets. For the EFOSC2 basic-set filters these offsets are negligible.

A menu for obtaining through focus exposures is also provided (`Def thr.  focus exp`).

During the night, the telescope focus may be checked by taking direct exposures of stellar fields through the focus wedge. Because the focus wedge doubles the number of images it is advisable to avoid taking focus exposures in crowded fields. Any filter without focus offsets may be used. At the 2.2m the telescope focus is a very well determined function of temperature, and the equation:

$$\Delta Focus = -19 \times \Delta T$$

may be used to correct the telescope focus for temperature variations. The nominal telescope focus for EFOSC2 is Focus = 4360 for $T = 15.0\ ^{\circ}C$. One encoder step corresponds to 5μm of secondary mirror translation, and to 40μm of focus change. The secondary moves down when the encoder steps increase.

Notice that the image quality at the edges of the EFOSC2 field is very sensitive to focus. Tests done on a globular cluster field show that in order to keep the Point Spread Function (PSF) constant to 10% over the full field, the focus must be controlled to better than 10 units. If the focus is off by 20 units, the FWHM of the images at the edge of the field is about 20% larger than at the center. Therefore, for wide field applications, it is recommended to check the focus often, and to use stars scattered over the full field when applying the focus wedge. Notice that the focus batch procedures (`EFOCUS, FOCUS`) use Gaussian fitting to the images inside the shown boxes to determine centroids. Therefore, for critical applications, make sure that you select single stars for focusing.

3.6 Centering an object in the slit

As mentioned above, slit viewing is not possible with EFOSC2. Therefore, the following method must be used to center an object in the slit.

You will receive an instrument set-up form which shows the optical configuration of EFOSC2 including slits, filters, and grisms. The slits and grisms you requested will be indicated either by an asterisk, or as `aligned` . This means that slits have been oriented to coincide with the CCD rows, and that the dispersion direction coincides with the CCD columns to a fraction of a pixel. Next to the slits, you will also see the slit position (e.g. `Y=510.5)`. This is the position on the CCD where the slit is located in projection. Therefore, to center an object in this slit, you must position it at any desired X (within the long slit) and at Y=510.5. The IHAP batch `EFPOINT` and MIDAS procedure `POINT` help you in doing this. Thus, the procedure to center an object in the slit is as follows:

- Point the telescope, acquire a guide star, and begin autoguiding *with relaxation.*
- Obtain a direct image of the object. Broad-band filters introduce very small offsets to the position of the slits (which are measured without filter), but you may want to check this by measuring the position of the slit with the filter that you will use for pointing. Remember that the slits are in the telescope focal plane so that once an object is centered it remains centered independently of the elements you introduce in the filter and slit wheels.
- Use the IHAP batch `EFPOINT` or MIDAS procedure `POINT` to determine the offset to be applied to the telescope (and guide probe) to bring the object to the position of the slit.
- If **IHAP** is used, apply the offset to the telescope and guide probe using the soft-key `Combined offset`. The TCS will take from IHAP the $\Delta\alpha, \Delta\delta$, and rotator angle parameters. If **MIDAS** is used, apply the offsets using the command: `OFF` $\Delta\alpha$ $\Delta\delta$ `ANGLE` where ANGLE is the position angle of the rotator. Usage of the soft-

key $\boxed{\texttt{Combined offset}}$ when IHAP is not used may result in an error and should therefore be avoided.

After a short delay the guide star will return to the autoguider box, and autoguiding will be automatically restarted. If this does not occur, start the autoguider manually *without relaxation* .

- Repeat the procedure to verify that the star is properly centered. This is important because the telescope drive system was not designed for accurate offsetting. EFOSC2 offsetting relies on the guide probe which must be checked. The batches `EFSLIT` (IHAP) or `SLIT` (MIDAS) will draw the slit on the graphics displays.

Warnings!

The pointing procedure will fail if the guideprobe is too close to one of its limits.

Also it may happen occasionally at extreme declinations that the telescope fails to offset in δ. If this occurs, manually center the guide star in the autoguider box, and restart the autoguider **without relaxation.**

There is some flexure in the instrument for declinations $\delta > +10°$. The shift in (Y) slit position ranges from ~ 0.1 pix at $+10°$ to about 0.3 pix at $+30°$ does not exceed 0.3pix.

3.7 Basic calibrations

The standard CCD calibrations: bias, dark, flat field, standard stars, and spectral lamps, are needed to properly calibrate EFOSC2 data according to the requirements of each specific observing program. The following calibrations, however, require special attention.

3.7.1 Flat fields

It is generally recommended to use sky flats for all direct imaging applications. Dome flats do not illuminate the full CCD uniformly. The residual of dividing a dome flat (illuminated with sunlight) by a sky flat through the same filter may be as much as 10% at the edges of the CCD. Sky flats may be obtained during evening and morning twilight. Extreme care must be taken NOT to saturate the CCD during these exposures. Thus, it is recommended to window the CCD to a small area (e.g. 100×100 pixels) and to use it as an exposuremeter to determine the appropriate exposure level. Begin with short exposure times to avoid saturation. A practical guide for twilight flat-field exposures is given by Tyson & Gal (A.J. **105,** p. 1206, 1993).

For narrow band work and for spectroscopy sky flats are not recommended. In these cases use dome flats illuminated by halogen lamps. *Notice that it is very important that spectroscopic flats be taken using the same slits used for science observations.*

3.7.2 Wavelength calibration

He, Ar, and Ne lamps are available for wavelength calibrations. The EFOSC program can handle up to 4 lamps using the `MC` (Multiple Calibration) option. Thus, wavelength calibration is straightforward except that for some grisms (in particular #1 and #2) the lamps are too strong and attenuation must be used. A continuous neutral density wheel has been installed for this purpose to attenuate the light of the calibration lamps by up to a factor of 100. The neutral density wheel is moved with a set of buttons located immediately below the RAMTEK monitor and its position in encoder units (EU) is indicated by the digital readout next to the buttons. The relation between transmission (%T) and EU is: $log(\%T) = 0.05 \times EU - 0.03$.

The exposure times for a 1.5$''$ slit range from a couple of seconds for He and Ar using Grisms 1 and 2 with maximum attenuation (EU=25), to He(2s) and Ar(120s) for Grism 9 without attenuation (EU=1). Remember, however, that saturation of the CCD must be strictly avoided so you must be extremely careful when doing wavelength calibration exposures. Therefore, always do some tests to determine the optimal exposure times for your particular set-up keeping in mind that, for long slit applications, *properly exposed wavelength calibrations are crucial to correct the curvature of the lines introduced by the grisms.*

A He-Ar atlas for the EFOSC2 grisms is presented in Appendix C.

Chapter 4

EFOSC2 efficiency

Indicative colour equations in the Bessel UBVRI system are given below. Capital letters denote the standard magnitudes and low case letters the instrumental magnitudes which were computed using counts in electrons per second. No extinction corrections were applied to the observations which were obtained at an airmass of 1.15. Notice that Gunn i instead of Bessel I filters are used at La Silla.

$$U - u = 20.55$$

$$B - b = 0.26 \times (B - V) + 23.03$$

$$V - v = 0.06 \times (B - V) + 24.38$$

$$R - r = 24.54$$

$$I - i = 23.17$$

Typical count rates through large apertures are given in Table 4.1 for 4 Landolt standards of widely different colours. The z rates correspond to the Gunn z band. The colour equations may also be used to estimate the expected count rates.

The measured total efficiency of EFOSC2 at the 2.2m telescope in spectroscopic mode is given in Table 4.2. These measurements were made in photometric weather and good seeing. A $5''$-wide slit was used to include all the stellar light.

Table 4.1: *Typical count rates in the UBVRI(Z) system*

Star	V	B-V	count rate ($\times 10^3 e^-$/sec) U	B	V	R	I	z
98-670	11.93	1.36	0.3	10.8	97.2	202	104.6	-
Mark A2	14.54	0.68	0.12	1.6	8.8	14.0	5.6	3.1
98-685	11.95	0.47	1.6	18.8	90.8	113.6	50.4	-
Mark A	13.26	-0.24	2.4	9.4	27.6	29.2	7.6	3.3*

* Notice that Mark A has a faint, extremely red companion

Table 4.2: *EFOSC2 efficiency in spectroscopic mode*

Monochromatic Magnitude LTT 9239:	13.4	12.8	12.4	12.2	12.0	11.9	11.8	11.8	11.7	11.6	11.6
Wavelength (nm)	350	400	450	500	550	600	650	700	800	900	1000
Grism #						e$^-$/sec/Å					
1	3.5	14	28	55	73	63	58	51	32	6.5	—
2	—	—	—	0	60	78	84	82	39	14	2
3	—	—	—	—	—	—	—	—	—	—	—
4	—	—	0	51	67	62	57	0	—	—	—
5											
6	—	0	25	53	72	70	67	54	0	—	—
7	5	13	22	0	—	—	—	—	—	—	—
8	—	—	—	45	61	—	—	—	—	—	—
9	—	—	—	—	—	45	51	—	—	—	—

Chapter 5

EFOSC2 observing batches

The CCD images are simultaneously transmitted to IHAP and MIDAS so that either system may be used for on-line data processing. However, IHAP processing is much slower than MIDAS which is therefore *strongly* recommended. Notice that at present there is no link between the MIDAS workstation and the 2.2m TCS computer. Therefore, frames in MIDAS appear without header information. For that reason, IHAP *must* be used for data saving, but only 100 Mby of disk space (the maximum allowed by IHAP) are available for data storage in the IHAP database. The commands `PURGE` and `PACK` must therefore be used to make space for new images. *Be sure that your data are stored on tape before using these commands.*

A DAT drive connected to the workstation is available for data storage. Remember, however, that images will be stored *without header information.* Therefore, the DAT may be used as backup in case some data are accidentally lost during the IHAP database cleaning, but *only the data stored by IHAP are archived and copied onto your personal data tape.*

The full 16-bit dynamic range of the CCD A/D converter is preserved in MIDAS and now also in IHAP. In MIDAS the numerical saturation level is 65,536 and intensities range from 0 to saturation. In IHAP the numerical saturation level is 32,768 and pixel intensities range from -32,768 to +32,768. Thus, the bias level in MIDAS will typically be around $180e^-$ and in IHAP about -32,588.

To log–on in the MIDAS workstation the username is `CCD` and the password is `lasilla`. The MIDAS observing procedures invoked are essentially identical to the corresponding IHAP batches and are briefly described below.

5.1 IHAP batches

A number of IHAP batches are available to the observers. The list of batches with a brief description of their use is given below. In most cases the batches have been adapted from EFOSC1. The batch programs have a help facility that may be called with the command: `BATCH,xxxxx,,HELP`

EFPOINT
Description: Point offsetting from direct image.
Syntax: `BATCH,EFPOINT,,XSLT,YSLT,[size],[angle]`
Parameters:

XSLT, YSLT	=	position of the slit.
size	=	(optional) size of centering box. Default = 15 pix.
angle	=	Position angle of the slit. Default = 90 deg.

Note that if angle=0 a small number (e.g. 0.01) must be given to avoid the default.

EFSLIT
Description: Draw slit position.
Syntax: `BATCH,EFSLIT,,[#],XSLT,YSLT`
Parameters:

#	=	(optional) file number. Default: G10.
XSLT,YSLT	=	slit position.

EFROTA
Description: Determine angle between two objects.
Syntax: `BATCH,EFROTA,,[CURSOR]`
Parameters:

CURSOR	=	(optional) Use cursor position instead of Gaussian fits.

EFOCUS
Description: Focus using focus wedge.
Syntax: `BATCH,EFOCUS,,[#]`
Parameters:

#	=	file number. Default G10.

EFSEE
Description: Determine seeing.
Syntax: `BATCH,EFSEE,,[#],[size],[FAST]`
Parameters:

#	=	file number. Default G10.
size	=	(optional). Size of centering box. Default = 15 pix.
FAST	=	(optional). No average given.

KDISPC

Description: Determine cuts automatically.
Syntax: `BATCH,KDISPC,,[#]`

TFOCUS

Description: Focus of telescope using through–focus sequences.
Syntax: `BATCH,TFOCUS,,[#],[start],[step],[box]`
Parameters:

#	=	(optional) File number. Default: G10.
start	=	(optional) Stating focus value. Default: 0.0.
step	=	(optional) Focus step. Default: 1.0.
box	=	(optional) Centering box size. Default: 20 pixels.

5.2 MIDAS procedures

As described above, the MIDAS observing batches may be run by clicking the corresponding button on the graphical X11 user interface that appears on top of the MIDAS display window. A description of the procedures invoked by these buttons is given below. The corresponding button in the X11 interface is also indicated.

`load/cut image [-n ]` Equivalent to KDISPC. The optional parameter (n) is the scaling factor as in the MIDAS command `load/image`.

focus: This is a pull-down menu with 2 options:
focus wedge (`@@ focus`) which is equivalent to EFOCUS, and
focus sequence (`@@ tfocus [start] [step]`) that is equivalent to TFOCUS.

seeing: `(@@ seeing)` . Equivalent to EFSEE.

point: `(@@ point [xslit] [yslit] [angle] [flag])` . Equivalent to EFPOINT. The procedure prompts for the parameters if not given. The angle is defaulted to 0. If the flag is set to `C` the graphics cursor is used to define the position instead of Gaussian fits (default).

slit: `(@@ slit xslit yslit)` . Equivalent to EFSLIT.

rotate: `(@@ rotate)` . Equivalent to EFROTA. This is a pull-down menu with two options for gauss, and cursor centering of the objects.

trace: This calls the MIDAS command `extract/trace`. The trace is extracted between a fiducial point and the position of the mouse cursor. Use the arrows to change the fiducial mark. The keyboard keys 1-9 may be used to speed up this motion.

catalog: This pull-down menu has options to list the headers of the EFOSC files in the MIDAS window, and to reset the catalogues. Once the catalogues are reset, they must be created again with the `create/icat` command. This is automatically done at the beginning of the session.

tape : This pull-down menu has options to manipulate the DAT drive attached to the workstation.

utils: This pull-down menu contains options to get the cursor and to print the graphics windows on the laser printer.

Chapter 6

EFOSC2 optical efficiency

The enclosed figures plot the efficiency of the EFOSC2 grisms. Efficiencies for grisms of similar resolving powers are plotted on the same figures. The average efficiencies for light polarized perpendicular and parallel to the grating rulings are shown for grisms 7 to 10. The effect of polarization is less than 10% for all grisms and all wavelengths.

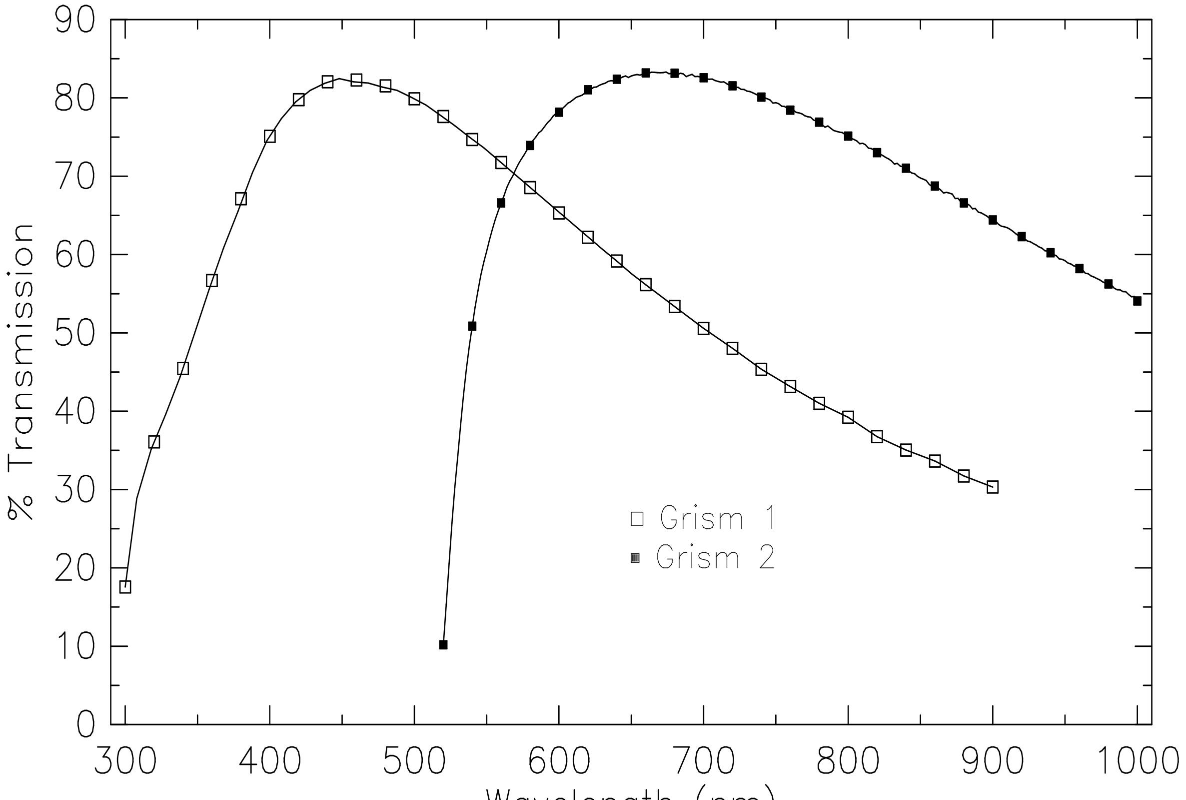

Figure 6.1: *Efficiency curves for Grisms #1 and #2*

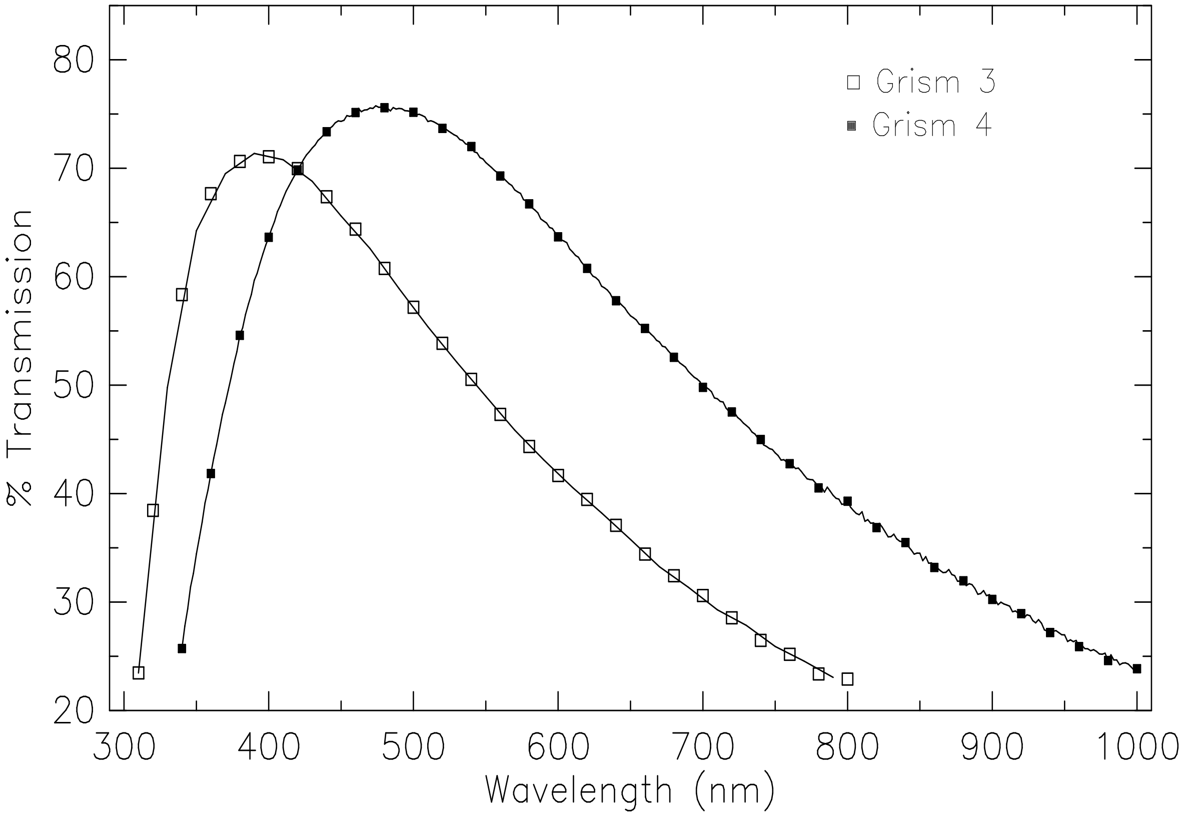

Figure 6.2: *Efficiency curves for Grisms #3 and #4*

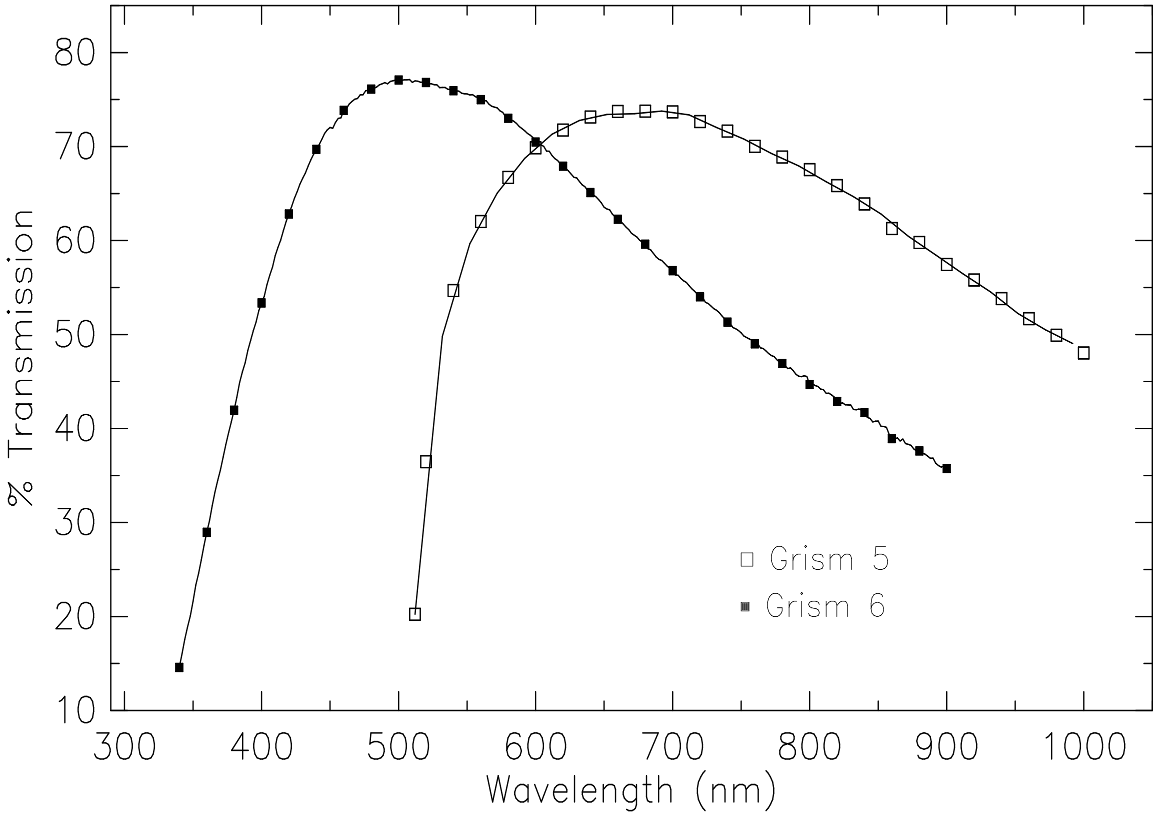

Figure 6.3: *Efficiency curves for Grisms #5 and #6*

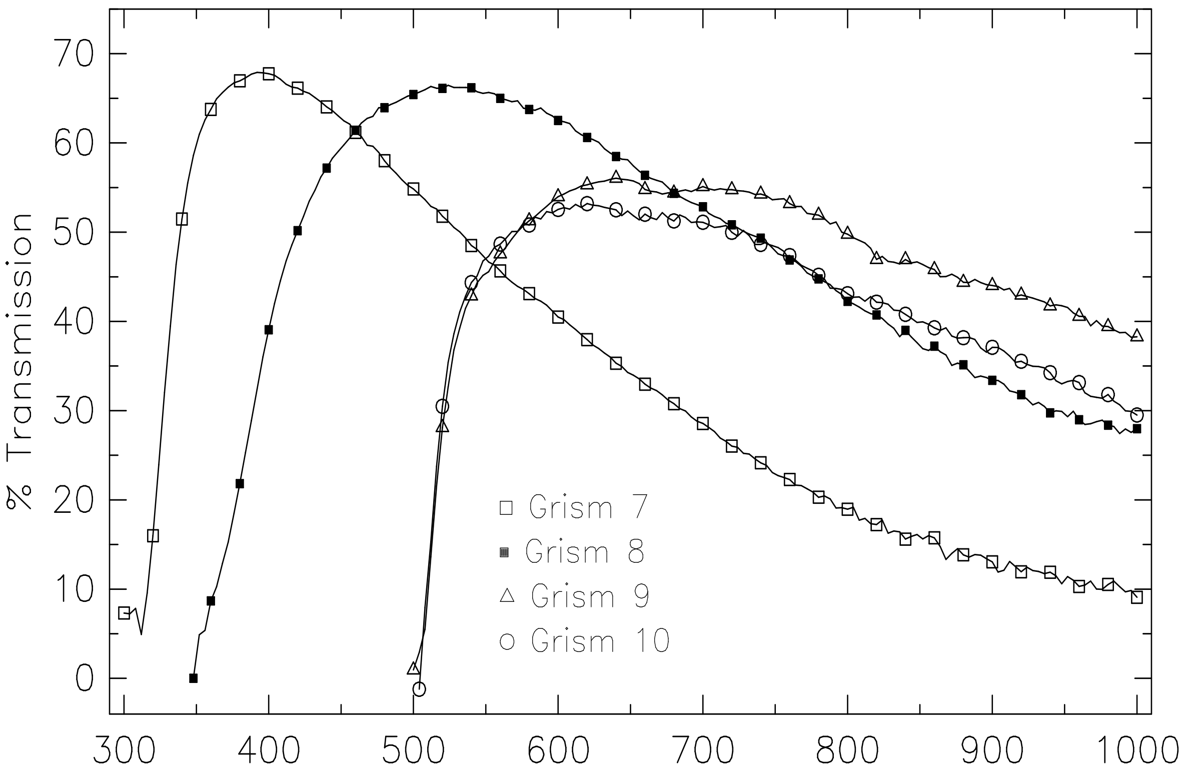

Figure 6.4: *Efficiency curves for Grisms #7, #8, #9, and #10. The full wavelength range plotted in these figures is much larger than the actual range covered by EFOSC2 which is given in Table 2.2.*

Appendix A

Check-list for EFOSC2

- Check in the TCS console if the instrument is correctly set up to EFOSC2 and if the rotation angle is the correct value. The autoguider orientation can be 0 or 3 depending on the rotation angle. (see Section 3.2).
- Check the pointing of the telescope and do a *Correct Coordinate* (see section A.2).
- Focus the telescope (see sections 3.5 and A.3).
- Go to your object (section A.4).
- Look for a guiding star from the DISCO console (section 3.2). When found start guiding with relaxation.
- In order to check the position of the object on the CCD take a short exposure.
- Use the MIDAS command `POINT` to obtain the offset that should be given to the telescope (see Section 3.6) in order to have your object where desired (for example, on the slit, for spectroscopic observations).
- If you need to change the orientation of the instrument go to the dome and rotate it manually (see Section 3.3, usually the night assistant will do this for you).
- In the TCS console press `Main Menu` and `Instrument spec` and change the the rotation angle to the new value and the autoguider orientation accordingly (it is important that you read the "Note" in Section 3.2 before doing this).
- Define and start your exposure. Guiding should be started without relaxation.
- Calibration with multiple lamps can be done by specifying MC in the form for exposure definition.
- Monitor the temperature of the telescope to find out when to refocus the telescope again.
- Remember to never saturate the CCD since it will have a strong remanence after saturation.

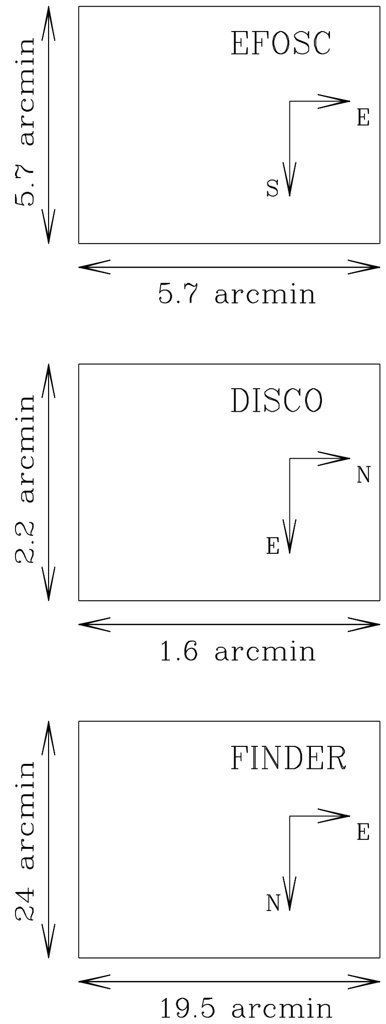

Figure A.1: *Field size and orientation for EFOSC2, DISCO, and FINDER*

A.1 Field Orientations

Appendix B

Using the TCS of the 2.2m telescope

Occasionally, in particular during the Summer holiday period, observers may need to operate the telescope without a night assistant. While there will always be one person on call to assist in case of problems, and to initialize/close the telescope at the beginning/end of the night, the observers will be most of the time alone. The following notes are intended as a user guide for the operation of the telescope under these circumstances.

B.1 Starting-up

This operation will normally be done by the night assistant on call. But they are simple, and knowledge by the observer may in some cases save some time at the beginning of the night, especially when twilight flats are to be done.

- Check that the red emergency knob, located on the telescope control panel (below UT clock) is OUT.
- Go to the dome and make sure that the dome control switch (dome control panel is behind the Zeiss console) is set to REMOTE
- At the Zeiss console press the ON buttons at numbers 1 and 2 (written in green pen on the console). These are the oil press ("Hydraulik") and the alpha–delta drives ("Antriebe"). Also make sure that the buttons marked in the sequence 3–7 are pushed in and are lit.
- Back in the control room, check if the yellow ESO/Zeiss button, located below the red emergency knob, is lit (if not, make sure that the last step was done correctly).
- Send the telescope to the zenith. To do this, on the TCS `Main Menu` press `Preset` and `Go to zenith`. A message should appear saying that the telescope is initialized.

- Press the dome slit power button (immediately left of the red emergency knob).
- If you want to point the telescope to the white screen in order to take dome flats go to `Main Menu`, `etc` and `Go to cal. point`
- If you want to open the dome, then, on the TCS console hit `Main Menu` and `Dome Control`. Open dome with the `Open Dome` option and set dome control to automatic by pressing `Automatic Dome`. Once open, turn off dome slit power.
- The mirror cover can be opened by pressing `Main Menu`, `etc` and `Open Mirror Cover`.
- Make sure that the correct instrument is specified to the TCS control program. For this press `Main Menu` and `Instrument spec`. A form will appear. Set the instrument to + DISCO (# 4) and the flag (autoguider orientation) to zero. Do not forget to change the Rotation Angle and the flat (if needed) if and when you rotate the instrument (as described in Section 3.2). The default value for the rotation angle should be 90 degrees.

The telescope is now ready to observe. The only remaining step is to reset the zero point of the pointing model (the so called `CC` *Correct Coordinates procedure.)*

B.2 Checking the pointing of the telescope

In order to use the `CC` *Correct Coordinates procedure* you must wait until it is dark enough so that bright stars can be seen. Remember that both the Guide Probe and the Finder cameras use Bosch intensified TV tubes that may be damaged if exposed to bright light. Therefore we normally wait until the beginning of nautical twilight to do the CC, but being very careful you can also do it some time before. In any event the procedure is as follows:

- Select a suitable star from the Astronomical Almanac (mag $\sim 3-6$). Enter into the Catalog (see Section A.3 below) as they will be useful throughout your run.
- Point to the selected star (see Section A.4).
- Turn on the Finder TV camera. The Finder monitor is the one located at the rightmost end of the console, immediately above the TCS keyboard. The switch is to the right of the FINDER TV camera screen, where it is written CAMERA ON.
- Make sure that the monitor is on and that noise appears on the screen. Otherwise adjust brightness and contrast levels.
- Slowly increase the tube high-voltage using the knob below the CAMERA–ON switch. Check that the signal does not become too bright.

- Try to find the star. Stars down to the limit of the catalog are easily visible on the screen. If the star is not immediately visible, either there is a problem with the coordinates or the dome is blocking the light to the finder that is a separate telescope mounted on the side of the main tube. The latter is most often the case. Switch the dome to `Manual` and move in both directions until the star is visible.
- Switch the telescope motion to `Set` and center the star on the pencil mark on the screen usually labeled EFOSC
- If very accurate pointing is needed, take an image with EFOSC (remember that you are looking at a very bright star so use an interference filter or a U filter and a 0.5 second exposure or shorter) and use the batch `POINT` to center the star where you want it to be on the CCD.
- In the TCS console, in `Main Menu` press `etc` and then `Point Measure`. To set the telescope pointing to the star coordinates press `Correct Coordinate`.

You are now ready to go.

B.3 Focusing the telescope

The procedures to focus the telescope with EFOSC are described in Section 3.5. In order to enable a change of focus the small white switch at the right edge of the TCS keyboard has to be in the upward position. Immediately left to this switch there are four buttons for focusing FAST or SLOW and to move DOWN or UP in focus steps. With these buttons one can change the telescope focus as needed.

It is advisable to check the temperature of the telescope several times during the night by pressing `Main Menu`, `etc` and `Long tel temp dis`. The important number is the one at the bottom line of the table, under column 2, the long Serrurier temperature. An equation that describes the change in focus steps as a function of temperature change is shown in Section 3.5.

B.4 Presetting the Telescope

In order to gain time during the night, particularly in cases when you do not have a night assistant, it is advisable that you enter the coordinates of the objects you will be observing in a catalogue, for easy access. This can be done on the TCS computer, by pressing `Main Menu`, `Catalogue` and `Enter to Catalogue` and by entering the coordinates and epochs of the objects appropriately. After this is done, when you want to point the telescope to a target just press `Catalogue`, `Preset`, `Go to Catal object` and give either the number or the name of the object in the catalogue. To list the catalogue, while in `Catalogue` press `list catalogue` and give the range of objects to be listed from 1 to 100.

You can also point the telescope to an object directly, without putting its coordinates in the catalogue. For this press `Preset`, then `Go to new object` and enter the coordinates accordingly.

Once the telescope is pointing to the object, a short exposure should be taken to check if the field is the correct one. If spectroscopy is needed the slit has to be placed on the desired position (see Section 3.6). Rotation of the slit is possible and it has to be done from the dome (see Section 3.3). If autoguiding is needed follow the instructions given in Section 3.2 on how to use the autoguider.

B.5 Shutdown Procedures

A night assistant will always be available to close down the telescope and the dome but the procedures are very simple and the observers can also do this themselves, if wanted. Essentially what has to be done is what was described in Section A.1, but in reverse order.

- Send the telescope to the zenith.
- Close the mirror cover.
- Press the dome switch power on.
- Close the dome and press the dome switch power off.
- In the dome, at the Zeiss control panel, press button number 1 only (oil press), to turn it off.
- Push red emergency knob IN.

Appendix C

He-Ar Atlas for EFOSC2 grisms

A graphical atlas of the Helium-Argon spectrum taken with the different EFOSC2 grisms is given below. All spectra were taken through a $1.5''$ slit.

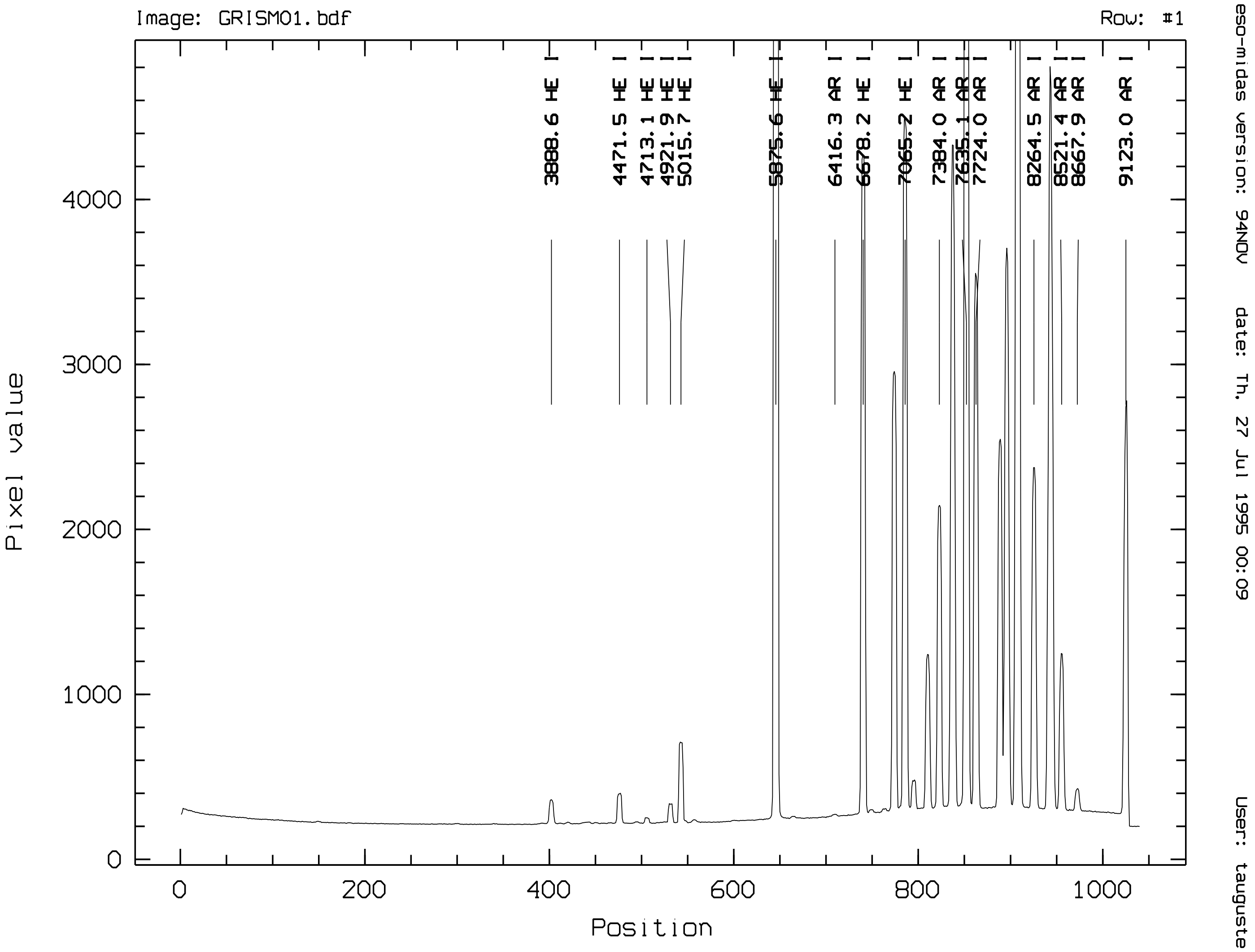

Figure C.1: *Helium-Argon atlas for Grism#1*

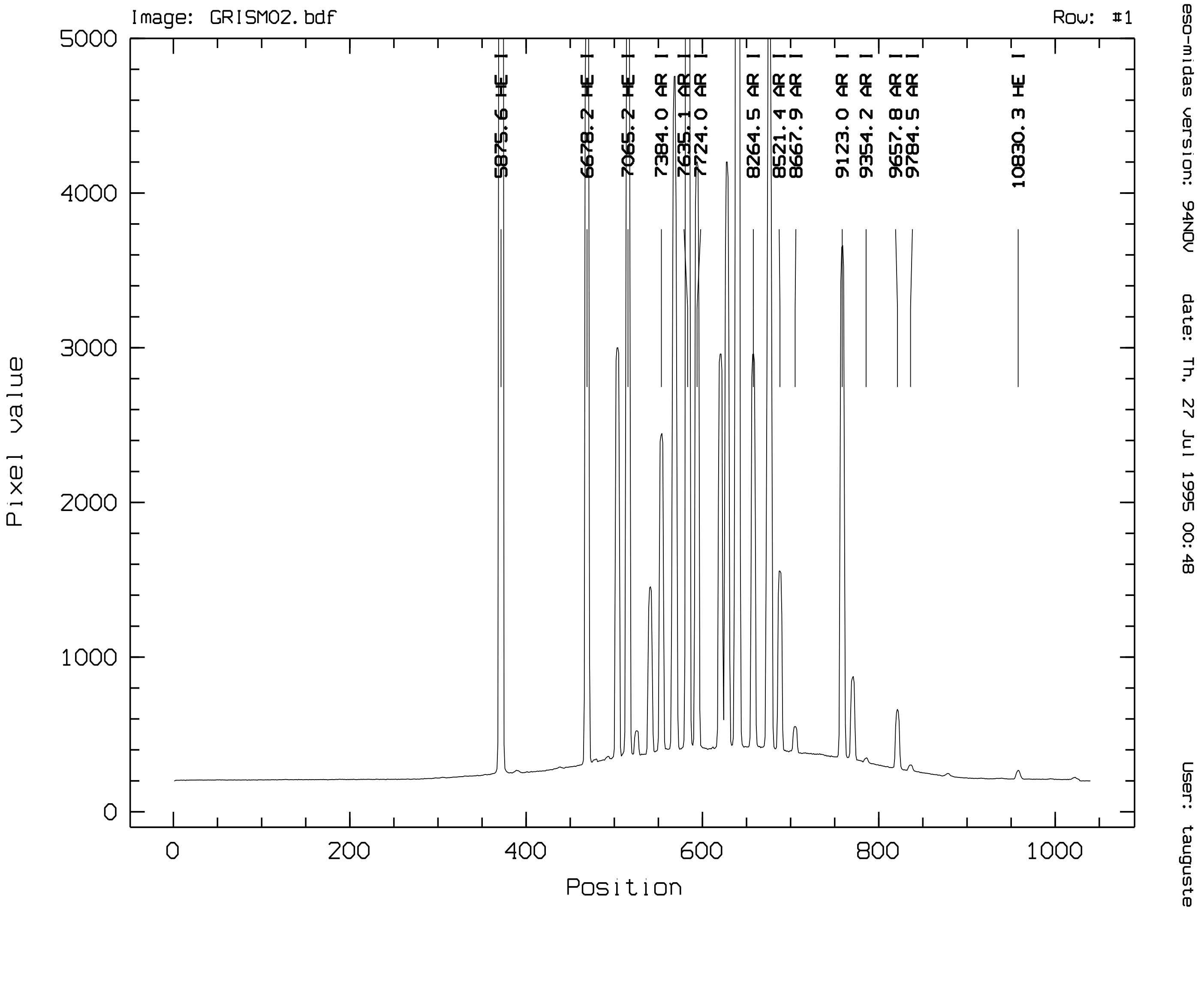

Figure C.2: *Helium-Argon atlas for Grism#2*

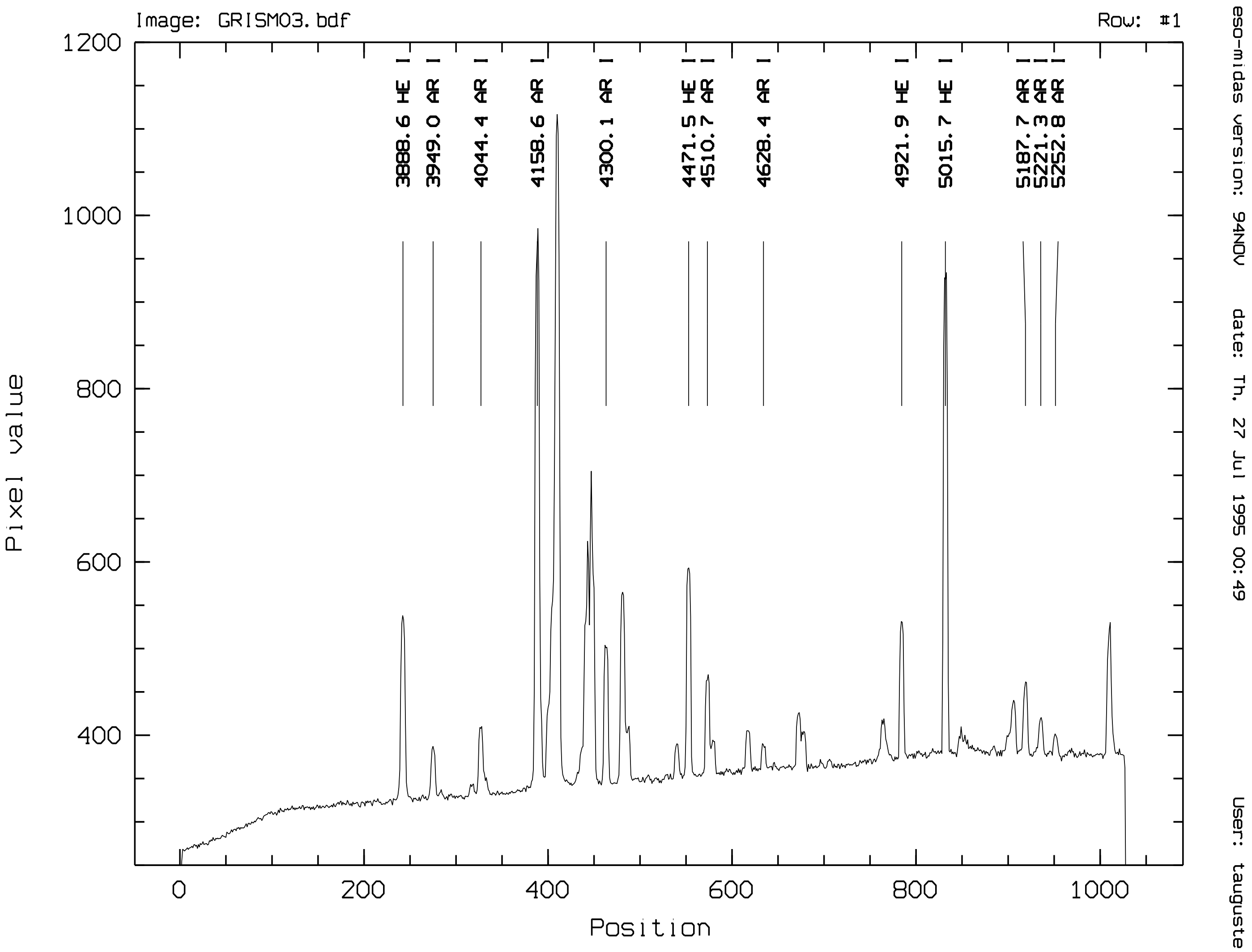

Figure C.3: *Helium-Argon atlas for Grism#3*

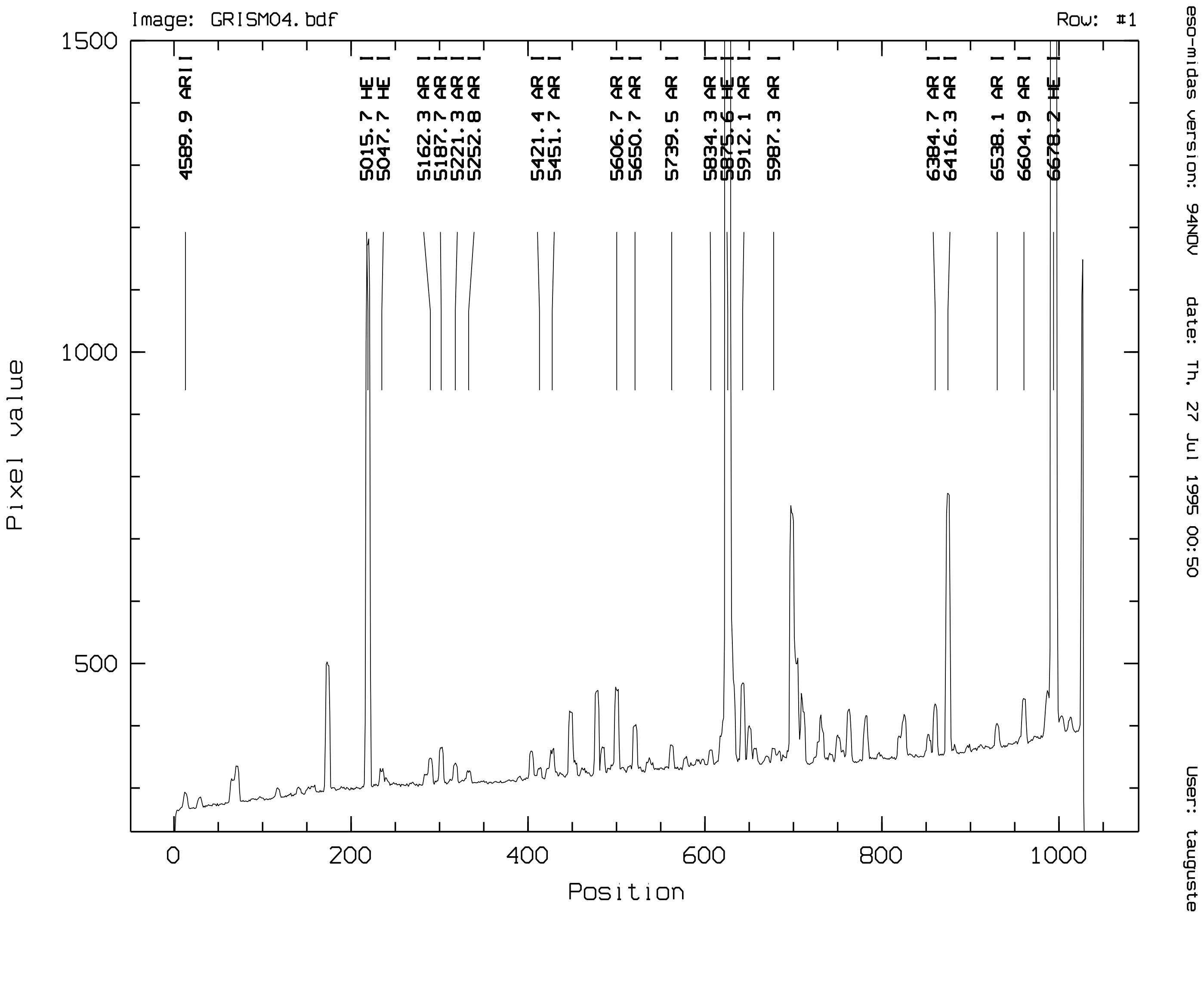

Figure C.4: *Helium-Argon atlas for Grism#4*

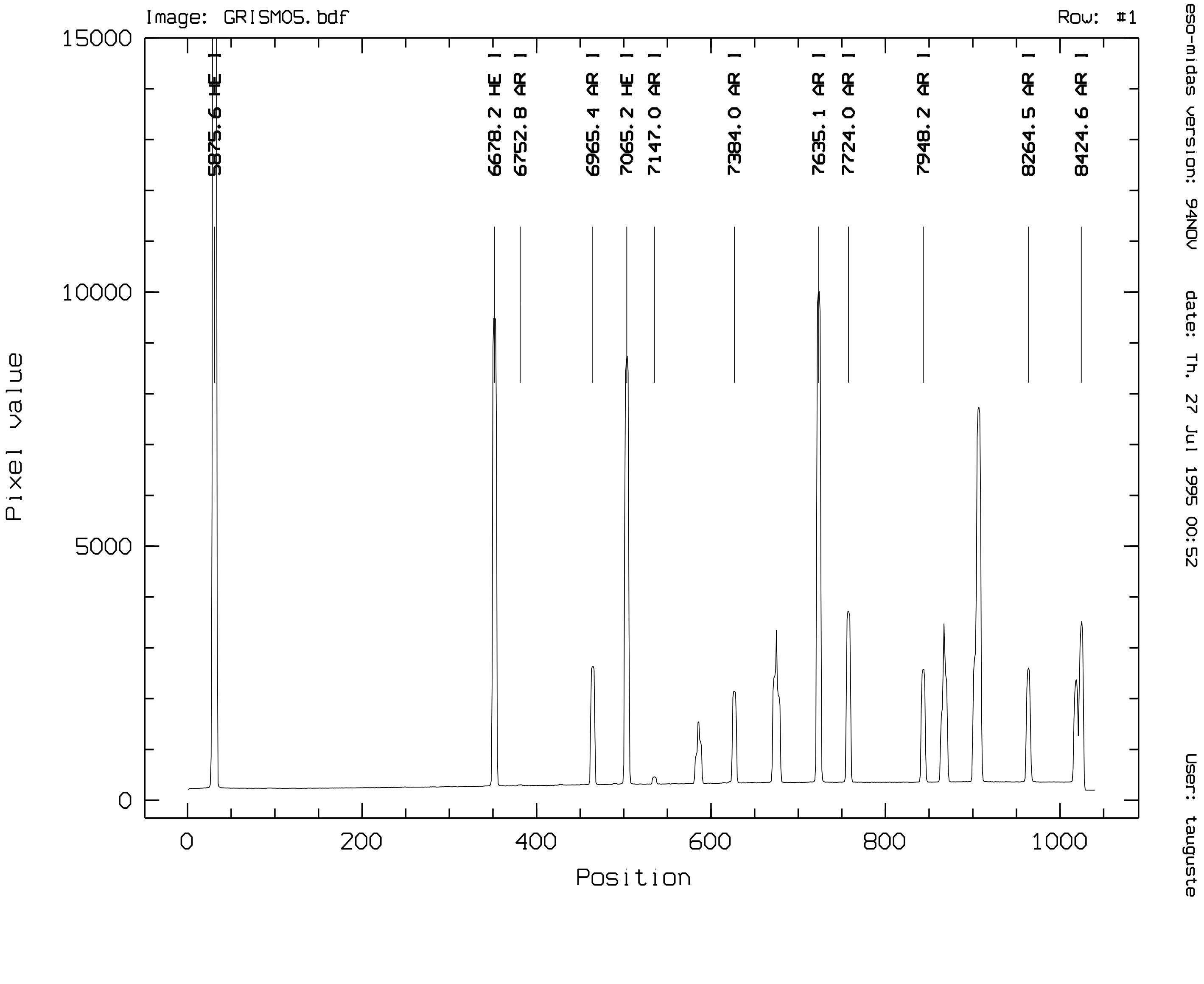

Figure C.5: *Helium-Argon atlas for Grism#5*

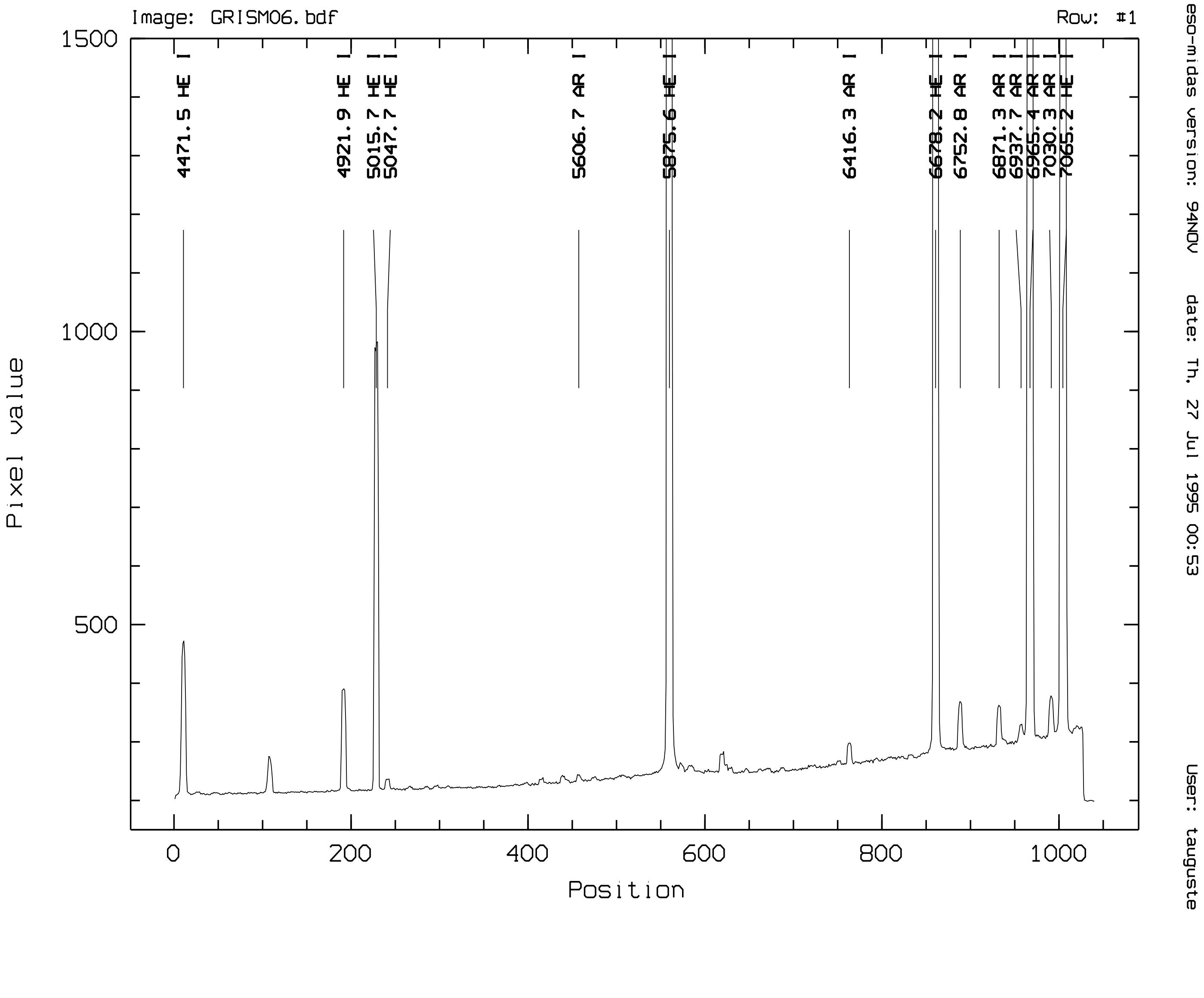

Figure C.6: *Helium-Argon atlas for Grism#6*

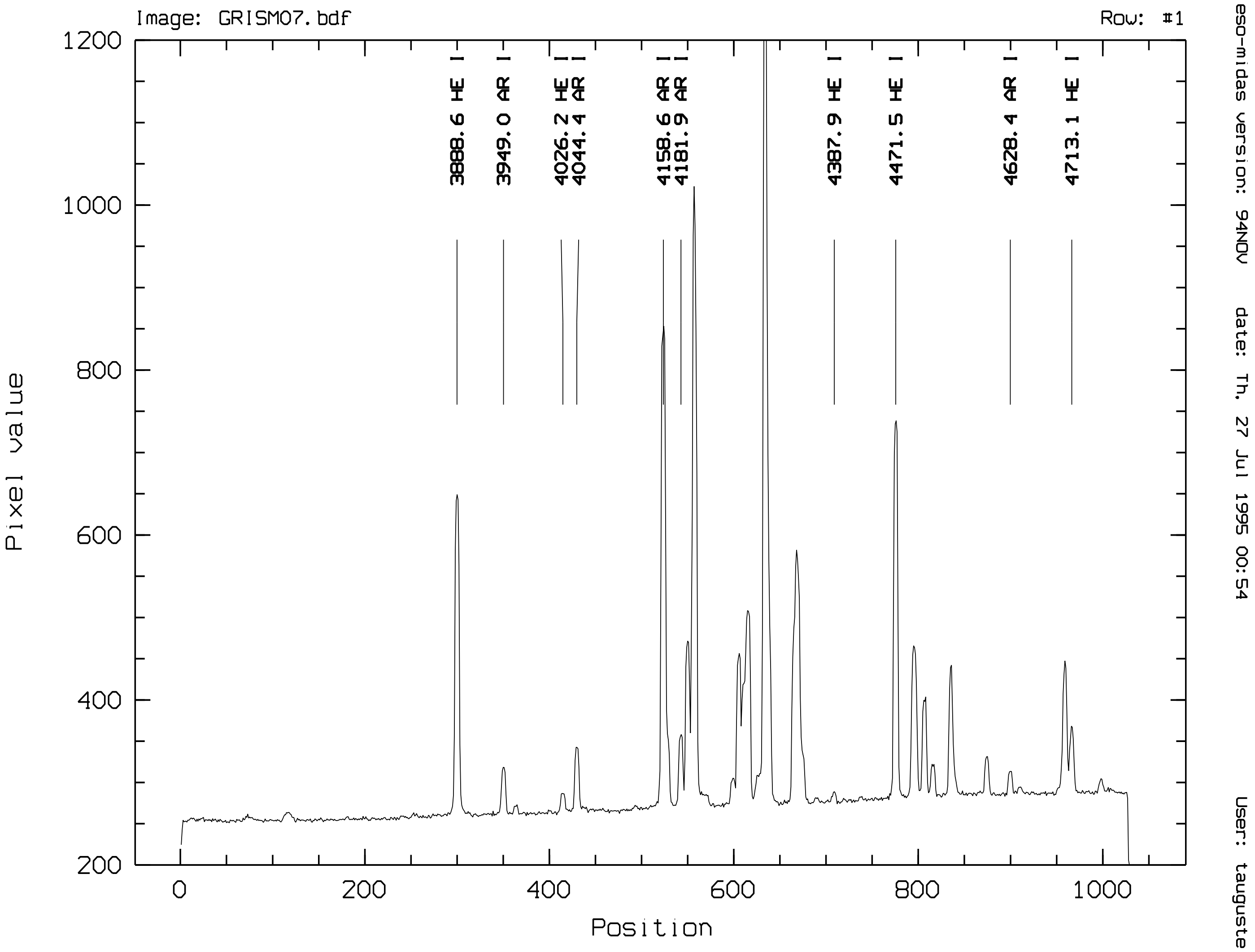

Figure C.7: *Helium-Argon atlas for Grism#7*

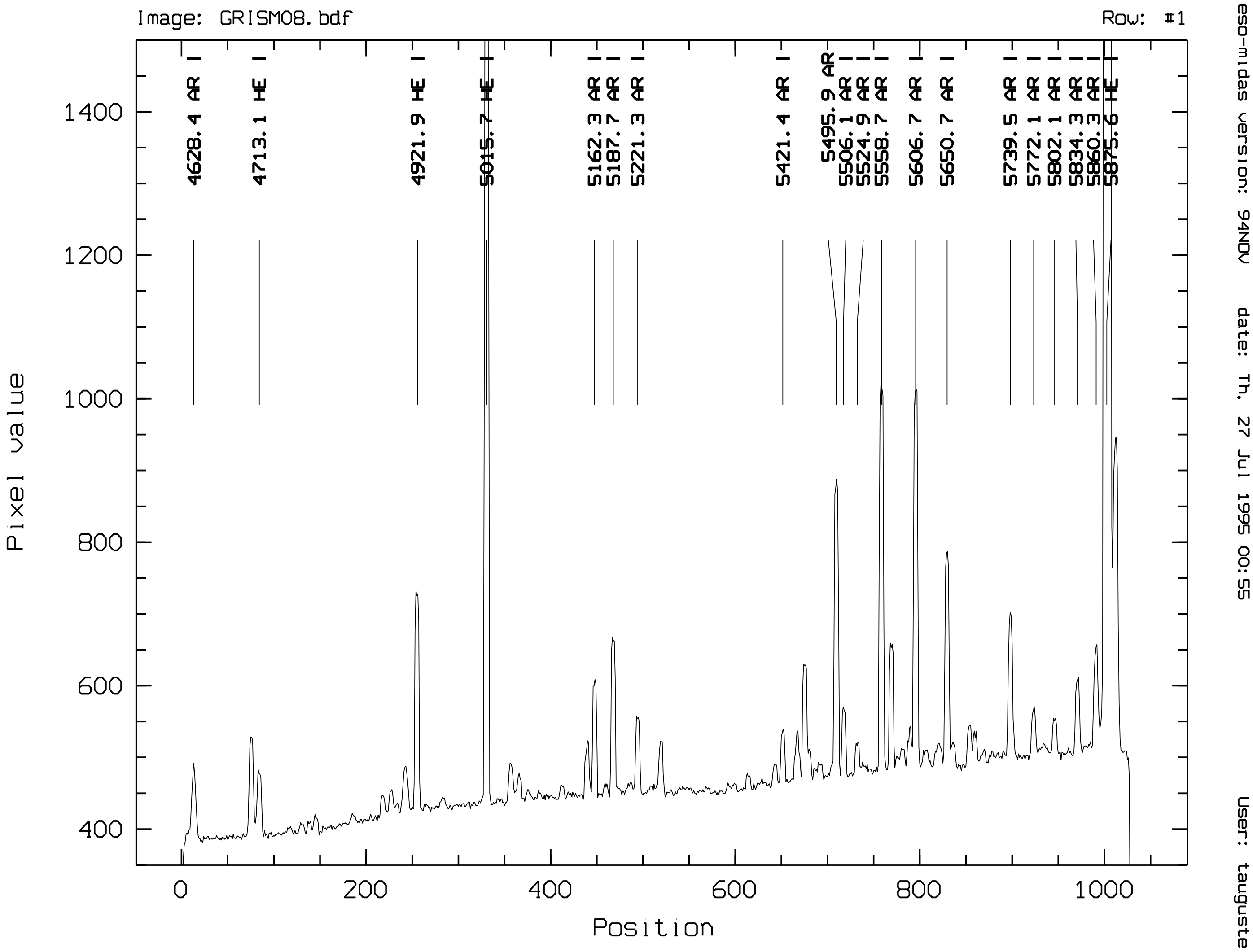

Figure C.8: *Helium-Argon atlas for Grism#8*

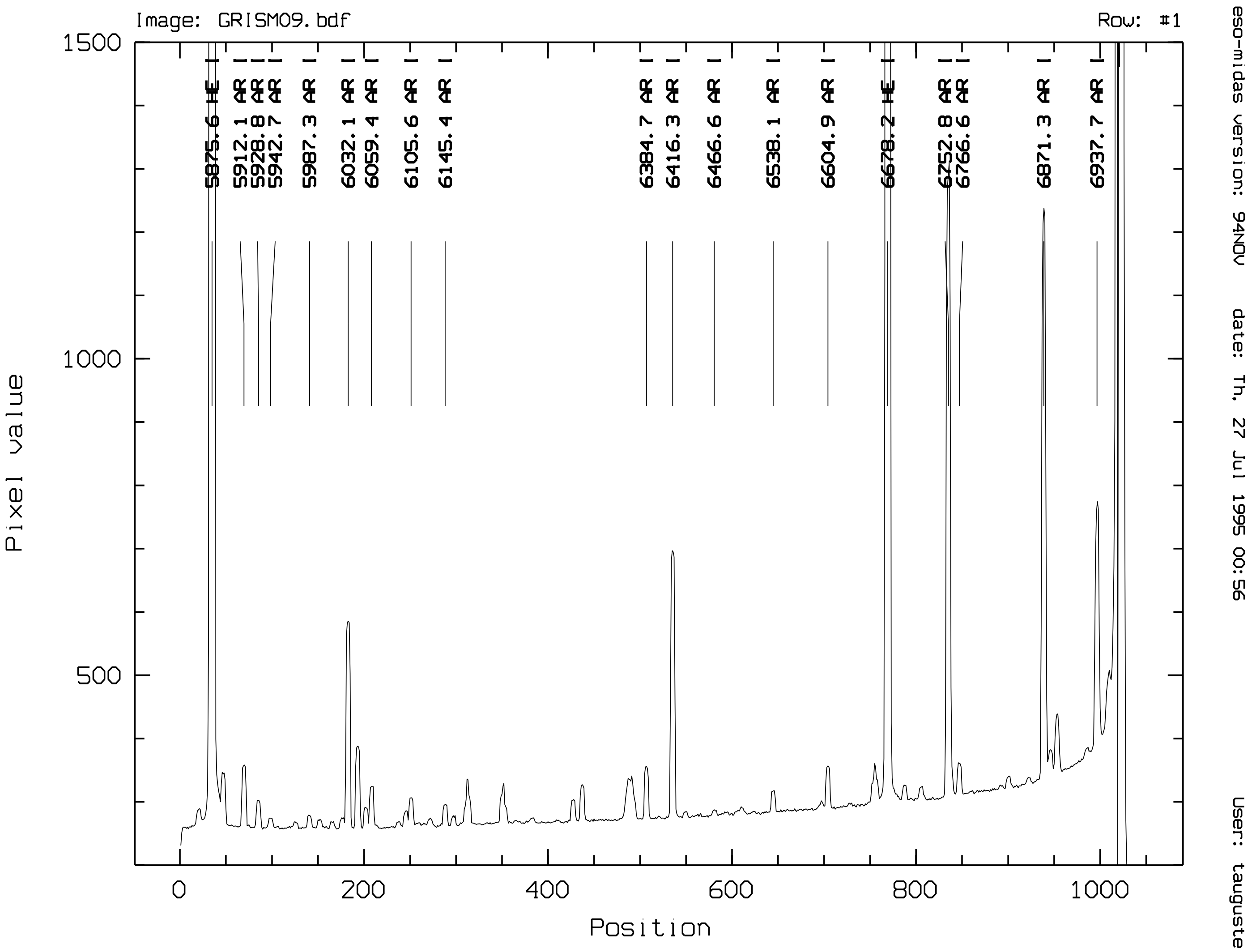

Figure C.9: *Helium-Argon atlas for Grism#9*

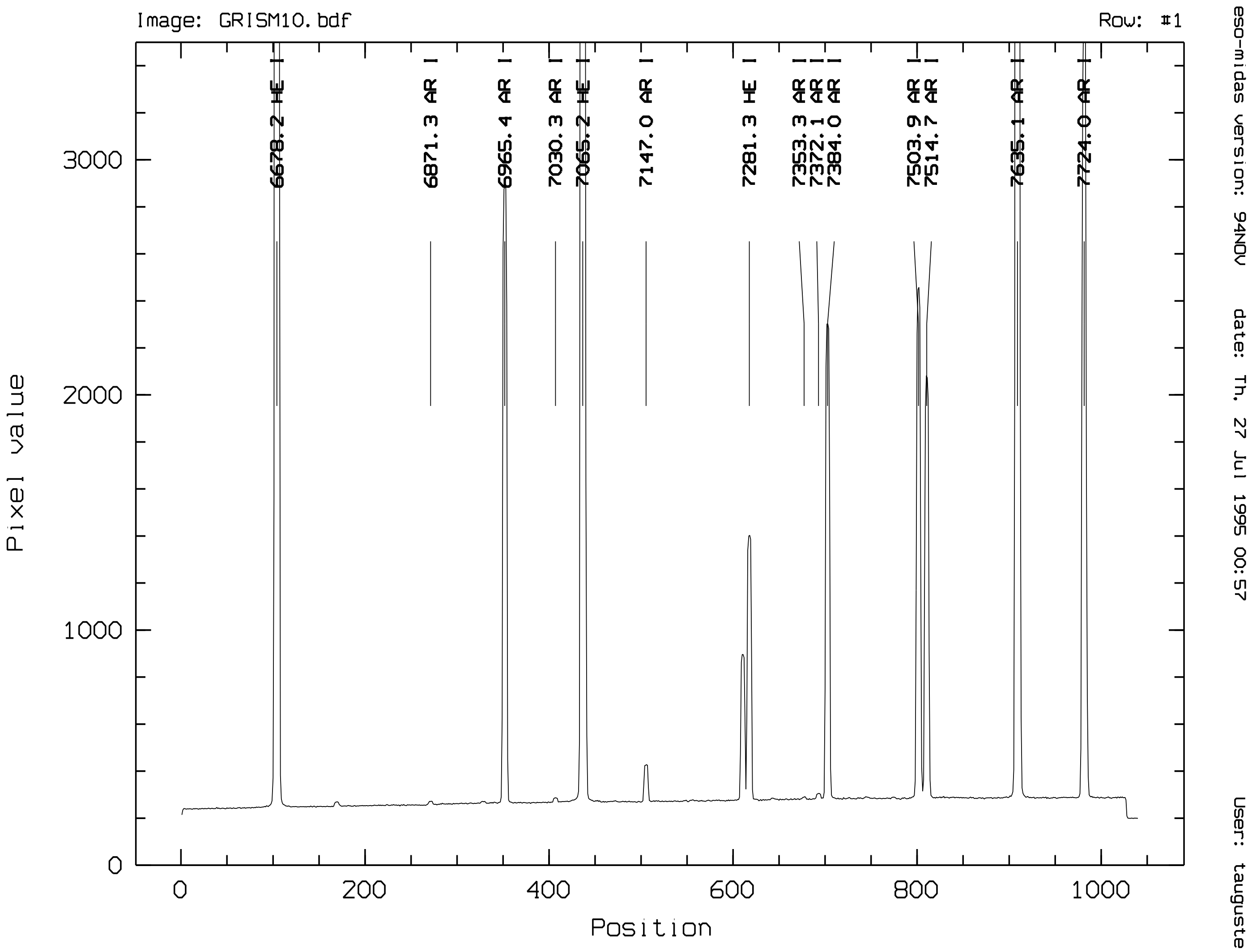

Figure C.10: *Helium-Argon atlas for Grism#10*