GIRAFFE

Setting up and observing procedure

L. A. Balona

1 Brief description of GIRAFFE

The SAAO fibre fed echelle spectrograph - GIRAFFE - consists of two components:

- The head which is placed at the Cassegrain focus to collects light from the star and direct it into the fibre (Fig. 1).
- The spectrograph, constructed on an optical bench in the coudé room, in which the light emerging from the fibre is dispersed and recorded by a CCD camera (Fig. 2).

The CCD camera is controlled by a PC running RTLinux in the observing room. The software, called `QUARTZ`, has the task of setting the exposure time, reading and displaying the CCD image and also controlling various tasks on the GIRAFFE head, such as the arc lamp and flatfield lamps. At the end of the exposure the FITS file is normally transferred to a Pentium II PC running Linux in which full display and reduction facilities are available. Using this machine, the FITS files can be copied to DAT tape. The DAT unit supports DDS-1 or DDS-2 tapes, the latter being the preferred medium. It is up to the observer to bring his own supply of tapes; none are available at Sutherland.

There are four PC's which the observer will use:

- A RTLinux PC called `giraffe` running `QUARTZ`.
- A Pentium-II SCSI Linux system called `s74` for data storage and reductions.
- A small RTLinux PC called `74in` running `EXPOSE` which monitors the light intensity emerging from the fibre.
- A 486 DOS PC for autoguiding.

This manual describes all the operations necessary to ensure proper operation of GIRAFFE. The topics are set in chronological order. These are the steps to be done on the first afternoon:

- Aligning the fibre at the beginning of the run.
- Operation of the control software, `QUARTZ`.
- Focusing the camera.
- Obtaining camera flatfields.
- Setting the prism position to obtain a given wavelength range on the CCD.
- Running the on-line reduction program, `XSPEC2`, to check the wavelength range selected.

The standard observing sequence for the night is as follows:

- Fill the cryostat with liquid nitrogen.
- Obtain fibre flatfields.
- Acquiring and guiding on the star.
- Operation of exposure meter program `EXPOSE`.

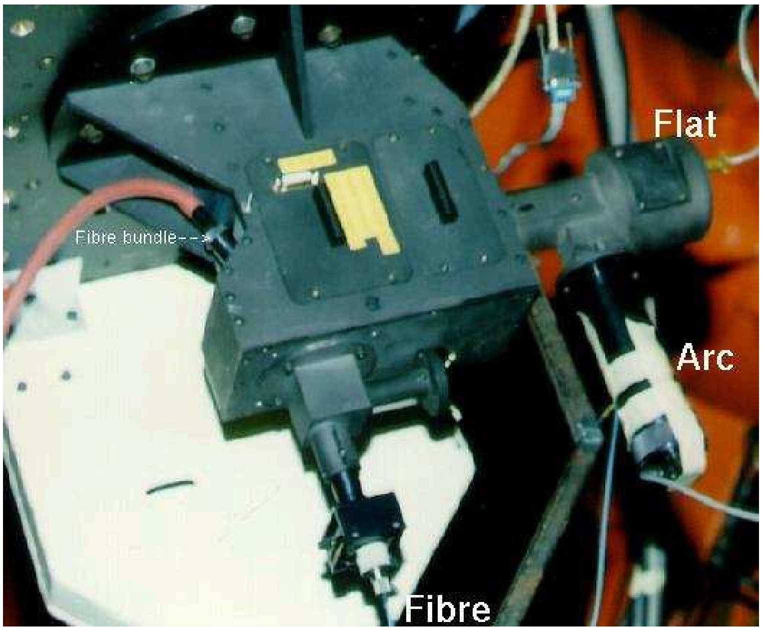


Figure 1: The GIRAFFE head at the Cassegrain focus of the 1.9-m telescope. The fibre can be seen emerging from its mounting (bottom). On the right are housings for the fibre flatfield lamp (horizontal) and Th-Ar arc (vertical with masking tape). The rubber connection on the left contains a fibre bundle directed at the entrance aperture of the fibre and leading to the field acquisition system.

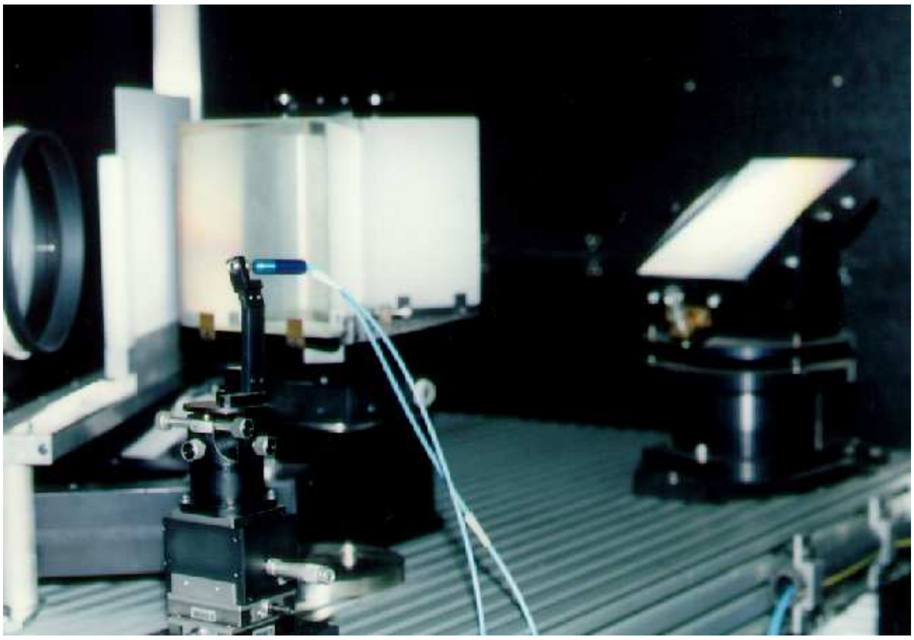


Figure 2: The other end of the fibre emerges in an optical bench situated in the coudé room. There are actually two fibres, but only one is in use. Here they are shown in the mounting. Behind them are the two prisms and the camera lens. On the right is the grating. On the left, out of the picture is a collimating mirror.

- Obtain arc spectra and stellar spectra.
- Finish the night with fibre flats.
- Storing data on DAT tape.
- Procedure to be followed at the end of a run.

The Appendix contains some details about the on-line reductions, how to calculated the S/N given the magnitude and exposure time. Graphs showing the wavelength range as a function of prism position and samples of wavelength drifts during the night are also shown.

2 Aligning the fibre

Before the GIRAFFE head is attached to the telescope, it is the responsibility of the observer to check that the optical fibre is correctly aligned. Arrange a time with the mechanical technician to be present when the GIRAFFE head is to be bolted to the telescope. The technician will have the head placed on a saddle with the fibre connected. In the coudé room you will find a tungsten lamp on a base and stand (Fig. 3). Shine the light onto the fibre so that it travels from the coudé room to the GIRAFFE head. Go to the GIRAFFE head and check that you can see light emerging from the fibre. Place the microscope on the flange and move it around until you can see the fibre (Fig. 3).

The first step is to focus the microscope so that the hole in the metal plate through which the light emerges is in sharp focus. The fibre mounting allows for fine positioning of the fibre in the X-Y-Z directions and also a small amount of tilt (Fig. 4). Move the fibre in the X and Y directions until it is nicely centered in the hole. For this purpose, you need the assistance of the technician. Once it is centered, move the fibre in the Z direction until it is in sharp focus. In other words, the hole and the fibre should both be in sharp focus and the fibre nicely centered. The fibre will move during the Z adjustment, so you need to iterate. When you are satisfied, ask the technician to bolt the head to the telescope.

3 Using QUARTZ to control GIRAFFE

The user should read the `QUARTZ` manual for a more detailed description of how to use the program. In this section we only give the simplest operational mode to get you started with `QUARTZ`.

3.1 Starting QUARTZ

The technicians would have set up the PC running `QUARTZ` in diagnostic mode. You need to exit from this mode and run `QUARTZ` in full operational mode. Using the mouse, move the cursor to `Exit` button.

`QUARTZ` runs under an account called `ccd`. You need to create a subdirectory in this account in which you can store your personalized `QUARTZ` settings. A suitable choice would be your initials. If a subdirectory by that name already exists (perhaps from a previous run of yours), you may use it, but you must delete the file named `disk.file`. My initials are `lab`, so to create a suitable subdirectory and run `QUARTZ`, I would type:

```
cd
mkdir lab
cd lab
quartz
```

A form will appear in which you are asked to select the name of the CCD. Click on the button and drag the mouse to select `MUS1`. At present there is only this choice. If you are running `QUARTZ` for the first time, a form will then appear to ask you for your *run number*. Every observer is assigned

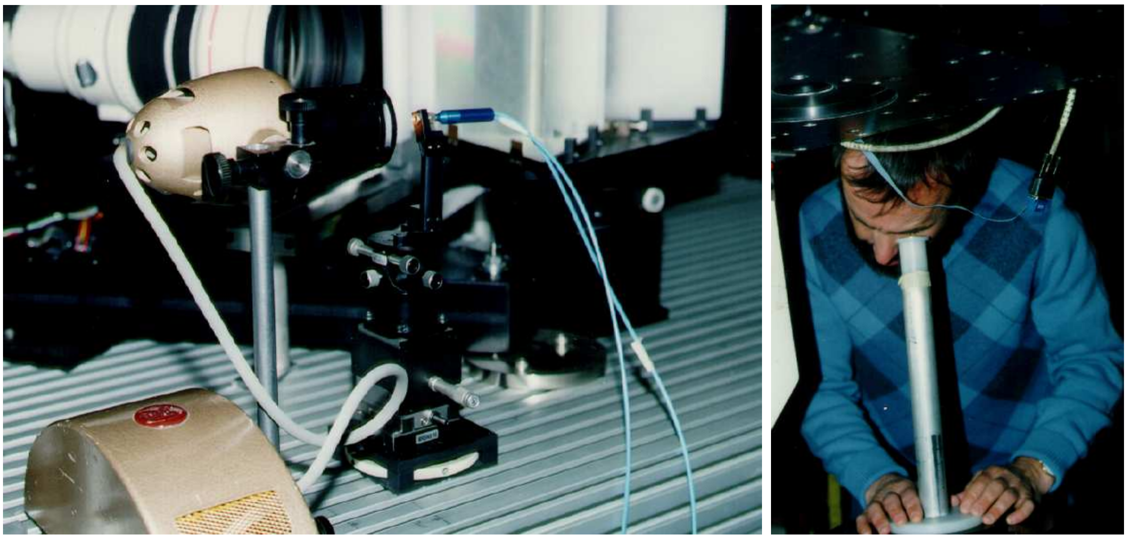


Figure 3: During the procedure of aligning the fibre, light is directed into the fibre (left). Here you see the lamp used for this purpose. The light emerging from the fibre at the telescope end is viewed by a microscope mounted on the GIRAFFE head before it is bolted to the telescope, so that the fibre can be accurately positioned (right).

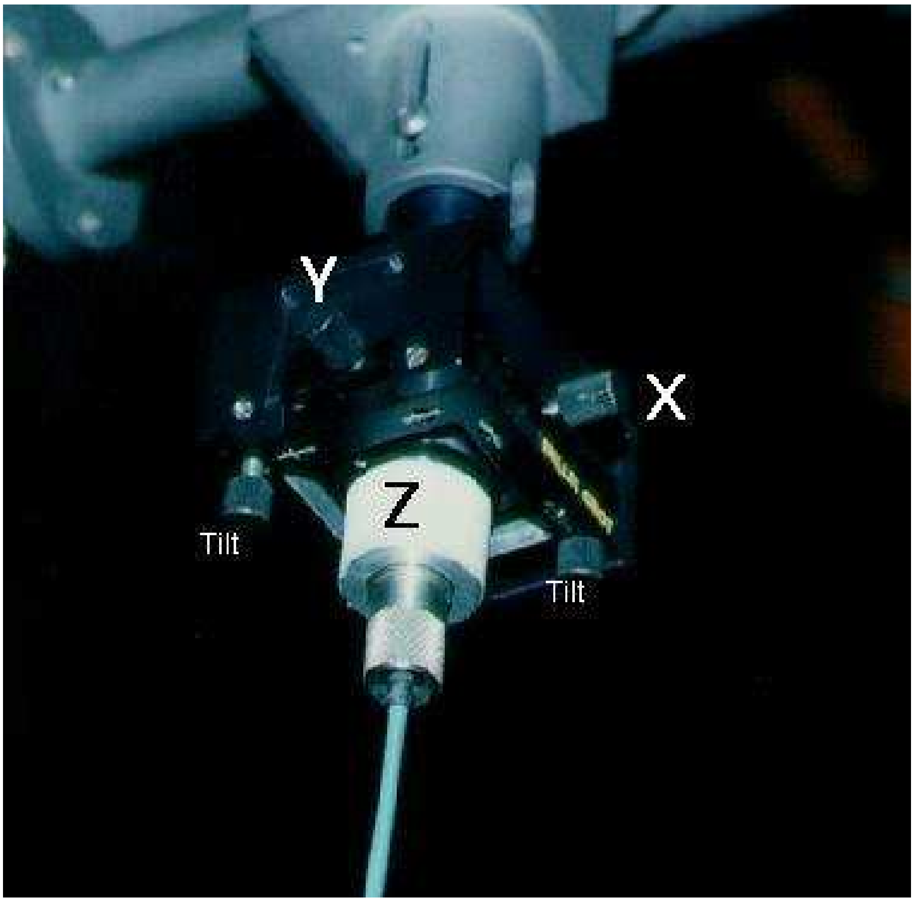


Figure 4: Here you see the fibre mount and the screws used to position the fibre in the X-Y directions. The silver barrel is turned to move the fibre in the Z-direction. The two vertical screws can be used to adjust the tilt.

a unique run number which you will find in the Giraffe log book. Look at the run number of the last user of Giraffe in this book and increment it by one. Enter this number and click on `OK`.

The next form requests the name of the setup file to use. This file contains all the personalized information for `QUARTZ`. If you do not have one, click on `General Setups` and choose the `giraffe.sup` file. This is a generalized setup file which you can modify at a later stage. Then click `OK` to proceed.

The next form to appear will remain for the rest of the night and consists of an image area which will display the CCD frame at the end of each exposure and a row of buttons on the right hand side.

3.2 Initializing the camera position and prisms

The CCD camera is mounted on a movable platform whose position is encoded and moved by `QUARTZ` commands. The same is true for the prism mount. At the start of a run *and also whenever there is a computer crash, power failure or transputer error* these must be initialized. Failure to initialize after these situations may well leave the remaining data unusable. You need to know which prism you are going to use and the relevant prism setting for the wavelength range that you desire. Consult the appendix on how to obtain this information.

To initialize, click on the `Init` drop-down menu and select `Find reference`. This will cause the camera mount to move until it finds the fiducial mark. Thereafter the prism mount will rotate until its fiducial mark is found. This procedure may take about two or three minutes.

After successful initialization, select `Define Blue` and type in the prism setting that you require for the blue prism. Select `Define Red` and do the same for the red prism. Type in any reasonable number if you are not going to use one or the other of the prisms). Then select `Red position Go` or `Blue position Go` depending on which prism you are going to use. This will cause the relevant prism to be placed in the position previously entered. This completes initialization of GIRAFFE.

3.3 Controlling the arc and flatfield lamps

The arc and flatfield lamps can only be switched on and off from `QUARTZ`. To switch on the ARC, simply click on the `Arc` button; clicking on it again will switch it off. The flatfield lamp may be switched on and off in the same way by clicking on the `Lamp` button. Normally, you would want to expose the arc or lamp for a certain time. This is done by entering the relevant *program* (see below).

Light from the arc and flatfield is directed onto the fibre by means of a mirror. This mirror needs to be in position 3 for the arc and flatfield lamps and position 1 while observing a star. Position 2 will direct the light to the sky fibre (not used at the moment). Whenever you click on the `Arc` or `Lamp` buttons, the mirror will be automatically positioned, but you can override this by clicking on the `Mir Pos` button.

3.4 Neutral density filters

Before the beam from the arc or flatfield enters the fibre, it passes through two filters. Firstly, there is a single colour filter which is used only for the flatfield lamp (Fig. 5). The purpose of this filter is to cut down the intensity in the red and push up the intensity in the blue to obtain a more evenly exposed fibre flatfield. The filter is moved in or out of the way by hand. You need to look at its position on the GIRAFFE head. Make sure it is out of the beam except when you are doing the fibre flats.

The beam from the arc or flatfield also passes through a circular glass wheel which has 18 levels of neutral density. Position 1 (no density) must be used for the arc. Position of 4 to 7 are typically used for the flatfield lamp. This position is selected from the drop down menu by clicking on the `ND Pos` button.

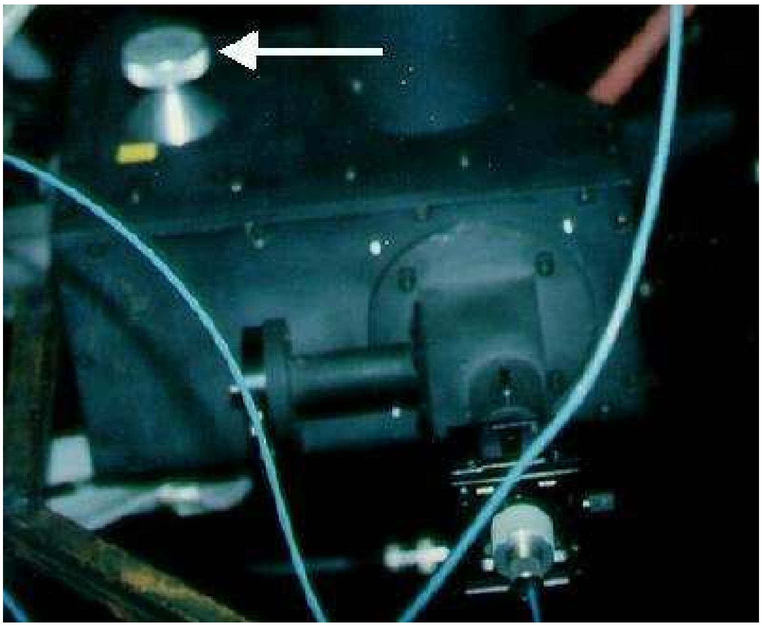


Figure 5: On the other side of the GIRAFFE head can be seen the silver knob (arrow) which can be rotated to remove or insert a colour filter for equalization of light intensity with wavelength for fibre flatfields.

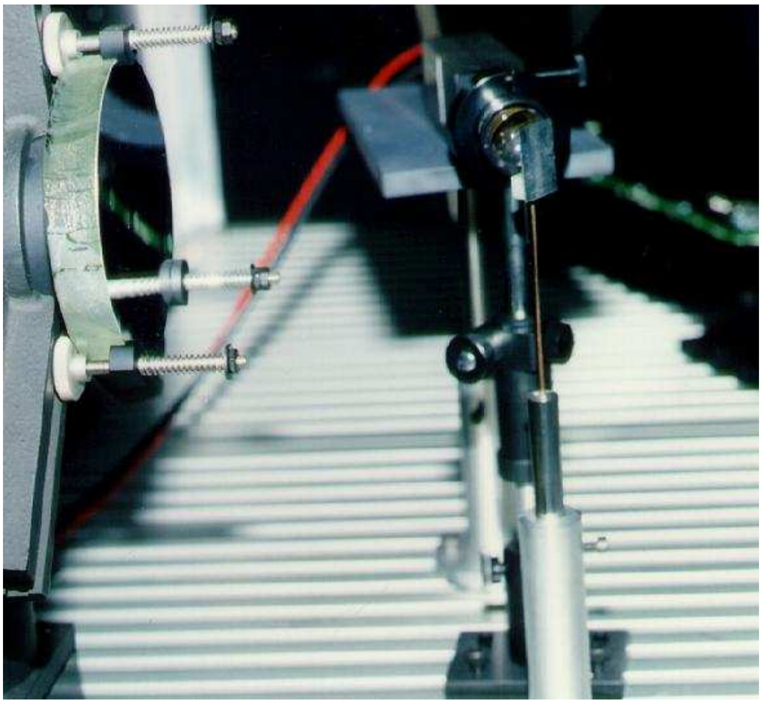


Figure 6: Light from the collimator (left) is intercepted by a small mirror (foreground right) and directed to an avalanche photodiode.

3.5 Controlling the avalanche photometric diode (APD)

In order to monitor the signal falling on the CCD during an exposure, part of the light which exits from the fibre is intercepted by a small mirror and directed to an avalanche diode (Fig. 6). This is a very sensitive device which records light intensities in a way similar to a photomultiplier tube. It is important that the light level is always below a certain threshold, otherwise there is the danger of destroying the device. For this reason, the device is protected by various electronic safety measures, but this does not mean that precautions need not be taken. The APD should always be switched off unless a star or arc is being observed. It is quite safe to leave it on during an arc exposure. However, *ensure that the avalanche diode is switched off before turning on the flatfield lamp.* Click the APD button to switch the APD on or off. The status of the APD is displayed on the button label itself.

Here is a table of typical positions

Object	**Colour filt**	**ND Filt**	**Mirror pos**	**APD**	**Typical exposure (secs)**
Arc	Off	1	3	[On]	5
Fibre flat	On	4	3	Off	5
Star	Off	1	1	On	?

The signal from the APD is displayed by the program `EXPOSE` running on a separate Linux PC. Monitoring this signal is essential to ensure that the maximum light from the star enters the fibre.

3.6 Programs

A program is a sequence of one or more lines of four numbers. The first number is the integration time in seconds. The second number is 1 if the image is to be stored on disk or 0 if you require a prompt. The prompt will allow you to choose to store or discard the image. The third number is 1 if you wish the program to repeat endlessly or 0 for no repeating. In the first case, a new exposure will start as soon as the previous one has ended. In the second case you need to start the new exposure by clicking on the `Expose` button. The fourth number has no effect at present, but is meant to select an appropriate ND filter (useful only for flat fielding). Up to 9 programs can be entered.

If you want to look at a particular program or change its contents, click on the `List Prog` button and select the program number from the menu. The program, if it exists, will be displayed on the text area to the left of the button. You may edit it if it exists or type in the program from scratch if the area is blank. When you have finished, click on the bottom left text area (the area immediately below the image area) to save the contents. Please remember to type in the final enter on the last line, otherwise the program will discard this line.

3.7 Activating a program

To put a program into operation, click on the `Apply Prog` button. There are three choices for a program: it can be used for observing a star, for the arc or for the calibration lamp. Select one of these from the submenu and then select the program number. The program will be displayed in the area to the left of the button. Which program is activated depends on whether the `Arc` button or `Lamp` button is pressed (or none of these if you are observing a star) at the start of the integration. The program that is displayed may be edited in the same way described above.

To change to a new program, simply select the appropriate program from the `Apply Prog` menu.

If a program is not activated, then `QUARTZ` will simply prompt you for the integration time (seconds) whenever the `Expose` button is pressed. This is the simplest mode of operation. You can deactivate or re-activate programs by selecting the appropriate entry in the `Prog List` menu.

4 Checking the camera focus

Next you need to expose the arc to check the camera focus. The first thing to do is to select a suitable exposure time for the arc. This will usually be 5 or 10 seconds. You can either put this in a particular program and activate it as described above, or simply press the `Expose` button, in which case you will be prompted for the exposure time. In either case, make sure that you have pressed the `Arc` button to switch it on before you press `Expose`.

With the arc image displayed, depress the `Gauss Fit` button just below the image. By clicking on a suitably isolated arc line the RMS X- and Y-width of the line will be displayed. If the camera is in good focus the RMS width should be about 1.0. Make sure the focus is good over the whole image by clicking on several arc lines. When finished, depress the `Gauss Fit` button.

If you need to focus the camera, go to the coudé room and locate the focus knob (Fig. 7). It is to be found on the base plate of the camera mount. You need to duck under the pipe which is used to fill the dewar with liquid nitrogen and open the flap covering the optical bench. If you do not know where to find it, please ask a technician. The focus does not change very much, so you can safely turn this knob by a quarter turn. You should note down the reading on the vernier scale, measure the RMS width of the arc at that reading, and continue measuring until you have passed the best focus. Plot the RMS width versus vernier reading and estimate the position of best focus. Set the vernier to that position and check the focus once more.

5 Obtaining camera flats

Camera flats are used for flat fielding. It involves shining a light source in front of the camera through a diffusing screen. In the coudé room you will find a small light bulb on a stand. Place this in front of the camera so that it will illuminate the camera lens without obscuration (Fig. 8). Push the translucent plastic diffuser in front of the camera and switch on the light. Record about ten well-exposed (counts between 30 000 and 60 000) frames. Please use the object name `CAMERA` for these frames.

6 Setting the required wavelength range

From the graphs and tables in the Appendix, you should be able to determine whether you require the red or blue prism and the approximate prism setting. In the `QUARTZ` program, type in the relevant setting and move the prism to that position. You now need to obtain at least one fibre flat and one arc frame at any given position. These frames must be saved on `s74`.

7 Note on flat fielding

A typical observing procedure consists of the following sequence of events. At the beginning of the run a series of “camera flats” is obtained. This is done by illuminating the camera with a uniform light source as mentioned above. The camera lens is covered with a sheet of translucent plastic to act as a diffuser. A camera flat can be used to determine pixel-to-pixel sensitivity differences. It should be noted that since the light path does not involve the grating, dependence of sensitivity on wavelength is not taken into account. However, we have found that camera flats produce somewhat better signal-to-noise (for GIRAFFE at least) because the blue orders are always under exposed by a considerable factor to avoid saturation in the red orders. The lack of good exposure in the blue leads to increased noise if a fibre flat is used for flat fielding.

A “fibre flat” or simply “flat” is obtained by sending light through the star fibre. This results in bands of illumination on the CCD which are in the same positions as the stellar spectra (these are called “orders”). It is a better method of removing the pixel-to-pixel variation because the wavelength dependence is taken into account. Apart from under-illumination in the blue, only a few pixels are illuminated in the direction perpendicular to the dispersion. The signal at the edges of the order are too weak to be used for flat fielding. If fibre flats are to be used for flat fielding,

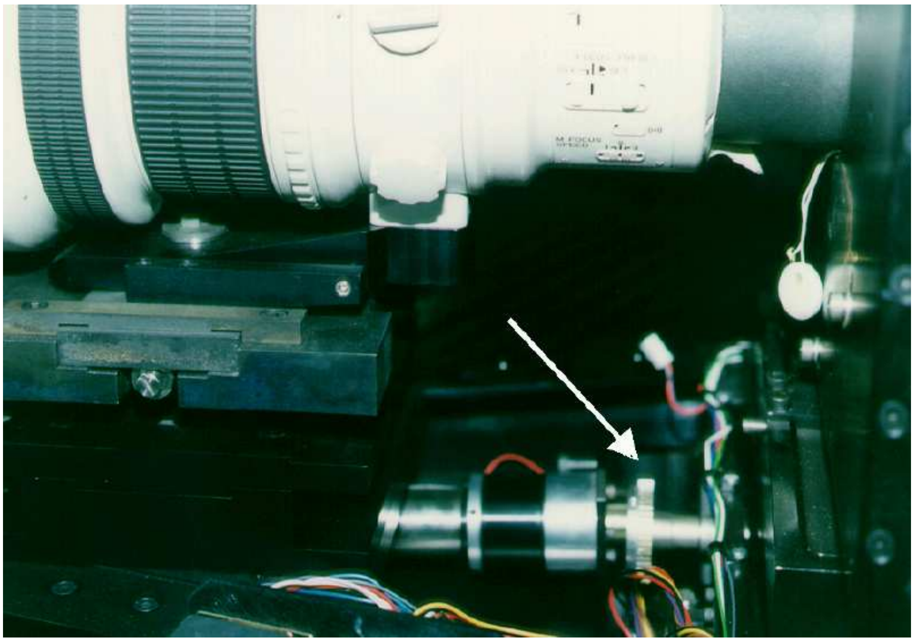


Figure 7: The location of the focus adjustment for the camera (arrow). This is the geared wheel attached to a vernier. The stepping motor in the background is not in use and should be disengaged.

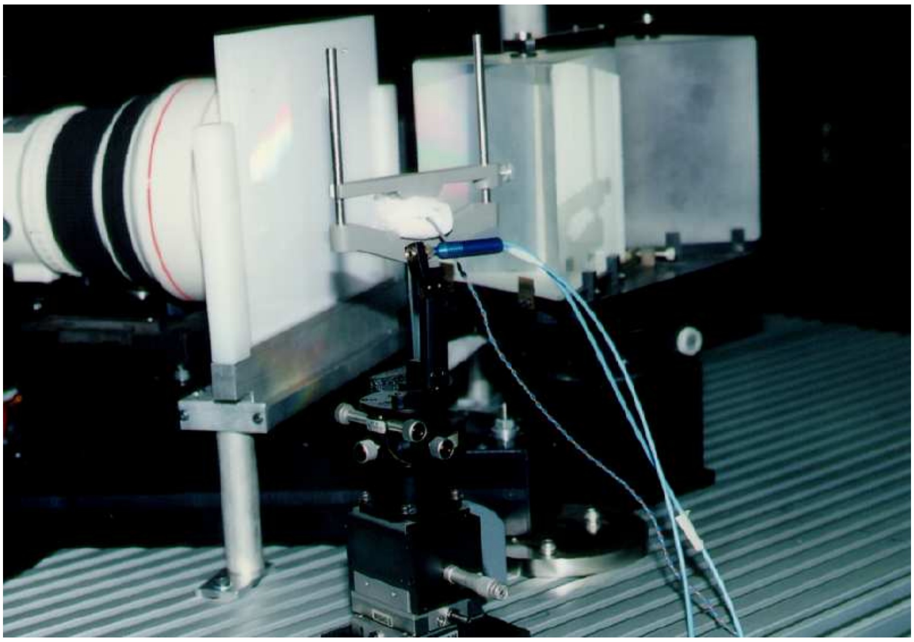


Figure 8: To obtain a camera flatfield, the translucent plastic screen is placed in front of the camera and illuminated by a small lamp held in a stand (behind the fibre).

pixel-by-pixel division of the star frame by the fibre flat cannot be used and a different approach is necessary (see appendix).

For GIRAFFE, we generally do not use fibre flats for this purpose, but they are essential to calibrate the overall wavelength sensitivity for each order (blaze correction). For this purpose, a smooth function is fitted to the intensity of the fibre flat order. This function is used as a divisor for the corresponding order in the stellar spectrum. If this is not done, the resulting spectrum is very curved and it is almost impossible to place the continuum. Two or three fibre flats should be taken at the beginning of the night (or just after a grating or prism motion or after a program crash or power failure) and again at the end of the night. These frames must not be saturated, otherwise they cannot be used.

8 Note on wavelength stability

Before the first observation of the night, two or three frames of the Thorium-Argon arc should be obtained. It has been found that there are significant shifts during the night, possibly due to temperature variations of the spectrograph. These shifts are particularly rapid immediately after the CCD cryostat has been filled. The shifts slowly relax back to the original value during the night. Maximum drift is typically 0.2 pixels, but can reach 0.5 pixels on some nights. It is strongly recommended that arc exposures be taken at regular intervals throughout the night so that this effect may be calibrated.

9 `XSPEC2` - Echelle reduction program

As mentioned above, the PC running `QUARTZ` controls the CCD and instrument, but the data, as FITS files, is automatically written to the `s74` Linux machine where it is stored in directory `/data/image`. The environmental variable `$IMAGEDIR` must be set to point to `/data/image` (or wherever the raw FITS files reside). This is set by default on `s74`, but if you using `XSPEC2` on another computer, type:

```
export IMAGEDIR=/data/ccd/lab/image
```

to set the environment variable. To show the current value of `IMAGEDIR`, use the command:

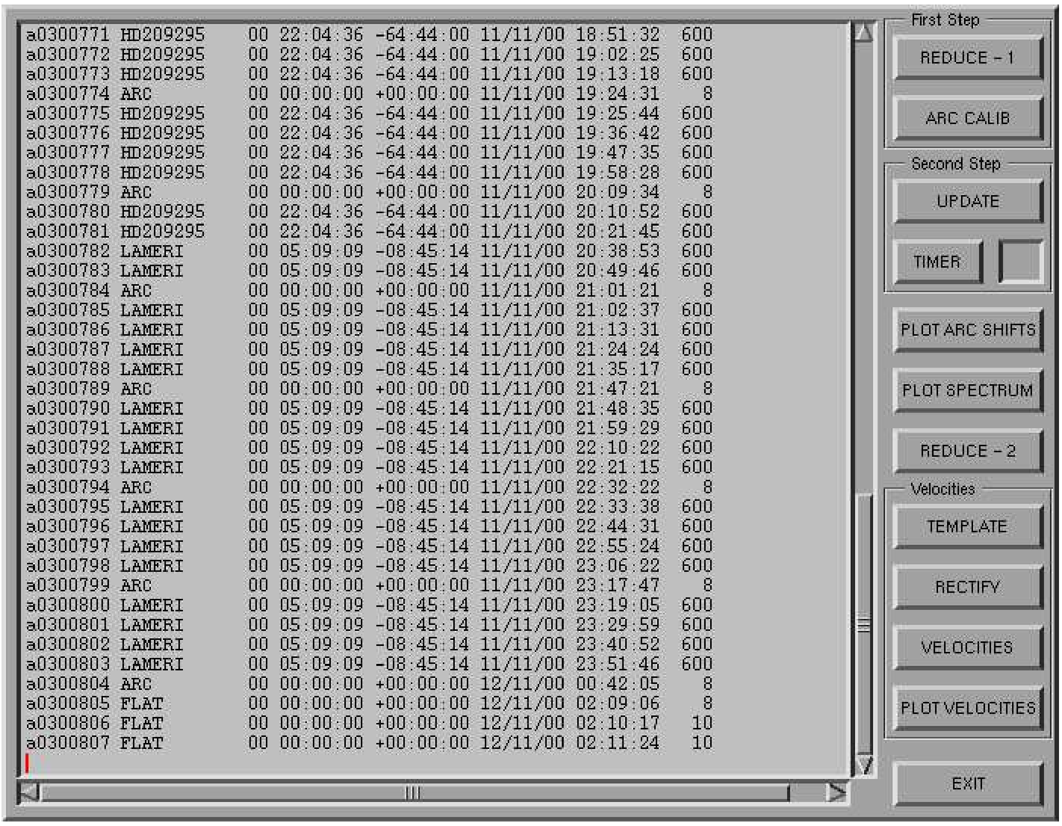
```
echo $IMAGEDIR
```

`QUARTZ` writes the raw FITS files in this directory with names of the form `a0050023.fits`. The first three numbers is the assigned run number; the remaining four digits allow for a maximum of 9999 files per run. The FITS frames can be examined by, for example, `ds9` or `xv`. To do so, you need to log in as `ccd` which puts you in the home directory `/data`. The FITS files should be in subdirectory `image`. These frames can be analysed to display a fully reduced spectrum on the screen. The program that reads these frames and performs the on-line reductions is called `XSPEC2`.

On `s74`, make sure you are logged in as `ccd`, open an `xterm` window and create a subdirectory for your own use. A good choice of subdirectory name will be your initials. In this subdirectory, create another subdirectory using the date as name, for example `Feb2324, Nov0607, Mar3101`. The idea behind the consecutive day numbers is to leave no doubt about the true date of the observations. For each night, create a new subdirectory. Go to this subdirectory and type in the following command:

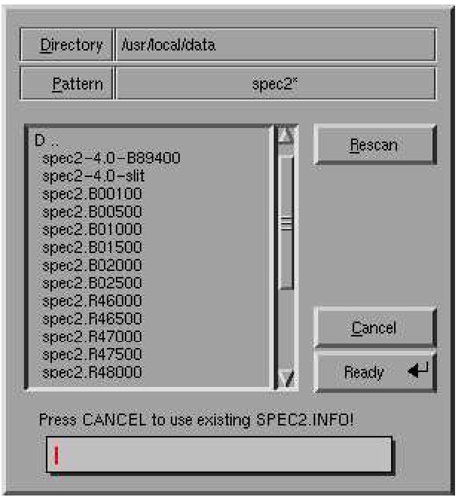
```
xspec2 &
```

This starts the `XSPEC2` program as a background task, displaying the form shown in Fig. 9. It consists of a window displaying details of spectra already obtained, as read from the files in the `/data/image` directory, and a row of buttons along the right hand side.



```
a0300771 HD209295     00 22:04:36 -64:44:00 11/11/00 18:51:32  600
a0300772 HD209295     00 22:04:36 -64:44:00 11/11/00 19:02:25  600
a0300773 HD209295     00 22:04:36 -64:44:00 11/11/00 19:13:18  600
a0300774 ARC          00 00:00:00 +00:00:00 11/11/00 19:24:31    8
a0300775 HD209295     00 22:04:36 -64:44:00 11/11/00 19:25:44  600
a0300776 HD209295     00 22:04:36 -64:44:00 11/11/00 19:36:42  600
a0300777 HD209295     00 22:04:36 -64:44:00 11/11/00 19:47:35  600
a0300778 HD209295     00 22:04:36 -64:44:00 11/11/00 19:58:28  600
a0300779 ARC          00 00:00:00 +00:00:00 11/11/00 20:09:34    8
a0300780 HD209295     00 22:04:36 -64:44:00 11/11/00 20:10:52  600
a0300781 HD209295     00 22:04:36 -64:44:00 11/11/00 20:21:45  600
a0300782 LAMERI       00 05:09:09 -08:45:14 11/11/00 20:38:53  600
a0300783 LAMERI       00 05:09:09 -08:45:14 11/11/00 20:49:46  600
a0300784 ARC          00 00:00:00 +00:00:00 11/11/00 21:01:21    8
a0300785 LAMERI       00 05:09:09 -08:45:14 11/11/00 21:02:37  600
a0300786 LAMERI       00 05:09:09 -08:45:14 11/11/00 21:13:31  600
a0300787 LAMERI       00 05:09:09 -08:45:14 11/11/00 21:24:24  600
a0300788 LAMERI       00 05:09:09 -08:45:14 11/11/00 21:35:17  600
a0300789 ARC          00 00:00:00 +00:00:00 11/11/00 21:47:21    8
a0300790 LAMERI       00 05:09:09 -08:45:14 11/11/00 21:48:35  600
a0300791 LAMERI       00 05:09:09 -08:45:14 11/11/00 21:59:29  600
a0300792 LAMERI       00 05:09:09 -08:45:14 11/11/00 22:10:22  600
a0300793 LAMERI       00 05:09:09 -08:45:14 11/11/00 22:21:15  600
a0300794 ARC          00 00:00:00 +00:00:00 11/11/00 22:32:22    8
a0300795 LAMERI       00 05:09:09 -08:45:14 11/11/00 22:33:38  600
a0300796 LAMERI       00 05:09:09 -08:45:14 11/11/00 22:44:31  600
a0300797 LAMERI       00 05:09:09 -08:45:14 11/11/00 22:55:24  600
a0300798 LAMERI       00 05:09:09 -08:45:14 11/11/00 23:06:22  600
a0300799 ARC          00 00:00:00 +00:00:00 11/11/00 23:17:47    8
a0300800 LAMERI       00 05:09:09 -08:45:14 11/11/00 23:19:05  600
a0300801 LAMERI       00 05:09:09 -08:45:14 11/11/00 23:29:59  600
a0300802 LAMERI       00 05:09:09 -08:45:14 11/11/00 23:40:52  600
a0300803 LAMERI       00 05:09:09 -08:45:14 11/11/00 23:51:46  600
a0300804 ARC          00 00:00:00 +00:00:00 12/11/00 00:42:05    8
a0300805 FLAT         00 00:00:00 +00:00:00 12/11/00 02:09:06    8
a0300806 FLAT         00 00:00:00 +00:00:00 12/11/00 02:10:17   10
a0300807 FLAT         00 00:00:00 +00:00:00 12/11/00 02:11:24   10
```

Figure 9: The main `XSPEC2` form.



Directory /usr/local/data

Pattern spec2*

```
D ..
  spec2-4.0-B89400
  spec2-4.0-slit
  spec2.B00100
  spec2.B00500
  spec2.B01000
  spec2.B01500
  spec2.B02000
  spec2.B02500
  spec2.R46000
  spec2.R46500
  spec2.R47000
  spec2.R47500
  spec2.R48000
```

Press CANCEL to use existing SPEC2.INFO!

Figure 10: This form will appear on pressing the `REDUCE-1` button if the configuration file, `spec2.info`, is not present in the subdirectory. Click on the template configuration file which is closest to the actual prism position you have chosen.

Enter date (eg: Mar0910):

Nov1213

Figure 11: This form, which allows you to choose which night is to be reduced, will always appear after clicking on the `REDUCE-1` button.

9.1 The configuration file `spec2.info`

To obtain a meaningful reduction you need the series of camera flats and a minimum of one fibre flat and one arc. You also need the appropriate configuration file for a given prism setting. This configuration file is called `spec2.info` and must be present in your subdirectory for `XSPEC2` to work. Templates of `spec2.info` files for a wide range of prism settings (both red and blue prisms) are available, so `XSPEC2` will ask you to select one of these template files if it does not find `spect2.info` in the current directory.

It is a good idea to use `XSPEC2` on the first afternoon to check the wavelength range you have chosen. As an example, we will assume that you have selected the red prism set to position 47500. Click on the button marked `REDUCE-1`. Because the subdirectory does not contain a `spec2.info` file, the pop-form shown in Fig. 10 will be displayed. This form lists the available templates which have file names as follows:

```
spec2.B00001 spec2.B00500 spec2.B01000 spec2.B01500 spec2.B02000
spec2.B03000 spec2.R45000 spec2.R45500 spec2.R46000 spec2.R46300
spec2.R46500 spec2.R47000 spec2.R47500 spec2.R48000
```

You need to select only one of these files. If you are using the red prism at position 47500, then the file you need is `spec2.R47500`, so click on that name and press `Ready`. This file will be copied to your subdirectory and renamed `spec2.info`. If the prism setting you have chosen does not correspond exactly to what is available, just select the one which is closest.

9.2 Selection of data set to be reduced

Next, a form requesting the date of the observations to be reduced will appear (Fig. 11). The current date is shown as default, but you may enter any appropriate date to reduce the data for that night. When satisfied, press the `OK` button.

While the standard procedure is to reduce the data on a night by night basis, the nightly data set must be subdivided if one of the following occurs:

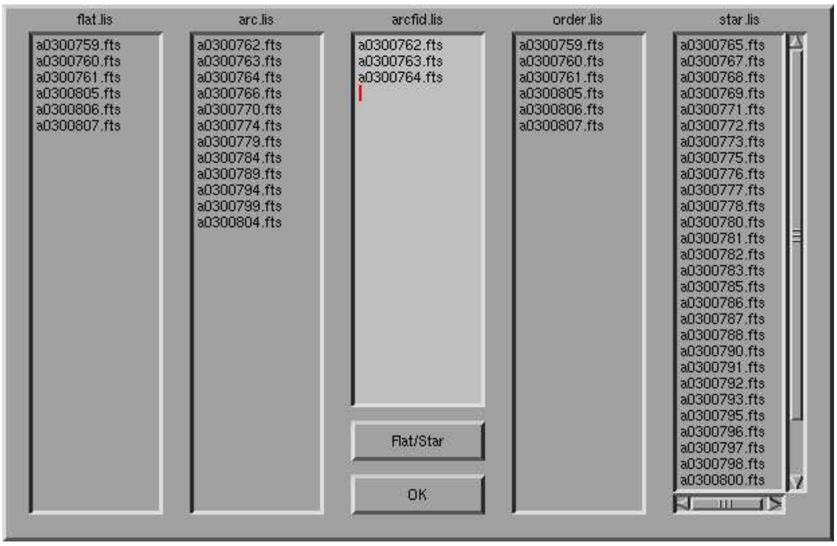
- A computer crash (most commonly a transputer error.
- Any change to the prism or prism setting.

In both cases it is necessary to re-initialize the camera and prism as described above and then set to the desired prism position. Following this, at least one fibre flat and arc frame is required prior to re-commencing observing. It follows that changing the prism setting during the night is wasteful of observing time and should be avoided.

9.3 Classification of frames

On the basis of the object name in the FITS header (given in brackets in the list below), the program classifies files according to the following types:

- Bias frames (`BIAS`).
- Camera flats (`CAMERA`).



flat.lis
a0300759.fts
a0300760.fts
a0300761.fts
a0300805.fts
a0300806.fts
a0300807.fts

arc.lis
a0300762.fts
a0300763.fts
a0300764.fts
a0300766.fts
a0300770.fts
a0300774.fts
a0300779.fts
a0300784.fts
a0300789.fts
a0300794.fts
a0300799.fts
a0300804.fts

arcfid.lis
a0300762.fts
a0300763.fts
a0300764.fts

order.lis
a0300759.fts
a0300760.fts
a0300761.fts
a0300805.fts
a0300806.fts
a0300807.fts

star.lis
a0300765.fts
a0300767.fts
a0300768.fts
a0300769.fts
a0300771.fts
a0300772.fts
a0300773.fts
a0300775.fts
a0300776.fts
a0300777.fts
a0300778.fts
a0300780.fts
a0300781.fts
a0300782.fts
a0300783.fts
a0300785.fts
a0300786.fts
a0300787.fts
a0300788.fts
a0300790.fts
a0300791.fts
a0300792.fts
a0300793.fts
a0300795.fts
a0300796.fts
a0300797.fts
a0300798.fts
a0300800.fts

Figure 12: Names of files belonging to five different classes are displayed in this form. The button named `Flat/Star` can be pressed if star spectra are to be used to determine the orders rather than the flat field (the default).

- Fibre flats (`FLAT`).
- Arcs (`ARC`).
- Stars (any other name).

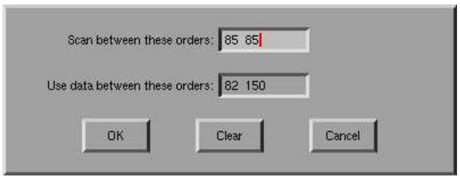
Please note that if you want `XSPEC2` to work effortlessly, you must use the keywords `BIAS, CAMERA, FLAT` and `ARC` for the object name when prompted by `QUARTZ`. Normally, `QUARTZ` will automatically assign the object name `ARC` whenever an exposure of the arc is taken and `FLAT` whenever an exposure of the fibre flat is taken. Bias frames are not normally required, as the bias is calculated from the overscan region on the CCD. However, it is available in case you wish to take separate bias frames.

Apart from these four classes of files, two more classes need to be described. The first is the class of fiducial (i.e. template) arc frames. The wavelength calibration is performed on these frames. It can be one single well-exposed arc frame, but it is probably best to take two or three separate arc exposures in succession. `xspec2` will examine the times of the arc exposures and suggest a suitable number of frames to be co-added and used as the fiducial arc frame. All other arc frames are used to determine the drift in wavelength through the night by cross-correlating each arc spectrum with the fiducial frame.

The final class is the frame, or combination of frames, to be used for determining the position of the orders. The obvious choice is to use the co-added fibre flats for this purpose. This is the only choice at the beginning of the night before you have observed any stars. It is also possible to use the co-added stellar spectra themselves for this purpose. If you are observing bright stars, this may be a better choice, but the results do not depend very much on whether you use fibre flats or stars.

9.4 File selection

`Xspec2` will search through the FITS headers and list the results of the classification in the form shown in Fig. 12. The file names can be edited if desired. Also, if you prefer using the co-added stellar spectra to determine the orders instead of the fibre flats, press the button marked `Flat/Star` which toggles between the two alternatives. Press `OK` to continue with the reductions.


Scan between these orders: 85 85

Use data between these orders: 82 150

Figure 13: This form allows selection of orders to be used for the wavelength calibration.

At this point, the reductions proper begin. The `xterm` window will display the output of the calculations as they progress. For details of these calculations, please refer to the appendix. After a short while the calculations will stop and we can proceed to calibrating the wavelength as a function of pixel position for each order using the co-added fiducial arc frames.

9.5 Two dimensional wavelength calibration

On this first pass just completed, the program extracts one-dimensional arc spectra. For each order, a simple quadratic polynomial fit of wavelength vs pixel position is adequate. The configuration file `spec2.info` contains several polynomial coefficients which describe the following:

- Central wavelength vs order number.
- Wavelength vs pixel position.
- Pixel position vs wavelength.

These polynomials can be used, together with the wavelength tables in `spec2.info`, to perform the calibration without interactive identification of arc lines. This applies even if there is a shift of as much as 200 pixels along the dispersion or a displacement of the orders in the Y direction.

To start the process, click on the button marked `ARC CALIB`, which displays the form shown in Fig. 13. In order for the wavelength calibration to proceed, the program needs to know the number of the first complete order on the frame. This number depends on the prism setting and is likely to be close to the range of values shown in the input box. If you are not sure of this number, tell the program to search for it by typing in the starting and stopping order numbers. For example, if the box shows the values (85 85), you may want to type in (80 90), which tells `xspec2` to calculate the fitting error assuming that the first complete order is order 80, then order 81 ... up to order 90. The correct order number will be the one which shows the smallest error. If the order is not the correct one, the error will be in the range 50 – 70. The correct order is obvious, because the error drops to less than 10.

The other input box requests the user to enter the orders to be used in calculating the error. Normally it is safe to use all the orders, so you can type values (1 999), for example. However, some orders in the extreme red or blue may lead to poor values owing to paucity of lines. On occasions, therefore, you may find that the smallest error is only a factor of 2 or 4 smaller. In this case, it is best to limit the orders to which the calibration applies.

Now we calibrate the central wavelength as a function of order number. A panel showing numbers from -9 to +9 is displayed. To select the degree of polynomial to be fitted, click on one of these numbers. A plot showing the points and the polynomial fit will be shown. If you click on zero, the last polynomial will be accepted as the final fit. A negative degree means that a polynomial of that degree will be fitted, the most discrepant point omitted, and another polynomial of the same degree fitted. In order to omit discrepant points, just click on the negative degree until you are satisfied. A polynomial in the range 5 – 7 is normally used for central wavelength as a function of order number.

In calibrating the central wavelength as a function of order number, only the *residuals* of the polynomial fit is shown, as otherwise it is difficult to see the goodness of fit. In other cases, the actual polynomial fit is shown. Choosing a degree of zero accepts the last fit and moves on to the next calibration.

The program calibrates the wavelength, λ, as a function of pixel number, x, for each order using the quadratic approximation:

$$\lambda = a_0 + a_1 x + a_2 x^2$$

The coefficients, a_0, a_1, a_2, are themselves smooth functions of the order. This is what is meant by a 2-D calibration. The point of a 2-D calibration is to minimize any systematic error which may have occurred using independent polynomial coefficients for each order and also to fill in those orders which have a poor calibration or no calibration at all (for lack of suitable arc lines). So the next step is to calibrate these coefficients as a function of the order by fitting a polynomial to each coefficient as a function of order number. Normally, a_0 requires a polynomial in the range 5 – 9, a_1 a polynomial of degree 3 and a_2 a polynomial of degree 1 or 2. The results of these four polynomial calibrations is the file `spec2.info.new` which is automatically copied to `spec2.info`.

9.6 Reductions - second phase

The extraction of the camera flats, fibre flats, fiducial arcs and wavelength calibration constitute the first phase of the reduction process. Extraction of stellar spectra and cross-correlation of arcs with the fiducial arc to determine wavelength drifts constitutes the second phase. For a full reduction, data for the whole night is needed since we need to know the wavelength drift as a function of time. In this section we describe the remaining steps for a full reduction. In the next section we describe how to obtain preliminary reductions for on-line display of the spectra at the telescope, omitting any correction for wavelength drift.

To proceed with the second, and final, reduction phase, click on the `REDUCE -2` button. Now we wish to calibrate the wavelength drift, expressed in pixels, as a function of time. A panel showing numbers from -9 to +9 is displayed. To select the degree of polynomial to be fitted, click on one of these numbers. A plot showing the points and the polynomial fit will be shown. If you click on zero, the last polynomial will be accepted as the final fit. A negative degree means that a polynomial of that degree will be fitted, the most discrepant point omitted, and another polynomial of the same degree fitted. In order to omit discrepant points, just click on the negative degree until you are satisfied. At this point, the polynomial is used to determine the pixel correction for the stellar spectra. This is followed by the reduction of the stellar spectra.

10 Automatic reductions

At the telescope, it is desirable to obtain reductions automatically. At the beginning of the night, it is necessary to proceed with phase 1 of the reductions, provided the fibre flats and at least one arc spectrum has been obtained. Once this step is completed, phase 2 can proceed automatically or can be initiated by pressing the `UPDATE` button.

In automatic reductions `xspec2` searches the image directory for new files. If none are found, it waits for a while and tries again. To start this process, press the `TIMER` button. A box will appear requesting the time, in seconds, that it must wait to poll the `image` directory. A good choice would be about 60 seconds. A new frame will be automatically classified and reduced without user intervention. For example, if an arc frame is taken, it will be cross-correlated with the fiducial arc to calculate the pixel displacement. A graph showing pixel displacement as a function of time will pop up. Clicking on the plot will make it disappear. It is possible to bring up this plot at any time by clicking on the `PLOT ARC SHIFTS` button. For a star frame, a new line will appear in the data window showing the frame number, object name, RA, DEC, date, UT, exposure time, number of saturated pixels in the frame and the signal-to-noise ratio. To plot this spectrum, or any other spectrum, click on the `PLOT SPECTRUM` button. This brings up a box requesting the order to be plotted. Click on the required number to see a plot of intensity vs wavelength for this order and the two other nearest orders. Click on the `EXIT` button on the order form to exit from plotting.

10.1 Data files

The reduction procedure creates many files in the working directory, all of which are described in the appendix. The most important files are the reduced one-dimensional, wavelength calibrated stellar spectra. These are designated by replacing the suffix `.fits` for the FITS raw image by the suffix `.bin`. For example, if the raw image frame is called `a0210033.fits`, the reduced spectrum is called `a0210033.bin`. In these files, the barycentric velocity correction has not been applied to the wavelength. However, `xspec2` creates a similar file staring with `b` in which the correction is applied. For example, in addition to `a0210033.bin`, you will find `b0210033.bin` which is corrected for the barycentric motion of the earth. You may wish do delete the `a` files and save only the `b` files or convert them to FITS format using the `bin2fits` program.

Note that whereas the `.bin` files contain the full data, the FITS files are re-sampled with wavelength overlap on each order dove tailed. In other words, it is a continuous spectrum sampled at equal wavelength intervals. Where the orders overlap, there could be abrupt changes in the continuum.

11 Using `lfits`.

`lfits` is a program which displays the FITS header in one-line form. If you are in a directory where there are FITS files (e.g. `/data/image`), the file name, object name, RA, DEC, UT and exposure time will be displayed on one line for each image. In other words, it will create an observing log for you.

The full options are `lfits [-n] [directorypath]`, where `n` will only display the last *n* FITS files. If `directorypath` is omitted it assumes the current directory. Here are some examples:

```
lfits /data/image > list
```

which can be used from anywhere to create a log file in file `list`.

```
lfits -20
```

which lists the headers of the last 20 FITS files.

12 The exposure meter

`EXPOSE` is a program which monitors the count rate from the photo-avalanche diode on the `GIRAFFE` optical bench in the coudé room. It runs on a dedicated PC called `74in`. You should normally leave this PC running Linux. When the PC is switched on, it will automatically boot into Linux mode. Logon to the system as `ccd` and start X-windows by typing

```
startx
```

The screen will blank out and a blue background will appear. On the top left hand of the screen you will see the `pager` window consisting of a small square subdivided into nine smaller areas. Next to it will be a display of the date and time according to the PC.

The pager window is a visual representation of the nine virtual screens that may be used. In other words, you can click on any of the nine squares to display a different virtual screen. The two display units can only display identical pictures and should not be confused with virtual screens. You can think of a virtual screen as if there are nine screens arranged in a square, only one of which is actually visible. For example, you may have `EXPOSE` in one screen, the monitor on another screen, `Netscape` on a third screen and an `xterm` window on a fourth screen. You can display any one of them on both display units by clicking on the appropriate square in the pager.

Start an `xterm` terminal window by clicking the left button of the mouse and choosing `Connections` and `Xterm`. To start `EXPOSE`, type `expose`

The most important button is the `Start/Stop` button. Click on this button to start an integration. If you wish to use it as an exposure meter, this action should coincide with the start of the integration on `QUARTZ`. The count rate from the APD is sampled every second and displayed in digital and graphical form. The accumulated number of counts is shown on the bottom right (window showing `CCD:`) and graphically on the bottom left. The accumulated count should be the approximately the same as shown by `QUARTZ` if the calibration is correct. This allows you to judge the exposure time.

Even if you are not interested in using `EXPOSE` as an exposure meter, it is essential to the operation of the instrument. You will need to run `EXPOSE` when guiding on a star to ensure that the count rate is maximized.

12.1 Calibrating the exposure meter

When `EXPOSE` is started, it reads a file called `expose.config`. If this file exists in the directory from where `EXPOSE` was started, it will read the values stored therein. If a local `expose.config` file does not exist, it will fetch a master copy from the system. The file looks like this:

```
#
#                      EXPOSE.CONFIG
#
#  Configuration file for GIRAFFE exposure meter.
#
     0  4000000  Counter no, Over-illum count rate
#
#
   0.0014     Calibration factor
#
#
 -32.3795  18.478000 -7200   Latitude, longitude, time zone
#
```

Lines beginning with a hash are ignored. The first line reads the default counter to be used (there are four counters numbered 0 - 3; GIRAFFE normally uses counter 0) and the maximum count rate (counts per second). Whenever the count rate is exceeded, a warning message will be displayed. To disable this warning message, set the count rate to zero in this file.

The second line is the factor which converts the accumulated counts from the APD to counts on the CCD. This factor can be set after your first exposure from within `EXPOSE`. The third line is used to display sidereal time and sun/moon information.

Calibration involves determining the factor which converts the accumulated counts from the APD to counts on the CCD. To determine this number, click on the `Calibrate` button and select `Calibrate CCD` after your first exposure. An input box will be displayed in which you must enter the accumulated count displayed by `QUARTZ`. You can also type in the factor directly by choosing `Enter Factor` in the drop menu.

You may not be interested in the direct count rate, but in the count rate with background removed. By clicking on `Background`, an input box will appear in which you can type in the background count to subtract.

Use the X- and Y-slides to adjust the scales on the graph. The graph is cleared whenever a new integration is started.

13 Recommended observing technique.

Here is a checklist of procedures to be followed on each night. This checklist is based on my own experience and may not suite you.

- At the start of your run, and perhaps at the end, obtain about 10 camera flats.
- At the start of every night, fill the cryostat. This action is a shock to the system; there should be an interval of at least 30 min before the first observation to allow things to settle down.
- Begin each observing session with three fibre flats. Remember to insert the colour filter at the GIRAFFE head, move the CVF to position 4 or thereabouts, and make sure the APD is off. The mirror must be in position 3.
- Just before observing the first object, do three arc exposures to serve as the fiducial arc for the night. Remember to remove the colour filter and set the CVF to position 1, mirror to position 3.
- Set on your first star, get the acquisition program running. Remove the colour filter, move the CVF to position 1, mirror to position 1 and switch on the APD. Start `EXPOSE`, maximize the star count and start autoguiding.
- During the first star exposure, run phase 1 of the reductions using `xspec2` and set it on automatic mode.
- Remember to obtain arc frames at regular intervals (approximately every 45 mins) during the night.
- If there is a program crash of any kind, you need to initialize the prisms and obtain new fibre flats and fiducial arcs. These data must be reduced separately.
- At the end of the night, finish off with three arcs and three fibre flats.

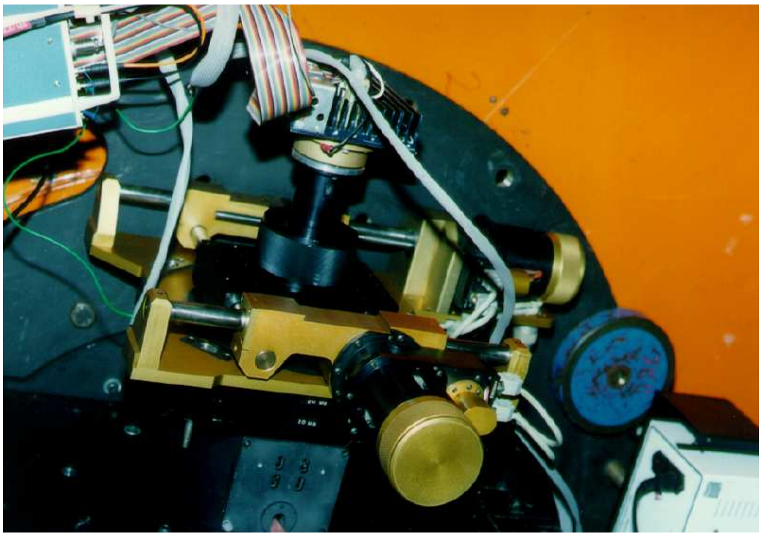


Figure 14: A small CCD (in box with cooling vanes at the top) is mounted on X-Y slides controlled by stepping motors (brass) and attached to the field acquisition box at the Cassegrain focus of the telescope.

14 Acquiring and guiding on the star.

The guider box, which is attached to the Cassegrain focus, contains a large mirror set at 45° which deflects the field to a CCD mounted on an X-Y slide (Fig. 14). The central part of this mirror can be removed to allow light to reach the instrument attached to the box - in this case GIRAFFE. Output from the CCD is displayed on a PC running the *aag-shame* software. This PC also controls the X-Y slide and the removable mirror.

You will need a guide star for every object you plan to observe. The X-Y slide position of these stars when your object is on the slit can be obtained from the following URL:

`http://orion.saao.suth`

and selecting `GUIDERS`. Fill in the RA and DEC of your object in the form. This will return a list of possible guide stars. Choose one which is brighter than 13 mag.

Start the acquisition program by typing `R`. The X-Y slides will be centered and the mirror moved out of the beam. Type `M` to place the mirror in the beam. Set the telescope on the star, which should be in the field of view. If you don't see the star, check the telescope focus. For GIRAFFE, the focus setting is about 1010 – 1030. In case of difficulty, set on a bright star in the vicinity and center it using the guider scope. Once you have the bright star centered on the screen, enter its true RA and DEC on the encoder terminal using the `S` command. Write down the RA and DEC offsets and the collimation correction for future reference. Now set on the program star which should be visible on the screen.

We now want the star to be positioned so that it is focused on the fibre aperture. To do this, the telescope has to be moved so that the star is near the top of the screen at screen coordinates of approximately (230, 30). Display two box cursors by typing in `2`. Then type `c` and move the mouse pointer to one of the cursors. Drag the cursor to this screen position. Center the star on the cursor. Now type `M` to remove the central mirror from the beam. Also, make sure that the mirror in GIRAFFE is out of the beam by moving it to position 1 in `QUARTZ`. Press the `F5` key to move the X-Y slide to coordinates (0, -5700). In this position, the CCD will be looking at the output from a fibre bundle which is focused on the fibre aperture. Use the `L` command to increase the contrast in the lookup table. You should see the star and the fibre aperture silhouetted against it. You may need to search for the star if it is not visible. Once you have centered the star on the aperture, move the second box cursor to the star and note its coordinates. it is a good idea to move the mirror back into place and centre the X-Y slides (`F6`). Adjust the box cursor so that it is centered on the star and note its coordinates for future reference. From now on, if you place a star in this box it should also be fairly well centered on the fibre. Type `M` to move the mirror from the beam.

At this point you should switch on the APD and start an integration on the exposure meter. Move the star until the count rate is maximized. Now press `F5` and enter the coordinates of a suitable guide star. Type `X`, place the mouse pointer on the guide star and type `Y` to start guiding. To stop guiding type `G`. Type `G` to re-start guiding.

It is important to try various focus settings while guiding. I generally set the best focus for the acquisition camera and then see how the count rate changes by changing the focus setting in steps of 5 units. The star will move off the fibre when you do this, so you need to wait until the acquisition is complete before noting the count rate.

15 Storing data on DAT tape.

The DAT drive on `s74` supports DDS-1 and DDS-2 DAT tapes. The preferred medium is DDS-2 which can store up to 4 GB of data. To copy files from disk to DAT, go to the directory in which the files are stored:

```
cd /data/image
```

and type the command:

```
datwrite
```

This program writes a file mark at the start of the tape, does a `tar` dump of all files and directories in the current directory and then unloads the tape. You may also use the standard `tar cv` command if you prefer. *Please do not attempt to append files to tape.* This is a dangerous procedure which may well give rise to an unreadable tape. Also, it is a waste of time to compress the files before storing on DAT, because the DAT unit automatically compresses. All you will achieve is to prolong considerably the storing of data on tape as compression is time consuming.

Note that the device name for the DAT unit is `/dev/nst0` on all machines at SAAO. However, there is never a need to use it, because the environmental variable `$TAPE` is always set to this device. Thus if you prefer to use `tar` rather than the `datwrite` script (which in any case calls `tar`), then all you have to do is type `tar cv`.

To check that files have been written using `datwrite`, load the tape (or rewind it) and type in:

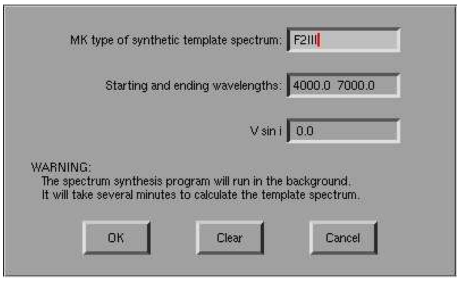
```
tar t
tar t
```

You need to type `tar t` twice because there is a file mark at the beginning of tape. To stop the printout, type `Ctrl-C` and then `mt offline` to eject the tape. To find out how much space you files will use, type in

```
cd
du -sm image
```

The number printed out will be in megabytes. A DDS-1 tape will hold 1500 Mb, a DDS-2 tape will hold 4000 Mb.

My preference is to copy the contents of `/data/image` onto two tapes, using them on alternate nights. Before going to bed, I set the one tape copying. The next night, I use the other tape. Note that the files are copied from the beginning and existing files on tape are overwritten. In this way I am assured of a backup in case anything goes wrong. On the last night, I make sure that both tapes are up to date. I then delete the contents of `/data/image`, so that only data from the last night will be recorded. I copy these data to a third tape, which then proceeds quite rapidly and I go to bed with two duplicate tapes containing all data except the last night and one tape with just the data from the last night.



MK type of synthetic template spectrum: F2III

Starting and ending wavelengths: 4000.0 7000.0

V sin i 0.0

WARNING:
The spectrum synthesis program will run in the background.
It will take several minutes to calculate the template spectrum.

Figure 15: The form requesting information for the synthetic template spectrum used in fitting the continuum. It appears when `TEMPLATE` is pressed.

16 Using `xspec2` for radial velocities

It is possible to obtain radial velocities by cross-correlation directly from the binary file output of `xspec2`. Before you embark on this procedure, you should note that cross-correlation only works if the star has a reasonably large number of relatively sharp lines. This excludes stars earlier than A5. For these early-type stars the positions of individual lines need to be measured and compared to their laboratory wavelengths.

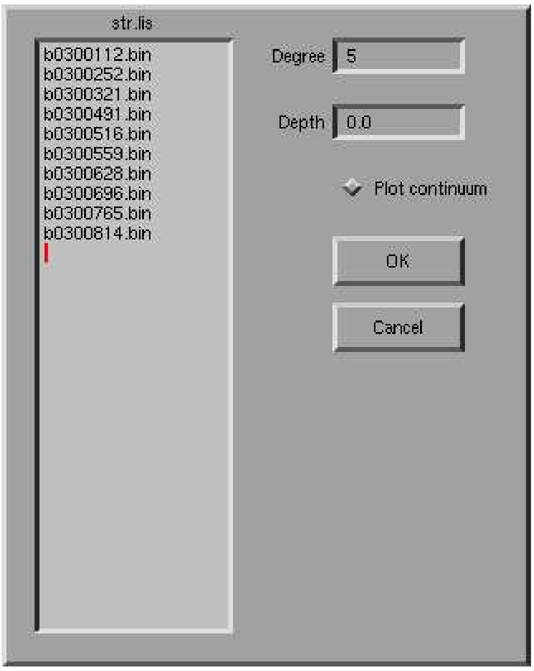
For cross-correlation to work, you need to place the continuum reasonably accurately. If this is not done, then variations in the continuum will distort the resulting correlation function and you will get wrong or meaningless results. Also you need to choose a spectrum to use as a template for cross-correlation. This will be known as the *fiducial spectrum*. The fiducial spectrum must closely resemble the spectra of the stars for which velocities are required. Therefore they should be restricted to a fairly narrow spectral type. It may be necessary to choose different fiducial spectra for different spectral types. Naturally, you would like the fiducial spectrum to have the highest possible S/N ratio and, if possible, have a well determined radial velocity. Remember that the resulting velocities will all be relative to the velocity of the fiducial spectrum.

In practice, I have found it most convenient and more accurate to use a synthetic fiducial spectrum rather than a spectrum of a real star. A large number of synthetic spectra for the wavelength range 4000 – 7000 Å have been calculated and stored on directory `/info/kurucz`. It is also quite easy to calculate a spectrum not covered by these models. The synthetic spectra are also very useful for placing the continuum automatically, though this software still needs to be improved.

16.1 Placing the continuum

Press the `TEMPLATE` button. This results in the form displayed in Fig. 15. Enter a convenient MK classification for the template of choice, the starting and ending wavelengths (use the default values 4000 7000), and the projected rotational velocity. A value of zero seems always to give the best results. Normally, the synthetic spectrum is already present on disk and will be copied across. If not, it may take some 10 – 20 mins to calculate a spectrum. Press `OK` when ready.

Next, press `RECTIFY`. In this step, placement of the continuum will be done automatically. The box shown in Fig. 16 will be shown. It lists the spectra that will be processed. For continuum placement, a polynomial of order 3 – 7 will be fitted to take out variations in the blaze. A degree of 5 is usually adequate. The box also requires a ”Depth” parameter which should be small (about 0.01) when the S/N is high and increasing to about 0.1 for S/N of 10 or less. Its exact value is not important. You may wish to see how well the continuum is placed by clicking on the toggle button, but remember that it will display every single order for the first spectrum. Press `OK` when ready. The rectified spectra are stored as, for example, `c0230036.bin`. We are now ready to proceed with calculating the velocities by cross-correlation.


str.lis

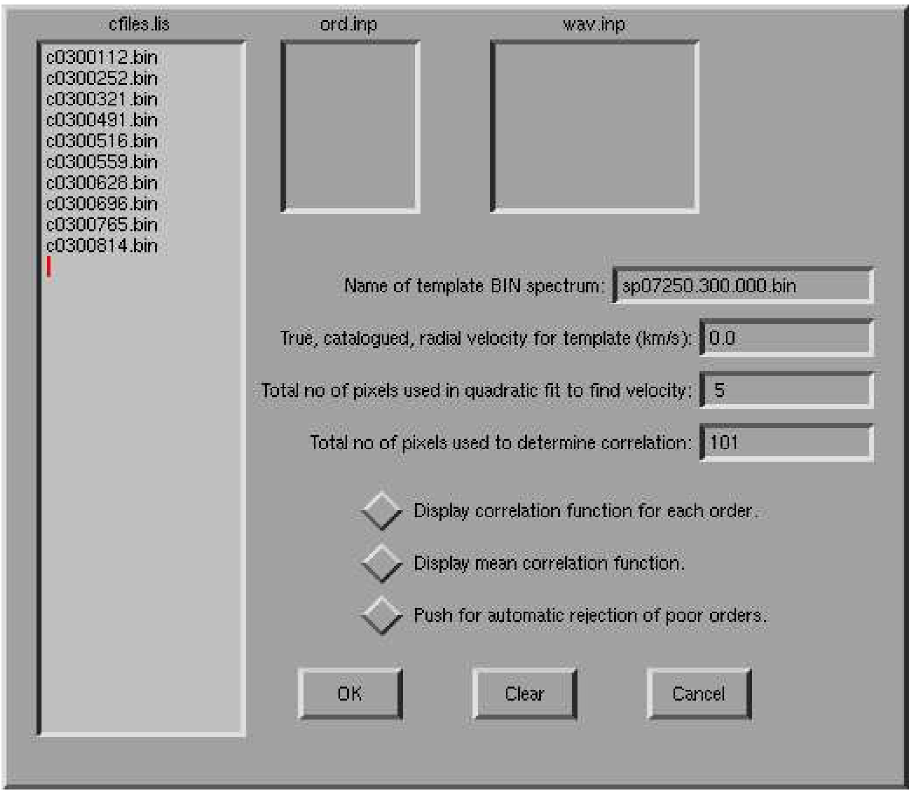
b0300112.bin
b0300252.bin
b0300321.bin
b0300491.bin
b0300516.bin
b0300559.bin
b0300628.bin
b0300696.bin
b0300765.bin
b0300814.bin

Degree: 5

Depth: 0.0

◇ Plot continuum

Figure 16: This form requests the order of the polynomial and the fractional continuum intensity (depth) allowed for the fit to the continuum. It appears when `RECTIFY` is pressed.


cfiles.lis

c0300112.bin
c0300252.bin
c0300321.bin
c0300491.bin
c0300516.bin
c0300559.bin
c0300628.bin
c0300696.bin
c0300765.bin
c0300814.bin

Name of template BIN spectrum: sp07250.300.000.bin

True, catalogued, radial velocity for template (km/s): 0.0

Total no of pixels used in quadratic fit to find velocity: 5

Total no of pixels used to determine correlation: 101

◇ Display correlation function for each order.
◇ Display mean correlation function.
◇ Push for automatic rejection of poor orders.

Figure 17: The form requesting information for cross-correlation of the template with individual spectra. It appears when `VELOCITIES` is pressed.

16.2 Cross correlation

Press the `VELOCITIES` button. The form shown in Fig. 17 will pop up. The left window shows the files to be processed. In the middle window you may wish to type in order numbers that should *not* be used in the cross correlation. Alternatively, or in addition, you may type in wavelength ranges to be omitted on separate lines. The program is robust enough to ignore wildly diverging results from certain orders (usually those containing the Balmer and telluric lines), so it is safe to leave these boxes blank.

The name of the template file is filled in for you, but you should note it down in case you need to use it again. It is of the form `sp07250.300.000.bin` which represent the effective temperature, gravity and projected rotational velocity of the model. You also need to fill in the true radial velocity of the star, which in case of a synthetic spectrum is zero. Next you need to fill in the number of points used to find the maximum of the correlation function. For narrow-lined stars, this should be about 5, but you may need to make it bigger if the star has broad lines. Then you need to fill in the velocity range, in pixels, that needs to be covered by the cross-correlation. A typical value is 101.

You may push the toggle button if you want the correlation function for each order of each spectrum to be displayed. This is most time consuming, but is useful to diagnose the cause for poor results from certain orders. You may also push the toggle button if you want the mean correlation function for each spectrum to be displayed (a good choice for the first time round). Finally, I recommend that you allow the program to omit discrepant orders. Press `OK` when ready.

Results of the calculation are displayed in the `xterm` window. Several files are created. Firstly, the mean correlation profile for each star is stored in the text files `c0230036.cor`, the calculations seen in the `xterm` window are stored in `xcor.out` and the radial velocities in `xcor.rv`.

The radial velocity curve can be plotted by pressing the `PLOT VELOCITIES` button.

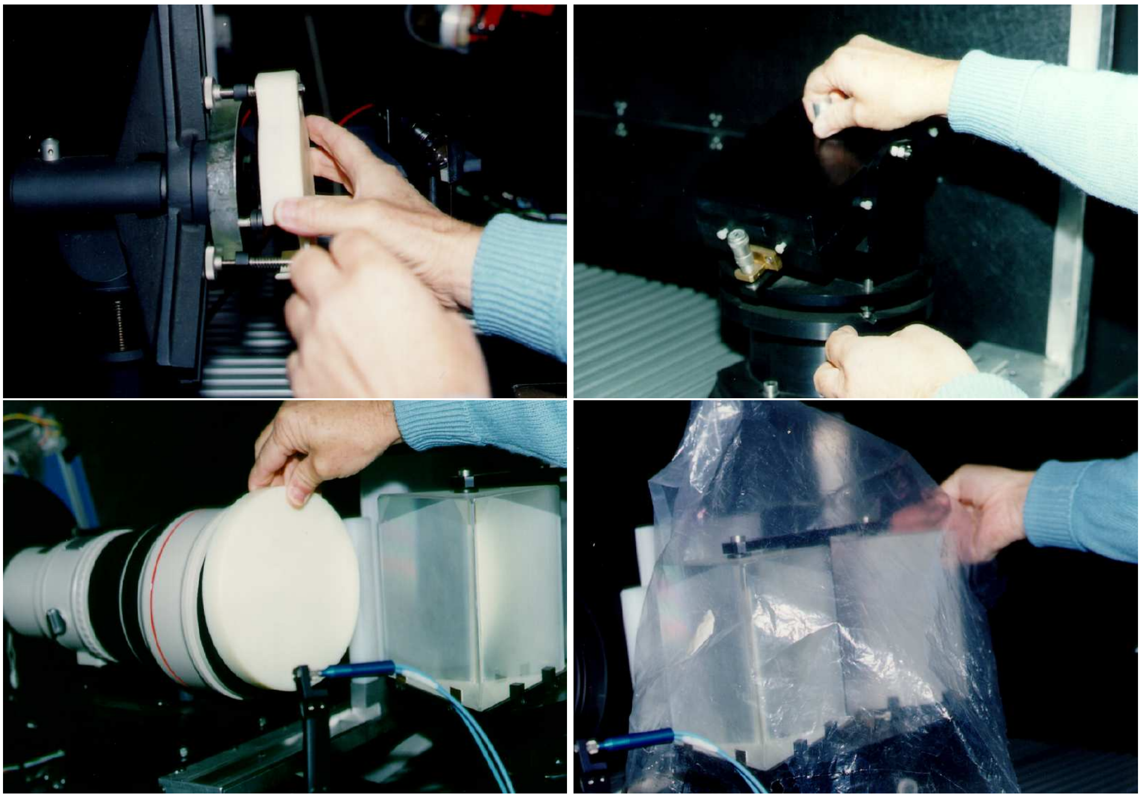


Figure 18: At the end of a run, the optics on the optical bench must be covered. Starting at the top left and working clockwise: covering the collimator; covering the grating (also done at the end of every night); covering the camera lens and covering the prisms.

17 Procedure to be followed at the end of a run

It is very important that the optics in the coudé room be protected from dust. For this reason, please ensure that the grating is covered when not in use (i.e. at the end of every night). At the end of your run, it is very important that *all optics are covered.* This is your responsibility. Proceed as follows:

- Cover the collimator (Fig. 18a).
- Cover the grating (Fig. 18b).
- Cover the camera (Fig. 18c).
- Cover the prisms (Fig. 18d).

Make sure that the cover over the optical bench are all closed and switch off all lights. Do not switch off the power on any of the control racks as this is the responsibility of the site technicians.

18 Appendix

18.1 spec2.info

Most of the data in this file should not be changed by the user. However, changes to these variables is quite safe and could be useful:

- `OPT`: This is set to `T` (true) by default, giving optimal extraction. You may want to change this to `F` to use the summation method rather than optimal extraction.
- `IDUMP`: Dump level - see below.

18.2 Dump files

There are several dump levels in `spec2.info` which can be selected by editing this file and changing the `IDUMP` flag. This is normally set to 0, which creates no dump files. Setting `IDUMP` to 1 generates several fits files:

- `arcord.fits`: This file shows the combined fiducial arc together with the lines defining the orders. If you are getting strange results with the wavelength calibration, look at this file and check if the loci of the orders are correct. If not, it probably means that the flats have moved position and no longer match.
- `flatord.fits`: This shows the combined flats together with the lines defining the orders. Since the order loci are normally defined by well-exposed stars, a displacement here means that the flats no longer match the stars and should not be used.
- `orders.fits`: This shows the combined flats order spectra together with the lines defining the orders. There should be very good agreement, since the loci are calculated from this frame.

For `IDUMP = 2` the following additional files are created:

- `arcxx.fits`: These are the extracted, straightened orders for the arc with order number `xx` relative to the starting order. Useful if you suspect the extraction is incorrect.
- `flatxx.fits`: As above, but for the flats.
- `objectxx.fits`: As above, but for the first star in the list.
- `arcfid.fits`: The combined fiducial arc file. Same as `arcord.fits`, but the order loci are not shown.
- `flatsum.fits`: As above, but for the flats.
- `ordsum.fits`: As above, but for the orders.
- `arc.dat`: The cross-sectional profile of the extracted combined fiducial arc for each order in `datin` format. You may wish to plot this by first copying the file to `datin.9` then running `giraffe` and selecting option 50 (for screen plotting) followed by option 1.
- `flat.dat`: As above for the combined flats.
- `object.dat`: As above for the first star in the list.

In addition, the output file `spec2.out` will contain much more detail, such as the background used, full details of the arc fitting, etc.

18.3 Background subtraction

Each frame is bias corrected and trimmed. The region used for background subtraction is midway between the orders. For each order, the run of background with pixel position (on either side of the order) is smoothed. The background at a given pixel position is given by the average of the smooth backgrounds at that position.

18.4 Flatfielding

In using fibre flats to correct pixel-to-pixel variations in the object spectrum, we hit a problem: what to do on the edges of the decker where the count is low. It is no good simply dividing the extracted star order by the star flat order. The noise due to the low count on the edges would give completely wrong results. The traditional way is to collapse the object order to a 1-D spectrum, collapse the star flat order to a 1-D spectrum and divide one by the other. This sounds wrong, but actually it is perfectly correct *provided the cross-section of the object profile is the same, or closely approximates, the cross-section of the star flat profile.* This is easy to prove and is done so in several references. For fibre-fed spectrographs, the profile of the flats and star are indeed the same.

While using fibre flats appears to be the best option, the exposure for the blue orders is much weaker than for the red orders (by an order of magnitude). This means one cannot attain enough photon statistics to make the method possible. Empirically, I have found that using camera flats produces better S/N than fibre flats. This is the default operation in `xspec2`.

18.5 Optimal extraction

The default operation of `xspec2` is optimal extraction. In this procedure, the profile perpendicular to the dispersion is calculated for each order from the flat fields. The profile is fitted to the stellar spectrum to provide the best estimate of the intensity at that point.

The alternative procedure is merely to sum the intensity at each point perpendicular to the dispersion. This method gives the same results as optimal extraction for bright stars. An enhancement of nearly a factor of three in the S/N ratio is possible by using optimal extraction on faint stars.

18.6 Performance of GIRAFFE

After several runs, we are now in a position to assess the general performance of `GIRAFFE`, the SAAO echelle spectrograph attached to the 1.9-m telescope. The most useful data for the purpose was obtained by J. Krzyminski during a project to measure the radial velocities of several Cepheids. These data comprise 196 observations of stars in the magnitude range 2.7 - 9.5. These data were obtained with the red prism. The measured spectral range is 5300 – 7200 Å.

One may expect the signal-to-noise ratio, S/N, to follow the law

$$\log(S/N) = C + 0.5\log(t_{exp}) - 0.2m$$

where C is a constant, t_{exp} is the exposure time and m the stellar magnitude. In Fig. 19 we show a plot of $\log(S/N)$ as a function of $X = 0.5\log(t_{exp}) - 0.2m$, with t_{exp} measured in seconds. The magnitude was simply taken as the mean V magnitude of the stars. Though the magnitude range can be as much as 0.5-mag for some Cepheids, this approximation is within the range of seeing variations and can probably be justified. The best fit (shown in the figure by the straight line) is given by:

$$\log(S/N) = 1.81 + 0.5\log(t_{exp}) - 0.2m$$

The standard deviation per point in $\log(S/N)$ is 0.21. Table 1 shows typical exposure times as a function of magnitude and S/N derived from this formula.

Table 1: Typical exposure times, in minutes, for a given stellar magnitude, m, and signal-to-noise ratio of 10, 50, 100 and 200 respectively.

m	10	50	100	200
2	-	.1	.3	1.0
4	-	.4	1.6	6.4
6	0.1	2.5	10.0	40.0
8	0.6	16.0	63.0	250.0
10	4.0	100.0	400.0	-
12	25.0	630.0	-	-

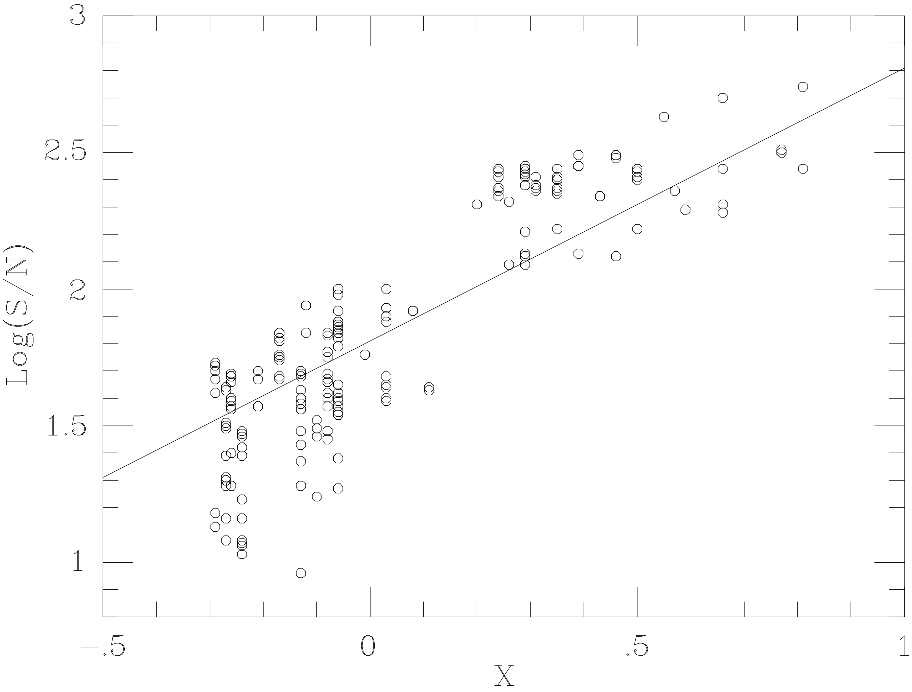


Figure 19: The logarithm of the signal-to-noise ratio as a function of $X = 0.5\log(t_{exp}) - 0.2m$, with exposure time t_{exp} in seconds and m in magnitudes.

Table 2: Calibrated on 5 Nov 2000

Red	λ_1	λ_2	Ord_1	Ord_2	Blue	λ_2	λ_2	Ord_1	Ord_2
46000	7000	4537	82	126	000	7119	4117	81	138
46100	6910	4499	83	127	100	7003	4087	82	140
46200	6827	4465	84	128	200	6893	4059	83	141
46300	6750	4433	85	129	300	6790	4033	85	142
46400	6680	4405	86	130	400	6695	4009	86	143
46500	6618	4379	87	131	500	6608	3986	87	143
46600	6563	4356	88	131	600	6528	3966	88	144
46700	6515	4336	88	132	700	6457	3947	89	145
46800	6476	4319	89	132	800	6395	3930	90	146
46900	6445	4304	89	133	900	6342	3915	90	146
47000	6423	4291	89	133	1000	6298	3902	91	147
47100	6411	4281	89	134	1100	6264	3890	91	147
47200	6407	4273	89	134	1200	6240	3880	92	147
47300	6414	4268	89	134	1300	6227	3872	92	148
47400	6430	4264	89	134	1400	6224	3865	92	148
47500	6457	4262	89	134	1500	6233	3860	92	148
47600	6494	4262	88	134	1600	6253	3856	92	148
47700	6543	4264	88	134	1700	6284	3854	91	148
47800	6603	4268	87	134	1800	6328	3854	91	148
47900	6674	4273	86	134	1900	6385	3854	90	148
48000	6758	4279	85	134	2000	6454	3857	89	148
48100	6854	4287	84	133	2100	6536	3860	88	148
48200	6962	4296	83	133	2200	6632	3865	87	148
48300	7084	4306	81	133	2300	6742	3872	85	148
48400	7219	4318	80	132	2400	6866	3880	84	147
48500	7367	4330	78	132	2500	7004	3889	82	147

The radial velocities of these stars were obtained by cross-correlation, the spectrum of a radial velocity standard, δ Sgr, being adopted as the fiducial spectrum. Cross-correlation of other radial velocity standards with this spectrum showed that the external standard deviation for a single spectrum is typically 0.15 km s^{-1}. The standard deviation for the Cepheid radial velocities could be judged by the scatter about their velocity curves and was found to be about 0.25 km s^{-1}. This suggests that accurate radial velocities for these late-type stars can be obtained for $S/N \approx 20$.

18.7 Prism settings and wavelength ranges

The table and figures show the central wavelength for the first and last complete orders at a particular prism setting. The first order number is also given (used in arc calibration). For the blue prism, the short wavelength region is essentially determined by the sensitivity of the CCD and is always shortwards of 3900.

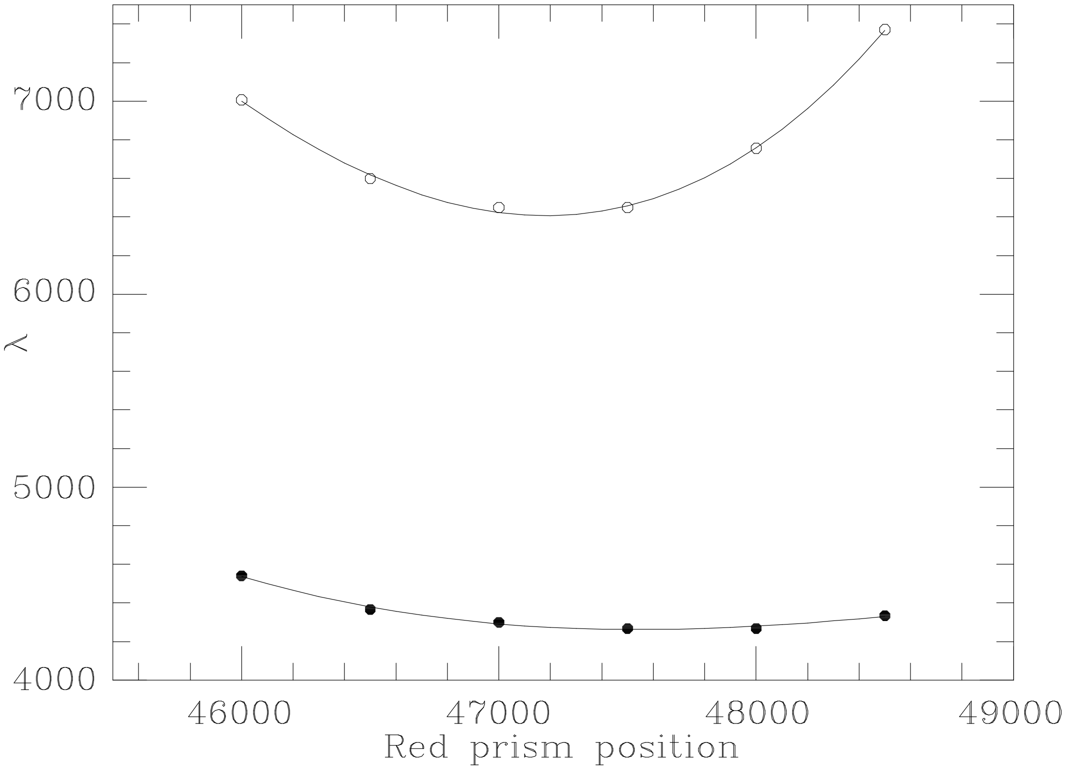


Figure 20: Minimum and maximum wavelengths for the red prism as a function of prism position.

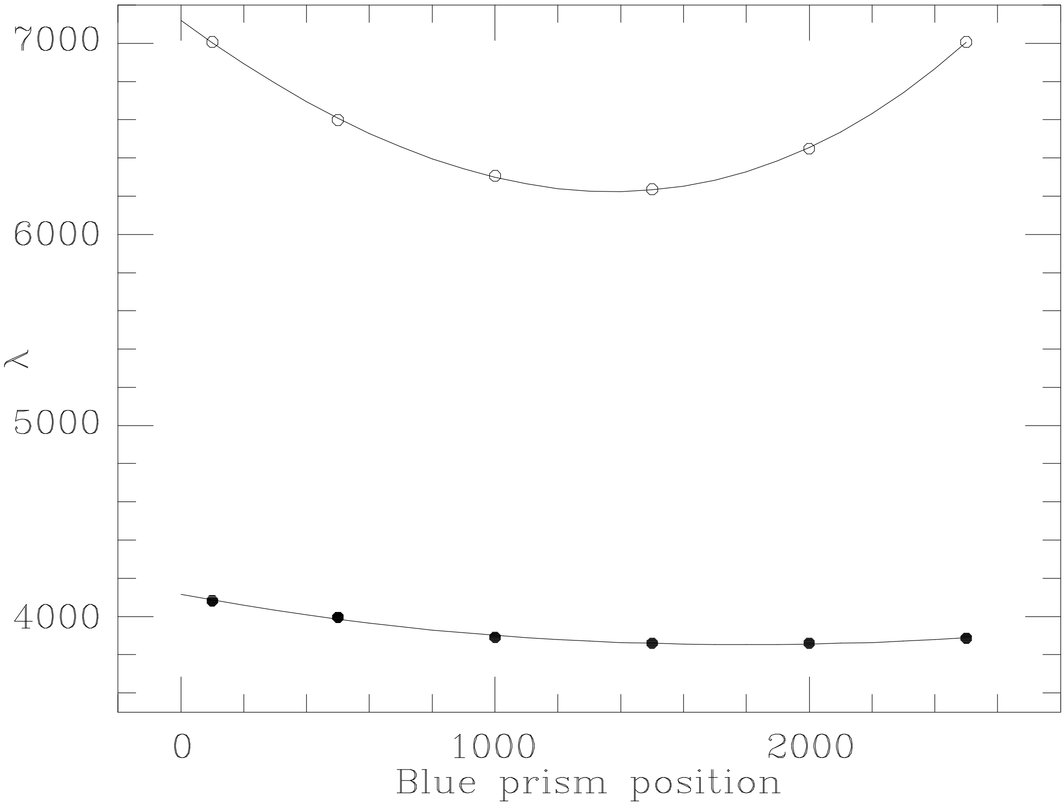


Figure 21: Minimum and maximum wavelengths for the blue prism as a function of prism position. The sensitivity drops sharply bluewards of 4000 Å.

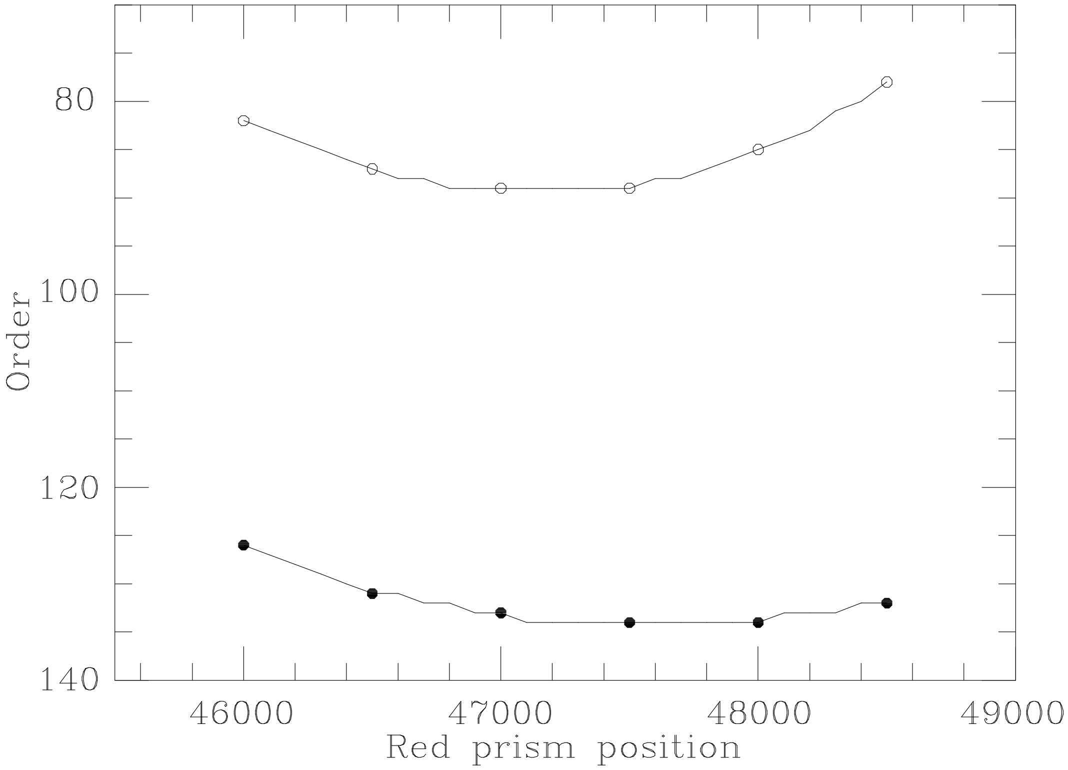


Figure 22: The number of the first visible order for the red prism as a function of prism position.

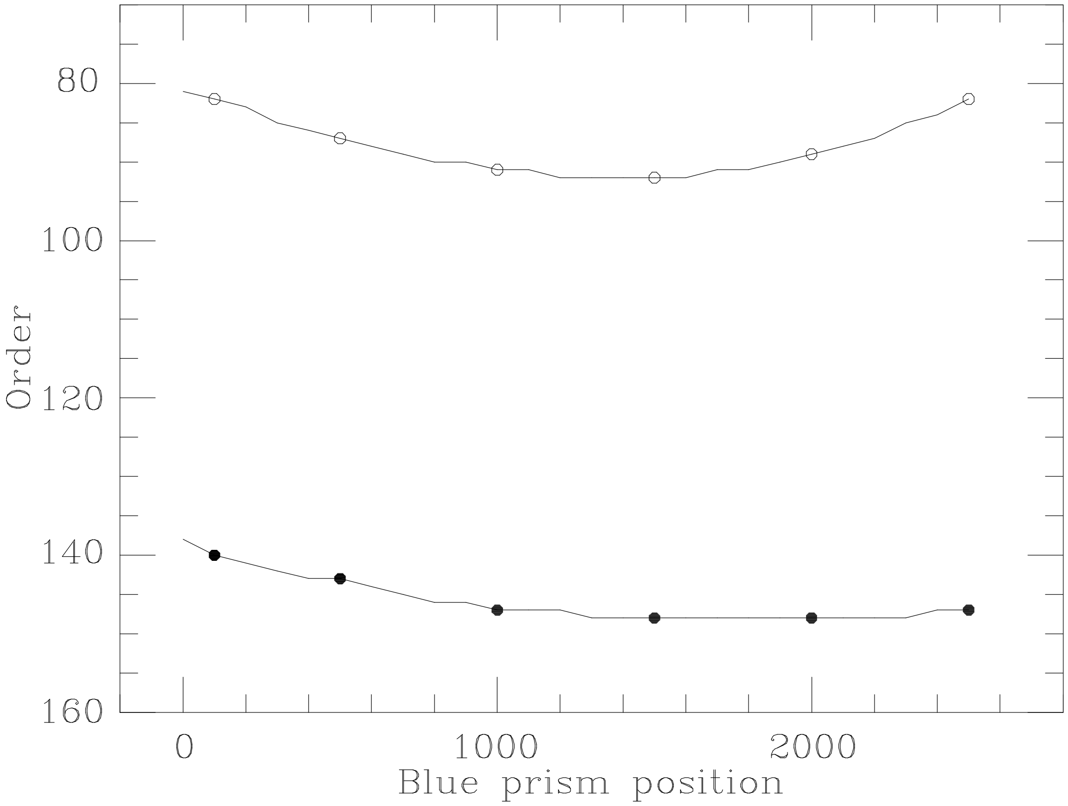


Figure 23: The number of the first visible order for the blue prism as a function of prism position.

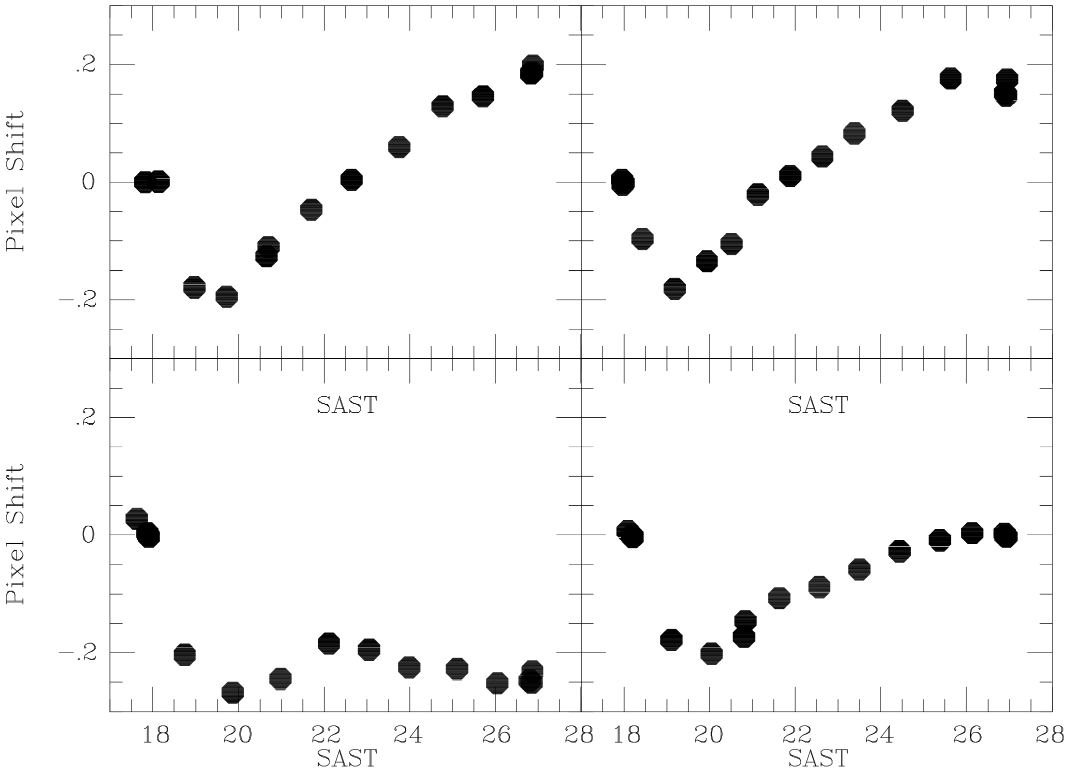


Figure 24: Examples of the pixel drift with time in the wavelength direction. Note the sharp change at the start of each night shortly after the dewar has been filled. Note that a shift of 1 pixel corresponds approximately to 3 km s^{-1} in velocity.