High resolution échelle spectrograph SOFIN

User's Manual

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Contents

Chapter 1

Introduction

The SOFIN spectrograph has been constructed for the Nordic Optical Telescope to provide spectroscopic observations with at very high spectral resolution. The spectrograph has been designed and manufactured in the Crimean Astrophysical Observatory in collaboration with the Observatory of Helsinki University. The first commissioning and observations were in June 1991. In October 1992 a new, remote controlled, slit unit was installed and the first tests with the shortest camera were carried out.

The current User's manual gives a detailed description of how to install and use the spectrograph, and is intended for the observers as well as for the supporting staff at the NOT. The User's manual consist of two parts: Operation and Software manuals. In Chapter 2 a general description of the spectrograph is given. The installation and preparations for an observing run is described in Chapter 3. Chapter 4 describes how to observe with the spectrograph. Chapter 5 gives some usefull recommendations concerning the selection of spectral regions from the échelle focal map. Maintenance of the Astromed CCD cameras is described in Chapter 6. The control software and auxiliary tools are described in Software manual. The three appendices describes the installation of the software, operation system guidelines and some features of the spectrograph optics.

A complete description of the optical design of the spectrograph is given in [1], the mechanical design in [2], the remote control electronics in [3] and the software design in [4].

Part I

Operation manual

Chapter 2

General description

2.1 Spectrograph design

The SOFIN high resolution échelle spectrograph consists of three main parts: the spectrograph itself mounted in the Cassegrain focus of the NOT, and the CAMAC crate and the Gateway-2000 personal computer in the control room.

In the spectrograph, the échelle grating is used as the dispersion unit and the cross-dispersion prism is used to separate orders. Figure 2.1 shows the spectrograph layout [1]. In the present configuration, the spectrograph has three optical cameras with focal lenghts 2000, 1000 and 350 mm, which are used in combination with two CCD cameras with 1152×770 and 1152×298 pixel sensors. Two of the three optical cameras can be installed in the spectrograph simultaneously, but only one of them can be used at a time. The switching procedure from one camera to another takes only a minute. *For safety reason, only a qualified person is allowed to switch the CCD cables.*

The spectrograph is remote controlled through the CAMAC interface from the computer in the control room. Only the procedures of switching between the optical and CCD cameras, changing the entrance slit height and focussing of the spectrograph are carried out manually. The control software also deals with the CCD cameras and image data acquisition. You can start, end, suspend and resume the exposure, read the CCD image, monitor the status of the CCD, change the wavelength region and so on. The software can display the stored image and estimate the number of counts. The software contains a number of data bases for the observed objects, spectral regions and the observing journal.

In order to guide on the star in the slit from the control room monitor, a TV-CCD camera is used. At present the camera available at the NOT is quite insensitive. Hence, if your stars are fainter than, say, 7^m (depending strongly on the seeing) it is recommended to bring *your own sufficiently sensitive intensified TV-CCD camera.*

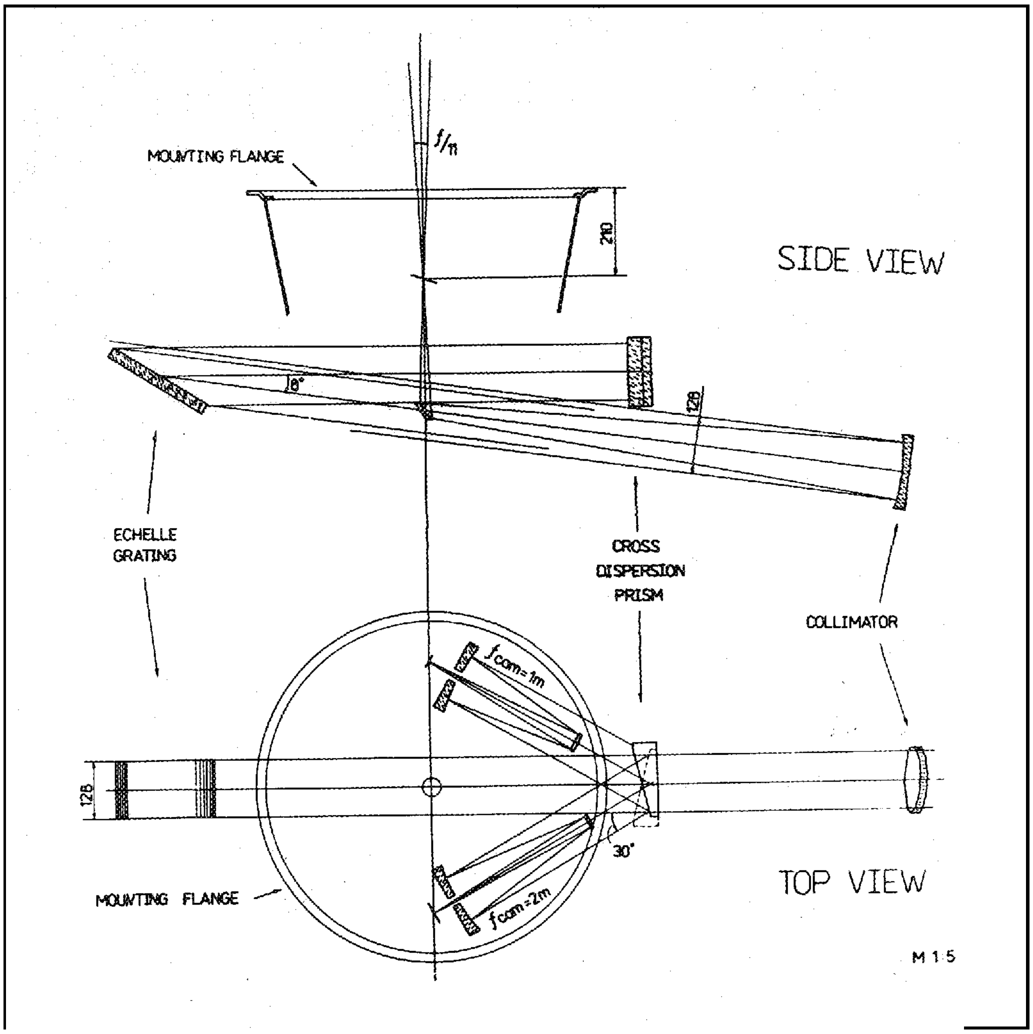

Figure 2.1: The optical layout of the SOFIN spectrograph. The special switching mechanism provides the light beam to be directed from one optical camera to other by turning the cross-dispersion prism around it axis. The shutter and filter wheel are mounted just under the entrance slit unit. The TV camera is not shown on the picture and placed over the échelle unit.

2.2 Spectrograph performance

The resolving power of the first camera is about 170000. With the optimal slit size this scales to two pixels in the central part of the CCD. For the second camera the resolving power is about half of that of the first (the optimal slit is twice as wider).

The spectrograph was designed to reach high resolving power. Because the CCD sizes are limited, the wavelength coverage of one order is relatively small. Thus, using the first camera gives échelle images that contain about 18 orders each of 22 Å, in the λ6100 Å region. The second camera gives about the same number of orders with the other CCD and the wavelength range of the orders is double that of the first camera. Only the third, low resolution camera (about 27000), can cover almost the all spectral orders.

Although both CCDs are coated, their quantum efficiency sets the limits to the spectral range of the spectrograph. The usable region starts from the atmospheric limit and extends up to 10800 Å, where the quantum efficiency of the EEV CCD becomes small. The maximum efficiency of the EEV CCD is at about 7000 Å.

The exposure time depends on a number of factors including the brightness of the object, signal to noise ratio required, spectral resolution, seeing, etc. If the seeing is good, which means at the NOT less than 0.7 arcsec, it is profitable to use the optimal slit size and so obtain the maximum resolving power.

For the first camera and the optimal slit size for a star of 7^m, a spectrum with signal to noise ratio 300 in the λ6000 Å region can be achieved with two hours of exposure time. The second camera gives the same signal to noise in one hour. Note however, that this estimate is valid only for good seeing. When the seeing is worse, the exposure times must be increased.

The accuracy of the spectrum with such signal to noise ratio will be defined by the precision of the flat field correction. For a spectrum with signal to noise ratio less than 25, the readout noise of the CCD will dominate the statistical noise of the stellar signal.

A typical échelle frame is shown in Figure 2.2.

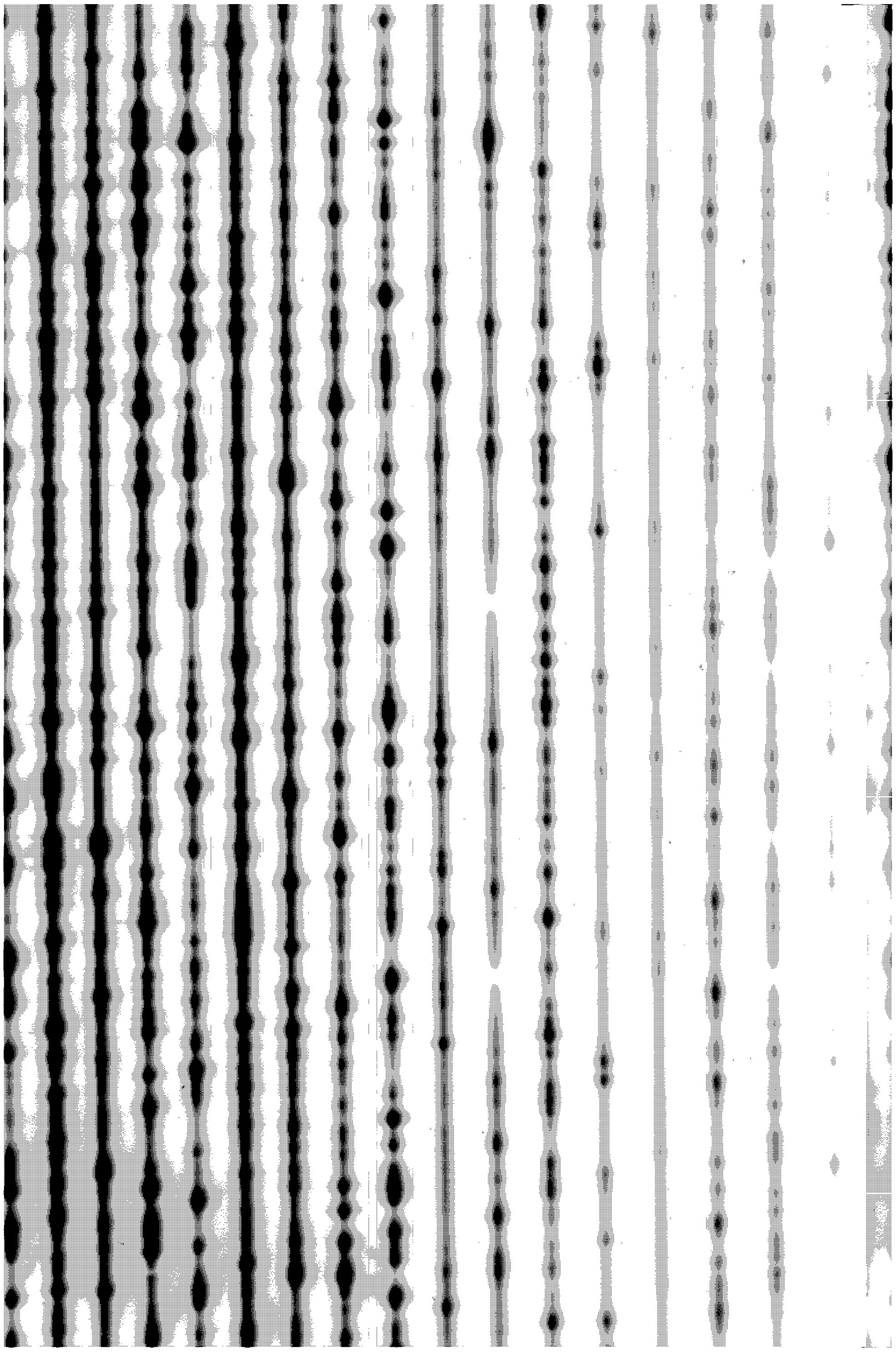

Figure 2.2: The échelle spectra of Y CVn in DNa $\lambda5893$ Å region taken with 1152×770 pixel CCD in the first camera.

Chapter 3

Preparations for observing run

3.1 Introduction

In this chapter the preparations before an observing run are described in detail. The following list summarizes the neccessary steps:

1. Pump CCD dewars (Section 6.2).
2. Connect the spectrograph cables (Section 3.2).
3. Mount CCD electronics racks on the spectrograph (Section 3.3).
4. Connect power cables (Section 3.4).
5. Install and adjust the TV camera (Section 3.5).
6. Remove the protecting cover of the échelle grating (Section 3.6).
7. Mount the spectrograph on to the telescope (Section 3.7).
8. Change an optical camera if necessary (Section 3.8).
9. Attach CCD cameras to the bayonet connectors (Section 3.9).
10. Install CCD cameras into the spectrograph (Section 3.10).
11. Connect the CCD cables (Section 6.4).
12. Fill dewars with nitrogen (Section 6.3).
13. Align CCD cameras (Section 3.12) and focus the spectrograph (Section 3.13).
14. Set up software for the observing run.

15. Start observing (Chapter 4).

It is important not only to complete each step but also to follow the right sequence. The full preparation procedure takes about 4–5 hours for two people. Pumping of two CCD dewars may take up to 8 hours.

3.2 Spectrograph cables

The cables are used to connect the electronics of the spectrograph to the CAMAC. **The spectrograph, CAMAC and computer must always be powered off whilst the connection is being made.**

The crate of CAMAC is placed near to the control computer. The rightmost position in the CAMAC crate is occupied by the controller unit. It must be connected to the computer with a separate round cable with AMPHENOL connectors. The position of the card connector is labelled on the rear panel of the computer.

The cables from the spectrograph must be put through the channel hole from the dome to the control room. It is easier to put it in this direction from top to bottom. The length of the cable is about 25 m and it is slightly longer than needed. The extra part of the cable should be placed near the computer. At the spectrograph end the cable must be connected to the panels on the round electronics box and also on the main body of the spectrograph. The correspondence of the connectors is indicated by labels on the cables.

The list of the cables is given below.

- Cables to be connected to the panel on the electronics box are for:
  - Stepping drive for échelle unit.
  - Stepping drive for cross-dispersion prism unit.
  - Pentaprism unit.
  - Unit for calibration lamps.
  - Shutter unit.
  - Filter unit.
- Cables to be connected to the panel on the top of TV camera on the main body of the spectrograph are for:
  - Slit unit.
  - Stokesmeter unit.
- Cable for TV camera (see Section 3.5).

- Spare coaxial cable.

All these cable connectors are of different types except the two for the pentaprism and slit units, which are similar.

The cables should be fastened to the electronics box by plastic ties to prevent damage of the cables due to bending near to the connectors.

The other end of the cables must be attached in a similar way to the rear panel of the CAMAC units. All connectors are labelled. The cable from the TV camera goes to one of TV monitors, available in the control room (see Section 3.5).

3.3 CCD electronics racks and cable

Two electronics units can be used for CCD cameras simultaneously during observations. Both ASTROMED white electronics boxes should be carefully attached to the bottom side of the panel, above the cross-dispersion prism unit.

The electronics racks must be positioned so that the rear panels face the opposite directions. The rear panels of the racks have a number of connectors and a cooling fan. The electronics rack with the **SOFIN** label must be put at the side of the second optical camera and the rack labelled **FLEX** must be put at the side of the first optical camera.

The flat ribbon cable should be connected to the rear panel of electronics box. The other end connects to the RISC card in the control computer. The position of the RISC card connector is labelled on the rear panel of the computer. See notes in Section 6.4 for safety precaution details.

3.4 Electrical power for the spectrograph

Here we describe how to power on the spectrograph. The power cable has to be connected to the telescope power outlet after the spectrograph has been mounted and all signal cables have been connected. Other power cables have to be connected to the spectrograph power splitter, placed at the bottom side of the CCD electronics plate.

- Main power cable of the spectrograph which comes from the round electronics box.

- Power cable of the Stokesmeter unit which comes from the spectrograph just over TV camera.

- Power cable for the TV camera.

- Two power cables for the CCD electronics.

3.5 TV camera

Visual monitoring of the position of the image on the spectrograph entrance slit is provided by a guiding TV camera. The light reflected from the slit jaws is directed through the optical elements to the TV camera. The TV camera is installed in the special port in the main body of the spectrograph, close to the electronics box.

Currently, only a non-intensified TV-CCD camera is available. It is sufficient for guiding objects brighter than 7^m, if the seeing is good. For fainter objects, an intensified TV-CCD camera must be used.

The ordinary CCD camera HITACHI does not need any special adapter to be installed into the port. Just insert the camera into the port and connect it to the power outlet. Take the spare TV monitor from the control room and the coaxial connection cable from the accessories box. Connect the TV camera to the monitor and turn the power on. Then refer to Section **??** for how to turn on the comparison spectrum lamp. After that, the image of the slit should be visible on the TV monitor (see Figure 4.1).

Then carry out the following steps.

1. *Camera adjustment.* A set of four adjustment screws around the port circlet is used to position the image of the slit in the centre of the TV monitor. Simultaneously one can try to find the best rough focus and, then, fix the adjustment screws.

2. *Camera focussing.* The special focusing mechanism can be used for further adjustment of the focus. Access to the focusing mechanism is available only when the spectrograph is not on the telescope.

    - Remove the black protecting cover from the spectrograph flange.
    - Undo two bolts which hold the optical pipe, to let it move freely on the rails. Find the approximate focus position and fix the bolts.
    - On the optical pipe, under the rails, there is a small objective handle to provide fine tuning of the focal distance.
    - Replace the black protecting cover of the spectrograph.

3.6 Echelle protecting cover

When the spectrograph is in the storage position and will not be in use for long time, a special protecting cover must be installed to prevent dust contamination of the échelle grating. The cover should be removed before use of the spectrograph.

Open the échelle grating unit marked by a label. To do that, unscrew the two bolts with handles and carefully remove the tube covering the whole échelle unit. Now you can access the échelle grating with the plastic glass protecting cover. *Slowly* pull out the plastic cover, holding it by the hole. **Any attempts to remove dirt or dust from the échelle are strictly forbidden.** Replace the tube on the grating unit and screw in the bolts back. Do not leave the grating unit without covering tube!

The cover plate must be kept in a clean, dustless and safe place. It is better to pack it into soft paper and a plastic bag.

To install the protecting cover, follow this procedure in reverse order.

3.7 Mounting spectrograph on the telescope

Lifting and attaching the spectrograph to the telescope should be done very carefully because it is possible to damage some vital parts of the instrument. In the present configuration, when not in use spectrograph is stored on the special carrier with wheels and without lifting drive. The lifting procedure takes about 15 – 20 minutes: do not rush!

In order to lift and attach the spectrograph, the following steps should be followed:

- Turn the rotator of the telescope to the 0° position.
- Remove the protecting cover from the flange of the spectrograph (yellow circle plate) if it is not already removed. Position the spectrograph with the connected cables under the flange of the telescope.
- *The proper position of the spectrograph, when its main axis (échelle – collimator line) is perpendicular to the horizontal axis of the telescope in such a way that the échelle end will look up.*
- Move the fork-lift truck under the spectrograph carrier from the side of the collimator unit.
- *It is strongly encouraged to put some buffer* between the forks of the lift truck and the bottom circle of the spectrograph carrier. This will absorb the shock when flange of the spectrograph touches the rotator of the telescope. The buffer will also allow adjustment of the holes of the spectrograph flange to the holes on the telescope flange. The best material for the buffer is a piece of soft plastic or, failing that, a piece of wood.
- Carefully lift and *watch the cables and your fingers.* Adjust the flange holes of the rotator and spectrograph by turning the carrier.
- Screw up the spectrograph to the telescope through all open holes. The screws should be tighten sequentially, a little at a time.

- Detach the carrier from the spectrograph. It holds the spectrograph with two semicircles around the collimator and échelle units.
- Carefully lower the spectrograph carrier and *watch the cables and your feet.* Move the carrier and fork-lift truck to a safe place.
- Plug the spectrograph power connector into the socket of the telescope.

To dismount and lower the spectrograph, follow the above steps in the reverse order.

3.8 Installation of the optical camera

The procedure to change the optical camera of the spectrograph is described. In the present configuration of the spectrograph, the long camera with a focal length of 2000 *mm* has been installed permanently in the optical port labelled **Camera 1** and the medium camera with focal length 1000 *mm* is in the port labelled **Camera 2**. The third short camera, with focal length 350 *mm*, can only be installed into the second port replacing the medium camera.

A spectrograph camera is fixed by eight nuts around the optical port circlet. While holding the camera, screw out these nuts and carefully move it out.

3.9 Attaching the CCD camera to the bayonet connector

The bayonet connector is used to install the CCD camera into the spectrograph. Any of two bayonet connectors can be used with any optical camera with any CCD camera.

The top of the bayonet connector consist of two semirings with six "ears" on its rim. Each ear has two holes for the bolts. One of the holes is used to fix the bayonet to the flange of the optical camera with a bolt with handle (four bolts in total). The other hole with an ordinary bolt is used to hold the semiring on the bayonet. On the semirings themselves there are bolts to tighten the CCD camera front panel to the connector.

Connector disassembling. Screw out all bolts from the connector ears. Release all tightening bolts. Remove the two semirings from the connector and the two semirings under them. Put the semirings aside and remember their position. Take out the red cover disk, if it is there.

Inserting the CCD camera. Insert the front panel of the CCD camera into the connector. A set of tiny screws on the outer part of the connector is used for centring the CCD camera inside of the connector. Release them to admit the camera for easy turning. The angular position of the camera is not important at this moment.

Connector assembling. Replace everything in reverse order. The inner semirings should be placed without overlapping. Do not fix the tightening bolts until the angular position of the CCD is adjusted. The bolts with handles should be screwed in, so that they do not step over the bottom plane.

3.10 Installation of the CCD camera

Two ports for the optical cameras of the spectrograph are marked by the labels **Camera 1** and **Camera 2**. The bayonet connector allows the easy installation and removal of the CCD camera.

The flange of the optical camera connector has six ears. In two of them there are tilted bolts which provide a fine tuning of the angular position of the CCD camera connector. One of two bolts has a handle. The second one has no handle and is used as stopper. These two ears of the optical camera connector must correspond to the position of the ears on the bayonet connector with cut angles.

First, detach the red protecting cover from the optical camera connector. To do that, turn the bolt with handle, mentioned above, and detach the cover after small turn.

Take the CCD camera, assembled with the bayonet connector, and *carefully* attach it to the camera connector. **Do not use brute force! You may damage the CCD sensor.** After attachment, turn CCD camera clockwise, until the adjustment ears coincide and they touch the stopper bolts. Screw in the bolt with a handle. Tighten the bayonet connector to the optical camera connector by screwing in the bolts with handles.

The CCD camera is now installed on the spectrograph, but still can be moved for alignment.

When the CCD cameras are correctly installed on the spectrograph, the electrical connector on the side of the dewar faces right.

3.11 Dismounting of the CCD camera from the spectrograph

- Undo the four bolts with handles on the semirings of the bayonet connector.
- Undo the bolt with handle at the ear of rim of optical camera connector.
- *Carefully* turn the CCD camera counter-clockwise and detach it from the optical camera.

3.12 Alignment of the CCD camera

During this procedure the image of the slit is aligned parallel to the CCD rows.

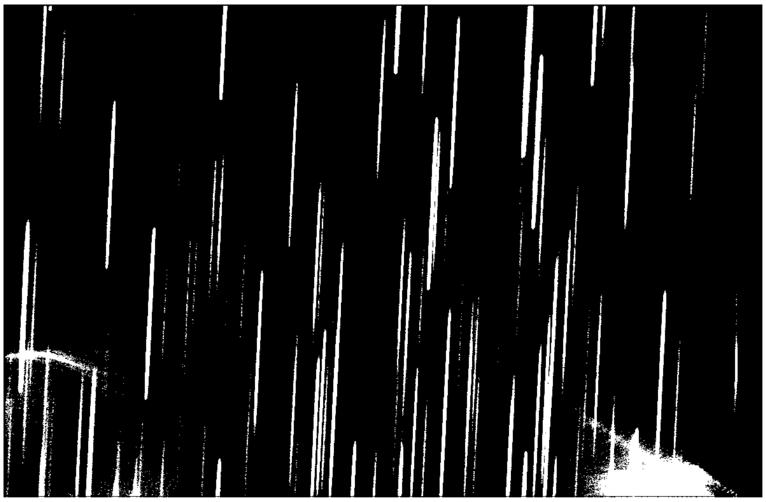

Figure 3.1: The comparison spectrum image taken with 1152×770 pixels CCD in the first camera. The dispersion direction is on horizontal axis. The slit height is increaced to the maximum. The non-aligned spectral lines are shown.

1. Start the control software for the spectrograph, refer to Section 4.4
2. Select the **`Observations | Comparison spectrum`** command in the menu of the program. Set the optimal slit width.
3. Select an appropriate spectral region and move the grating and prism.
4. Choose the optical camera to be aligned by switching the cross-dispersion prism.
5. Increase the slit height to the maximum, refer to Section 4.6.
6. Make an exposure. The program will show the tilted spectral lines on the CCD image. An example of such a frame is given in Figure 3.1.

   In the following steps we assume that rough alignment of the CCD camera is needed and the camera is loose in the bayonet connector.

   - Turn the CCD dewar by hand and repeat exposures until spectral lines are aligned vertically.
   - Adjust the centre of the CCD image to the known spectral line by moving the CCD camera, using small screws on the side of the bayonet connector. Fix these screws when you are finished.
   - Tighten the CCD front panel to the bottom side of the bayonet.

7. The fine alignment of the CCD camera is provided by turning two bolts in the ear of the optical camera connector. Undo the attachment bolts of the bayonet connector which have handles. Turn the adjustment bolt and repeat exposures until the spectral lines are properly aligned.

8. Fix both alignment and stopping bolts in the optical camera connector. Fix the attachment bolts of the bayonet connector. And now, even if you take CCD camera off the spectrograph and put it back, the orientation and centering of the CCD sensor will be exactly the same.

9. Return slit height to the normal size.

3.13 Focussing the spectrograph

The focussing unit is placed in the optical camera and has no remote control. The focussing handle looks like a ring around the optical camera and is placed close to the camera connector. It has three fixing handles. The ring has a ruler around it, which shows the current position of the focus.

- Start the control software for the spectrograph, refer to Section 4.4
- Select the `Observations | Comparison spectrum` command in the menu of the program. Set the optimal slit width.
- Select an appropriate spectral region and move the grating and prism.
- Choose the optical camera to be aligned by switching the cross-dispersion prism.
- Make a series of exposures and find the best focus by turning the focussing ring.
- Tighten the fixing handles on the ring.

Chapter 4

Observations

4.1 In the afternoon

- Fill the CCD dewars with liquid nitrogen(Section 6.3). Refer to Section 6.2.5 how to maintain a good vacuum.
- Transfer observation image files from the control computer, to release hard disk space for the forthcoming observations (Section **??**).

4.2 Before observations

- Run the control program (Section 4.4).
- Fill the CCD dewars again with liquid nitrogen.
- Initialize the CCD electronics unit (Section 4.7) and wait until the temperature becomes stable (Section 4.8). After that, reinitialize the CCD unit. Repeat operations with the other CCD unit.

4.3 During the night

- Select the required optical camera for the observation. The following are manual operations with the spectrograph:

  1. Switch the cross-dispersion prism to the necessary direction, according to the labels **Camera 1** or **Camera 2**, by turning the handle on the prism unit shield. Turn it to the end until it stops and tighten the handle.

2. Check that the flat ribbon cable is connected to the CCD electronics unit to be used. See notes in Section 6.4.

- Check that the CCD temperature is stable and at the working level (Section 4.8).
- Select and set up the spectral region. This takes a few minutes.
- Point to the object to be observed.
- Turn the telescope rotator to the position that minimizes spectrograph flexure. The best position is when the rotator is at zero angle at the middle of the exposure.
- Centre the stellar image on the entrance slit visible on the TV monitor (Section 4.6). The stellar image is not visible when a flat field or comparison spectrum exposure is proceeding. Focus the stellar image on the entrance slit according to the focussing procedure of the telescope by tuning of its secondary mirror. Find a suitable offset guide star and start tracking.
- Set up a suitable slit width and height (Section 4.6).
- Make a bias frame (Section 4.9).
- Make a comparison spectrum frame (Section 4.10). **If an intensified TV camera is used, it is vital for the camera that it is powered off temporarily before starting the comparison spectrum exposure.**
- Make the exposure of the target (Section 4.12).
- Make the flat field frames (Section 4.11) and the comparison spectrum frame (optional).
- *Only* when last step is completed, can the telescope be moved to the next object.

4.4 Running the control system

1. Turn on the CAMAC power at the front panel of the crate.
2. Enter your own work directory and starts the control program (Section 8).
3. Start the initialization sequence of the spectrograph (Section 4.5).

4.5 Initialization of the spectrograph

The remote control system of the spectrograph is implemented on number of electronics cards in the CAMAC standard.

Once the power to the CAMAC is switched on, some of the spectrograph devices may start to move into random position. In addition, the operation modes of some units might be switched in the wrong way. Using the spectrograph in such condition will lead to incorrect behaviour of the remote control units. To avoid this, the electronics *must* be initialized, once the power of the CAMAC has been turned on.

The initialization sequence is provided by the spectrograph control program. Once it starts, select the `Setup | Equipment | Initialize devices` command and press `Enter`. The initialization process includes the following operations:

- Close the shutter.
- Move the pentarism to the position when the slit open for starlight.
- Turn off the flat field and the comparison spectrum lamps.
- Move the échelle grating and cross-dispersion prism to their zero position. This operation is the longest and takes about 5 minutes.
- Turn the filter wheel to its zero position.
- Close the slit.

When the process has been completed, the spectrograph is ready for the remote control operations.

4.6 Entrance slit unit

The proper picture of the slit jaw mirrors as seen on the TV monitor is given in Figure 4.1.

The slit height can be changed manually in the spectrograph. Turn the blue cover of the hatch labeled **Slit** on a side of the spectrograph. The slit height handle is placed at the left, near to the inlet of the hatch and perpendicular to the optical axis of the telescope. Turn it clockwise to increase the slit height.

Making a couple of comparison spectrum exposures, set up the suitable height of the slit. The orders should not overlap and there must be enough interorder space (at least 5 pixels or even more) for subtraction of the background level.

The slit width is controlled remotely from the computer. Refer to Table C.2 in Appendix C.2 for how to determinate the appropriate slit width.

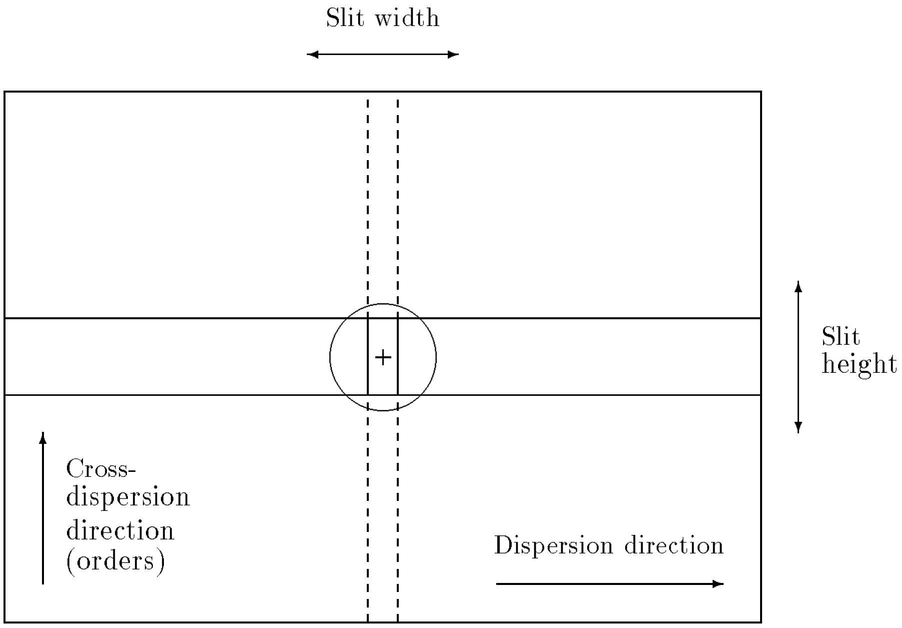

Figure 4.1: A sketch of the entrance slit of the spectrograph as seen on the TV monitor.

4.7 Initialization of the CCD

Once the CCD electronics unit is powered on and the dewar is filled with liquid nitrogen, the electronics should be initialized before operating CCD device.

The CCD electronics unit has no hardware identifiers yet and the program does not know which CCD device is being used. There is a setup file which is specific for a given CCD camera and defines the control voltages of the sensor. The assignment between CCD camera and setup file is given by the software identifier, which must be correctly choosen from the **`Setup | CCD`** menu. After the assignment is done, you must start the initialization batch process.

The working mode of the CCD sensor is remote controlled from the computer and a number of basic parameters is stored in the setup file. Values of some parameters are sensitive to the current temperature of the CCD. The initialization program will adjust these parameters for current temperature to optimize CCD sensor performance.

There are important notes:

- The final initialization of the CCD must be done only when temperature of the sensor becomes stable.
- Change of the temperature between initialization and readout of the CCD more than

about $5K$ leads to the noticeable increase of the CCD sensor noise.

Once both CCDs are initialized before observations, the electronics units will control the CCD temperature and hold the control voltages if the electronics unit has not been powered off. Switching of the flat ribbon cable from one unit to the other does not influence the voltage setup or dewar heater temperature.

4.8 Measuring the CCD temperature

The following items appear in the program window.

- CCD sensor #1 - temperature of one side of the CCD chip.
- CCD sensor #2 - temperature of the other side of the CCD chip.
- Sink sensor - temperature of the liquid nitrogen in the dewar container.
- Rack sensor - temperature of the CCD electronics rack.
- Heater - temperature controlled by the heater circuit.
- Time counter - showing time elapsed since the temperature measurement program started.

All temperature values are in Kelvins (K).

If an electronics unit is not initialized or not powered on before running the program, an error message will appear on the screen.

4.9 Making bias frames

The bias frame should usually be obtained after initial use of the CCD camera or after changing to different camera. To improve the bias frame structure, a number of frames should be obtained with the following averaging of them. The program, first, checks that the shutter is closed, then cleans the CCD a few times and begins the number of readings of the CCD bias frames. The number of bias frames depends on the signal to noise ratio of the target frame. Usually about 3–4 frames are required.

4.10 Making a comparison spectrum frame

For high signal to noise observations, the comparison spectrum frame should be obtained before and after the exposure of an object, in order to correct any flexure of the spectrograph. The hollow cathode Thorium-Argon lamp is used as the source inside the spectrograph.

Set up the exposure time and start an exposure. The exposure time for the calibration lamp is about 2–4 sec. The program, first, cleans the CCD a few times before starting the exposure. When the exposure is started, the program turns the pentaprism unit into the corresponding position and opens the shutter. When the exposure is finished, the shutter is closed and readout of the CCD occurs. The obtained image is displayed on the screen. At the end of procedure, the program turns the pentaprism unit back into the initial position when the entrance slit is open to admit the light from the target.

4.11 Making flat field frames

The number of counts in the flat field frame should be about the same as for a target image. To increase signal to noise ratio of the flat field frame, the program allows to get a number of frames and then average them to obtain the mean flat field frame. The signal to noise ratio for the mean flat field frame should be as large as possible compare with the target image in order to reduce degradation of the signal to noise ratio during data processing.

An internal source in the spectrograph is used for making of flat field frames.

You will be asked by the program for the exposure time and the number of exposures. The exposure time depends on the spectral region being used and equals about 0.5 sec at 7000 Å. The minimal time of the exposure is 0.1 sec.

Before starting the exposure, the program turns the pentaprism unit into the corresponding position and cleans the CCD a few times. Then it opens the shutter and switches on the lamp. The exposure is started. When it is finished, the program closes the shutter and starts to read the CCD. After the number of successive exposures, the program turns the pentaprism back into the initial position. The program displays the last obtained image on the screen.

4.12 Making the observation

Select the object name from the data base and set the exposure time. The object should be centred on the entrance slit by the TV monitor and the correct slit width and height must be selected. Before start the exposure, the program cleans the CCD a few times. Once the exposure is started, the program displays the watch window with the following lines:

- Start at ...- Local time that exposure is started.
- End at ...- Time exposure will finish.
- Elapsed time ...- Time elapsed since the start.
- Time left ...- Time remaining before exposure is completed.

You can suspend and resume the exposure. Once the exposure is suspended, the shutter is closed and the program waits for the next commands. When it is resumed, the program opens the shutter and prolongates the end of the exposure. You can prematurely stop the exposure. Once it is completed, the program closes the shutter and reads out the CCD image. The image obtained is displayed on the screen. The last option of the exposure menu allows the exposure to be aborted: the program just closes the shutter and nothing more is done.

4.13 Problems

- No light in the spectrograph – a bias frame is obtained instead of the expected image of the light source.
  1. The cross-dispersion prism is not in the proper position. Check that its handle has been turned to the direction which corresponds to the optical camera being used.
  2. The other CCD electronics unit has been connected to the computer. Check that the flat ribbon cable connected to the correspondent CCD electronics unit.
- Improper noise in the CCD image.
  1. Check the CCD temperature. If the temperature is not more than about $5K$ from the working temperature, you should try to initialize the CCD electronics again. Otherwise, add liquid nitrogen into the dewar, then wait until the temperature is stabilized and reinitialize CCD electronics.
  2. The electrical grounding problem. Check the position of the small switcher at the round CCD cable (Section 6.4). The switcher, placed close to the connector on the dewar, should be turned to the position indicated by label $\boxed{\mathbf{1}}$.
  3. The direction of the telescope has been changed whilst reading of the CCD. This may have produced electrical disturbances and increased the CCD noise.
- No light from the object in the TV camera.
  1. The pentaprism has not moved to proper position and it obscurates the entrance slit for the light coming from the telescope. This is the position of the pentaprism when comparison spectrum or flat field frame exposures are in progress. When these are finished, exit from menu window to allow the pentaprism unit to turn to the initial position.
  2. The TV camera is dead. Test it by using the dome lamps.

Chapter 5

The selection of spectral regions

5.1 Introduction

There are three optical cameras and two different format CCDs available for the observations with the spectrograph.

The first camera with focal length 2000 mm is permanently installed in the optical port of the spectrograph and is usually used with a 1152×770 pixel CCD. In such combination the CCD frame covers about 18 orders each of 22 Å in the $\lambda6100$ Å region. The height of an order in this camera is about 25 pixels and depends from the slit height. A resolving power up to 175000 can be achieved near to the H_α $\lambda6563$ Å spectral line. In order to obtain the maximum resolving power, the entrance slit must be scaled to two pixels at the CCD centre. The aberration image of such slit will then be about 4 pixels at the edges of the CCD.

The second camera with focal length 1000 mm is installed in the second optical port and can be replaced with the third optical camera, with focal length 350 mm. These cameras are usually used in combination with the 1152×298 pixel CCD. For the second camera, the CCD frame covers roughly the same number of orders (twice the scaling but half the number of CCD columns), each about 45 Å. With the optimal slit size projected on to two pixels of the CCD, a resolving power up to 84000 can be achieved near to the H_α $\lambda6563$ Å spectral line. The resolving power of the third camera is of order 30000.

The second optical camera can be used also with the large CCD (1152×770 pixels). The number of orders covered by the CCD can be increased, in this case, by a factor of 2.6.

5.2 Focal plane map of the spectrograph

The focal plane map of the spectrograph is given in Figure 5.1. The échelle deflection angle in degrees is on the horizontal axis. The angle corresponds to the steps of the stepping drive which turns the grating. The zero deflection angle corresponds to about 10900 steps of the drive. The angle of the cross-dispersion prism is on the vertical axis and it corresponds to the steps of the stepping drive which turns the prism. The upper point of the vertical axis corresponds to about 4000 steps of the drive.

The horizontal tilted lines are spectral orders which are numbered from 20 to 60 at the right side of orders. The vertical tilted lines are curves of equal efficiency of the échelle grating, and they are numbered at the top from 10 to 100 % (in the centre).

At the centre of graph (centre of the $45th$ order), three boxes are shown which correspond to the CCD frames for the three optical cameras. The length of the horizontal side of the boxes is 1152 of the CCD rows. The narrow box is the 1152×770 pixel CCD as seen from the first optical camera (2000 mm). The medium-size box is the 1152×298 pixel CCD as seen from the second optical camera (1000 mm) and the large box corresponds to the same CCD with the third camera (350 mm).

The straight vertical lines show the resolving power of the spectrograph. The resolving power is a function of the deflection angle of the échelle, as well as of the entrance slit image width and camera focus (refer to Appendix C for more details). At the top of the graph, the values of the resolving power are given for different deflection angles for the three cameras. It was assumed that the entrance slit image width is equal to two pixels of the CCD.

The positions of a number of known spectral lines are marked on the graph with symbols shown in the key.

The cross-sections of the orders and the lines of equal efficiency are given in Table 5.1. The numbers in the table correspond to the wavelength of the CCD centre. The wavelength range and the number of orders covered by the CCD frame for two cameras are given in Table 5.2. The wavelength range is changed by not more than 5 %, from a deflection angle of zero to ± 2 degrees. In the table all wavelength values are given in Å.

λ_{blue} Blue wavelength end of an order covered by the given CCD with the given optical camera.

λ_{blaze} Wavelength at the centre of an order.

λ_{red} Red wavelength end of an order.

$\Delta\lambda$ Wavelength range of an order.

Δk Number of orders in the CCD frame.

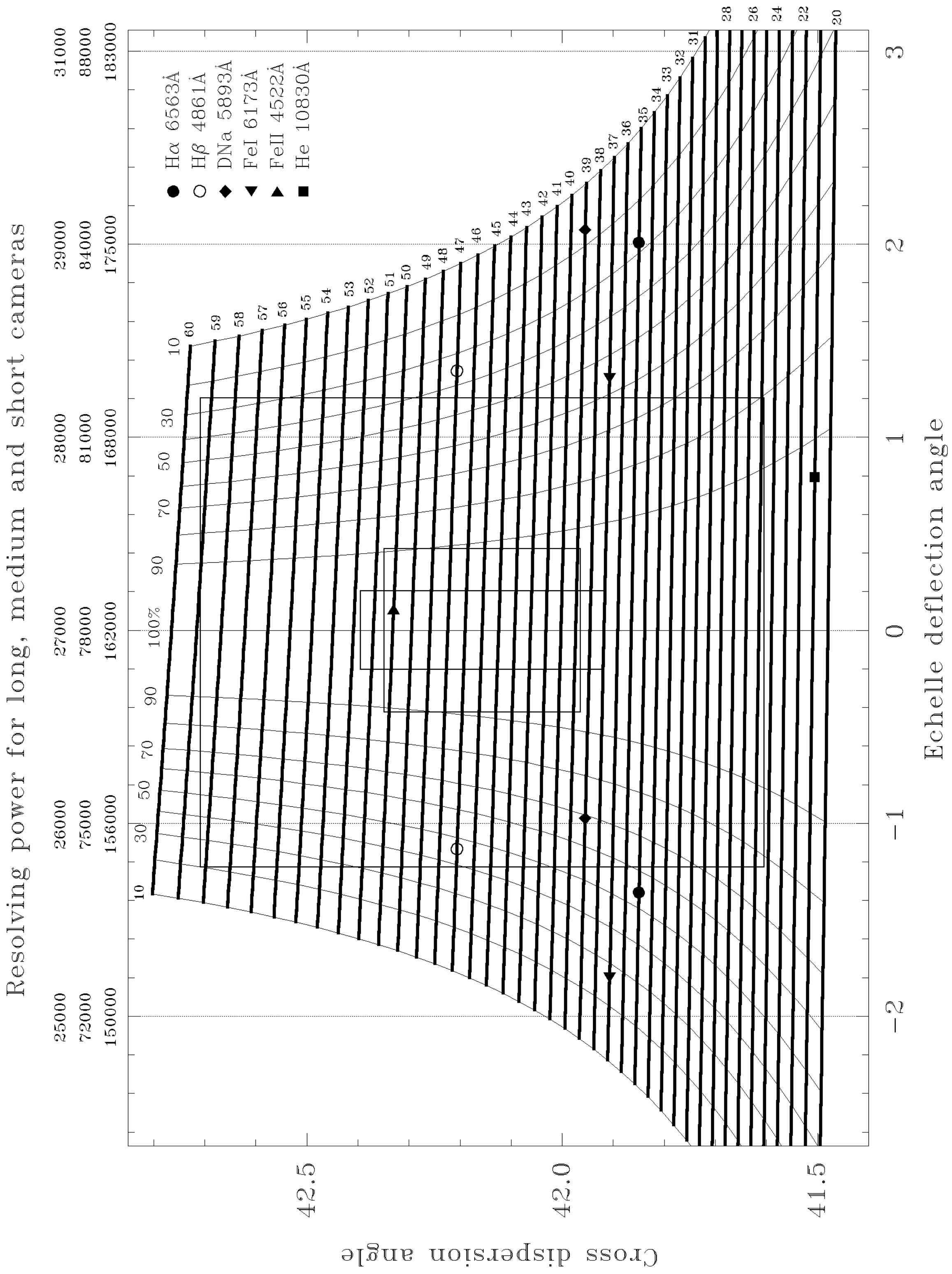

Figure 5.1: The échelle spectrograph focal plane map. All explanations are given in the text.

Table 5.1: Wavelength at échelle focal map

Order	Echelle efficiency (blaze function) in %																		
number	10	20	30	40	50	60	70	80	90	100	90	80	70	60	50	40	30	20	10
60	3719	3725	3730	3733	3737	3741	3744	3749	3754	3765	3776	3781	3785	3789	3793	3797	3801	3806	3812
59	3781	3787	3792	3796	3800	3804	3808	3812	3817	3829	3840	3845	3850	3854	3858	3862	3866	3871	3877
58	3845	3852	3857	3861	3865	3869	3873	3877	3883	3895	3907	3912	3917	3920	3925	3929	3933	3938	3945
57	3912	3919	3924	3928	3932	3937	3940	3945	3951	3963	3975	3981	3986	3990	3994	3998	4003	4008	4015
56	3981	3988	3993	3998	4002	4006	4010	4015	4021	4034	4046	4052	4057	4061	4066	4070	4075	4081	4088
55	4052	4060	4065	4070	4074	4079	4083	4088	4094	4107	4120	4126	4131	4136	4140	4145	4150	4156	4163
54	4126	4134	4140	4144	4149	4154	4158	4163	4169	4183	4197	4203	4208	4213	4218	4222	4227	4233	4241
53	4203	4211	4217	4222	4227	4231	4236	4242	4248	4262	4276	4283	4288	4293	4298	4303	4308	4314	4322
52	4283	4291	4297	4302	4307	4312	4317	4323	4329	4344	4359	4365	4371	4376	4381	4386	4392	4398	4407
51	4366	4374	4380	4386	4391	4396	4401	4407	4414	4429	4445	4451	4458	4463	4468	4473	4479	4486	4494
50	4452	4460	4467	4473	4478	4483	4488	4495	4502	4518	4534	4541	4547	4553	4558	4564	4570	4577	4586
49	4541	4550	4557	4563	4569	4574	4579	4586	4593	4610	4627	4634	4641	4646	4652	4658	4664	4671	4681
48	4634	4644	4651	4657	4663	4669	4674	4681	4689	4706	4723	4731	4738	4744	4750	4756	4762	4770	4780
47	4731	4741	4749	4755	4761	4767	4773	4780	4788	4806	4824	4832	4840	4845	4852	4858	4865	4873	4883
46	4833	4843	4851	4857	4864	4870	4876	4883	4892	4911	4930	4938	4946	4952	4958	4965	4972	4980	4991
45	4938	4949	4957	4964	4971	4977	4984	4991	5000	5020	5040	5048	5056	5063	5070	5076	5084	5092	5104
44	5049	5060	5068	5076	5082	5090	5096	5104	5113	5134	5155	5164	5172	5179	5186	5193	5201	5210	5222
43	5164	5176	5185	5192	5199	5207	5214	5222	5232	5253	5275	5285	5293	5300	5308	5315	5323	5333	5345
42	5285	5297	5307	5315	5322	5330	5337	5346	5356	5378	5401	5411	5420	5428	5436	5443	5452	5462	5475
41	5412	5424	5434	5443	5450	5459	5466	5475	5486	5509	5533	5544	5553	5561	5570	5578	5587	5597	5611
40	5544	5558	5568	5577	5585	5594	5602	5611	5622	5647	5672	5683	5693	5702	5711	5719	5728	5739	5754
39	5684	5698	5709	5718	5727	5736	5744	5754	5766	5792	5818	5830	5841	5849	5859	5868	5877	5889	5904
38	5831	5845	5857	5867	5876	5885	5894	5905	5917	5944	5972	5985	5996	6005	6015	6024	6034	6047	6063
37	5985	6001	6013	6023	6033	6043	6052	6063	6076	6105	6134	6147	6159	6169	6179	6189	6200	6213	6230
36	6148	6165	6177	6188	6198	6209	6218	6230	6244	6275	6306	6319	6332	6342	6353	6364	6375	6389	6406
35	6320	6337	6351	6362	6373	6384	6394	6407	6421	6454	6487	6501	6514	6525	6537	6548	6560	6575	6593
34	6502	6520	6535	6547	6558	6570	6581	6594	6609	6644	6679	6694	6708	6719	6732	6744	6756	6772	6792
33	6695	6714	6729	6742	6754	6767	6778	6792	6808	6845	6882	6898	6913	6925	6938	6951	6965	6981	7002
32	6899	6920	6936	6950	6962	6976	6988	7003	7020	7059	7098	7116	7131	7144	7158	7172	7186	7204	7226
31	7116	7139	7156	7170	7184	7198	7211	7227	7245	7287	7329	7347	7364	7378	7392	7407	7422	7441	7465
30	7348	7372	7390	7405	7420	7435	7449	7466	7485	7530	7574	7594	7612	7627	7643	7658	7675	7694	7720
29	7595	7620	7640	7656	7672	7688	7703	7721	7742	7789	7837	7858	7878	7893	7910	7927	7944	7966	7993
28	7859	7886	7907	7925	7941	7959	7975	7994	8017	8067	8119	8142	8162	8179	8197	8215	8234	8257	8287
27	8143	8172	8194	8213	8231	8249	8266	8288	8311	8366	8422	8446	8468	8486	8506	8525	8546	8570	8602
26	8447	8478	8502	8523	8542	8562	8580	8603	8629	8688	8748	8774	8798	8818	8839	8859	8882	8908	8943
25	8775	8809	8835	8857	8878	8899	8919	8944	8972	9035	9100	9129	9155	9176	9199	9221	9245	9274	9311
24	9130	9166	9195	9219	9241	9264	9286	9313	9343	9412	9482	9513	9541	9564	9589	9614	9640	9671	9712
23	9515	9554	9585	9611	9635	9661	9684	9713	9746	9821	9898	9931	9962	9987	10014	10041	10069	10104	10148
22	9933	9976	10010	10038	10064	10092	10118	10150	10185	10268	10351	10388	10422	10449	10479	10508	10539	10577	10625
21	10390	10437	10474	10505	10534	10564	10592	10627	10666	10756	10848	10889	10926	10956	10989	11021	11055	11096	11150
20	10891	10943	10983	11017	11049	11083	11113	11152	11195	11294	11395	11440	11481	11514	11551	11586	11624	11669	11729

Table 5.2: Spectral region coverage by CCDs for two optical cameras

Order number, k	First camera (2000 mm) with 1152 × 770 pixel CCD					Second camera (1000 mm) with 1152 × 298 pixel CCD				
	λ_{blue}	λ_{blaze}	λ_{red}	$\Delta\lambda$	Δk	λ_{blue}	λ_{blaze}	λ_{red}	$\Delta\lambda$	Δk
60	3758	3765	3771	13	6	3751	3765	3779	28	5
59	3822	3829	3835	14	7	3814	3829	3843	28	6
58	3888	3895	3901	14	8	3880	3895	3909	29	7
57	3956	3963	3970	14	9	3948	3963	3977	29	8
56	4026	4034	4041	14	10	4019	4034	4048	30	9
55	4100	4107	4114	15	12	4092	4107	4122	30	9
54	4176	4183	4190	15	12	4167	4183	4198	31	9
53	4254	4262	4270	15	12	4246	4262	4278	31	10
52	4336	4344	4352	15	12	4328	4344	4360	32	10
51	4421	4429	4437	16	12	4413	4429	4445	33	10
50	4510	4518	4526	16	12	4501	4518	4534	33	10
49	4602	4610	4618	16	14	4593	4610	4627	34	10
48	4698	4706	4714	17	14	4688	4706	4723	35	11
47	4797	4806	4815	17	14	4788	4806	4824	35	11
46	4902	4911	4919	17	14	4892	4911	4928	36	12
45	5011	5020	5029	18	15	5001	5020	5038	37	12
44	5125	5134	5143	18	15	5115	5134	5153	38	12
43	5244	5253	5262	19	15	5234	5253	5272	39	12
42	5369	5378	5388	19	16	5358	5378	5398	40	12
41	5500	5509	5519	20	16	5489	5509	5530	41	12
40	5637	5647	5657	20	16	5626	5647	5668	42	14
39	5782	5792	5802	21	17	5770	5792	5813	43	14
38	5934	5944	5955	21	17	5922	5944	5966	44	14
37	6094	6105	6116	22	18	6082	6105	6127	45	14
36	6263	6275	6286	22	18	6251	6275	6298	46	14
35	6442	6454	6465	23	18	6430	6454	6477	48	14
34	6632	6644	6655	24	18	6619	6644	6668	49	14
33	6833	6845	6857	24	18	6819	6845	6870	51	15
32	7046	7059	7071	25	18	7033	7059	7085	52	15
31	7274	7287	7300	26	18	7259	7287	7313	54	15
30	7516	7530	7543	27	19	7501	7530	7557	56	15
29	7775	7789	7803	28	19	7760	7789	7818	58	15
28	8053	8067	8082	29	18	8037	8067	8097	60	15
27	8351	8366	8381	30	17	8335	8366	8397	62	15
26	8672	8688	8703	31	16	8655	8688	8720	64	14
25	9019	9035	9051	32	15	9002	9035	9068	67	13
24	9395	9412	9429	33	14	9377	9412	9446	70	12
23	9804	9821	9838	35	13	9784	9821	9857	73	11
22	10249	10268	10286	36	12	10229	10268	10305	76	10
21	10737	10756	10775	38	11	10716	10756	10796	79	9
20	11274	11294	11314	40	10	11252	11294	11336	83	8

Chapter 6

Astromed CCD maintenance

6.1 Introduction

The readout noise of the CCD depends on the working temperature of the CCD. To minimize the noise, the CCD control software provides optimization of the voltage setup for given working temperature. If the temperature during the readout time is out of range, there will be a noticeable increase in the readout noise. The stability of the temperature depends strictly on the quality of the vacuum in the CCD dewar. The Astromed CCD dewar keeps the working temperature $120K$ for about 5 hours with the pressure of vacuum vessel approximatly 10^{-5} $mbar$.

6.2 Pumping of the CCD

A turbomolecular pump machine is available at the NOT. This is an excellent device for pumping a CCD dewar for a number of reasons. It is a "clean" pump which does not contaminate the inner parts of the dewar and CCD sensor with oil, which would lead to the irreparable damage of the camera. The pump machine has a quite high efficiency. It takes only a few hours to reach the working pressure of 10^{-6} $mbar$ starting from atmospheric pressure.

It is not possible to damage the CCD during pumping, but in some circumstances one can damage the pump itself. For instance, if you open the dewar valve too quickly during pumping in the turbo mode, the large difference in the pressure between the dewar and the pump can damage the turbo pump vessel. The pump has a reliable safety system to prevent such problems. Nevertheless follow the instructions, and do not take risks.

6.2.1 Precautions

- *Under no circumstances should the dewar be pumped when it is cold.* The CCD dewar contains a sorption pump whose function it is to remove the remaining gas molecules once the dewar has been pumped and the valve closed. It operates by absorbing the gas molecules when cold.

- *Allow the sorption pump to cool down for about half an hour before filling with liquid nitrogen.* When the dewar is pumped, the sorb material is heated to allow the gas, previously absorbed, to be degassed. Filling the liquid nitrogen while the sorption pump is hot can destroy it.

6.2.2 Preparation steps

Turn on the power to the pump by pressing the green button on the upper right side of its front panel. Check that the main switch of the operation mode is in zero position.

Connect the flexible tube from the pump to the dewar vacuum outlet. The pump tube has a large sized outlet connector. Use the special small adapter to connect it to the Astromed dewar, which has a small outlet connector. Remove the black shield from the vacuum valve of the dewar. Use the tie rings with the wing nut to fasten the outlets. Tighten the tie rings to prevent air seepage during evacuation.

Make the connection between the external power supply and the internal sorption pump. To do this, take the black power supply unit named "Mascot" from the Astromed CCD kit box and the cable with red and black wires. Plug the connectors to the power supply (the colours are important: connect like colours) and the other end to the connector of the sorption pump at the top of the dewar. Turn the voltage power tuner to the zero position and the current tuner to the middle position.

6.2.3 When the vacuum in the dewar is good

1. Turn the main switch to the position $\boxed{\mathbf{1}}$. This starts the evacuation of air from the connector tube and inner environment of the pump. Wait a few minutes until the green lamp on the electronics unit of the pump labelled $\boxed{< 10^{-2}}$ comes on. The coarse pressure gauge at the left top side of the front panel will then show the pressure to be less than 10^{-2} $mbar$.

2. Turn the main switch to the position $\boxed{\mathbf{2}}$. Wait again a few minutes until the yellow lamp, placed under the power switch and labelled $\boxed{\mathbf{27000}}$, comes on. Now, the pressure in the environment is low enough to start the turbomolecular mode.

3. Turn the main switch to the position $\boxed{\mathbf{3}}$. The turbo mode starts. Wait until the green lamp, beneath the power switch, comes on. Switch on the precision pressure

gauge, placed on the right side of the electronics unit, by pushing down the switch labelled $\boxed{/\backslash/\backslash/\backslash}$. When it is on, the green lamp under this switch comes on, and the gauge shows the actual pressure.

The next step is to open throttle valve of the pump that is situated under the main switch. Turn it slowly until the lamp on the electronics unit labelled $\boxed{\underline{\triangledown}}$ comes on. Watch the pressure on the gauge: the arrow must not cross the red strip of the ruler. If it does, then stop opening the valve until the pressure becomes stable. Following these steps, open the throttle valve completely.

4. The most delicate operation is opening the CCD dewar valve. Unscrew the valve a little. Turn the valve slowly to prevent air seeping through the sealed ribbon rings in the valve stem. Watch the pressure gauge continuously. Cease opening of the valve if the gauge arrow goes outside the green strip of the ruler and resume when it returns to the previous position. Open the dewar valve until 3–5 grooves of the thread appear.

   The arrow on the red strip on the gauge scale indicates that the pressure is near to the limit. If the pressure is out of range, the valve of the pump machine will close without any precautions. If that happens, follow the next steps:

   - Close the throttle valve of the pump.
   - Turn the main switch of the pump to the position $\boxed{\mathbf{0}}$.
   - Go to Section 6.2.4, which describes how to pump the dewar with no vacuum.

5. When the pressure reaches a value of about 10^{-4} $mbar$, switch the sorption pump heater on. To do that, switch on the power of the supply unit and set the voltage to about 30 volts. Check the current, which must not exceed 0.2 A. The sorption pump starts degassing previously absorbed gas. After about one hour switch off the power to the heater.

6. The pumping procedure takes not more than four hours and depends on the vacuum quality in the dewar. When the pressure is about 10^{-6} $mbar$ the procedure can be halted. Follow to the next steps:

   - Firmly close the valve of the CCD dewar.
   - Close the throttle valve of the pump.
   - Turn the main switch of the pump to the position $\boxed{\mathbf{0}}$.
   - Switch off the power of the pump by pressing the red button at the right side of its front panel.
   - Disconnect the pump tube from the adapter and close the outlet with the plastic protecting cover to prevent contamination of the vacuum valve.
   - Replace the black shield on the dewar valve. Let the sorption pump cool down before filling the dewar with liquid nitrogen. This takes about half an hour after the heater has been switched off.

6.2.4 When there is no vacuum in the dewar

1. Follow the 1*st* step of the previous section. While waiting for the green indicator to light up, open the valve of the dewar until 3–5 grooves of the thread appear. Open it slowly to prevent damage to the dewar by air jets.

2. Proceed with the 2*nd* and 3*rd* steps, skip step number 4, and then complete the last steps.

6.2.5 How to maintain a good vacuum

A few reasons for degradation of the vacuum quality in a dewar:

- Outgassing of the materials in the dewar to degrade the vacuum quality in time. The internal sorption pump is intended to absorb such gas. *While dewar contains liquid nitrogen the sorption pump will maintain a good vacuum.* Heating of the sorption pump cleans the sorb material from the accumulated absorbed gas. Pumping whilst heating of the sorb material from time to time to maintain a better vacuum.

- Seeping of air through the sealed ribbon rings of the valve stem due to its contamination. The valve and its outlet must be kept clean all the time. *The outlet of the valve must be covered with the plastic cover.* Any dirt or dust on the outlet should be carefully removed before evacuating the dewar or releasing the vacuum. Nevertheless, it is sometimes necessary to clean up the valve.

6.2.6 Clean up the vacuum valve

1. Remove the black shield from the vacuum valve of the dewar.

2. Very slowly release the vacuum from the dewar. *Do not turn the valve quickly – air jets can damage the CCD and the inner part of the dewar.* Cease turning when air starts to enter the dewar. Wait until it is filled with air and open the valve completely. Release the valve stem from the valve tube.

3. Clean up the valve tube and its stem with two rubber rings, by using soft material and alcohol based liquid cleaner. When these are clean, use the vacuum silicon grease from the CCD kit box to coat these parts of the valve to prevent air seeping through.

4. Replace the stem and start the pumping procedure, according to Section 6.2.4.

6.3 Filling dewar with liquid nitrogen

Filling the dewar with liquid nitrogen is a routine procedure. To do it, just put the tube from the nitrogen pressurised container in the outlet of the nitrogen vessel, open the vessel and wait until liquid nitrogen starts to spill in. Filling with nitrogen can be done at any position of the dewar even when it is inverted.

To prevent leaking of the nitrogen during observations when telescope is moving, use a special tube with thread at the middle and handle at the end. When the filling procedure is completed, screw this tube in to the dewar outlet. The inner end of the tube will be positioned close to the vessel bottom and will prevent nitrogen from spilling out.

If the nitrogen vessel of the dewar is empty and is at room temperature, the consumption of the liquid nitrogen will be higher while related shields and supports cool down. In this case, carry out the filling procedure twice.

6.4 How to connect the CCD

The CCD is a delicate and static sensitive device. The CCD chips supplied by Astromed Ltd. are top quality units and fairly expensive to replace. They are easily damaged by careless handling and this section describes the procedures that *must be followed* to guarantee that CCD chip remains in top condition.

The CCD dewar has the main CCD connector on its side. The pins of the CCD chip are connected *directly* to the pins of the output connector. The connector is a 55-way Amphenol part that is supplied with a bayonet latching cover which has been lined with electrically conducting foam to short all the pins together via a moderately high resistance path. A covering cup ensures that each and every pin of the CCD chip is connected to a common ground when the CCD is not in use.

It is vital that the CCD is only connected or disconnected to the electronics unit when this unit is powered off. There are no outside light indicators that show that the electronics unit is off. Only the fan, visible at the rear panel of the electronics, being at rest denotes that the power is off.

When the power is off, the CCD cable is connected **first** to the electronics unit. Then the other end which has a large multi-way connector is attached/detached to the dewar connector exactly in the following sequence:

- Connect cable to the CCD camera as follows.

  1. Check again that the electronics unit is powered off and that the blades of the fan are at rest.
  2. Check that the small switch near to the cable connector is switched to the position $\boxed{\mathbf{1}}$. The outer shell of the connector will be earthed.

3. It is highly recommended that you touch by hand some metal surface close to the CCD dewar to earth any static charge on your body.
4. The cover cap of the CCD connector is removed by turning. **Under no circumstances should the connector pins be touched by fingers**.
5. The outer shell of the cable connector is touched to the metal edge of the CCD connector to ensure that the static charge is earthed.
6. The cable connector is adjusted to the CCD connector by turning, and installed immediatelly.
7. Power to the electronics unit can be turned on.

- Disconnect the cable from the CCD camera as follows.

  1. Check again that the electronics unit is powered off and that the blades of the fan are at rest.
  2. Check that the small switch near to the cable connector is switched to the position $\boxed{\mathbf{1}}$. The outer shell of the connector will be earthed.
  3. It is highly recommended that you touch by hand some metal surface close to the CCD dewar to earth any static charge on your body.
  4. Remove the cable connector attached to the CCD connector.
  5. Touch the foam insert of the CCD connector cap cover against the metal edge of the CCD connector and then install it immediatly. **Under no circumstances should the connector pins be touched by fingers**.

Further important notes:

Note 1. If the cable connected to the dewar has to be detached from the electronics unit, then this must only be done once the cable has **first** been disconnected from the CCD dewar.

Note 2. The flat ribbon cable between electronics unit and computer can be attached and detached even when the power is on. The cable provided logical signals and it is not possible to damage either CCD unit or the computer.

Note 3. The flat ribbon cable is very thin, soft and delicate. It is very easy to damage its shield while the cable lies on the dome floor, by moving heavy equipment across the cable. If the computer and the electronics unit are powered on, a short circuit of the cable wires on the ground will **destroy** either the RISC card or the electronics unit. Repair of these units have to be done (expensively) by Astromed Ltd., England.

Part II

Software manual

Chapter 7

Introduction

7.1 The menu bar and menus

The software is controlled from a menu environment. The menu environment consists of three parts visible on the screen: the menu bar at the top, the window area in the middle, and the status bar at the bottom.

The menu bar is the primary access to all the menu commands. The only time when the menu bar is not visible is when you are moving to another program. You can choose the menu commands in the following way:

1. Press `F10` to activate the menu bar: the highlighted menu title appears. The next thing you type pertains to it, and not to any other environment component. The title of the currently *selected* menu is highlighted.
2. Use the arrow keys to select the menu you want to display. Then press `Enter`. To cancel an action press `Esc`.

   As a shortcut for this step, just press the highlighted letter of the menu title. For example, from the main menu bar, press `F` to quickly display the **`File`** menu. From anywhere, press `Alt` and the highlighted letter to display the menu you want.
3. Again use the arrow keys to select the command you want. The currently *selected* menu command is highlighted. Then press `Enter`.

   Again, as a shortcut, you can just press the highlighted letter of a command to choose it once the menu is displayed.

   At this point, the software program either carries out the command or displays another menu.

If a menu command is followed by a colon (:), choosing the command displays a dialog box. If the command is followed by an arrow (▷), the command leads to another submenu.

A command without either a text string or an arrow indicates that once you choose it, that action occurs. Some of menu commands are unavailable when it would make no sense to choose them.

You can use a number of keyboard shortcuts (or hot keys) to access the menu bar and choose commands. Press `Alt` and the highlighted letter of the command (you need to hold down `Alt` while pressing the highlighted letter) to display the menu or carry out the command. Once the menu is displayed, press the highlighted letter to carry out the command.

Many menu items have corresponding hot keys, one- or two-key shortcuts that immediately activate that command or dialog box. The `Esc` key is used to exit from the menu window.

7.2 Status line

The status line appears at the bottom of the screen. The status line includes the following functions:

- It reminds you of basic shortcuts or hot keys applicable at that moment in the active window.
- It tells what the program is doing and how you can stop the process.
- It offers one-line hints on any selected menu command.

The status line changes as you switch windows or processes.

7.3 Dialog boxes

If a menu command is followed by a colon (:), the command opens a dialog box. A dialog box consist of a number of input boxes, which allow text to be entered.

You can type any alphanumeric characters as text. If you continue to type once you reach the end of the box, the contents automatically scroll. If there is more text than shown in the box, arrowheads appear at the ends (◁ and ▷). Most basic text-editing keys work in the text box, as follows:

`←` `→`	moves the cursor one character to the left or right.
`Ctrl←` `Ctrl→`	moves the cursor one word to the left or right.
`Home` `End`	moves the cursor to the beginning or end of a line.

`Ins`	toggles between *replace* and *insert* modes.
`Del`	deletes the character at the cursor.
`Backspace`	deletes the character to the left of the cursor.
`Ctrl-Del`	deletes the word at the cursor.
`Ctrl-Backspace`	deletes the word to the left of the cursor.
`Tab` `Shift-Tab`	moves the cursor to the next or previous input box.
`Enter`	accepts input and exits dialog box.
`Esc`	discards input and exits dialog box.
`F1`	displays the help screen.

The input text will be typed in the menu command line followed by the colon. If the text string does not fit to the output field of the menu line, the displayed text is truncated and the last three characters are replaced by dots (...).

7.4 Data base handling

A number of data bases are implemented by the software. Once the data base window appears in the window area of the menu, it displays the records of the data base file. The data base window itself consists of three parts visible on the screen: the header bar at the top of the window, the records area at the middle, and the status bar at the bottom. The data base record contains a number of fields. The beginning and end of a field are indicated by delimiters (|) in the header bar. To operate with data base records, the highlighted bar is used, which we will refer to here simply as the cursor.

A number of the special commands to manage data bases are given in the separate sections. Most of them are general and given here:

`↑` `↓`	moves the cursor one line up or down. As a shortcut for the commands which move the cursor, you can just type the first few letters of the *first* field of the record you want to select. The program will search for the combination of the letters you typed among the following records. The cursor will move to that record.
`PgUp` `PgDn`	moves the cursor to the previous or following page.
`Home` `End`	moves the cursor to the first or last record of the data base.

`Ctrl-Home`	moves the cursor to the first line of the records area of the window.
`Ctrl-End`	moves the cursor to the last line of the records area of the window.
`←` `→`	moves the cursor one field of the record to the left or right.
`Ctrl←` `Ctrl→`	moves the cursor one character of the record to the left or right.
`Tab` `Shift-Tab`	moves the cursor to the next or previous column, if the application program supplies a multi-column table in the data base window. Otherwise, moves the cursor to the next or previous record.
`Ins`	marks (highlights) a record. Press this key when the cursor is on the marked record to unmark the record.
`F2`	sorts the records of the data base. Once the key is pressed, the dialog box appears and you can select the sorting order of the fields in the record.
`F4`	edits the record at the cursor. The dialog box appears and you can modify the selected fields of the record.
`F5`	creates a new record. The record at the cursor is copied to the end of data base file. The dialog box appears and you can modify any field of the new record.
`F7`	selects the fields to be displayed at the records area of the data base window. Once the key is pressed, the dialog box appears and you can select the order of the fields to be displayed.
`Enter`	selects the record at the cursor and exits data base.
`Alt-X`	exits data base. The selected record is the same as before.
`F1`	displays the help screen.

7.5 Graphical marker

To indicate relevant parts of the graphical image on the screen, the special graphical marker is used in the window area of the menu environment. The marker is the highlighted rectangle that you can move by the arrow keys of the keyboard. The size of the rectangular box is not fixed and can be altered by use of the keys. The physical coordinates of the marker corners are displayed in the message line at the bottom of the screen. The length of sides of the marker box in the physical coordinates are displayed in the brackets (). A number of keys are used to manipulate the graphical marker as follows:

`Tab`	toggles the speed of motion of the marker. The minimum is one pixel per keystroke and the maximum is approximately 15 pixels of the graphical screen per stroke. The current toggle is indicated as `Low speed` or `High speed` in the section of the message line at the bottom of the screen.
← ↑ → ↓	moves the marker in the direction indicated.
`Shift ←` `Shift →`	changes the size of the marker box. The left top corner of the box remains fixed and only the right side is moved in the direction indicated (you need to press `Shift` when using the arrow keys).
`Shift ↑` `Shift ↓`	changes the size of the marker box. The left top corner of the box remains fixed and only the bottom side is moved to the direction indicated.
`Alt ←` `Alt →`	changes the size of the marker box. The centre of the marker remains fixed and the width of the box is altered (contraction or expansion).
`Alt ↑` `Alt ↓`	changes the size of the marker box. The centre of the marker remains fixed and the height of the box is altered (contraction or expansion).
`Ctrl ←` `Ctrl →`	changes the size of the marker box. The centre of the marker remains fixed and the area of the rectangular box is altered (contraction or expansion).
`Ctrl ↑` `Ctrl ↓`	changes the size of the marker box. It works in the same way as the previous case, but if either of the two keys is pressed, the box is transformed to a square.
`Alt-C`	toggles the marker box size between three states as follows: • Expands the marker box up to the axes of the graph. • Squeezes the box to a horizontal line at the centre of the graph. • Squeezes the box to a vertical line at the centre of the graph.
`F2` `Ctrl-F2`	changes the colour of the marker box. Use the first key to increase the colour index, and the second to decrease the index.

When you press the control key, the status line at the bottom of the screen informs you of the keystrokes available.

Chapter 8

The control program

The control program forms an integrated environment to control the CCD and the spectrograph operations. Everything you need during observations to select a spectral region, start up the CCD camera, start and stop an exposure, read the CCD image of the observed échelle spectrum and so on is supplied by this program. The control program manages a number of different subprograms, described below, which provide the functions mentioned.

8.1 Entering and exiting the program

You just move into your own work directory, where the observing programme should be carried out. All data you obtain during observations will be collected in this directory. If you are not familiar with the computer system, refer to the Appendix B for how to create such a directory.

Then just type `sofin` at the DOS command line.

The program loads the setup parameters from a file, which has been previously saved. If the file does not yet exist, the program creates a default setup file.

There are two ways to leave the program.

- To exit from the program permanently, choose the `Exit` command in the menu bar (or just press `Alt-X`). All changes in the setup will be saved in the file before exiting.

- To leave the program temporarily to enter commands at the DOS command line, choose `File | DOS Shell`. The program stays in the memory, but you are transferred to DOS. You can enter any normal DOS commands, and you can run other programs from the command line. When you are ready to return to the program, type `exit` at the command line and press `Enter`. The program reappears just as you left it.

8.2 Setup menu

The `Setup` menu lets you select and save some parameters which will be used by the control program. The menu also lets you prepare the CCD and the equipment for the observations. Press `Alt-S` to activate the `Setup` menu.

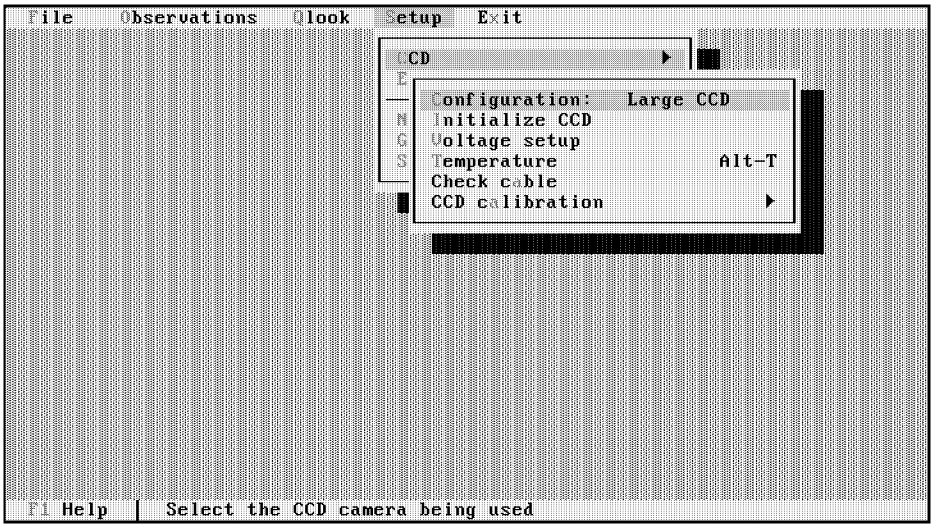

Figure 8.1: The CCD setup menu of the control program.

8.2.1 CCD menu

The `Setup | CCD` command lets you select the CCD configuration, initialize the CCD electronics unit, control the CCD temperature and so on. Once you call this command the menu appears on the screen which looks like in Figure 8.1.

`Configuration` The command line is followed by the identification name of the selected CCD camera. If the CCD has not been selected, the program prints `Undefined` instead. Press `Enter` and the data base window appears on the screen (Figure 8.3) which contains different configurations of the CCD cameras. Refer to Section 8.2.2 for how to use the CCD configuration data base. Choose the CCD you want to use and press `Enter`. The name of the selected CCD is typed in the menu command line.

`Initialize CCD` Use this command once the CCD electronics unit is powered on, and the dewar is filled with the nitrogen and the CCD sensor has cooled down. The initialization procedure depends on your choise of the CCD.

`Voltage setup` The command displays the current setup of the CCD control voltages.

`Temperature` The command displays a window which contains the temperatures of the CCD system (see Figure 8.2). Refer to Section 4.8 for more details.

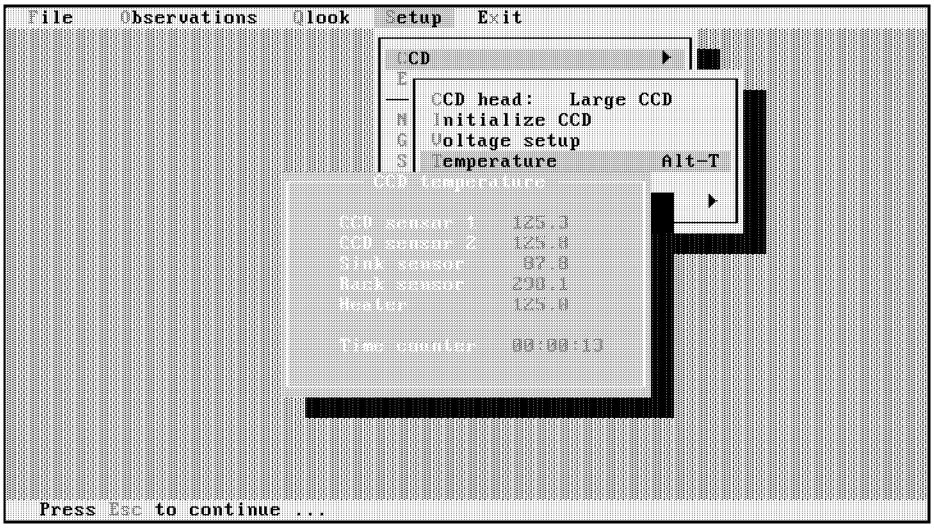

Figure 8.2: The control program displays the CCD temperature.

`Check cable` This command provides the checkout of the cable between the CCD electronics unit and the control computer.

`Calibration` The command lets you make the calibration of the CCD response on the light. As the result, the linearity curve of the CCD can be obtained.

8.2.2 CCD configuration

The CCD camera must be first selected. Otherwise the control program do not know which camera you want to use. The `Setup | CCD | Configuration` command provides the selection. The command displays the data base window (see Figure 8.3) which contains the records of the different configurations of the CCD cameras.

The CCD configuration record contains the following parameters:

`Name` is the idendification name of the CCD configuration record. It can be any convenient name.

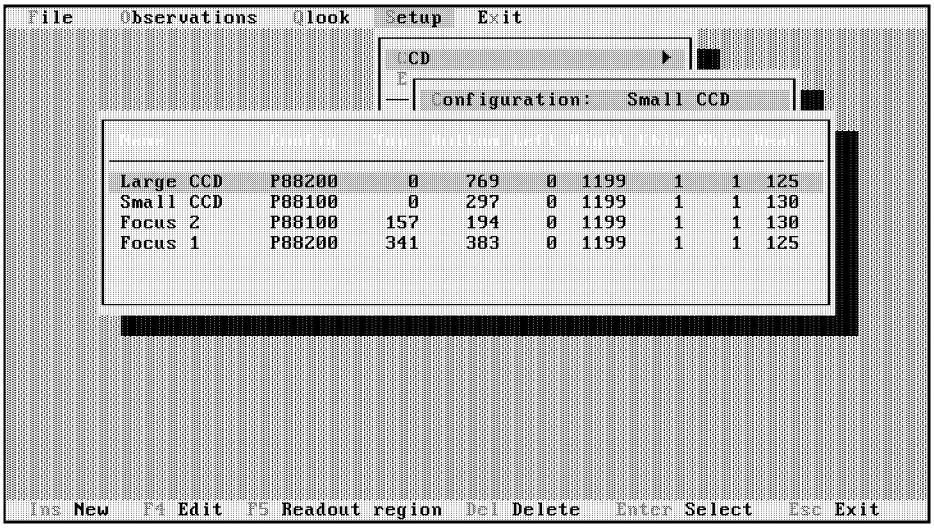

Figure 8.3: Selection of the CCD configuration. The path name is not shown in the data base window. Use arrow keys to move the records to the left or right.

`Config` is the name of the configuration file which is used by the CCD control programs. This file defines given CCD system and contains a number of the specific parameters such as voltage setup, sensor size and other. The name is defined during the installation of the software and *can not be altered by user.*

`Top` is the first column of the CCD readout region. Remember that the coordinates of the CCD region are counted from zero and not from one.

`Bottom` is the last column of the CCD readout region. It is the number of columns minus one.

`Left` is the first row of the CCD readout region.

`Right` is the last row of the CCD readout region.

`Cbin` is the hardware binning factor of the CCD columns. The value equals to one for the normal pixel by pixel reading mode.

`Rbin` is the hardware binning factor of the CCD rows. The value equals to one for the normal pixel by pixel reading mode.

`Heater` is the preset temperature of the CCD heater.

`Path` is the path of the CCD control programs. The control program can implement different kind of CCD systems and the control programs are placed in separate directories. To distinguish different CCD cameras which belong to the same system, the separate configuration files are used. The path is defined during the installation of the software and *can not be altered by user.*

You can select any default configuration of the CCD cameras from the list. According to the example in Figure 8.3, it can be `Large CCD` with 1152×770 pixels sensor or `Small CCD` with 1152×298 pixels. But you can create your own configuration of those CCD cameras. For instance, you may want to make a series of short exposures and you interesting only some part of the whole CCD image (it can be testing exposures for searching of the spectral region or for estimation of the exposure time of an observing object). It would be much more faster if you will use a smaller readout region. It is a good idea to do not change the default configuration of the CCD which is used, but create a new record in the data base just for your purposes.

Most of the commands concerning the operations with the data bases are described in Section 7.4. A number of special commands are given here and the shortcuts of the commands are displayed in the status line of the screen.

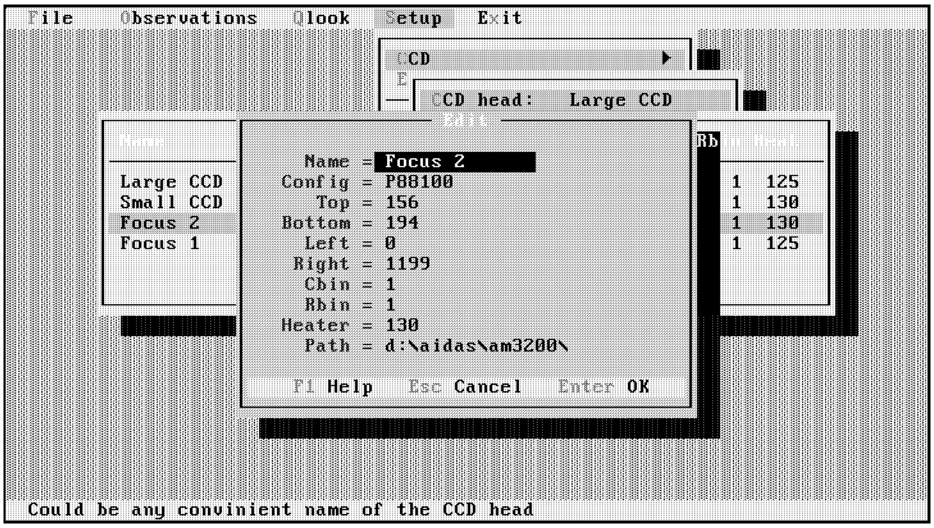

Figure 8.4: Edit the parameters of the CCD configuration.

`Ins` Adds a new CCD configuration record in the present list. Once the key is pressed, the dialog box window appears on the screen (Figure 8.4).

`F4` Edits the selected record of the CCD configuration. You can alter the parameters, for instance, the CCD heater temperature.

`F5` Selects the CCD readout region. Before using this command, you should make an exposure or select some image in the data base and display it on the screen. Select the suitable region of the image which is covered by the graphical marker box and press `Alt-X`. After that, you must return to this step and press the key. The program reads the coordinates of the corners of the marker box and puts them into the record as a readout region.

If you want to overscan the CCD during its reading, you can increase the bottom or right corners of the region. Select this configuration and exit from the `Setup` menu. Make the test exposure (a flat field would be better) and select suitable region. Return to the CCD configuration data base and press `F5`.

`Del` Deletes the highlighted record from the list.

`Enter` Selects the highlighted record and exits from the data base.

`Esc` Discards the selection and exits from the data base.

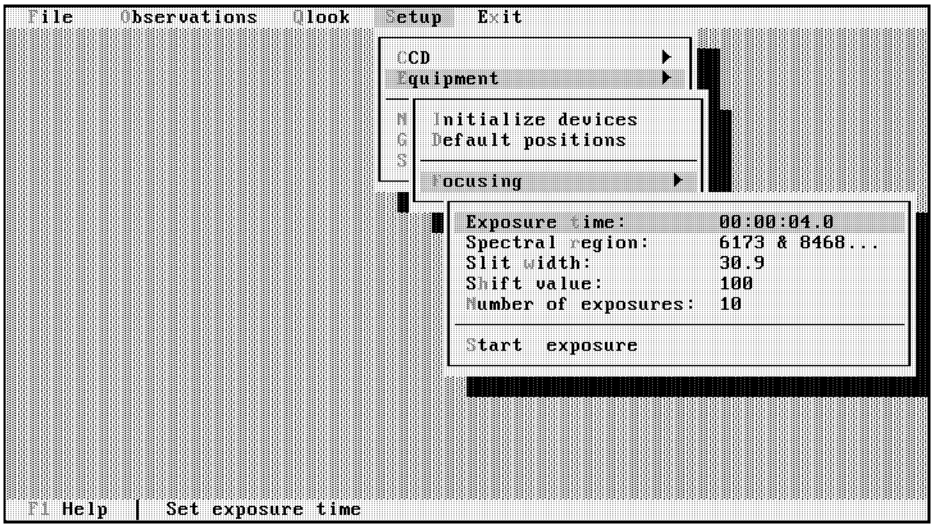

Figure 8.5: Menu of the `Equipment` command and submenu of the `Focusing` command.

8.2.3 Equipment menu

The `Setup | Equipment` command lets you prepare the equipment for the observations. The menu of commands is shown in Figure 8.5.

`Initialize devices` Starts the initialization of the spectrograph. Details of this procedure are given in Section 4.5. The program changes some of the setup parameters: the slit width and filter number will be zero, the spectral region becomes `Undefined`. You should care about preset of those parameters before starting the first observation.

`Default positions` This command works in the same way as the previous command, but moves the slit, grating and prism, and filter units to the positions where they were during the last observation. The name of the selected spectral region, the slit width and filter number will be the same in the command lines of menus as it was when you left the control program after the last observations.

`Focusing menu` This is an experimental version of the focussing procedure. The idea is to make a number of exposures of the comparison spectrum in a special spectral region. The program moves the grating specified number of steps after each exposure and observer turns the focussing ring of the optical camera. After several exposures, the program reads the CCD image and displays it on the screen. You can find the optimal focus by choosing the most narrow line in a series of exposures on the same image.

8.2.4 Naming image files menu

The `Setup | Naming image files` command lets you select your favourite names of the images which you will get during observations and assignes the current number of the file. The menu of commands is shown in Figure 8.6.

`Image number` The command allows you change the current number of the next image file which will be written on the disk. The current number is displayed on the command line. Use this command if you want to have a continuous numbering of the image files before the next observing run. Press `Enter` and the dialog box appears on the screen. Correct the number and press `Enter` to accept the input or `Esc` to discard. The maximal length of the number can not be more than 8 digits.

`Template` The command lets you select the template of the image file names. Press `Enter` and the dialog box appears on the screen. The template consist of several parts: the suffix, digital field and the extension separated by a dot. Maximal length of the suffix plus digital field is 8 characters. The number of zeros in the digital field defines the format of the numerical name of the file. The value in the file name is preceeded by zeros if the number of digits is less than the length of the digital field. You can omit or alter the suffix and/or the file extension.

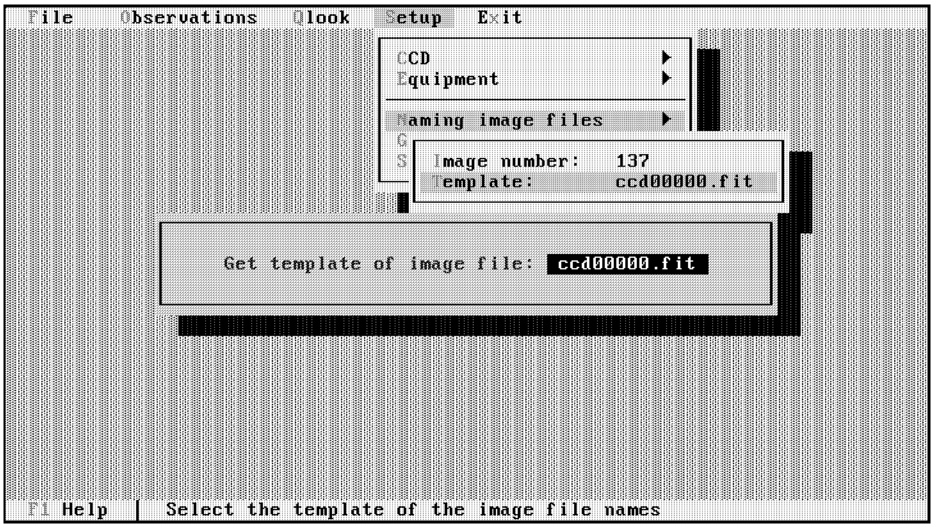

Figure 8.6: The file naming menu commands are used in order to select the current image file number and the template for the image files. The dialog box on the screen lets you change the form of the file names.

8.2.5 General FITS comments menu

The `Setup | General FITS comments` command lets you invoke the names of the telescope and instrument, the observers' names and the comments string. This information will be written into the header of the image files. The menu of commands is shown in Figure 8.7. The strings are displayed in the command lines of the menu.

`Telescope` The field goes to the `TELESCOP` record of the FITS header. Maximal length is 32 characters.

`Instrument` The field goes to the `INSTRUME` record of the FITS header. Maximal length is 32 characters.

`Observer` The field goes to the `OBSERVER` record of the FITS header. Maximal length is 32 characters.

`Comments` The field goes to the `COMMENTS` record of the FITS header. Maximal length is 72 characters.

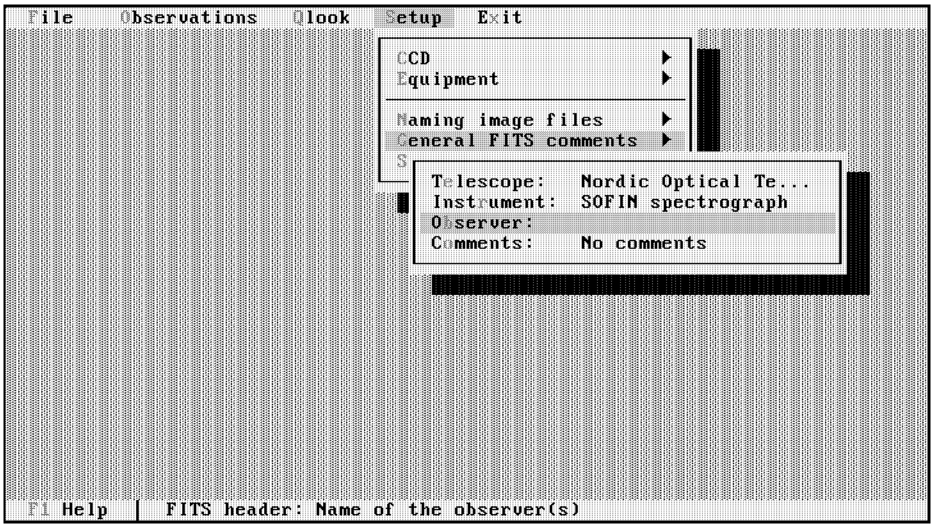

Figure 8.7: Commands used in order to input some records of the FITS header.

8.2.6 Save configuration

The `Setup | Save configuration` command saves all parameters that have been changed in the program in the disk file. The program saves the parameters automatically when you exit from program or temporarily leave the program to the DOS shell. The program reads the stored parameters once you run the program. Use this menu command just for safety reason.

8.3 Observations menu

The `Observations` menu provides taking of the object and calibration frames. Press `Alt-O` to open the menu.

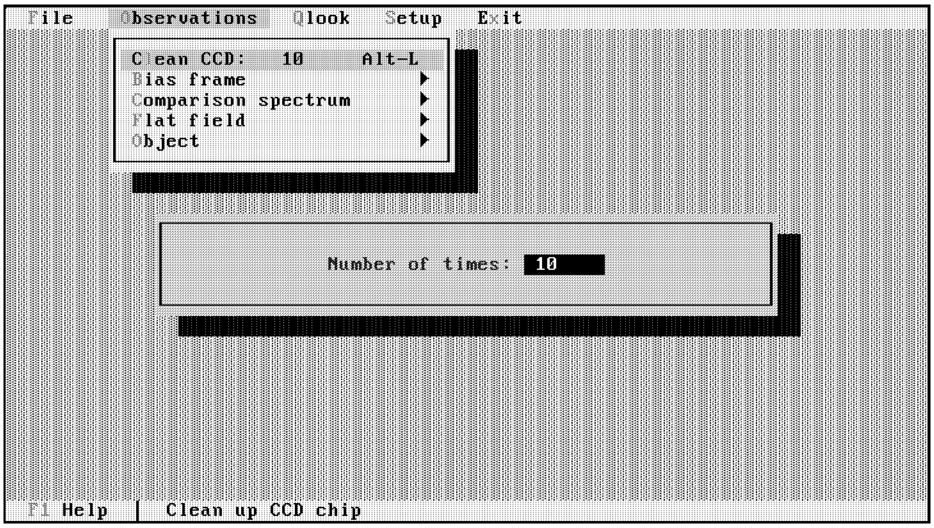

Figure 8.8: The clean CCD command. In the dialog box you can select how many times you want to clean the CCD sensor.

8.3.1 Clean CCD

The `Observations | Clean CCD` command opens a dialog box to input the number of times you want to clean the CCD (see Figure 8.8). After you have pressed `Enter`, the program starts to clean up the CCD. The same number of cleanings will be used later before starting an exposure.

8.3.2 Bias frame menu

The `Observations | Bias frame` command opens the bias submenu shown in Figure 8.9.

`Number of frames` The command activates a dialog box where you will be asked how many bias frames you want to obtain. The bias frames can be averaged afterwards. Select the appropriate number and press `Enter`. The selected number is displayed in the command line.

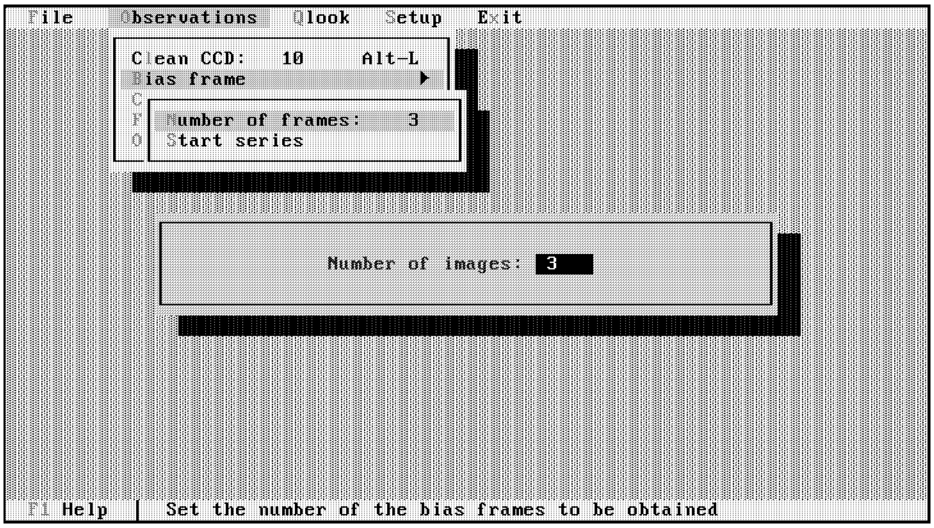

Figure 8.9: The bias frame menu

`Start sequence` The command initiates taking of bias frames. The program checks that the shutter is closed, then cleans the CCD specified number of times (`Clean CCD` command) and makes the number of read out of the CCD. The program writes each frame on the disk and writes the specified fields of the file header in the data base. When the sequence of "zero" exposures is completed, the program diplays the last image obtained on the screen.

8.3.3 Comparison spectrum menu

The `Observations | Comparison spectrum` command opens the comparison spectrum submenu shown in Figure 8.10.

`Spectral region` The command allows you to select the spectral region you want and moves the grating and prism to the specified region. You can choose the filter and the program turns the filter wheel to the specified filter number. You can specify the optical camera number, but the switching operation is not remote controlled. Press `Enter` in order to get the spectral regions data base on the screen. Choose or add your spectral region record from the data base and press `Enter` again to confirm the selection. The name of the selected spectral region will be printed in the command line of the menu. If the region was not selected, the program types `Undefined` in the command line. You must select the region before the next steps.

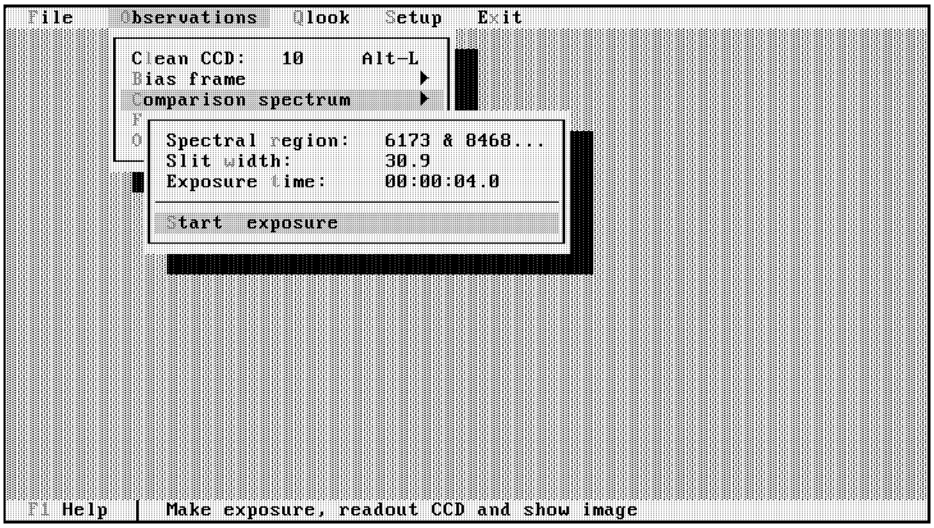

Figure 8.10: The comparison spectrum menu.

`Slit width` The command lets you select the entrance slit width. Once you pressed `Enter`, the dialog box appears and you can input the width in microns. After you pressed `Enter` again, the slit width will be typed in the command line.

`Exposure time` The command lets you select the exposure time of the comparison spectrum lamp. Press `Enter` for the dialog box to appear and input the time. After you have pressed `Enter` again, the exposure time will be typed in the command line.

`Start exposure` The command initiates taking of the image of the comparison spectrum. The program cleans the CCD specified number of times (`Clean CCD` command), switches on the lamp and opens the shutter.

The waiting window appears on the screen to display the exposure process. When the exposure is completed, the program closes the shutter. You can make the exposure shorter or interrupt it: press `Esc` key whilst the waiting window is visible on the screen and exposure is going. The program will write into the image header the effective exposure time, i.e. elapsed time.

When the shutter is closed and the lamp is off, the program reads the CCD image and writes it on the disk. The specified fields of the file header are written in the data base. The image obtained is displayed on the screen.

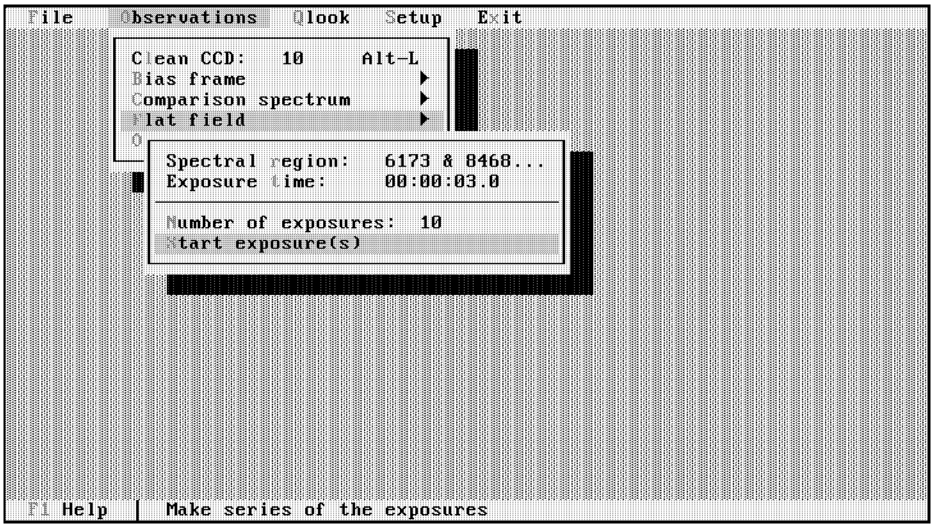

Figure 8.11: The flat field menu.

8.3.4 Flat field menu

The `Observations | Flat field` command opens the flat field submenu shown in Figure 8.11.

`Spectral region` The command allows you to select the spectral region you want and moves the grating and prism to the specified region. You can choose the filter and the program turns the filter wheel to the specified filter number. You can specify the optical camera number, but the switching operation is not remote controlled. Press `Enter` in order to get the spectral regions data base on the screen. Choose or add your spectral region record from the data base and press `Enter` again to confirm the selection. The name of the selected spectral region will be printed in the command line of the menu. If the region was not selected, the program types `Undefined` in the command line. You must select the region before the next steps.

`Exposure time` The command lets you select the exposure time of the flat field lamp. Press `Enter` for the dialog box to appear and input the time. After you have pressed `Enter` again, the exposure time will be typed in the command line.

`Number of exposures` The command activates a dialog box where you will be asked how many flat field frames you want to obtain. The flat field frames can be averaged afterwards. Select the appropriate number and press `Enter`. The selected number is displayed in the command line.

`Start exposure` The command initiates taking a sequence of flat field frames. The program cleans the CCD specified number of times (`Clean CCD` command), switches on the lamp and opens the shutter.

The waiting window appears on the screen to display the exposure process. When the exposure is completed, the program closes the shutter. You can make the exposure shorter or interrupt it: press `Esc` key whilst the waiting window is visible on the screen and exposure is going. The program will write into the image header the effective exposure time, i.e. elapsed time.

When the shutter is closed and the lamp is off, the program reads the CCD image and writes it on the disk. The specified fields of the file header are written in the data base. When the sequence of flat field exposures is done, the program displays the last image obtained.

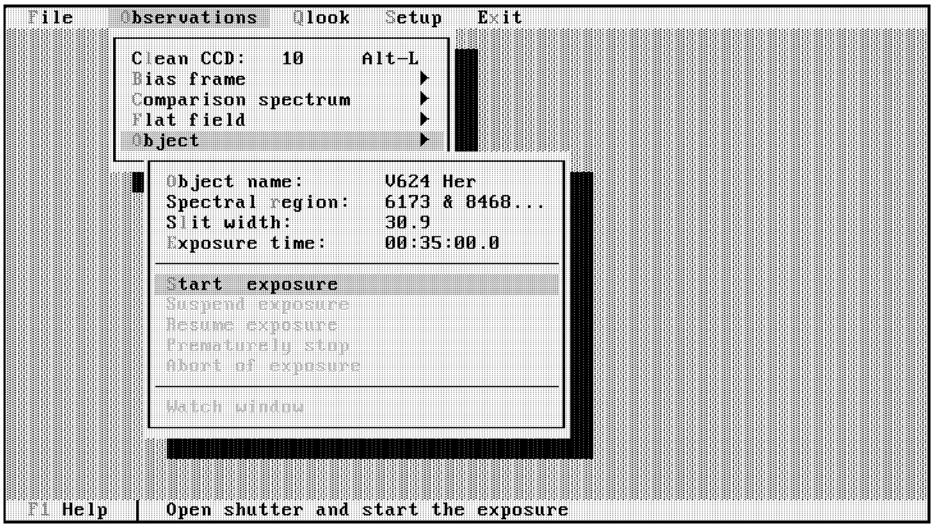

Figure 8.12: The object menu.

8.3.5 Object menu

The `Observations | Object` command opens the object submenu shown in Figure 8.12.

`Object name` The command lets you select the object which you want to observe. The command opens the window and types the records of the objects data base. Make your selection and press `Enter`. The name of the selected object will be printed in the command line of the menu. If the object was not selected, the program types `Undefined` in the command line. You must select the object before the next steps.

`Spectral region` The command allows you to select the spectral region you want and moves the grating and prism to the specified region. You can choose the filter and the program turns the filter wheel to the specified filter number. You can specify the optical camera number, but the switching operation is not remote controlled. Press `Enter` in order to get the spectral regions data base on the screen. Choose or add your spectral region record from the data base and press `Enter` again to confirm the selection. The name of the selected spectral region will be printed in the command line of the menu. If the region was not selected, the program types `Undefined` in the command line. You must select the region before the next steps.

`Slit width` The command lets you select the entrance slit width. Once you pressed `Enter`, the dialog box appears and you can input the width in microns. After you have pressed `Enter` again, the slit width will be typed in the command line.

`Exposure time` The command lets you select the exposure time of the object. Press `Enter` for the dialog box to appear and input the time. After you have pressed `Enter` again, the exposure time will be typed in the command line.

`Start exposure` The command initiates the exposure. The program cleans the CCD specified number of times (`Clean CCD` command) and opens the shutter.

During the exposure you *can*

- suspend and resume exposure, prematurely stop it and abort the exposure.
- increase or decrease the exposure time by using the `Exposure time` command.
- look on the exposure status and watch when it is completed.
- exit from the `Object` menu.
- call the `Qlook` command to display the stored images.
- exit from the program.

During the exposure you *can not*

- start the exposure again.
- change the spectral region by `Spectral region` command.
- clean the CCD and make the calibration frames.
- change the working directory by `File | Change directory` command.
- stay at the objects data base when the exposure is finished. You must exit from it in time, otherwise the new CCD frame cannot be read.

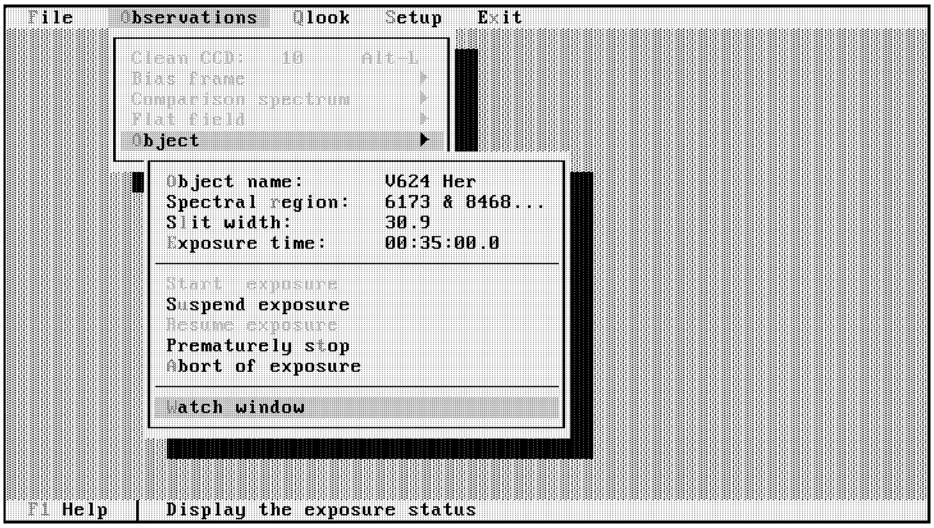

Figure 8.13: The menus as they are seen on the screen when the exposure is going.

Corresponding commands in the menus are lowlighted as seen in Figure 8.13 and you can not call them.

The program will finish the exposure automatically only *if you moved back* to the `Object` menu. When the exposure is completed, the program closes the shutter, reads the CCD image and writes it on the disk. The specified fields of the file header are written in the data base. The image obtained is displayed on the screen.

`Suspend exposure` The command lets you temporarily stop the exposure until you call the next command `Resume exposure`. The program closes the shutter and prolongates the end of the exposure. The command does not decrease the exposure time.

`Resume exposure` The command lets you continue the exposure which was previously suspended. The program opens the shutter and continues to count the exposure time. The exposure time will be the same as before resuming, but will completed later.

`Prematurely stop` The command lets you stop the exposure before it finishes. The program works in the same way as if the exposure was finished by the exposure time counter.

`Abort exposure` The command lets you cancel the exposure. The program just closes the shutter.

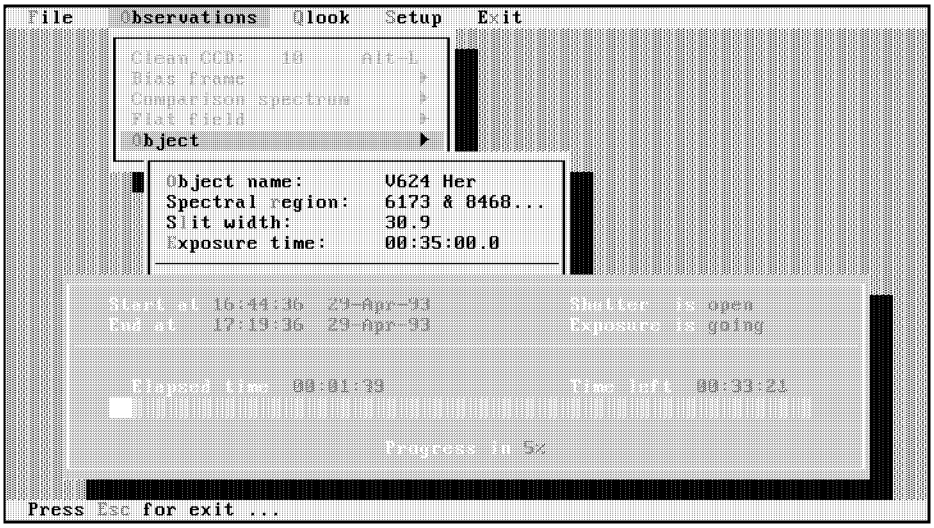

Figure 8.14: The watch window displays the status of the exposure.

`Watch window` The command lets you display the status of the exposure going. In the window a number of items are displayed (refer to Figure 8.14) as follows:

`Start`	is local time that exposure is started.
`End`	is local time exposure will finish.
`Elapsed`	is time elapsed since the start.
`Time left`	is time remaining before exposure is completed.
`Progress`	is the fraction of the elapsed time to the exposure time in percents.
`Shutter`	is the position of the shutter (`open/closed`). It is `closed` when the exposure is suspended.
`Exposure`	is the status of the exposure (`going/suspended`).

To exit from the watch window press $\boxed{\texttt{Esc}}$.

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Appendix A

Installation of the software

A.1 Hardware requirements

The software requires the following hardware in order to run:

- IBM/PC/AT computer.
- Standard or Super VGA card and display.
- Math coprocessor.
- Expanded memory 4–8 MB.
- Hard disk drive with the capacity 200-400 MB as bulk memory for an images storage.

A.2 Config.sys

The control software requires the installation of the expanded memory drive. Installation of the standard DOS drive is given by the example:

```
devicehigh=c:\dos\emm386.sys
```

The EMM page frame should not placed in the video memory address area. Using of the cache memory for the disk drive is highly recommended. An example:

```
devicehigh=c:\dos\smartdrv.sys 384 /e
```

The following string is vital for the software, because it produces a software interrupt to control the exposure:

```
stacks=8,256
```

If there are problems where the program hangs after the exposure is completed, try to increase stack size.

A.3 Autoexec.bat

The location of the system environment variables as `Imager`, `Dbase` should be given in the *Autoexec.bat* as following:

```
set IMAGER d:\asid\imager
set DBASE  d:\asid\dbase
```

A.4 Location of the control program

In order to start the control program from any directory in the disk, you should locate the path of the program. Create and write the batch file `sofin.bat` into the general directory in the system path. The batch file should contain:

```
d:\aidas\sofin\shell.exe
```

To run the control program, move first into your own work directory, then type `sofin` at the DOS command line and press `Enter`.

Appendix B

Operation system guidelines

B.1 DOS commands

Some of the useful DOS commands are given below.

$<$ *letter* $>$: Changes current drive to drive $<$ *letter* $>$. The letters `A` and `B` denote floppy drives, letter `C` a system hard disk and letter `D` a work disk.

`mkdir` *name* Creates a directory with *name* name.

`cd` *name* Enters into the subdirectory with *name* name.

`cd..` Goes from a subdirectory into the parent directory.

B.2 Norton Commander

The Norton Commander is a commercial program and is used in addition to the DOS shell. A brief description of the principal commands is given.

F1 A complete on-line help for the program.

F2 Calls a user menu which includes a number of macrocommands. To invoke a new command, press **F9 C M**, then select *Main* option and press **Enter**.

F3 The viewer program that displays the contents of the selected file.

F4 Edits the selected file.

F5 Copies file(s) from one panel to other. This makes a single copy of the file covered by bar or makes a group copy of the selected files.

F6 Moves file(s) from one panel to other. This works in the same way as **F5**.

F7 Makes a directory. Enter a directory name and press **Enter**.

F8 Deletes file(s). Deletes a single file covered by the bar or a group of selected files. The confirmation window will appear.

F9 Calls a pull-down menu for advanced operations. Press **Enter** and move cursor to left-right or up-down to select an option.

F10 Exits from the Norton Commander program.

Alt-F1 Selects other drive for the left panel.

Alt-F2 Selects other drive for the right panel.

Alt-F4 Edits file by using an alternative editor.

Alt-F7 Finds file in the current drive.

Alt-F8 History menu. A window with a number of previous commands appears. Select an item and press **Enter**.

Alt-F9 Toggles between 25 and 50 lines per screen.

Alt-F10 Shows a directory tree for the current drive and makes a selection.

Tab Toggles between left and right panels.

Ins Selects files for group operations. The file name covered by the bar will be selected. Press key twice to unselect the file.

Gray + Selects files for group operations. A window with a wildcard field appears.

Gray - Unselects files. A window with a wildcard field appears.

Enter Different actions will be done depending on the selected item:

- Runs executable file with `.exe`, `.com` or `.bat` extension.
- Enters subdirectory, if the item is marked `SUB-DIR`.
- Goes up from subdirectory to the parent directory, if the item is marked `UP-DIR`.

Ctrl-E Recalls recent commands which were typed on system prompt.

Ctrl-U Swaps panels on screen.

Ctrl-O Toggles between panels and screen.

Ctrl-Enter Copies a file name into bottom line where system prompt is placed.

Appendix C

Spectrograph optics

Table C.1: Basic optical parameters for the telescope + spectrograph system.

Aperture of telescope	2560 mm
Cassegrain focus length	28160 mm
Scale at slit of the spectrograph	0.133 mm/sec
Diameter of collimator	128 mm
Effective focal length of collimator + filter	1400 mm
Echelle grating	79 $grooves/mm$
Blaze angle	$R2 = 63.435°$
Angle γ	$4°$
Working orders	$20 - 60$
Long camera	2079 mm
Medium camera	1000 mm
Short camera	348 mm
EEV CCD #1	1152×770 $pixels$
EEV CCD #2	1152×298 $pixels$
Pixel size	22.5 μm

C.1 Basic properties of échelle

The échelle grating equation is written as follows:

$$\sin\ \alpha + \sin\ \beta = Nk\lambda \tag{C.1}$$

where:

α - Angle of the incident beam on the échelle.

β - Angle of the diffraction beam.

N - Number of a grooves of échelle per 1 mm.

k - Order number.

λ - Wavelength of the light beam.

The incident and diffraction beam angles have the following geometry:

$$\alpha = \theta + \gamma + \varepsilon \ \ \text{and} \ \ \beta = \theta - \gamma + \varepsilon \tag{C.2}$$

where:

θ - The blaze angle of the échelle.

γ - The fixed angle between optical axes of collimator and cross-dispersion prism.

ε - A deflection angle of an échelle apart from the blaze.

Then, Equation C.1 can be simplified as:

$$\sin(\theta + \varepsilon) = \frac{Nk\lambda}{2\cos\gamma} \tag{C.3}$$

The efficiency of the échelle with respect to the blaze intensity is defined by the function:

$$\frac{I_\lambda}{I_{\lambda_{blaze}}} = \left(\frac{sin\ u}{u}\right)^2, \ \ \text{where} \ \ u = \pi\left(k - \frac{\lambda_1}{\lambda}\right) \tag{C.4}$$

Hereafter λ_1 is the wavelength in the blaze angle for the first order and equals 225885.67 Å (22.6 μm). The efficiency curves of the échelle used in the spectrograph are shown in Figure C.1.

For a given value of the parameter u, the wavelength at the red (+) and blue (−) ends of an order are written as:

$$\lambda_k^{\pm} = \frac{\lambda_1}{k \mp u/\pi} \tag{C.5}$$

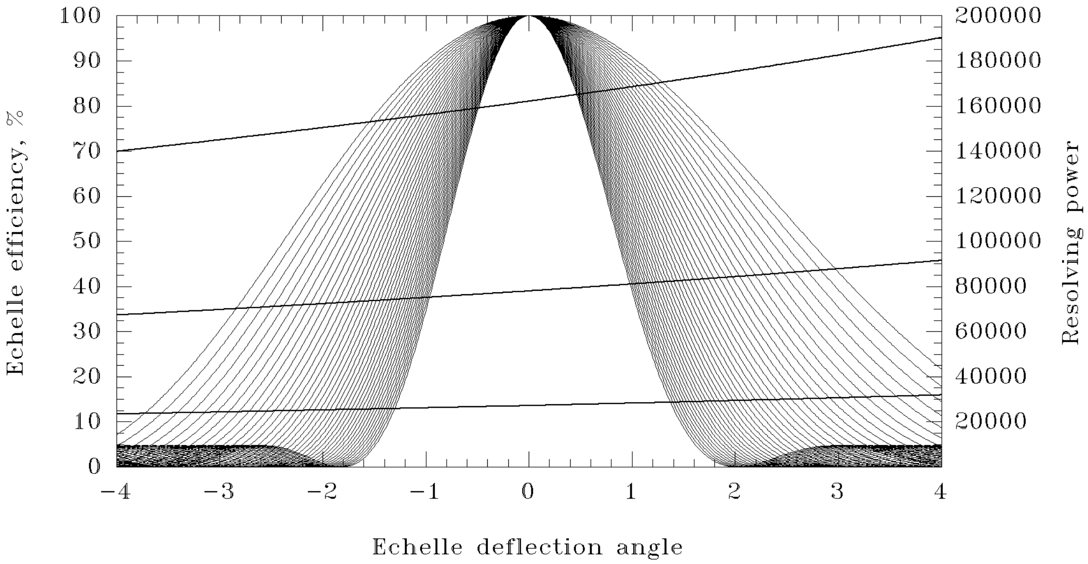

Figure C.1: The échelle efficiency (%) for all spectral orders as function of the deflection angle. Zero angle corresponds to the blaze angle and values are given in degrees. The outer curve is the red $20th$ order and the inner curve is the blue $60th$ order. The three tilted curves shows the resolving power of the spectrograph for three cameras. The upper curve corresponds to the long camera, the middle to the medium camera and the lower curve to the short camera. The entrance slit image corresponds to two pixels of the CCD in use.

From Equation C.4, the efficiency will be maximum when $u = 0$ and the wavelength at the blaze angle of k^{th} order is:

$$\lambda_k^{blaze} = \lambda_1/k \tag{C.6}$$

According to Equation C.5, at the point where $u = \pi/2$, we have $\lambda_k^+ = \lambda_{k-1}^-$. It means that the wavelength at the red end of the order equals to the wavelength of the blue end of the previous order. The efficiency of the échelle is 40.5 % at these wavelength.

Lists of the blaze wavelength and the wavelength at the order ends are given in Table 5.1.

The reciprocal angular dispersion of an échelle can be written as follows:

$$\frac{d\lambda}{d\beta} = \frac{\cos\beta}{Nk} = \frac{\cos(\theta - \gamma + \varepsilon)}{Nk} \quad \text{and} \quad d\beta = \frac{p}{f_{cam}} \tag{C.7}$$

where:

$d\beta$ - Angular separation obtained for two different wavelength separated by $d\lambda$.

f_{cam} - Focal length of the camera.

p - The entrance slit image width on the CCD.

The resolving power of the échelle derived from Equations C.7 and C.3 can then be written as follows:

$$R = \frac{\lambda}{d\lambda} = \frac{2 \cdot \tan(\theta + \varepsilon)}{1 + \tan(\theta + \varepsilon) \cdot \tan\gamma} \cdot \frac{f_{cam}}{p} \tag{C.8}$$

For blaze angle $\tan(\theta + \varepsilon) = 2$ and $\gamma = 4°$, Equation C.8 becomes as:

$$R_{blaze} = 3.51 \cdot \frac{f_{cam}}{p} \tag{C.9}$$

The resolving power values at the blaze angle are given in Table C.2, and the curves as function of the deflection angle of the échelle are shown on Figure C.1 for the three optical cameras.

C.2 Optimal slit width

When the entrance slit width is equal to the optimal width, the optimal sampling of the slit image is obtained on the CCD pixels. Optimal sampling of the slit image can be achieved when it projects onto two pixels of CCD.

Table C.2 shows the behaviour of the output parameters of the spectrograph as a function of width of the entrance slit image. The wider slit is used to minimize the light loss on the slit when a lower resolving power is preferred.

Figure C.2 shows how the entrance slit was calibrated by a direct measurements of its width by using a microscope. The slit width is measured in the tilted position (13.5°) of the slit jaws. The linear fit for the slit width in microns as function of Stepping Drive Units (sdu) is:

$$w = 2.1 + sdu/7.2 \tag{C.10}$$

The minimal entrance slit width is $w = 28.5\ \mu m$ at $sdu = 190$ and the maximal value is $w = 400\ \mu m$ ($0.4\ mm$) at $sdu = 2880$.

The expression for the square of the width of the entrance slit image contains two quadratic terms, namely the squares of the width of the geometrical projection of the slit plus the aberration term and, secondly, the width of the diffraction image:

$$p^2 = (Mw + A(x))^2 + \left(1.44 \frac{\lambda}{d_{coll}} f_{cam}\right)^2. \tag{C.11}$$

Here:

$M = f_{cam}/f_{coll}$ - Magnification factor of the spectrograph. See Table C.3.

w - The entrance slit width.

Table C.2: Parameters of the entrance slit for a monochromatic beam at the centre of the $35th$ order at $\lambda 6453$ Å (close to H_α region).

	Camera 2000 mm					Camera 1000 mm					Camera 350 mm			
p	R	w	α''	T	sdu	R	w	α''	T	sdu	R	w	α''	sdu
2.0	162162	24	0.18	0.23	158	78000	51	0.39	0.48	355	27144	149	1.12	1056
2.5	129730	32	0.24	0.30	214	62400	67	0.51	0.62	469	21715	194	1.46	1382
3.0	108108	40	0.30	0.37	269	52000	83	0.62	0.74	583	18096	239	1.80	1708
3.5	92664	47	0.35	0.44	325	44571	99	0.74	0.85	696	15511	285	2.14	2034
4.0	81081	55	0.41	0.51	379	39000	115	0.86	0.94	810	13572	330	2.48	2360
4.5	72072	62	0.47	0.57	434	34667	130	0.98	1.00	924	12064	375	2.82	2685
5.0	64865	70	0.53	0.64	489	31200	146	1.10	1.00	1037	10858	420	3.16	3011

p Entrance slit image width in *pixels*.

R Resolving power at the échelle blaze angle.

w Linear slit width in *microns* (μm).

α Slit width projected onto sky, in *angular seconds*.

T Slit transmission coefficient for a homogeneous disk of a star with a diameter of $1''$.

sdu Stepping Drive Units for given slit width.

$A(x)$ - Abberration of a camera as a function of the distance from centre of image. The value adopted for the calculations is 8 μm at the centre of image.

λ - Wavelength of the monochromatic beam.

d_{coll} - Aperture of the collimator.

The transmission of star light through the entrance slit is calculated for a homogeneous disk by using the equation:

$$T = 1 - \frac{2\alpha - \sin 2\alpha}{\pi} \tag{C.12}$$

where $\alpha = \arccos(w/d_\star)$ and $d_\star$ is the diameter of stellar image in the linear scale.

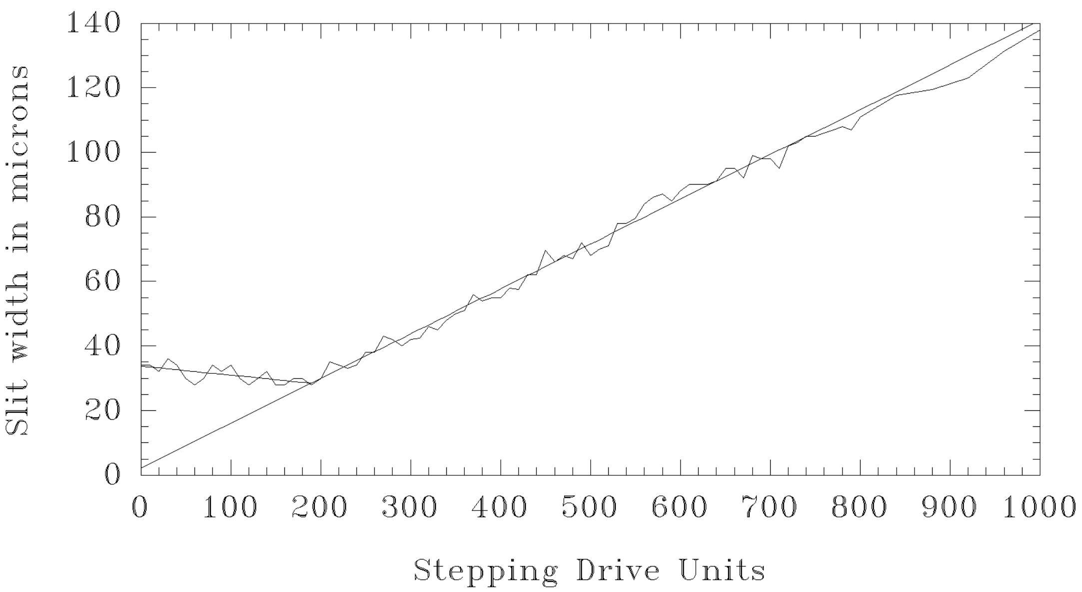

Figure C.2: The slit width calibration as function of the Stepping Drive Units.

Table C.3: Magnification factor of the spectrograph.

f_{cam}	$M = f_{cam}/f_{coll}$
2000 mm	1.485
1000 mm	0.714
350 mm	0.249