SXR208 Observing the Universe

Observatory Manual

The Open University

Contents

1 Introduction **2**

1.1 Health and Safety 2

1.2 The site 3

1.3 The telescopes and instruments 3

2 Telescopes **3**

2.1 The domes 3

2.2 The Meade LX200 telescope 5

2.3 Telescope handset 8

2.4 Telescope control using the Autostar II (LX200GPS) handset 9

2.5 Telescope control using the LX200 handset 13

3 MaxIm DL software **18**

3.1 Introduction 18

3.2 The top-level menus 18

3.3 Getting started with MaxIm DL 20

4 CCD Camera **25**

4.1 The STL1001E CCD camera 25

4.2 Camera control using MaxIm DL 26

4.3 CCD observations 32

5 Spectrographs **34**

6 CCD data-reduction using MaxIm DL **36**

6.1 Calibration 36

6.2 Aligning and combining frames 39

6.3 Aperture photometry 40

7 Data analysis and graph plotting using Excel spreadsheets **44**

7.1 Getting started 44

7.2 Data entry and spreadsheet formulae 46

7.3 Plotting graphs 49

7.4 Airmass calculation spreadsheet 57

7.5 Saving and printing results 58

Appendix 1: Quick observing guide for CCD photometry **58**

Appendix 2: Quick observing guide for spectroscopy **60**

Appendix 3: Bright star list **61**

SUP 00066 5
3.1

1 Introduction

This manual contains information required for the operation of the specific telescopes and software that you will use for the activities in SXR208. You should already be familiar with the material in *Observing the Universe* which includes information on telescopes, CCDs, spectrographs, observing procedures and data-reduction techniques in general.

Section 2 of this manual describes the telescopes and their operation.

Section 3 describes the basic properties of MaxIm DL, which is the software used to control the CCD cameras and perform the image processing and data reduction.

Section 4 describes the CCD cameras and use of MaxIm DL to control them.

Section 5 describes the set-up of the spectrographs.

Section 6 describes the use of MaxIm DL for CCD photometry data reduction.

Section 7 describes the use of Excel spreadsheets for data analysis and plotting.

The appendices contain quick guides to observing and a list of bright stars.

This manual should not be regarded as a comprehensive guide, but it should contain enough information, in combination with the Project Notes to conduct the observations. If you find any errors or omissions, or have suggestions for improvements, please inform your tutor so that we can update it.

Additional information can be found in folders kept in each of the domes as well as in built-in help commands within the software packages.

1.1 Health and Safety

You should regard the observatory as a scientific laboratory. Under the Health and Safety at Work Act, the Open University must provide a safe working place to ensure that students and other persons are not exposed to risks to their health and safety. It is the responsibility of students of the University to protect themselves, and others who may reasonably be expected to be affected, from hazards resulting from their work or behaviour. It is therefore your clear duty to adhere to the instructions and advice given by the Course Director and tutors.

Many of the projects involve astronomical observations, which necessarily take place in the dark. For your personal safety, the safety of others and the prevention of damage to expensive equipment you should take extra care to be aware of potential hazards. In addition to instructions provided at the briefing on the first day of the Residential School, the following general guidelines should be followed at all times:

- Do not run on the observatory site.
- Always carry and use a torch when moving around at night to see and be seen.
- At least two people should be present at any time when working in the domes.
- Always ensure that you understand the instructions before operating any equipment.
- Be aware of the dangers of equipment that may move or may have moved without your realizing it.
- Be cautious of condensation which, even on clear nights, may make paths and steps slippery, or may reduce the friction on dome and shutter rails.

- You must follow the instructions in the Project Notes and must not alter any experimental procedure. You must not handle equipment or materials that are not part of the project.
- You should report immediately any mishaps, however minor, to a tutor.
- Eating and drinking in the laboratory or domes is forbidden.
- Smoking is permitted only in designated areas.

1.2 The site

The Observatori Astronomic de Mallorca (OAM) is located south of the village of Costitx near the centre of the island of Mallorca.

Longitude E2° 57′ 06″

Latitude N39° 38′ 38″

Altitude 203 m

On the site you will find 7 domes containing telescopes used for SXR208 project work, the planetarium, the cafeteria and the main observatory building housing several larger telescopes and the laboratory for non-observational projects.

1.3 The telescopes and instruments

Each of the 7 domes (*Schmidt*, *Mutus*, *Galileo*, *Kepler*, *Tycho*, *Clavius* and *Copernic*) houses a 10 or 12-inch Meade LX200 Schmidt–Cassegrain telescope with a computer drive system and hand controller.

Five of the telescopes are equipped with filter wheels and CCD cameras and the other two telescopes have spectrographs. The detailed specifications of the telescopes and instruments may be different from dome to dome and may change as new equipment is purchased or developed. We have tried to include instructions which allow any telescope, controller, CCD or spectrograph to be used. You will be informed of any variations before you start observing.

2 Telescopes

This section describes the operation of the telescopes and controllers and includes only the information you are likely to need to undertake the SXR208 projects. More details can be found in the manufacturer's telescope instruction manual, a copy of which is available in the folder in each dome.

2.1 The domes

Each of the telescopes is housed in a rotating dome with an entrance that also serves as the observing slit. The perimeter of the dome area is illuminated by red strip lights.

Two of the domes (*Schmidt* and *Mutus*) have wheelchair access.

There are a number of unlit steps of variable height between the other domes. Take care not to trip when walking in the dark.

Always ensure that a tutor is present when opening and closing the domes.

2.1.1 Dome opening

The shutter covering the entrance is in two sections. The dome is locked with two padlocks securing the lower panel of the shutter. The key cannot be removed from the locks when they are open.

- Undo each lock, remove from the retaining ring, then close the lock and remove the key.
- Pull the base of the lower panel away from the dome and slide the panel down.
- Place the padlocks and lower panel in a position where they will not obstruct access to the dome and will not be a tripping hazard.
- Always ensure that one person is standing on either side of the dome so that the upper panel of the shutter can be supported from either side.
- Undo the bolts on the inside of the lower edge of the upper panel.
- Keeping your hands away from the runners, push the upper panel upwards along the slide until it is approximately halfway up. From the other side of the dome, pull the panel down until it is fully open where it is supported by the bolt brackets on the inside. The panel may occasionally be sticky; pull it firmly but carefully.

2.1.2 Dome operation

Dome rotation is performed *manually*.

- Ensure that all obstructions inside the dome are clear of the walls and shelves.
- **Inform other observers** working in the dome that you intend to move it **before** doing so.
- Push against the rim of the entrance or use one of the joints on the wall inside.
- Do not use the shelves or other projections to push the dome.
- The wheelchair access domes, *Schmidt* and *Mutus*, must be rotated from the outside, since the dome and the floor rotate together. They may require some effort to rotate. Push against the bulges in the dome either side of the entrance. One person can remain inside the dome while it is rotated. Ensure that loose cables do not wrap themselves around the telescope pier.

When observing, ensure that the telescope is pointing through the observing slit (this may be an obvious statement but it is surprisingly easy to forget when you are concentrating on obtaining data and particularly after you have moved the telescope). The observing slit is sufficiently wide that, if initially positioned correctly, it will need to be checked no more often than every 15 minutes.

The design of the dome is such that the view of the sky is partially obscured near the zenith (directly overhead). At zenith distances of less than 20° (altitudes of greater than 70°) part of the shutter will effectively reduce the aperture of the telescope. This has two effects – it reduces the amount of light from any astronomical source and increases the background sky signal due to light sources in the dome illuminating part of the dome or shutter within the field-of-view. If your observations require photometric conditions (as in Project 3, the Stellar Photometry project) then you will not be able to observe at altitudes greater than 70°. However, if your observations involve relative photometry (as in Projects 2, 4 and 5) it is still possible to obtain useful data, although as the zenith distance decreases, the signal-to-noise ratio will decrease. The projects have been designed as far as possible to avoid this constraint.

2.1.3 Dome closing

- Before closing the dome, ensure that the telescope cover is on to protect it from any dust or dew that is dislodged.

- Ensure that one person is standing on either side of the dome so that the upper panel of the shutter can be supported from either side.
- From outside the dome, push the upper panel back over the dome about halfway. From the front, pull the panel down ensuring that it does not travel beyond the closed position. It will need supporting – do not let it drop under its own weight as it will run off the rails! Be careful of water run-off if dew has settled during the night.
- Put the bolts on the inner edge of the panel into the holes in the edge of the dome entrance.
- Replace the lower panel and bolt in place.

2.2 The Meade LX200 telescope

Each dome contains either a Meade LX200 or LX200GPS. The latter has a built in GPS system and a different type of computer control drive and handset. Instructions are included for both types.

2.2.1 Telescope structure

Figure 2.1 shows the design of a Schmidt–Cassegrain telescope. It has a spherical primary mirror with a lens (called a correcting plate) at the entrance aperture to correct for spherical aberration. The correcting plate holds a convex secondary mirror which reflects the light through a central perforation in the primary mirror to the focal plane. The benefits of this system are its short physical length compared with its focal length, and the sealed tube which helps keep most of the optical surfaces clean and well aligned.

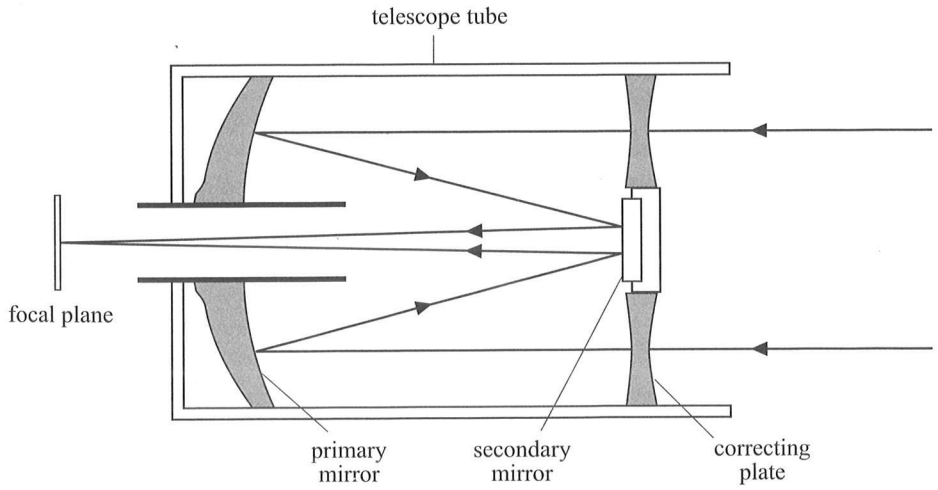

Figure 2.1 The optical design of a Schmidt–Cassegrain telescope.

Do not touch the optical surfaces of the telescope. Small amounts of dust will not significantly affect the image quality. If condensation appears on the corrector plate during the night, use the hair dryer provided, on a cool setting, to remove it.

The 12-inch LX200 has an aperture diameter of 30.5 cm and a focal length of 3.048 m resulting in a ratio of F/10.

Figure 2.2 illustrates the main components of the telescope and controller. Their functions are described in the following sections.

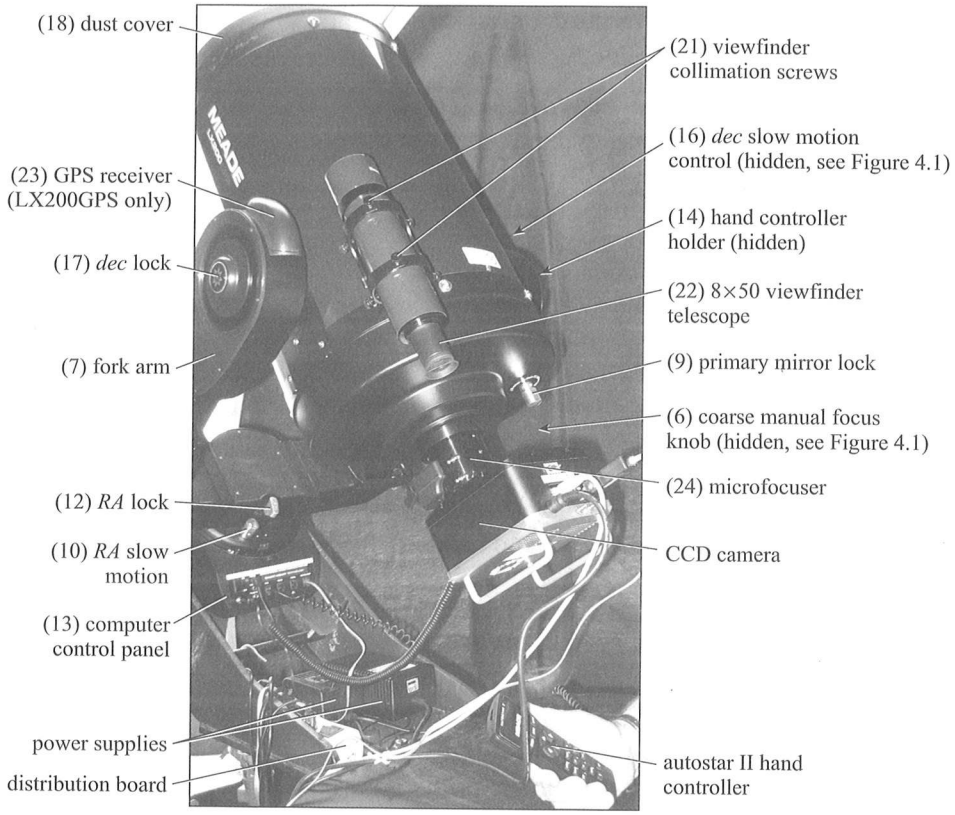

Figure 2.2 A Meade 12-inch LX200GPS Schmidt–Cassegrain telescope with Autostar II hand controller. The numbered items match the key in the manufacturer's telescope manual. Explanations of their function are provided in this manual.

2.2.2 Telescope movement and pointing limits

The numbered items match the key in the manufacturer's telescope manual. Explanations of their function are provided in this manual. The telescope is mounted between the two fork arms (7) positioned on an angled 'wedge' to produce an equatorial mount. The arms of the fork point at the north celestial pole. The telescope rotates about an axis through the fork to change its declination. The fork itself rotates with respect to the wedge to change the right ascension.

The telescope has been set up to be operated using the hand controller. **The telescope should always be moved using the handset** (see Section 2.4.5 or 2.5.5 and Section 2.4.6 or 2.5.6), **never by manual control.**

The right ascension lock (12) **should not be adjusted**. It will be fully engaged (rotated fully clockwise) to engage the *RA* motor drive.

The declination lock (17) **should not be adjusted**. It will be fully engaged (rotated fully clockwise) to engage the *dec* motor drive.

The right ascension slow motion control (10) **should not be used**. It is for manual adjustment of right ascension when the *RA* lock is in the unlocked position. Operation with the *RA* lock fully locked may cause damage to the internal gear system and will result in loss of alignment.

The declination slow motion control (16) **should not be used**. It is for manual adjustment of declination with the declination lock in the locked position but the power must be off for it to operate correctly.

Details of the use of the controller to move the telescope can be found in Section 2.4.5 or 2.5.5 and Section 2.4.6 or 2.5.6.

The fork mount allows any direction in the sky to be observed when an eyepiece is in place. However, the CCD cameras or spectrographs are too large to pass through the arms of the fork and therefore limit the declination which can be observed. **Check the declination limits in force on the telescope you are using before you start observing.**

2.2.3 Electrical connections

The power to the telescope is provided from a socket on the central pier **which must not be removed**. Sockets are available for other uses, e.g. for the dome flat illumination lamp (see Section 4.3.3). Switches for low-level dome illumination (red and white) are also on the pier. **Keep the red low-level dome illumination lights on when you are observing.**

The distribution board (shown in Figure 2.2 or may be attached to the pier) provides power to the computer control panel (13). **None of the connections should be removed**. The illuminated switch should be on when observing and turned off at the end of the night. The power supplies on the wedge are connected to the distribution board. The free sockets can be used for powering the laptop used for CCD control and data acquisition (Section 4). The pier and positioning of switches are slightly different in each dome. In particular, the wheelchair access domes, *Schmidt* and *Mutus*, have lower piers.

Figures 2.3 and 2.4 show the two types of computer control panel with letter labels to match the manufacturer's telescope manual. The on/off switch (A) should be turned on at the beginning of observing and not switched off unless the observations have been completed or the dome is unoccupied. The telescope pointing set-up process (Section 2.4.3 or 2.5.3) must be conducted *each time* the power is switched on.

The connectors for the 12V DC power (B), focus port (C), handset port (F) and autoguider port (H) (if fitted) should be left in at all times. The N/S switch (LX200 only) should be positioned to 'N', *not* as shown in Figure 2.4!

The reticle port (D) provides power for an illuminated eyepiece reticle (not in use due to CCD operation).

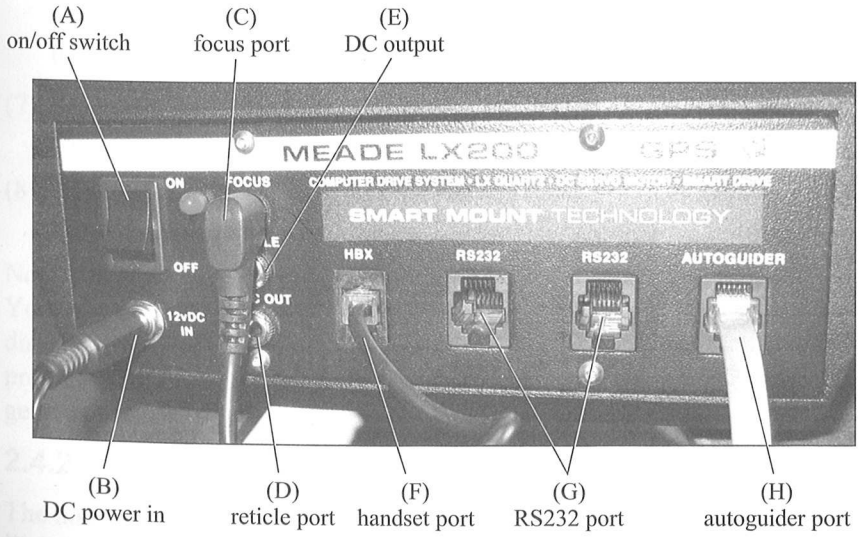

Figure 2.3 Telescope computer drive controls for LX200GPS. The letters (A)–(H) refer to the manufacturer's manual.

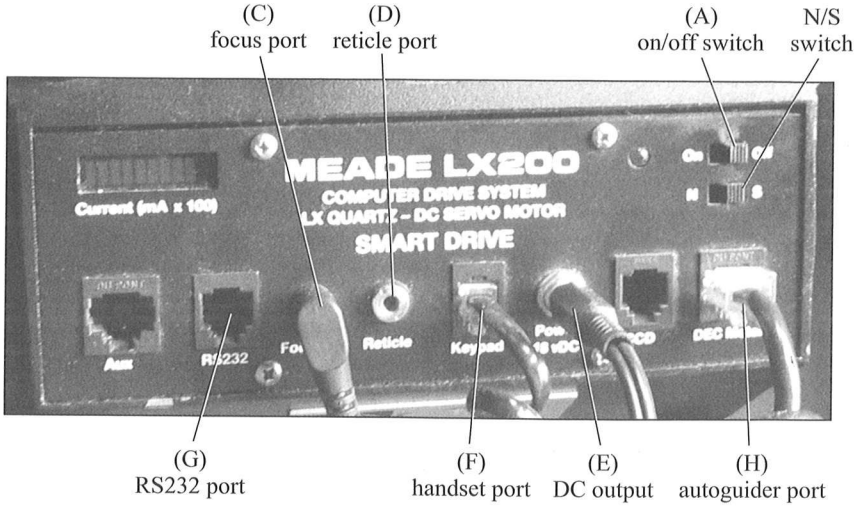

Figure 2.4 Telescope computer drive controls for LX200. The letters (A)–(H) refer to the manufacturer's manual.

2.3 Telescope handset

The telescope is controlled using the handset. There are two types of handset: the Autostar II, found with the LX200GPS telescopes shown in Figure 2.5a and the older style handset used with the LX200 telescope, shown in Figure 2.5b. Many of the functions are identical but the keypad layout and operation are slightly different.

The operation of the Autostar II handset for the LX200GPS is described in Section 2.4, while the LX200 handset is described in Section 2.5.

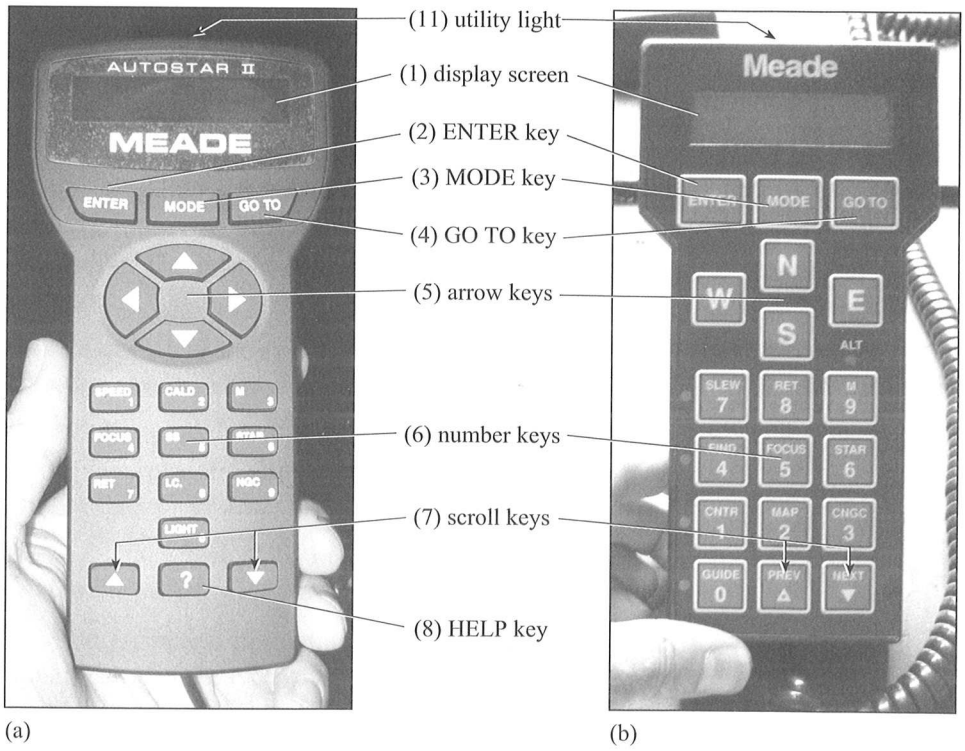

Figure 2.5 Telescope control handsets: (a) Autostar II handset used with LX200GPS telescopes, (b) handset used with LX200 telescopes. The numbers (1) to (8) and (11) above are used in a different part of the manual from the numbers used in describing the telescope in Figure 2.2.

2.4 Telescope control using the Autostar II (LX200GPS) handset

2.4.1 Handset layout

Numbers refer to Figure 2.5.

(1) **DISPLAY SCREEN**: 2-line illuminated display of menus (Section 2.4.2) and information about the telescope or object.

(2) **ENTER key**: Used to move through menus or select menu items (similar to a return key on a computer).

(3) **MODE key**: Used to move up the menu structure (similar to an ESCAPE key on a computer). It also cycles through the 5 operating modes. If pressed and held for more than 2 seconds, information on the telescope pointing and status is displayed.

(4) **GO TO key**: Press to move the telescope to the coordinates of the currently selected object. **This should not generally be used for moving the telescope** (see Section 2.4.6).

(5) **ARROW keys**: Have two functions:

(i) Moving the telescope (Section 2.4.5).

(ii) Scrolling through alphanumeric characters when entering data (Section 2.4.2).

(6) **NUMBER keys**: Press to input digits 0 to 9. Each key also has a specific function or shortcut to a menu which is printed on the key.
1 SPEED: Changes telescope-drive speeds (Section 2.4.5).
2 CALD: Press to shortcut to the Caldwell catalogue of celestial objects.
3 M: Press to shortcut to the Messier catalogue of nebulae.
4 FOCUS: Press to display the focus control menu (Section 2.4.8).
5 SS: Press to shortcut to the Solar System object library.
6: STAR: Press to shortcut to the star catalogue menu.
7: RET: Press to display the reticle control menu (not in use).
8: I.C.: Press to shortcut to the Index Catalogue of galaxies and nebulae library.
9: NGC: Press to shortcut to the NGC catalogue of galaxies and nebulae library.
0: LIGHT: Press to turn on the red utility light (11) on the top of the handset.

(7) **SCROLL keys**: Press to access options within a particular menu (Section 2.4.2).

(8) **? HELP key**: Press to access the 'Help' file and scroll through the options. Press MODE to return to the original screen.

Note: the Autostar II handsets are notoriously unreliable due to poor manufacture. You may need to repeatedly press buttons for them to register. Press firmly and directly down on the centre of the button. Check that you have not made multiple presses. Some operations require a hold of up to 2 seconds to register. Try not to get frustrated with the handset!

2.4.2 Handset menu structure

The handset operation is performed using menus. Messages are displayed on the illuminated **DISPLAY SCREEN**.

Press the **ENTER** key to go deeper into the menu levels or edit a value. To select a menu item or edit a value press and release the ENTER key. The handset emits a short beep and performs the requested action.

Press **MODE** key to move back one level towards the top menu level.

Press **SCROLL** keys to move through the options available at each level.

Use the **NUMBER** keys to enter digits. (Note each number key has an additional function mentioned above.)

Use the **ARROW** keys to enter characters and digits. Use the 'up arrow' ▲ and 'down arrow' ▼ keys to scroll through the characters. The down arrow key begins with the letter 'a' and the up arrow begins with the number '9'. The 'left arrow' ◄ and 'right arrow' ► keys move the cursor across the display. (Note these keys are also used for moving the telescope.)

There are 6 top-level menus on the LX200GPS Autostar II handset:

- Object menu: Includes a library of potential targets including bright stars, the planets, star clusters, nebulae and galaxies using a number of different catalogues. This will be the only menu you are likely to use for your observations.
- Setup Menu: Used to set up telescope alignment and characteristics. **The telescope should already be set up for your use. Do not change any of the settings in the menu**.
- Utilities menu: Used to set up a range of timers and alerts. **Do not change any of the settings in this menu**.
- Glossary menu: Gives definitions of astronomical terms.
- Guided tour menu: Provides a guided tour of the best celestial objects available. **Do no use this function to move the telescope.**
- Event menu: Displays times of past, present and future astronomical events.

The menus and sub-menus that are required for your observing run are described in the relevant sections below. A full description of all the menus is available in the manufacturer's telescope manual.

2.4.3 Setting up the telescope pointing

When the telescope controller power switch is turned on, the handset becomes operational. A message about acquiring GPS signals will appear.

- When set-up is complete, ignore any request to set up pointing (the CCD camera or spectrograph will get in the way). Press the MODE key until a top-level menu item is displayed.
- Check the *local* time (top line in mode 3). If it does not match the correct *local* time, consult your tutor to re-enter it.

In order to refine the telescope pointing (i.e. ensure that it is pointing at exactly the coordinates indicated) it is necessary to point at a known object and confirm the coordinates for that object.

- Use the bright star list (Appendix 3) and a star map (can be found in the dome folder) or a planisphere to select an appropriate star and identify it in the sky.
- Select the star using the handset. Press the STAR key (NUMBER key 6).
- Select the 'Named' star option. Press the ENTER key. Select the appropriate star's name from the list using the SCROLL keys. Press the ENTER key.

- Slew the telescope to point towards the star using the ARROW keys (Section 2.4.5).
- Centre the star on the cross-hairs in the viewfinder telescope (22) using the ARROW keys.
- Press the ENTER key and in response to the request to synchronize, press the ENTER key again. A beep will signify that the drives are now operating.

When the CCD camera is set up this synchronization process can be repeated by centring in the CCD field (see Section 4.2.5) and synchronizing positions.

2.4.4 Telescope status display

- Press and hold the MODE key for more than 2 seconds. On release, the current values of *RA* and *dec* are displayed.
- Use the SCROLL keys to display Altitude and Azimuth; Local time and local sidereal time; timer and alarm status; date; site coordinates; battery status. **If any of these indicate unexpected values do not attempt to change them.** Consult a tutor for advice.
- Press the MODE key to return to the previous menu.

2.4.5 Moving the telescope using the handset arrow keys

- Press the ARROW keys to move the telescope in the direction implied:
  - ▲ moves the telescope to higher *dec*.
  - ▼ moves the telescope to lower *dec*.
  - ▶ moves the telescope to higher *RA*.
  - ◀ moves the telescope to lower *RA*.

(Note that the direction of motion of the telescope when pressing the left and right arrows is opposite to the way you would expect!)

- The speed of motion can be set to a range of values as indicated in Table 2.1.
- Set the speed by pressing the SPEED key (NUMBER key 1) and then a NUMBER key from 1 to 9. The speed is shown on the display for about 2 seconds.

Table 2.1 Telescope drive speeds.

Autostar II speed	Description	Comment
9	Very fast	Moves the telescope quickly across the sky ($8° s^{-1}$).
7–8	Fast	For centring object in viewfinder telescope.
4–6	Slow	For centring target in eyepiece or on CCD.
1–3	Very slow	To keep target on eyepiece cross-hairs (not used).

2.4.6 Moving the telescope using catalogue positions

Once the telescope pointing has been set up (Section 2.4.3) then the telescope can be pointed at any celestial object that is in the libraries.

- Select the object of interest. This can be done either by using the menu structure or the shortcut number keys:

  Using the menu structure

Use the MODE key and SCROLL keys to select the Object menu. Press the ENTER key. Use the SCROLL keys to select an appropriate catalogue group. The choices are Solar System; Constellations; Deep Sky; Star; Satellite; User Objects; Landmarks; Identify; Browse. You are likely to use only the Star, Deep Sky and Solar System options. Press the ENTER key. Work through the sub-menus until you find the catalogue and object of interest. Select the object using the ENTER key.

Using the shortcut number keys

Press one of the shortcut number keys (see Section 2.4.1) and work through the sub-menus until you reach the object you require. Press the ENTER key to select the object.

- You can find information on the object by using the SCROLL keys.
- Do not press the GO TO key to move the telescope to the target position, unless it is close to the current position, to avoid damaging the photometer/spectrometer. **Make sure that the target is above the horizon and has a declination lower than the limit imposed by the CCD camera or spectrograph before instructing the telescope to move to it. Preferably use the Arrow keys to move to the required position.**
- **EMERGENCY STOP: If you want to stop the telescope during its movement towards the target position for any reason, press the GO TO key again.** If this does not work then you can switch off the telescope drive using the ON/OFF switch (A) on the computer control panel. However, you will then need to set up the telescope pointing again (Section 2.4.3). **Do not switch off the power to the distribution board as this will also turn off the power to the CCD camera (or spectrograph) and the laptop.**

2.4.7 Finding your target

- Move to the nominal target position. If your target is not in one of the catalogues (Section 2.4.6) there are several ways to move to it, including making a new catalogue entry for it. However, for your SXR208 observational projects we recommend moving the telescope using the ARROW keys (Section 2.4.5) until the position on the telescope status display (Section 2.4.4) matches the desired position.
- Once the telescope is pointing at the nominal position see if you can identify the field using the CCD camera (Section 4.2.5).

When slewing over large distances across the sky, particularly through the zenith, the pointing of the telescope may not be sufficiently accurate to point directly at your target.

- If you cannot identify the target in the CCD image, but it is bright enough to identify in the viewfinder telescope, centre it on the cross-hairs using the ARROW keys with the appropriate speeds (Section 2.4.5).
- If you cannot identify the target and it is too faint to identify in the viewfinder telescope then you will need to move the telescope to a nearby bright star (use Appendix 3) and synchronize the positions (Section 2.4.3). You should then be able to move directly to your target position using the ARROW keys (Section 2.4.5).

2.4.8 Focusing

The telescope focusing is a two-stage process:

(i) Coarse focusing using the coarse manual focus knob (6).

(ii) Fine focusing using the microfocuser (24) and handset.

Before focusing, you will need to set up the CCD camera (Section 4.2.2) and be able to see a continuously updated image of a star in the CCD (see Section 4.2.5).

If the star image is very large (it will appear with a ring structure) you will need to adjust the coarse focus. This is not generally required – consult your tutor if the telescope is badly out of focus.

- Turn the primary mirror lock (9), if present, clockwise to unlock it (it will require a large number of rotations).
- Adjust the coarse manual focus knob step-by-step to home in to the best focus position when the star images are as small as possible.
- Turn the primary mirror lock anticlockwise to lock it.
- Do not use or touch the coarse focus knob once you have set the coarse focus. If you do so, then repeat the steps above.

The fine focus is performed using the handset.

- Press the FOCUS key.
- 'Focus control speed fast' is displayed. Press the SCROLL keys to cycle through the four focus speed options (FINE, SLOW, MEDIUM, FASTEST) and press the ENTER key to select the desired speed.
- Use the up and down ARROW keys to bring the star into fine focus.

You can check the Full Width Half Maximum (FWHM) of a star profile using the *information window* in MaxIm DL (Section 3.3.5) to determine the quality of the focus and seeing. Ensure the star is not saturated (counts $\geq$ 60 000).

It should not take long to obtain a reasonable focus. Do not agonize over obtaining the smallest possible FWHM. The column of air through which you are making the observations is constantly changing, affecting the seeing over timescales of minutes.

Note that if you are using a spectrograph, you will need to ensure that the slit-viewing CCD is focused on the slit **before** you focus the telescope. Consult your tutor for details.

2.4.9 Parking the telescope

At the end of observing the telescope should be 'parked' on the observer's meridian (pointing south so that the fork arms are level) with the telescope pointing at about 45° to the horizontal. This should be done using the ARROW keys rather than any programmed command in the handset menus.

Turn off the telescope power supply. If you made a mistake and wish to continue observing you must repeat the power up and pointing set-up procedures (Section 2.4.3).

2.5 Telescope control using the LX200 handset

2.5.1 Handset layout

Numbers refer to Figure 2.5.

(1) **DISPLAY SCREEN**: 2-line illuminated display of menus (Section 2.5.2) and information about the telescope or object.

(2) **ENTER key**: Used to move through menus or select menu items (similar to a return key on a computer).

(3) **MODE key**: Used to move up the menu structure (similar to an ESCAPE key on a computer) or cycle through the top-level menus. Use Mode 2, see Section 2.5.2.

(4) **GO TO key**: Press to move the telescope to the coordinates of the currently selected object.

(5) **ARROW keys**: Have two functions:

(i) Moving the telescope (Section 2.5.5).

(ii) Scrolling through alphanumeric characters when entering data (Section 2.5.2).

(6) **NUMBER keys**: Press to input digits 0 to 9. Each key also has a specific function or shortcut to a menu which is printed on the key.
1 CNTR: sets telescope drive speed to 'centre' rate – slow (Section 2.5.5).
2 MAP: turns on the utility light (11) if fitted.
3 CNGC: Press to access an NGC, UGC or IC catalogue object.
4 FIND: Set telescope drive speed to 'find' rate – fast (Section 2.5.5).
5 FOCUS: Operates the microfocuser if fitted (Section 2.5.8).
6: STAR: Press to access the stars and planets catalogue.
7: SLEW: Set telescope drive speed to 'slew' rate – very fast (Sect. 2.5.5).
8: RET: Press for reticle brightness control (not in use).
9: M: Press to select a Messier catalogue object.
0: GUIDE: Set telescope drive speed to 'guide' rate – v. slow (Sect. 2.5.5).

(7) **SCROLL keys**: Press to access options within a particular menu (Section 2.5.2).

2.5.2 Handset menu structure

The handset operation is performed using menus. Messages are displayed on the illuminated **DISPLAY SCREEN**.

Press the **ENTER** key to go deeper into the menu levels or edit a value. To select a menu item or edit a value press and release the ENTER key. The handset emits a short beep and performs the requested action.

Press **MODE** key to cycle through the top menu levels or move back one level towards the top menu level.

Press **SCROLL** keys to move through the options available at each level.

Use the **NUMBER** keys to enter digits. (Note each number key has an additional function mentioned above.)

Use the **ARROW** keys to enter characters and digits. (These are called arrow keys because they are marked with arrows on the Autostar II handset.) Use the N or S keys to scroll up or down through the characters. The S key begins with the letter 'a' and the N key begins with the number '9'. The W and E keys move the cursor across the display. (Note these are also used for moving the telescope.)

The menu structure on the LX200 handset is rather different from the Autostar II. Although it is more restricted, it is somewhat easier to use. There are 5 top-level menus (modes):

- MODE 1: Telescope/Object Library: This contains two sub-menus, Telescope and Object, which duplicate the functions of the Setup and Object menus on the Autostar II. **Do not change any of the settings in the Telescope sub-menu.**

- MODE 2: Coordinates/GO TO: Lets you see where the telescope is pointing and allows you to enter new *RA* and *dec* coordinates for a target not in the catalogue.
- MODE 3: Clock/Calendar: **Do not change any settings.**
- MODE 4: Timer/Frequency: **Do not change any settings.**
- MODE 5: Keypad off/brightness adjust. **Do not change any settings.**

The menus and sub-menus that are required for your observing run are described in the relevant sections below. A full description of all the menus is available in the manufacturer's telescope manual.

2.5.3 Setting up the telescope pointing

When the telescope controller power switch is turned on, the handset becomes operational. When setup is complete, press the MODE key to cycle through the top-level menus.

IMPORTANT: Check the local time (top line in mode 3). If it does not match the correct local time then the handset memory has forgotten the date and time. Consult your tutor to re-enter it.

In order to refine the telescope pointing (i.e. to ensure that it is pointing at exactly the coordinates indicated) and start the telescope's sidereal drive, it is necessary to point at a known object and confirm the coordinates for that object.

- Use the bright star list (Appendix 3) and a star map (can be found in the dome folder) or a planisphere to select an appropriate star and identify it in the sky.
- Slew the telescope to point towards the star using the ARROW keys (Section 2.5.5).
- Centre the star on the cross-hairs in the viewfinder telescope (22) using the ARROW keys.
- Select the star using the handset. Press the STAR key (NUMBER key 6).
- Enter the appropriate catalogue number for the required star (Appendix 3), or: Press the ENTER key to display the 'name' option and use the SCROLL keys to select the appropriate name from the list.
- Press the ENTER key.
- Press and hold the ENTER key until 'matched' is displayed.

When the CCD camera is set up this process can be repeated by centering the star in the CCD field (see Section 4.2.5) and synchronizing positions.

2.5.4 Telescope status display

- Press the MODE key repeatedly to move to the top-level menu.
- Use the SCROLL keys to select MODE 2 Coordinates/Go to.
- Select the Coordinates sub-menu to show where the telescope is pointing.

2.5.5 Moving the telescope using the handset arrow keys

- Press the ARROW keys to move the telescope in the direction implied:

  N moves the telescope to higher *dec*.

  S moves the telescope to lower *dec*.

  E moves the telescope to higher *RA*.

  W moves the telescope to lower *RA*.

(Note that the direction of motion of the telescope when pressing E and W buttons is opposite to the way you would expect!)

- The speed of motion can be set to a range of values as indicated in Table 2.2.
- Set the speed by pressing the SLEW, FIND, CNTR or GUIDE number keys.

Table 2.2 Telescope drive speeds.

LX200 speed	Description	Comment
SLEW	Very fast	Moves the telescope quickly across the sky (8° s^{-1}).
FIND	Fast	For centring object in viewfinder telescope.
CNTR	Slow	For centring target in eyepiece or on CCD.
GUIDE	Very slow	To keep target on eyepiece cross-hairs (not used).

2.5.6 Moving the telescope using catalogue positions

Once the telescope pointing has been set up (Section 2.5.3) then the telescope can be pointed at any celestial object that is in the libraries.

- Select the object of interest. This can be done either by using the menu structure or the shortcut number keys:

  Using the menu structure

  Use the MODE key to select MODE1 Telescope/Object Library. Use the SCROLL keys to select Object library menu. Press the ENTER key. Select the catalogue and object of interest and press the ENTER key.

  Using the shortcut number keys

  Press one of the shortcut number keys (see Section 2.5.1) and work through the sub-menus until you reach the object you require. Press the ENTER key to select the object.

- You can find information on the object by using the SCROLL keys.
- Do not press the GO TO key to move the telescope to the target position, unless it is close to the current position, to avoid damaging the photometer/spectrometer. **Make sure that the target is above the horizon and has a declination lower than the limit imposed by the CCD camera or spectrograph before instructing the telescope to move to it. Preferably use the Arrow keys to move to the required position.**
- **EMERGENCY STOP: If you want to stop the telescope during its movement towards the target position for any reason, press the GO TO key again.** If this does not work then you can switch off the telescope drive using the ON/OFF switch (A) on the computer control panel. However, you will then need to set up the telescope pointing again (Section 2.5.3). **Do not switch off the power to the distribution board as this will also turn off the power to the CCD camera (or spectrograph) and the laptop.**

2.5.7 Finding your target

- Move to the nominal target position. If your target is not in one of the catalogues (Section 2.5.6) there are several ways to move to it, including making a new catalogue entry for it. However, for your SXR208 observational projects we recommend moving the telescope using the ARROW keys (Section 2.5.5) until the position on the telescope status display (Section 2.5.4) matches the desired position.

- Once the telescope is pointing at the nominal position see if you can identify the field using the CCD camera (Section 4.2.5).

When slewing over large distances across the sky, particularly through the zenith, the pointing of the telescope may not be sufficiently accurate to point directly at your target.

- If you cannot identify the target in the CCD image, but it is bright enough to identify in the viewfinder telescope, centre it on the cross-hairs using the ARROW keys with the appropriate speeds (Section 2.5.5).
- If you cannot identify the target and it is too faint to identify in the viewfinder telescope then you will need to move the telescope to a nearby bright star (use Appendix 3) and synchronize the positions (Section 2.5.3). You should then be able to move directly to your target position using the ARROW keys (Section 2.5.5).

2.5.8 Focusing

The telescope focusing is a two-stage process:

(i) Coarse focusing using the coarse manual focus knob (6).

(ii) Fine focusing using the microfocuser (24) and handset.

Before focusing, you will need to set up the CCD camera (Section 4.2.2) and be able to see a continuously updated image of a star in the CCD (see Section 4.2.5).

If the star image is very large (it will appear with a ring structure) you will need to adjust the coarse focus. This is not generally required – consult your tutor if the telescope is badly out of focus.

- Turn the primary mirror lock (9), if present, clockwise to unlock it (it will require a large number of rotations).
- Adjust the coarse manual focus knob step-by-step to home in to the best focus position when the star images are as small as possible.
- Turn the primary mirror lock anticlockwise to lock it.
- Do not use or touch the coarse focus knob once you have set the coarse focus. If you do so, then repeat the steps above.

The fine focus is performed using the handset.

- Press the SLEW or FIND key for fast focusing or the CNTR or GUIDE keys for slow focusing.
- Press and hold the FOCUS key and then press and hold one of the SCROLL keys to adjust the focus.

You can check the Full Width Half Maximum (FWHM) of a star profile using the *information window* in MaxIm DL (Section 3.3.5) to determine the quality of the focus and seeing. Ensure the star is not saturated (counts $\geq$ 60 000).

It should not take long to obtain a reasonable focus. Do not agonize over obtaining the smallest possible FWHM. The column of air through which you are making the observations is constantly changing, affecting the seeing over timescales of minutes.

Note that if you are using a spectrograph, you will need to ensure that the slit-viewing CCD is focused on the slit **before** you focus the telescope. Consult your tutor for details.

2.5.9 Parking the telescope

At the end of observing the telescope should be 'parked' on the observer's meridian (pointing south so that the fork arms are level) with the telescope pointing at about 45° to the horizontal. This should be done using the ARROW keys rather than any programmed command in the handset menus.

Turn off the telescope power supply. If you made a mistake and wish to continue observing you must repeat the power up and pointing set-up procedures (Section 2.5.3).

3 MaxIm DL software

3.1 Introduction

MaxIm DL is a powerful CCD image-processing package optimized for astronomical data reduction. This short guide will introduce you just to the main features of MaxIm DL. The most important commands and operations for the SXR208 projects are described later in this manual. If you want to learn more about MaxIm DL you will need to consult the built-in *Help* menu or the printed manual which is kept in the laboratory.

MaxIm DL is available on the laptop in each dome for CCD data acquisition and on the PCs in the laboratory for data reduction. (Note that the keyboards on the laptops have a Spanish layout.)

> In all sections describing software the term 'click' refers to the left-hand mouse button unless otherwise indicated.

To start MaxIm DL, double-click on the MaxIm DL icon 

on the desktop.

The main screen is shown in Figure 3.1.

Figure 3.1 The MaxIm DL start-up screen.

3.2 The top-level menus

There are 10 main menus found at the top of the screen, some of which have shortcut icons shown on the *View* toolbar immediately below the menus. (There are toolbars available for most of the other menu functions which have not been selected here.)

In this short guide we will describe the menu options rather than the shortcuts. Once you are familiar with the commands you may find it easier to use the

shortcut icons which are displayed next to each command and can be placed on the toolbar using the *Toolbars* command in the *View* menu.

The main menus and some of their more important items are listed in the sections below. Many of the functions are self-explanatory and the built-in help provides detailed descriptions.

3.2.1 The *File* and *Edit* menus

The *File* menu contains options for file manipulation, such as opening, closing, saving and printing.

The *Edit* menu contains options for copying, pasting, adjusting image orientation and display.

3.2.2 The *View* menu

The *View* menu contains the main operations windows for telescope control (not used) CCD control, zooming, and various information windows.

The *CCD Control* window () operates the CCD camera. Its use is described in Section 4.2.

The *Screen Stretch* window () is used to adjust the way in which images are displayed (Section 3.3.4).

The *Information* window () provides numerical data on objects within an image (Section 3.3.5).

The *FITS Header* window lists the information stored with an image. All images taken with the CCD cameras are stored in a format called FITS (Flexible Image Transport System).

The *Zoom* window provides a magnified view of the region of the image near the cursor (Section 3.3.3).

The *Line Profile* window allows you to draw a graph of the counts along a user defined line or box across an image.

The *Night Vision* command reduces and reddens the light emitted by the screen to prevent glare and help maintain dark vision while observing (Section 3.3.6).

3.2.3 The *Analyse* menu

The *Analyse* menu contains the astrometry and photometry data-reduction commands.

The *Pinpoint Astrometry* command is used to determine the coordinates of objects within an image (not used in SXR208 projects).

The *Photometry* command is used to initiate the aperture photometry window to determine magnitudes of objects within an image or series of images (see Section 6.3.1).

The *Open Photometry File* command is used to retrieve photometry reduction information associated with data files that have been saved when performing aperture photometry.

3.2.4 The *Process* menu

The *Process* menu contains commands to calibrate images and manipulate pixel values.

The *Set Calibration* command is used to set up the combined bias, dark and flat-field frames to use for calibration (see Section 6.1.1).

The *Create Master Frames* command is used to save the combined files set up using *Set calibration* to save time with future processing (see Section 6.1.2).

The *Calibrate* and *Calibrate All* commands are used to perform calibration on open images (see Section 6.1.3).

The *Align* command is used to align a number of images.

The *Combine* command is used to align and then combine a number of images, e.g. to improve the signal-to-noise ratio (see Section 6.2.1).

3.2.5 The *Filter*, *Color* and *Plug-in* menus

The *Filter* and *Color* menus contain image-processing commands that are not required for the SXR208 projects.

The *Plug-in* menu allows you to add your own image-processing algorithms and is not required for SXR208.

3.2.6 The *Window* menu

The *Window* menu is used to select between images that are currently open and adjust how they are displayed.

3.2.7 The *Help* menu

The *Help* menu provides built-in help.

- Click on *Help topics* in the *Help* menu to open the *Help* window (Figure 3.2).
- You can work through the contents or tutorials shown.
- If you wish to know about a specific command or process, click the *Index* tab to search through a comprehensive index of terms. Alternatively, click the *Search* tab to enter your own search word or phrase.

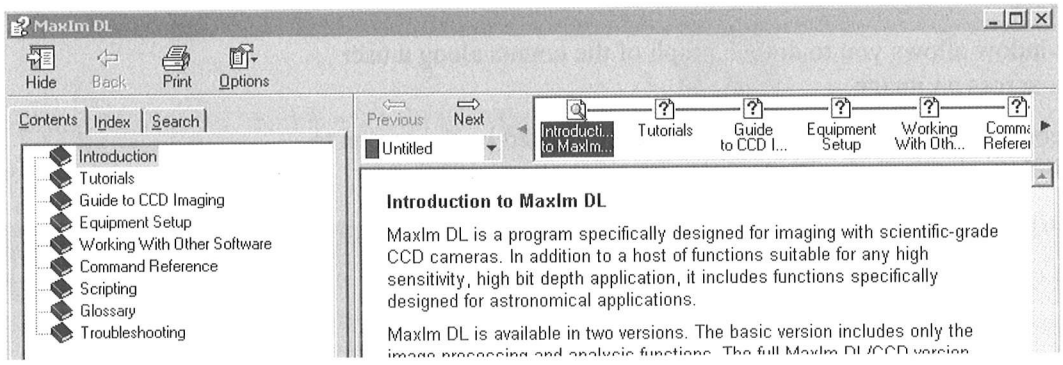

Figure 3.2 The MaxIm DL *Help* window.

3.3 Getting started with MaxIm DL

Section 4 describes how to obtain images using MaxIm DL to control the CCD camera and the data-reduction procedures are described in Section 6. In this section we describe some of the basic tools in MaxIm DL for image viewing and navigation.

3.3.1 Organizing your data

- Laptops in each dome are labelled by telescope name. PCs in the laboratory are numbered 1 to 7. All data taken with the telescopes should be stored and saved on lab PCs within the OU folder on the desktop.

- A 'week folder' should have been created on each PC for each week of SXR208, e.g. year05week01pc01 corresponds to 2005, SXR208 week 1, PC number 1.
- When observing, save your data in a new 'night folder' for each night with a standard name including the telescope and date, e.g. Sep10_moon_p01_Tycho (corresponding to September 10, group 'moon', project1, telescope 'Tycho'). Individual image files should have a common identifier (e.g. the observer's initials) followed by a unique three-digit number to identify the image and a user supplied suffix (see Section 4.2.6). You should ensure that all files from one night follow the same convention so that you can easily identify them from your observing log (Section 4.3.1).
- Before starting data analysis on the laboratory PC, ensure that your raw data are copied to a folder of the same name within the folder set up for your observation week. If you are reducing the data, make another copy of the folder and its contents to work in, e.g. Sept10_moon_p01_Tycho_work. This ensures that if you make a mistake in the processing you do not overwrite your original raw images.
- Archive data is stored in the folder LocalArchive on each PC or laptop. Make a copy within your night folder to use when working on the data.

3.3.2 Opening, saving and closing files

Click on the *Open* command in the *File* menu and the *Open* window will appear (Figure 3.3).

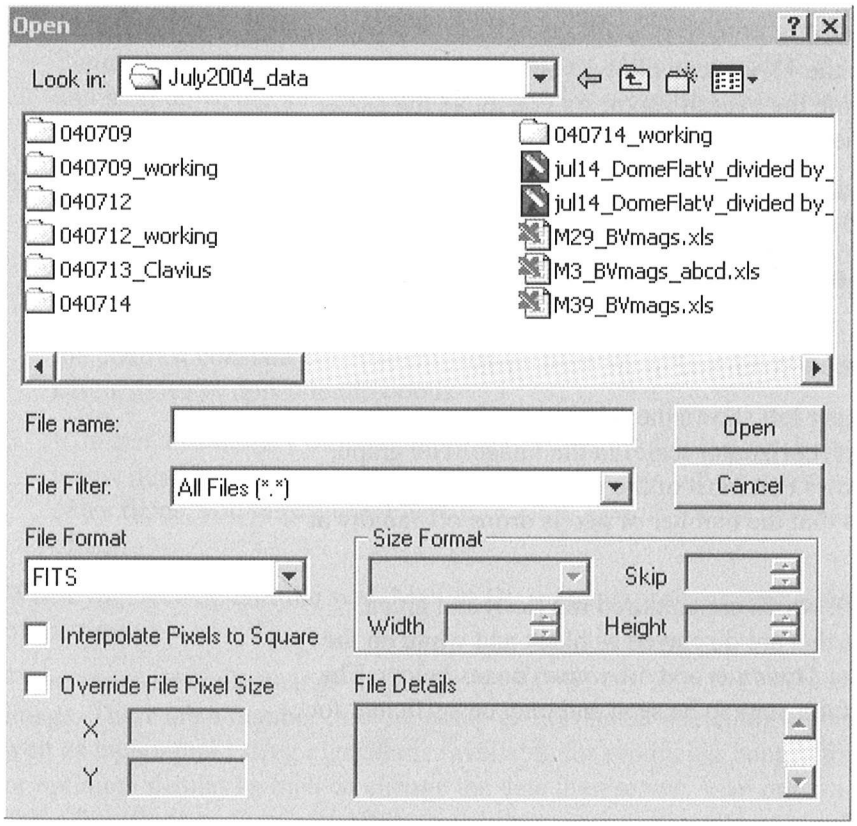

Figure 3.3 The *Open* window.

- Set *File Filter* to All Files (*.*).
- Ensure that Interpolate Pixels to Square and Override File Pixel Size are off.
- Select the folder and file you want to open in the top fields.

When you select a file in the field some information from the FITS header is displayed in the *File Details* field.

- You can select multiple files using the SHIFT and CTRL keys on the keyboard:
  Click on the first file required, hold the SHIFT key down and click on the last file required and the whole range will be selected.
  Hold the CTRL key down and click to select additional files.
- When you have selected the file or files you want, click *Open*.
- Use the *Save* and *Save as* commands to save any files you want to keep, such as raw or processed images. Note that *Save* uses the current filename as default so you will overwrite previous versions.
- Use the *Close* and *Close all* commands to close the images (you will be prompted to save any changes. Be careful not to overwrite files you wish to keep).

3.3.3 Navigating an image: *Zoom* and *Rotate*

The images produced with the CCD camera are too large to be displayed on your computer screen at full resolution.

- You can navigate the image using the bars on the right-hand side and bottom of an image.
- To zoom the entire image in or out, use the *Zoom in* and *Zoom out* commands in the *View* menu, the  shortcut icons, or the magnification field next to them on the toolbar.
- The *Zoom Window* command in the *View* menu allows you to see a magnified part of the image without changing the overall zoom. As you move the cursor around the image a magnified view appears in the *Zoom Window*.
- If the images do not have the desired orientation then the *Flip, Mirror, Rotate Right, Rotate Left,* or *Rotate 180* commands from the *Edit* menu can be used.

3.3.4 Adjusting brightness and contrast: The *Screen Stretch* window

- Click on the *Screen Stretch Window* command in the *View* menu.

The large histogram graph on the upper left shows the relative number of pixels (vertical scale) at each intensity level (horizontal scale) in the image. The graph, for a typical astronomical image, shows that most of the pixels are grouped on the left (dark) side of the histogram, and that the number of pixels drops off rapidly at brighter levels (right side).

The small triangular pointers (carets), which are coloured red (left) and green (right), indicate the brightness levels that are displayed as black and white on the screen, with their values shown in the *Minimum* and *Maximum* boxes below. The default settings are chosen to allow faint stars to be seen and may be sufficient for your needs.

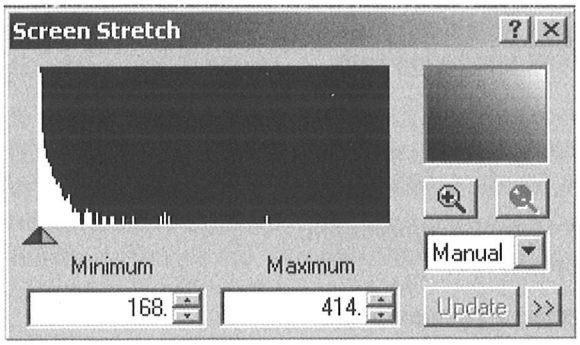

Figure 3.4 The *Screen Stretch* window.

You can change the brightness and contrast of an image in a number of ways:

1 Using the automatic levels: Click on the small arrow next to the field showing *Manual* and choose one of the settings.

2 Using the *Quick Stretch* Box (the small shaded window at the upper right): Point the mouse at the *Quick Stretch* box and press and hold down the left-hand button on the mouse. The mouse cursor changes to a 'four arrows' shape. You can now adjust the image contrast and brightness as follows:

   Move the mouse upwards to increase brightness.

   Move the mouse downwards to decrease brightness.

   Move the mouse right to increase contrast.

   Move the mouse left to decrease contrast.

3 This function is also available without using the *Screen Stretch* window. Simply point the mouse at any image window. Hold down SHIFT, then press and hold down the left-hand mouse button. You can now make the same adjustments described above.

4 Moving the carets: Placing the carets close together produces a high contrast; conversely placing them far apart produces a low contrast. Reversing the positions of the two carets will produce a negative image. When moving the carets with the mouse, experiment with holding down either the SHIFT or CTRL keys. The SHIFT key makes the carets move along together, keeping the contrast constant but changing the brightness. The CTRL key makes the carets move in opposite directions.

5 You can also modify the Maximum and Minimum fields directly by typing in a new number and then pressing ENTER. Note: if you type in the numeric entry fields, you must press ENTER or click *Update* for the new value to take effect.

When you become familiar with MaxIm DL you will probably use method 3 most of the time.

These processes only change the image display and do not affect the data in the image. There are a number of more complex non-linear stretching algorithms as well as image-processing algorithms (available for producing images for printing or optimum display) which do change the data themselves. **You must not use these functions as they will affect your data.**

3.3.5 The *Information* window

The *Information* window displays a variety of information on selected areas of the image.

- Click on *Information Window* in the *View* menu, or use the shortcut icon. The window can remain open as a floating toolbox without interfering with other commands.

The *Information* window has four modes of operation: *Aperture*, *Region*, *Area*, and *Astrometric*. The default setting, shown in Figure 3.5, is Aperture mode.

The mouse cursor will change to a cross-hair and bull's-eye when the *Information* window is active and the cursor is over the selected image or preview.

The maximum and minimum values, median, average and standard deviation are given for all pixels within the central circular aperture. The sizes of the various elements of the circular cursor can be changed using the mouse to access the right-click menu (see Section 6.3.1).

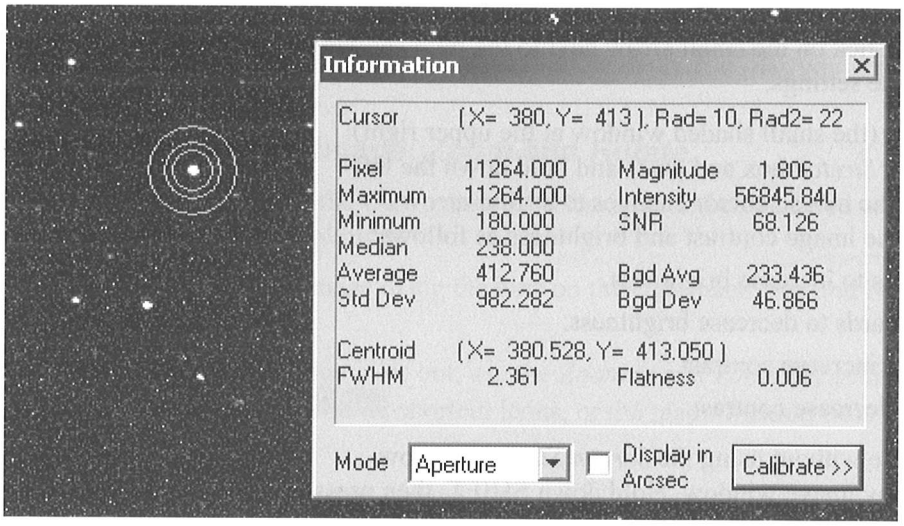

Figure 3.5 The *Information* window in Aperture mode.

The *Information* window is useful to:

- Assess if star images may be saturated. The maximum counts in a raw image pixel are 65 535 so avoid using stars in calibrated images with counts above 60 000.
- Determine the seeing/focus using the Full Width Half Maximum (FWHM).
- Obtain an estimate of the signal-to-noise Ratio (SNR) you may get from photometry.
- Perform absolute photometry.

The photometry provided in the *Information* window is not as accurate as that obtained from the *Photometry* command (Section 6.3.1) when small apertures are used because it does not use pixel interpolation. However, it is sufficiently accurate for our requirements when large apertures are selected. The *Photometry* command performs aperture photometry relative to a reference star in the same image and is not therefore suitable for the Stellar Photometry project (Project 3). The use of the *Calibrate* button is described in the Project Notes.

You can find out more about the other modes for the *Information* window using *Help*.

3.3.6 The *Night Vision* command

Selecting *Night Vision* in the *View* menu toggles the night-vision mode on or off. Three types of night-vision display are available and can be adjusted using the

Night Vision window under the *General* tab of the *File Settings* window accessed through the *File* menu.

In the default red mode, all menus, dialogue boxes, etc., are switched to red. (Icons and toolbar buttons are not affected.) Red light helps maintain the human eye's dark adaptation because it does not as readily destroy the 'visual purple' photosensitive pigment of the scotopic vision system ('rod' cells). Since this function changes the 'system colours', other applications will be affected to some extent.

Night-vision mode is automatically switched off when MaxIm DL is shut down.

4 CCD Camera

The following section describes the use of the STL1001E CCD camera. Some of the telescopes may be equipped with other types of CCD. They may have a different pixel size and field-of-view and different read-out and noise characteristics but their operation with MaxIm DL should be identical. **Your tutor will provide you with any additional information required.**

4.1 The STL1001E CCD camera

The STL1001E CCD camera (Figure 4.1) has a 1024 × 1024 chip with 24 μm pixels, a 6-position filter wheel and built-in cooler. The chips have few cosmetic faults and a fast readout with low noise when the cooler is used. Figure 4.1 shows the camera mounted on an LX200GPS telescope ready for observation.

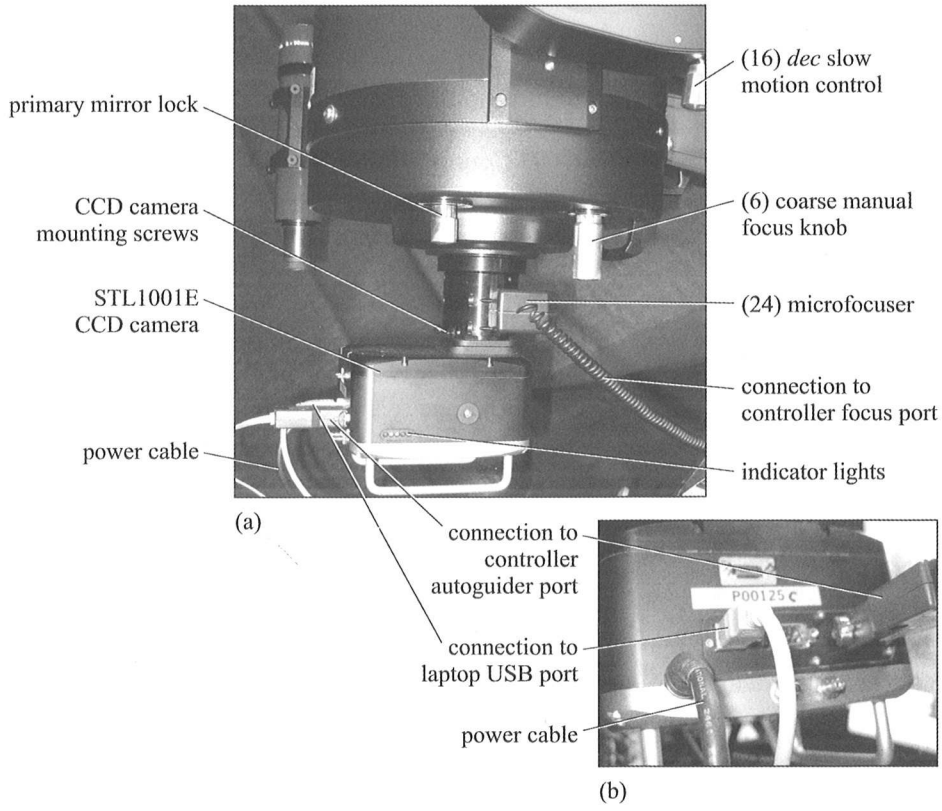

Figure 4.1(a) An LX200GPS telescope with an STL1001E CCD camera mounted. (b) Close-up of the camera itself with its connections.

The connection to the laptop should be via one of the USB ports. Note that in the configuration shown in Figure 4.1, the connectors for the camera are facing away

from the telescope fork. This provides the maximum possible declination limit but results in a chip orientation with north down when images are displayed. This can be rectified after the telescope and CCD are set up for observing (Section 4.2.3).

The orientation of the camera can be changed using the mounting screws. This should not be necessary. **Check with your tutor if you think the camera needs rotating. Do not attempt this yourself.** The camera is heavy and the mounting screws need to be tightened carefully so that they grip the tube firmly.

The field-of-view of the CCD is given by

$$\text{field-of-view} = \frac{\text{linear size of detector}}{\text{focal length of telescope}}$$

$$= \frac{1024 \times (24 \times 10^{-6}\,\text{m})}{3.048\,\text{m}}$$

$$= 8.07 \times 10^{-3}\ \text{radians}$$

$$= 28\,\text{arcminutes.}$$

Therefore

$$\text{pixel size} = \frac{\text{field-of-view}}{1024}$$

$$= 1.7\,\text{arcseconds.}$$

4.2 Camera control using MaxIm DL

4.2.1 The *CCD Control* window

The CCD camera is controlled by MaxIm DL, the same software that you will use for data reduction.

- Open the MaxIM CCD window (Figure 4.2) using the *CCD Control* option from the *View* menu or by clicking the toolbar icon.

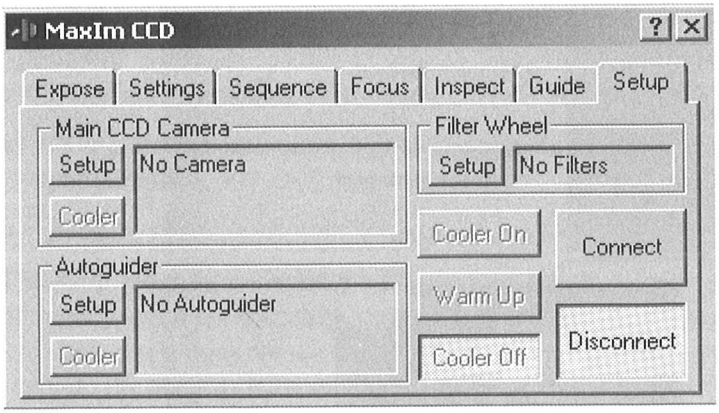

Figure 4.2 The *MaxIm CCD* window with the *Setup* tab selected.

The CCD window has 7 tabs:

Setup: To connect to the camera, turn on the cooler and identify filter-wheel positions (Section 4.2.2).

Settings: Set up imaging settings such as windowing and auto calibration (Section 4.2.3).

Expose: Take individual exposures (not automatically saved to disc) (Section 4.2.4).

Focus: Continuous CCD readout (data not saved) for focusing and object finding (Section 4.2.5).

Sequence: Set up imaging sequences for observation which are automatically saved to disc (Section 4.2.6).

Guide: Autoguider – not used in SXR208.

Inspect: Used to display star profiles while focusing.

4.2.2 Preparing the CCD for observation: The *Setup* tab

- Click on the *Setup* tab of the *MaxIm CCD* window.
- Check that the correct CCD camera driver is selected in the *Main CCD Camera* zone. It should be 'SBIG Universal'. **If it is not correct, consult your tutor for the appropriate driver name**. Click the *Setup* button and select the camera driver from the list provided.
- Connect to the CCD camera by clicking *Connect*.
- Turn the cooler on by clicking the *Cooler on* button. The target cooler temperature should already be set. It is important that the chip remains cool to minimize the dark current and at a constant temperature to ensure stability. If it is set too low, then on a warm night the cooler may not be able to reach it. A value of –15 °C is likely to be the default but it will probably need to be raised if the night is particularly warm (a value in the range –5 °C to –10 °C is recommended). It can be adjusted using the *Cooler* button in the *Main CCD Camera* zone.
- If you are performing a photometry project, click *Setup* in the *Filter Wheel* zone to check the names and locations of the filters. This should have been correctly set up for your specific project, usually with B, V, R, I filters and Clear. (Note that these are sometimes incorrectly referred to as B = Blue, G = Green, R = Red, I = Infrared and W = White respectively.) **If the list of filters does not match what you expect, consult your tutor.**
- Ensure the CCD has cooled to the operating temperature before starting observations.
- When you have finished observations, click *Warm Up*. When the temperature is above 0 °C click *Cooler Off* and *Disconnect*.

It is useful to have audible signals when an exposure is completed.

- You can set this up within the *Audible Alarms* tab on the *Settings* window accessed from the *File* menu.

4.2.3 CCD readout options: The *Settings* tab

The *Settings* tab can be used to *window* the CCD (i.e. reduce the area read out); for binning pixels before readout; and to perform some calibration before saving data.

The *Subframe* zone should read left 0, top 0, width 1024, height 1024. The *X-binning* and *Y-binning* values should be 1. *Auto Calibration* should be set to *None*. **You should not change any of these settings. Click reset to return to default values.**

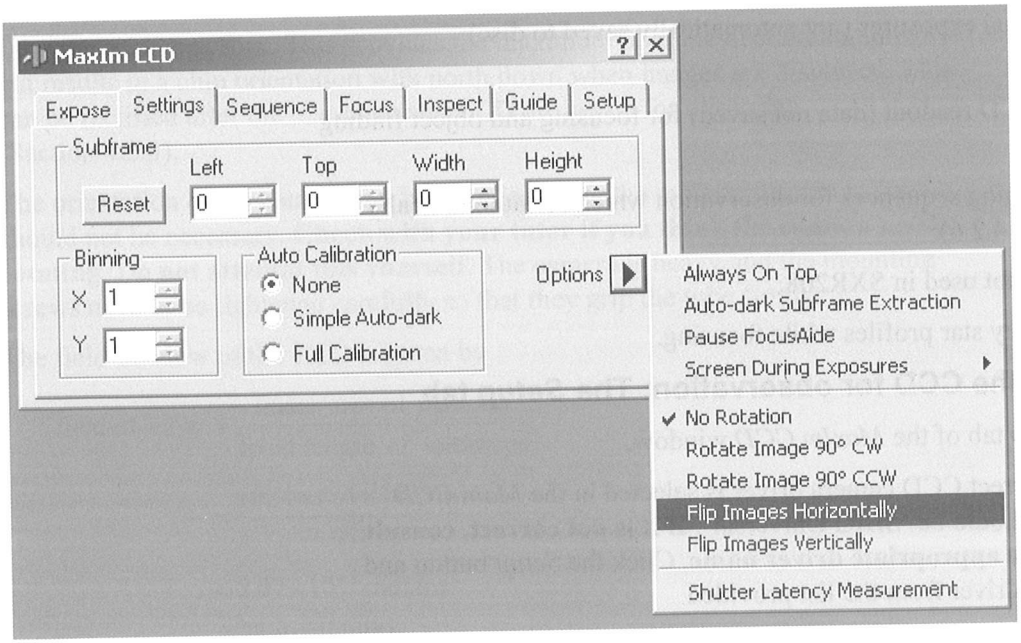

Figure 4.3 The *Settings* tab of the *Maxim CCD* window with the *Options* button selected.

The orientation of the CCD images can be changed using the *Options* box (Figure 4.3). You will need to check the orientation of the CCD (Section 4.1). In the nominal position with the cables pointing away from the mounting, the image will be inverted. **Consult your tutor if the CCD is not orientated this way or you have a different CCD camera.** If the CCD is in the nominal position:

- Click the *Options* box.
- Select Flip Images Horizontally and Flip Images Vertically.

All other settings should not be selected.

4.2.4 Taking individual exposures: The *Expose* tab

Use the *Expose* tab (Figure 4.4) if you wish to take individual images (frames) that you may not want to save, for example to test exposure levels when taking flat fields.

You are recommended to use observing sequences (see Section 4.2.6) for all your real observations to ensure that data are saved correctly.

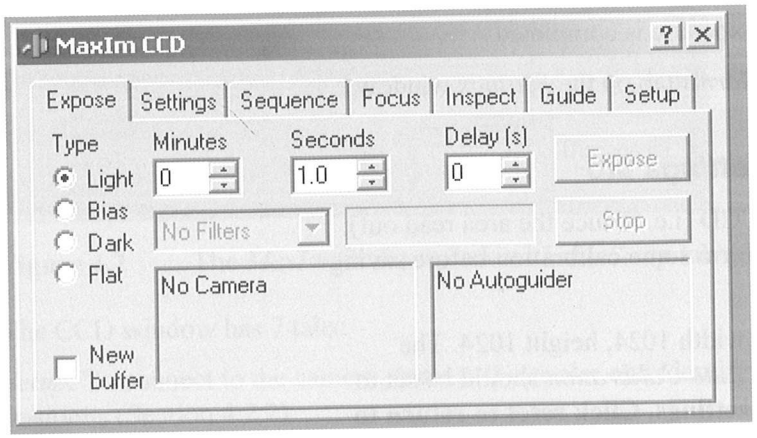

Figure 4.4 The *MaxIm CCD* window with the *Expose* tab selected.

- Click the box for the type of image you wish to take:

Light for a normal exposure with the shutter open.

Bias to take a bias frame (shutter remains closed and exposure time is zero).

Dark to take a dark frame (shutter remains closed).

Flat to take a flat field (operation as for *Light* but the frame is recognized by MaxIm DL as a flat-field frame).

- Set the exposure time in minutes and seconds.
- The *Delay* field allows you to specify a delay time after the *Expose* button is pressed before the exposure will begin. When a sequence of images is taken, this delay is added before each exposure in the sequence. This should normally be set to zero.
- Select the filter required using the *Filter* field.
- Click the *Expose* button to start the exposure. The *Stop* button will be enabled. The field to the lower left will inform you of the progress of the exposure.

Note that the Expose command does not save files automatically. If you wish to save an image use the *Save as* command from the *Files* menu. **You should take care to adhere to your naming convention (Sections 3.3.1) and not to overwrite files saved from Sequence observations (Section 4.2.6)**.

4.2.5 Continuous CCD readout: The *Focus* tab

When focusing the telescope (Section 2.4.8 or 2.5.8), setting up the pointing (Section 2.4.3 or 2.5.3) or finding a target (Section 2.4.7 or 2.5.7), it is useful to have a continuous view to see the effect of changes in the focus or telescope position, as you would when using an eyepiece. The *Focus* tab can be used for this (Figure 4.5).

The *Focus* tab provides a duplicate set of exposure controls, condensed into a compact format. The operation is similar to that for the *Expose* tab but the filter cannot be changed.

- Make sure that image type *Light* is selected and the appropriate filter is in place using the *Expose* tab, before going to the *Focus* tab.
- Set the exposure time in seconds.
- If the *Dark* button is selected then a dark frame will be taken first and subtracted from all subsequent images. This is not generally necessary for focusing or centring on a bright object so switch it off to save time. (However, if you use the *Focus* tab for finding and centring on faint objects such as nebulae you may need to use it.)
- Ensure the *Continuous* button is on so that the images are constantly updated.
- Press the *Start Focus* button to start an exposure sequence. When an exposure is in progress, the *Start Focus* button is disabled, and the *Stop* button is enabled.
- Perform your focus (Section 2.4.8 or 2.5.8) or centring (Section 2.4.3 or 2.5.3) procedures. Remember to allow time for the next exposure to be taken and read out to see the effects of adjusting the focus or telescope position. Short exposure times are recommended!
- Press the *Stop* button to finish.

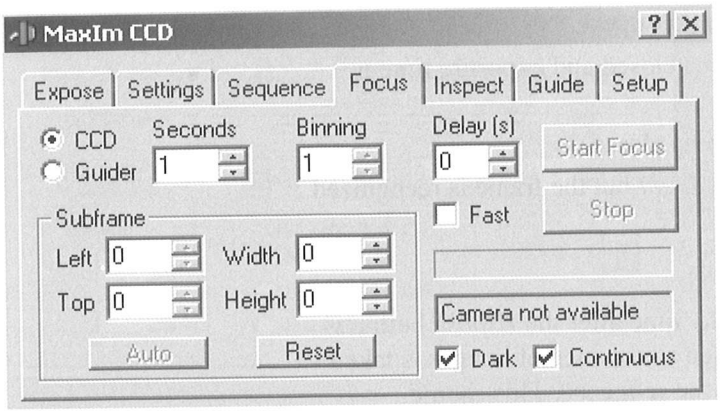

Figure 4.5 The *MaxIm CCD* control window with the *Focus* tab selected.

4.2.6 Performing imaging sequences: The *Sequence* tab

The *Sequence* tab is used to obtain a sequence of observations and save them automatically. It is the recommended method for routine observations.

- Specify a base filename for the images in the *Autosave Filename* field. **It is important that you adhere to file naming procedures (Section 3.3.1) to ensure that you can identify your observations**. A three-digit sequence number is automatically appended to this filename to identify each exposure, followed by a user-specified suffix that distinguishes each different 'type' of exposure within the sequence, e.g. different filter, binning, etc. The suffixes are specified in *Sequence Setup* described below. Do not include a file extension in the Autosave Filename; images acquired by a sequence are always saved in FITS format with the '.fit' extension. The sequence number and suffix for the image currently being exposed, downloaded, or saved are concatenated and displayed in the read-only *Suffix* field.
- Specify the first sequence number that will be used in the *Start at* field. This allows you to use the same base filename without overwriting previous files or changing the destination folder for the acquired images. The sequence number is automatically updated as you observe. **However, if you save files produced by the Expose command (Section 4.2.4) remember to update the sequence number to prevent overwriting files.**

With the exception of the *Start* and *Stop* buttons, described below, all other controls for configuring a sequence are accessed from the *Options* button (Figure 4.6).

- Specify the folder to which the image files will be automatically written using *Set Destination Path* in the *Options* menu.
- When *Overwrite Files* is ticked, MaxIm CCD will always save files regardless of whether there was a file with the same name already on the disk. When it is switched off, an attempt to overwrite a file will cause the exposure sequence to abort. Be aware of the option you have chosen!
- Ensure *Full Frame* is ticked so that if you accidentally set sub-frames in the *Settings* tab, they will not be applied.
- Do not change any other settings in the menu accessed from the *Options* button.
- Click the *Options* button and select *Setup Sequence* from the menu.

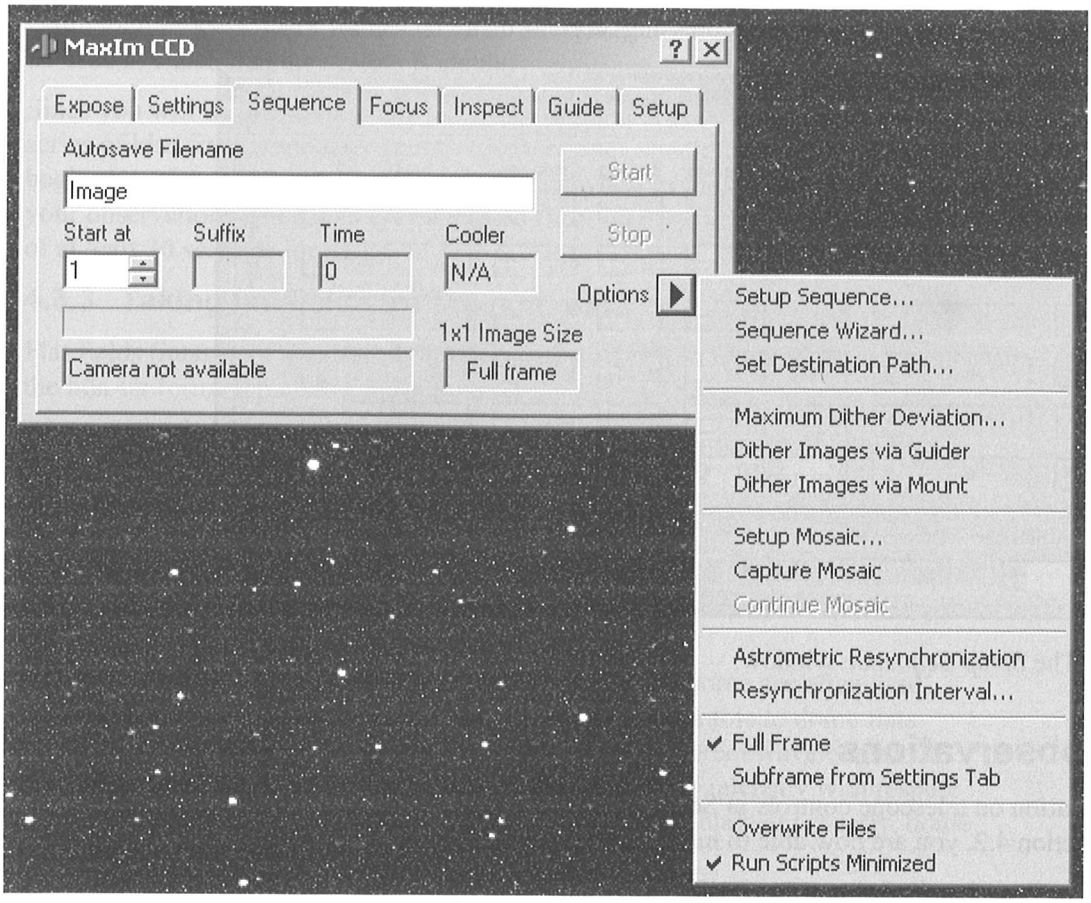

Figure 4.6 The *Sequence* tab of the *Maxim CCD* window with the *Options* button selected.

Figure 4.7 shows an example *Setup Sequence* window in which a set of 10 exposures, each of 60 seconds in the V filter has been selected. (Note that 'No Filters' appears in the *Filter* window because this figure was made without a CCD camera attached.) Other non-selected options are to take a series of 10 bias fames, 10 dark frames, 10 flat-field frames in either B or V filters or 10 target frames in the B filter.

To enter a sequence:

- Click an *Enable* box and enter the chosen observation type; filter; a suffix which will be added to the filename; the exposure time in seconds (not used for bias frames); pixel binning (keep equal to 1); the number of repeats to be performed in the sequence.
- Previously used sequences can be kept but only an enabled sequence will be run.
- Ensure the *Delay First* and *Delay Between* fields are set to 0 if you want continuous observations.
- Click OK to return to the *Sequence* window.

IMPORTANT Do not enable more than one sequence at a time as this will cause duplicate file numbers to be created.

An observation sequence can now be run.

- Click *Start* to start the enabled sequence. Information on the frame being taken and the progress of the sequence is provided in the information fields. Each image will be displayed after it is downloaded.

- You can abort the sequence at any time by pressing *Stop*.

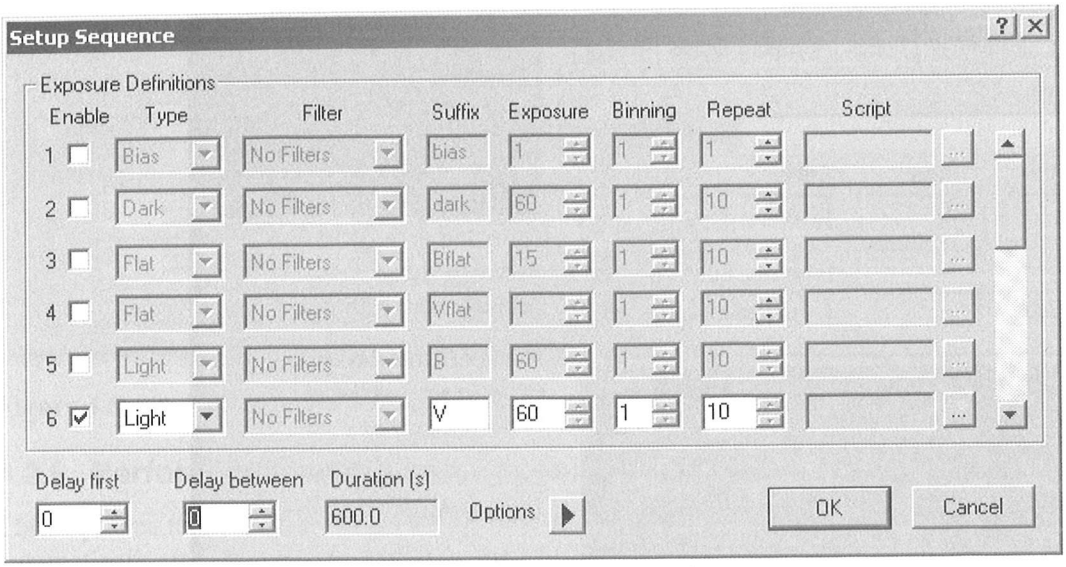

Figure 4.7 The *Setup Sequence* window.

4.3 CCD observations

Using the information on telescope controls in Section 2 and the MaxIm DL commands in Section 4.2, you are now able to make some observations.

Remember to save your data in the appropriate folder (Section 3.3.1).

4.3.1 Observing logs and data transfer

Observing log sheets will be provided and they should be completed as you observe.

It is essential that you complete the header sheet and record the saved image numbers that will uniquely identify your data. If you follow the file naming conventions (Section 3.3.1) then you will have a unique frame number for each observation. Include any information you think will be helpful when you reduce the observations in the comments box. This is particularly important when things go wrong!

You should keep one master observing log throughout the night. Write copies as required for other group members.

In many of the projects, the data will be reduced while the observations continue. The data should be transferred using the USB memory sticks provided. They have a capacity of at least 128 Mb which corresponds to approximately 60 frames. You are advised to transfer data in blocks of 50 frames. Make a note in the observing log when frames have been transferred.

The observing team will need to coordinate the acquisition and transfer of data and ensure that the appropriate information from the master log sheet is available to the data reduction team.

4.3.2 Taking bias and dark frames

Bias frames can be taken at any time.

The dark current depends on the design and temperature of the CCD camera chip. Ideally, dark frames should be taken before every set of observations. However, if the chip is maintained at a constant temperature by the cooler then the dark frames should be stable, and they can be scaled for different exposure times in the

calibration process. Dark frames taken on several occasions during the night can be used to check that the system is stable.

Since you will be processing data as you go along it is good practice to take a series of bias frames and dark frames (5–10 of each should be sufficient) at the beginning of the night. MaxIm DL automatically scales the dark frames to match your observations when data are calibrated (Section 6.1). Select an exposure time of at least 30 seconds for darks.

4.3.3 Taking flat fields for imaging data

Flat fields (images of a uniformly illuminated surface) are required to correct for the non-uniform response of individual pixels in the CCD.

The twilight sky provides a suitable surface. However, the timing of 'sky flats' is critical. The sky must not be so bright that it saturates the CCD during short exposures or so faint that inordinately long exposures are required and stars become visible.

An alternative that is more suitable for your projects is to provide your own uniformly illuminated surface.

At professional observatories, illuminated screens in the dome are often used, hence the name 'dome flats'. Sky flats are generally preferable to dome flats because of subtle differences in the CCD response to different wavelengths. A typical artificial light source has a different distribution of intensity with respect to wavelength from that of the twilight sky. However, if obtained properly, dome flats will be adequate for your needs.

To obtain dome flats:

- Using the handset, point the telescope to a low altitude. Do not point the telescope to the horizontal as this may damage the gears when it reaches the internal limiters.
- Hold the flat-field screen in front of the telescope as far back as possible.
- Hold the lamp close to the telescope so that it illuminates the screen uniformly but does not shine directly onto the corrector plate. Be careful that the telescope tube does not cast a shadow on the screen.
- For each filter that you plan to use, take some test exposures using the *Expose* command (Section 4.2.4) until you obtain a count level of between 20 000 and 30 000. Initially, try 1-second exposures with the V filter and 15-second exposures with the B filter.
- For each filter that you plan to use, run a sequence of 5–10 flat frames using the *Sequence* command (Section 4.2.6).

4.3.4 Observing your target

The instructions for moving to, finding and centring on a target are given in Sections 2.4 and 2.5. Follow the instructions in the Project Notes for each target.

Although the telescope drives are set up to compensate for the Earth's rotation, small errors in the drive speed accumulate and images will drift across the frame. This occurs even for large telescopes and is usually compensated for using *autoguiding* where a guide star is used to adjust the position of the telescope to keep the field centred. To avoid additional complications you will not use autoguiding for the SXR208 projects.

When doing spectroscopy, you will be able to see the slit via the slit-viewing CCD, and hence can adjust the guiding of the telescope to keep an object centred

in the slit. For imaging however, you will need to ensure that your exposure times are short enough that drive errors do not affect the images. Exposures from 30 seconds to 1 minute should be possible. Bright objects will need shorter exposures to prevent saturation. Longer exposures can be built up by taking many short exposures and combining them in the data-reduction process. The short readout times for the CCD cameras in use mean that there is very little inefficiency and there is the added benefit of reducing the effects of cosmic rays and the possibility of image saturation. On the debit side, you incur an additional dose of readout noise with each exposure.

Use the *sequence* command to take repeated short exposures. The image may drift during the whole sequence but this can be corrected in the combination process (Section 6.2.1).

5 Spectrographs

The OAM has several spectrographs and several CCDs. On any particular observing run, various combinations may be in use. The setup you use may be slightly different from that described here, and different from that used by the last group of students to visit the observatory. Change is all part of real astronomy, as facilities continue to be refined and software is updated with new capabilities. The Project Notes were developed in 2003 and 2004 for a spectrograph called TRAGOS (Figure 5.1), which contains a transmission grating as its dispersing element. Your tutor will help you with the set-up.

TRAGOS is fitted with two CCDs: one CCD records the spectrum, and a CCD webcam feeds an image of the field-of-view of the telescope to the computer screen to help you to line up the telescope on the object of interest.

The slit is a rectangular aperture measuring 25 μm × 3 mm. In order to bring the image of a target star into the spectrograph slit, you need to be able to view the slit. The light that does not pass through the slit to the spectrograph is reflected onto the webcam, allowing the observer to verify that the target is centred on the slit and hence that some of its light is entering the spectrograph. The slit-viewing CCD webcam is shown in the upper right part of Figure 5.1.

The collimator ('B' in Figure 5.1) of focal length f_{col} is a distance f_{col} from the slit. Since the slit is at the focal point of the collimator, the lens gives rise to a collimated beam of light that passes on to the dispersing element (in this case a transmission grating) and then to the camera lens. The dispersing element does not refocus the light, so the light at any given wavelength is still collimated when it reaches the camera lens.

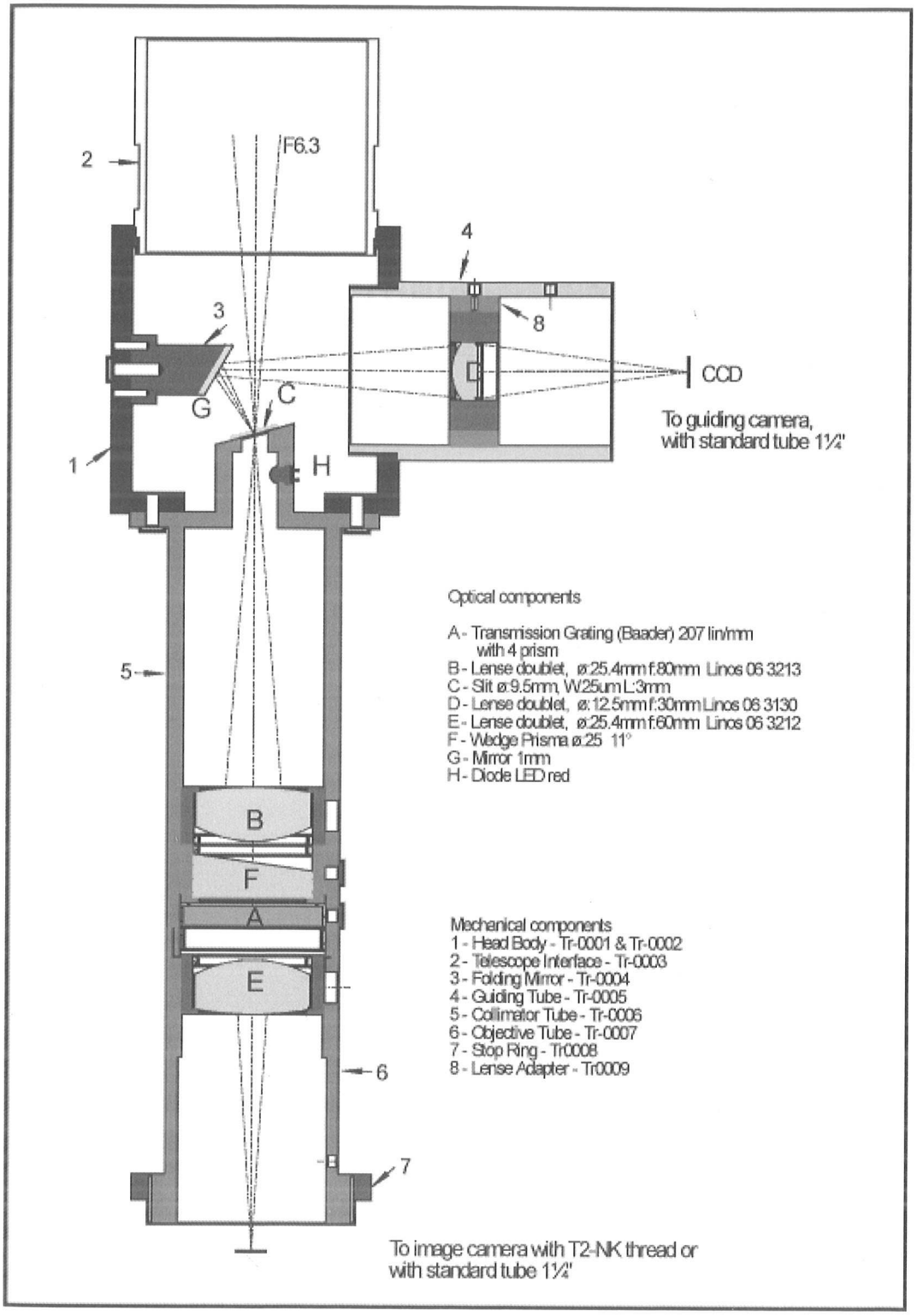

Figure 5.1 Mechanical drawing of TRAGOS (excluding CCDs), showing the optical path (electronic figure supplied by Vadim Burwitz).

Consequently the camera lens ('E') of focal length f_{cam} will bring the light to a focus again at a distance f_{cam} from the lens, at which point the CCD is located. That is, the light that emanated from a point at the slit is brought back into focus again, on the CCD. The dispersing element redirects different wavelengths in different directions, so the focused images of the slit fall in different locations depending on their colour.

A hollow cathode lamp whose spectral lines have known wavelengths is used to identify the wavelength that corresponds to each pixel in the spectrum. The spectrum of a hollow cathode lamp (e.g. Figure 5.2) will be obtained by your tutor as a demonstration.

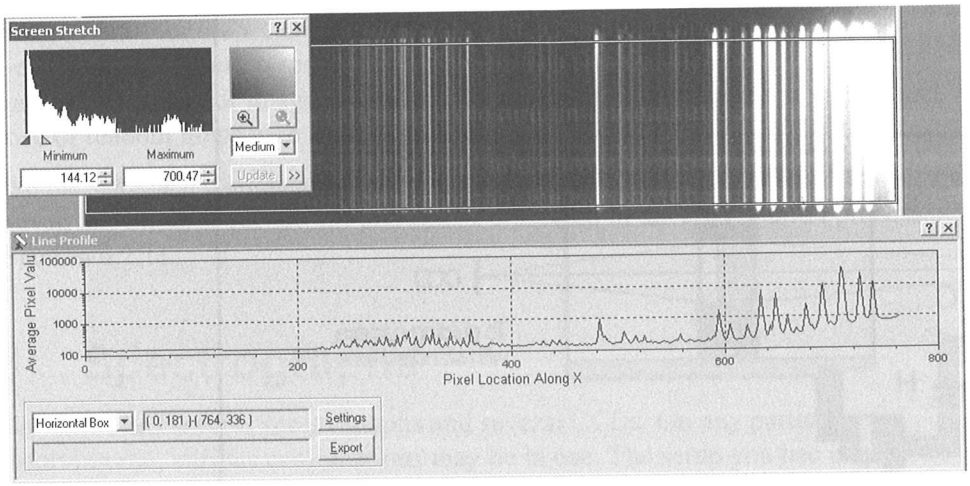

Figure 5.2 Spectrum of a HeAr hollow cathode lamp, with wavelength increasing from left to right. Note that the display range minimum has been set almost to zero, and the display maximum has been set to only around one-fifth of the data maximum, to emphasize the weak lines.

When you point the telescope towards a star, it almost certainly will not immediately arrive on the slit of the spectrograph, due to small inaccuracies in the telescope pointing. Look through the finder telescope mounted on the side of the main telescope to identify the target, and move the telescope to bring it to the centre of the field-of-view, which is usually marked with cross-hairs. Then go back to the slit viewing webcam to locate and centre the target star on the slit.

6 CCD data-reduction using MaxIm DL

The data reduction is carried out on the PCs in the laboratory located in the main observatory building.

The basic MaxIm DL commands and procedures have been introduced in Section 3. Commands from the *Process* and *Analyse* menus are used to reduce the data before transferring it to Excel spreadsheets for plotting.

6.1 Calibration

Before any useful information can be gained from the images they must be bias-subtracted and dark-current subtracted and flat-fielded. All these processes are performed using routines from the *Process* menu.

Slightly different procedures are suggested for the spectroscopic data – details can be found in the Astronomical Spectroscopy Project Notes (Project 1).

6.1.1 Preparing the calibration files: The *Set Calibration* command

The *Set Calibration* command is used to set up the calibration files to be used to process a set of images. A set of bias frames, dark frames or flat-field frames is called a *group*.

- Click on the *Set Calibration* command in the *Process* menu. The window shown in Figure 6.1 will appear.

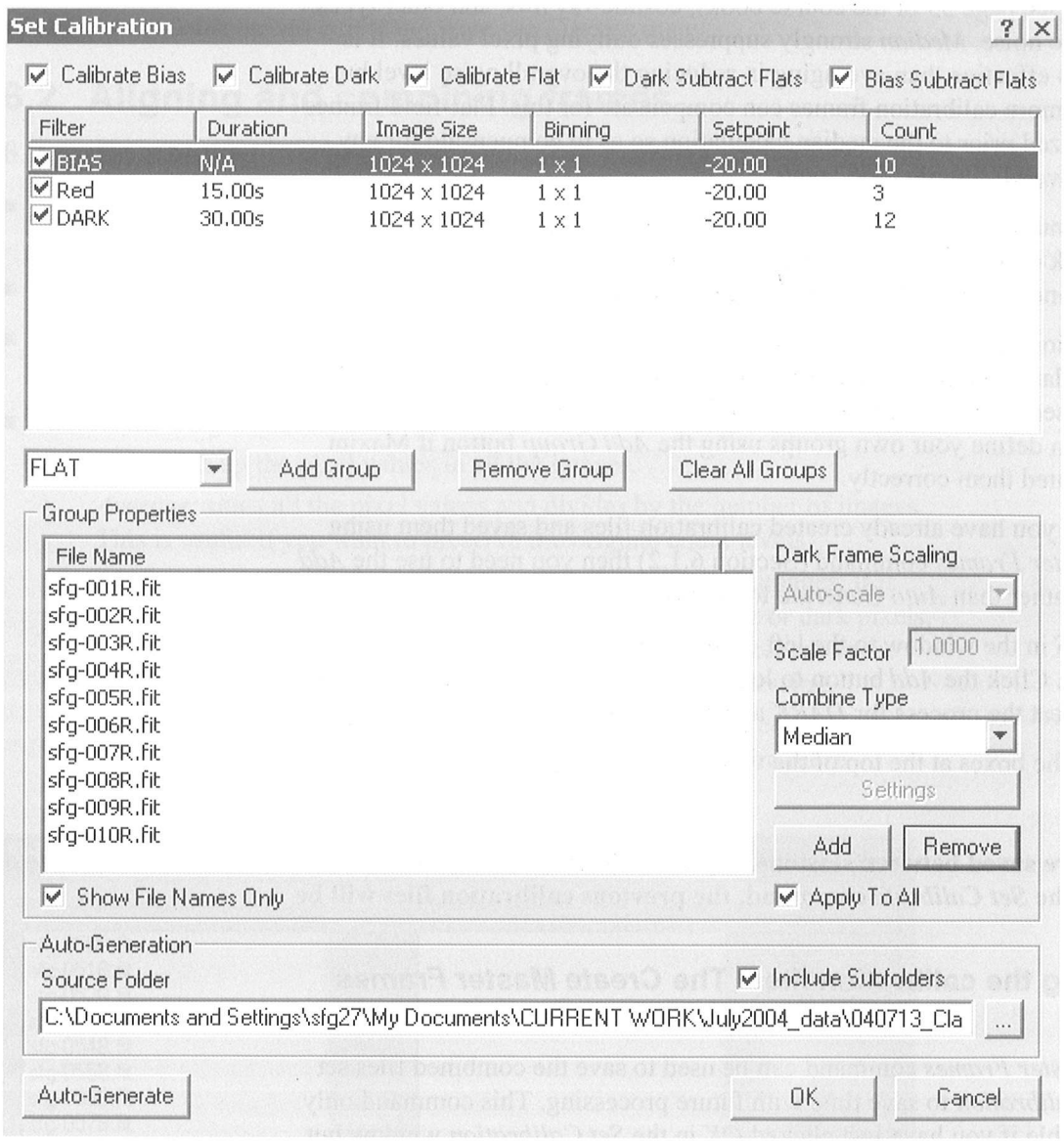

Figure 6.1 The *Set Calibration* window.

- In the *Auto generation* zone click on the '…' button on the right to select the source folder containing your data.

If you are creating calibration frames for the first time:

- Click the *Auto Generate* button and Maxim DL will automatically scan the source folder, and any FITS images present will be divided into groups containing images with similar properties. Figure 6.1 shows the result of this process. The groups will have titles corresponding to the first filter in the group. In the example shown the first group (selected) is the set of bias frames. The second group is a series of flat-field frames taken using the R filter and the third group is a set of dark frames.
- You can add or remove files to or from a group using the *Add* or *Remove* buttons. If a group is missing you can use the *Add Group* button to create one and locate the appropriate files.
- Ensure the *Apply to all* box is ticked and select *Median* in the *Combine Type* field. This specifies the algorithm to be used for combining the images in the

group into a single, master image. The available algorithms are *Average*, *Median*, *Sigma Clip* and *SD Mask*. Choosing *Median* is useful for suppressing bad pixels (see page 55 of the course book), cosmic-ray hits, and other types of impulsive noise. *Median* strongly suppresses outlying pixel values. It is slightly less effective than averaging in reducing the overall noise level but combining more calibration frames can compensate for this. Flat-field frames are normalized prior to the median calculation so as to compensate for any change in overall illumination levels.

- For dark groups, select *Auto-scale* in the *Dark Frame Scaling* field to ensure that the dark current is correctly removed from frames even if they do not have the same exposure time as the dark-group frames.

During calibration, MaxIm DL will select the three groups of calibration frames – bias, dark and flat – that best match the currently active image. If you don't wish a group to be used then you can delete the entire group using the *Remove Group* Button. You can define your own groups using the *Add Group* button if Maxim DL has not created them correctly.

Alternatively if you have already created calibration files and saved them using the *Create Master Frames* command (Section 6.1.2) then you need to use the *Add Group* button rather than *Auto Generate* to load your saved calibration files.

- Select *BIAS* in the window to the left of the *Add Group* button and then click *Add Group*. Click the *Add* button to locate and load the saved combined bias frame. Repeat the process for *DARK* and *FLAT* (for the appropriate filter).
- Ensure all the boxes at the top of the window are ticked.
- Click *OK*.

The settings are saved between sessions. If you calibrate an image without first running the *Set Calibrate* command, the previous calibration files will be loaded.

6.1.2 Saving the calibration files: The *Create Master Frames* command

The *Create Master Frames* command can be used to save the combined files set up using *Set Calibration* to save time with future processing. This command only becomes available if you have just clicked *OK* in the *Set Calibration* window but haven't yet calibrated any images.

- Click Create Master Frames in the Process menu.
- One master image is generated for each image group created by *Set Calibration* and they are displayed as image buffers.
- Save the master frames so that they can be used in future applications of *Set Calibration*. Be careful to ensure that the file names are self-explanatory.

6.1.3 Calibrating images: The *Calibrate* and *Calibrate All* commands

- Open the images that you wish to calibrate using the *Open* command from the *File* menu.

To calibrate the currently selected image:

- Click the *Calibrate* command from the *Process* menu.

If a valid calibration is not set, an error message appears. If the calibration was set on a previous MaxIm DL session, the calibration files will be loaded again, if still available.

To calibrate all open images that have not already been calibrated during this MaxIm DL session:

- Click the *Calibrate All* command from the *Process* menu.

6.2 Aligning and combining frames

6.2.1 Combining images: The *Combine* command

- Click the *Combine* command from the *Process* menu. The *Select Images* window (Figure 6.2) will open.
- Select the images to be combined using the >> or *Add all* buttons.
- Click *OK* and the *Combine Images* window (Figure 6.3) will open together with the *Information* window overlaid on the first selected image.
- Select the *Output* mode which determines the way the images are combined:

  Sum: adds up the pixel values in all the images.

  Average: sums all the pixel values and divides by the number of images. This is useful if you want to preserve the original count levels.

  Median: takes the median or middle value from all of the images. It is useful when some pixels are extremely bright or dark (hot or dark pixels, cosmic-ray hits). The *Normalize* option will remove differences in the image scaling which could interfere with the median processing.

  Sigma-Clip and *SD Mask:* combination modes attempt to combine the best features of the *Median* and *Average* modes, but require more intensive calculations.

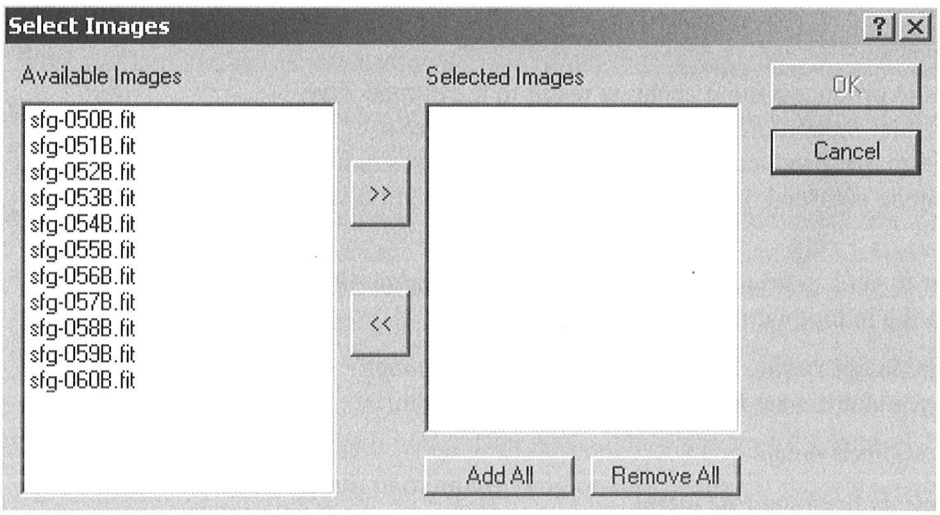

Figure 6.2 The *Select Images* window.

- Set the *Align Mode* to either *Auto – correlation* (which shifts but does not rotate each image to match up star patterns to sub-pixel level and works well if the offset between the images is very small) or *Auto – star matching* (which shifts and rotates images to match up star patterns and should be used if there are large differences between the images). *None* combines the images with no shifting. There are many other specialized align modes which are not required for SXR208.

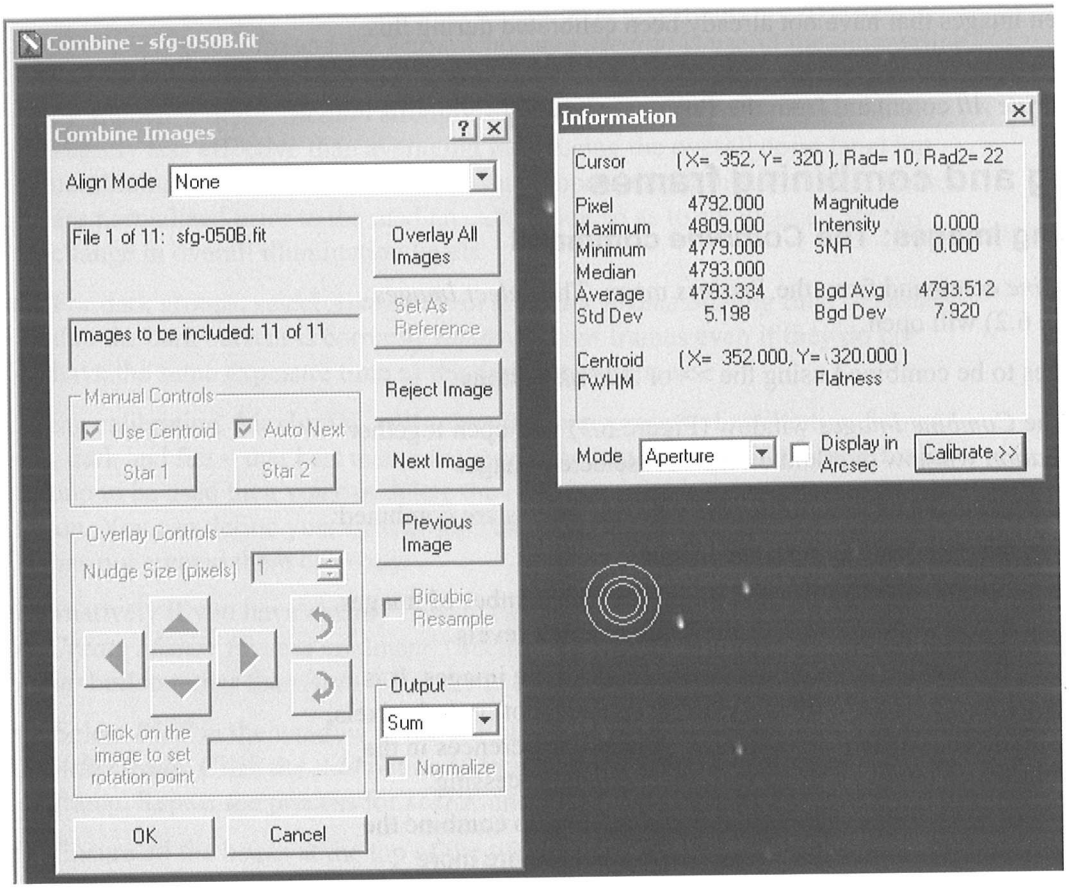

Figure 6.3 The *Combine Images* window.

When the images are rotated or resized, MaxIm DL will interpolate the values of the pixels in the input images to produce a more accurate result in the output. Two interpolation modes are available. *Bicubic Resample* (recommended) uses a higher-order resample algorithm that produces a crisper result, but requires more processing time. When this mode is turned off, a simple bilinear interpolation is used.

- Click *Overlay All Images* to get a preview of the overlay. Click *Overlay All Images* again to return to the individual images.
- You can scroll through the images using *Next Image* and *Previous Image* buttons and remove any you don't want using the *Reject Image* button.
- Click *OK* to produce a combined image.
- Save the image using *Save As* from the *File* menu.

6.2.2 Aligning images: The *Align* command

The *Align* command from the *Process* menu performs the same function as the *Combine* command without combining them. It is used to search for moving or variable objects by blinking between frames. It is not currently used for SXR208 projects.

6.3 Aperture photometry

6.3.1 Performing aperture photometry: The *Photometry* command

The *Photometry* command provides accurate photometric measurements on one or more images, and allows for the plotting of light curves. It uses a 'median–

mean' algorithm for background subtraction and takes into account partial pixels inside the measurement annulus.

- Click the *Photometry* command in the *Analyse* menu to open the *Photometry* window (Figure 6.4) and the *Information* window which will both be superimposed on the first image.

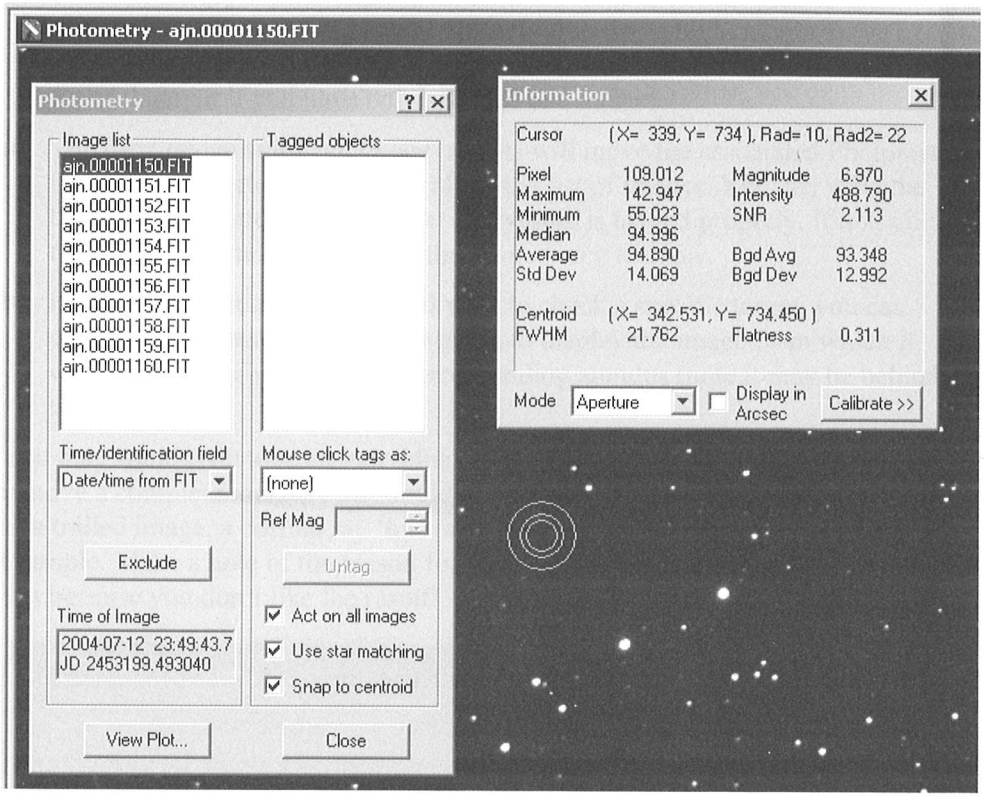

Figure 6.4 The *Photometry* window and *Information* window with the image under consideration in the background.

- The *Image list* contains all the currently open images in date/time order. You can exclude an image from the list by selecting it and clicking the *Exclude* button. If you want to restore it at any time click the *Include* button. The image list will automatically be set in order of time by reading the FITS headers. (The default of *Date/Time from FIT* shown in the *Time/Identification* field will work for all images taken with the OAM cameras.)
- When you select an image it will appear behind the *Photometry* window.

  If you wish to perform photometry only on this image set the *Act on all images* tick-box off.

  If you want to apply the photometry to all open images set the *Act on all images* tick-box on. The programme will automatically find the nearest star to the tagged position on all subsequent fields. If this fails because the field has shifted by a large amount during the observations then you will need to select *Use star matching*.
- Set the *Snap to Centroid* tick-box on so that objects will automatically be centred in the measurement aperture.
- When the cursor is held over the image, a series of annuli will appear. The central circle is the aperture in which photometry is performed. The background is determined in the annulus between the outer two circles. You can resize the photometry aperture and background sky annulus by clicking the right-hand button on the mouse whilst the pointer is over the image,

which reveals the *Right click menu* (Figure 6.5). Use *Set Aperture Radius*, *Set Gap Width* and *Set Annulus Thickness* to set the aperture radius, the gap between the aperture and the inner edge of the background annulus, and the difference between the radii of the circles defining the sky annulus, respectively. The Project Notes will advise you on the optimum values.

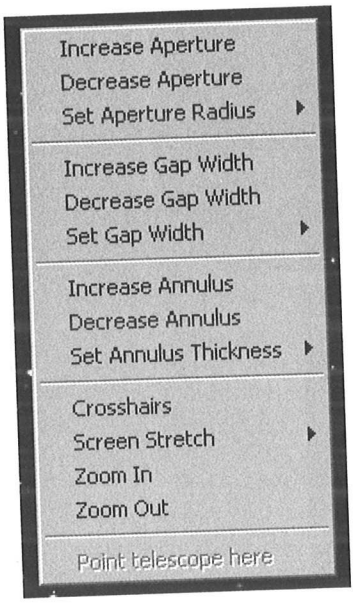

Figure 6.5 The *Right click* menu.

Next you need to identify or 'tag' each of the objects to be measured. There are four types of object:

Reference star: All photometry is performed relative to this star.

Check star: Object used to check that the reference star is constant in brightness.

Object: Target object for photometry.

Moving Object: Target object for photometry that moves relative to the stars.

- Use the *Mouse click tags as* field to select *New Reference Star*. Then use the mouse to position the photometry aperture on the chosen object in the displayed image (you can navigate the image, zoom in or out and move the superimposed windows around to access your object) and click to position it.
- When you tag a reference star, you need to set its known magnitude in the *Ref Mag* field. By definition, a reference star has the same magnitude in every image. If you tag more than one reference star, you must set the magnitude for each; the results will be averaged. You can edit the reference magnitude at any time by selecting the star in the *Tagged Objects* list and typing the new value in *Ref Mag*. The Project Notes 4 and 5 will advise you on how to use reference stars for different types of observation.
- Repeat the tagging process for all check stars and objects as required.
- Moving objects must be manually tagged on at least two different images to enable the Photometry tool to calculate a 'track' giving the probable location of the object at the time associated with every image in the set. Therefore, when a *New Moving Object* is initially tagged, *Act on all images* is ignored. After changing to a different image (double-click on the appropriate frame in the *Image list*), pick the identification assigned to the new moving object from *Mouse click tags as* (e.g. Mov1) and click on the object in the new

image. For best results, you should usually tag moving objects in the first and last images of a data set.

The next stage of the process is to look at the data you have obtained and correct any errors.

- Once all the objects are tagged, click *View Plot...* to see the results. The *Photometry plot* window (Figure 6.6) will now appear and a light curve of each of the objects is displayed. The 'light curve' will appear as a single point for each target if you have only selected one image!
- The *Next Image* and *Prev Image* buttons will move the associated Photometry image buffer back and forwards along the list of images. You can view the tagged objects and make sure that everything is tagged properly. If not, click the *Back* << button to return to the *Photometry* window.
- If you notice unusual values, and want to check a specific target, you can click on any measurement in the graph to display the image from which it was derived and highlight the corresponding annulus (note it may be behind the window).

You may want to remove an individual object from one or all of the images, or remove a complete image. You should do this only if there is a good reason, such as a trailed image, a cosmic ray 'hit' on a target, a misidentification, or cloud, for example. Make a note of the reason for removing any frame. Do not remove data just because you don't like the result!

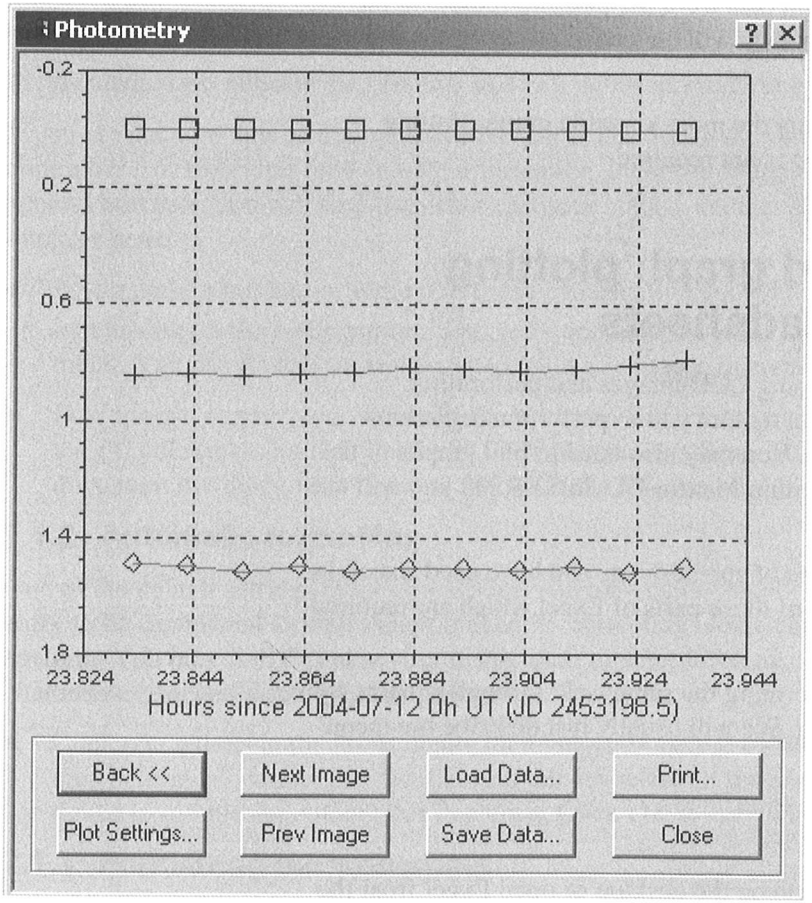

Figure 6.6 The *Photometry plot* window.

- To remove a tagged object: If you want to remove a tag from a star, select it in the *Tagged Objects* list and click *Untag*. The button *Act on all images* controls whether the object is deleted from every image in which it appears,

or only the one named in the *Image list* and currently appearing in the photometry image window. (Objects which are not tagged in the currently selected image do not appear in the *Tagged Objects* list, but do appear in *Mouse click tags as*.)

- If you want to remove an entire image, right-click on any point in the graph to display a pop-up menu showing the name of the image contributing that point and the three images immediately before and after. Images which were processed are checked, while those which were excluded using *Exclude*, are not. You can change the inclusion/exclusion status of any of these images by clicking on its name in the pop-up menu. The graph is immediately drawn with or without the affected point.
- When you are happy with the data, click *Save data...* to save it to disk as a .csv (comma separated values) file which can be read by Excel. The resulting file contains the measured magnitude of each star relative to the comparison star, along with its index number. Use a filename which identifies the target object, date and block number in the sequence (e.g. VariableX_Sep10_1.csv).

6.3.2 The *Open Photometry File* command

The *Open Photometry File* command allows you to re-open any saved photometry results.

- When you have selected the file, click *Open* to load it into the plot. *The Discard All* button is enabled only if data has already been loaded. Clicking *Discard All* erases all previous loaded data from the plot and returns to the *Photometry plot*. Otherwise, the new data will be loaded on top of the old data to form a combined plot.

In the SXR208 activities you will be using the more versatile graph-plotting routines in Excel so use of this command is not required.

7 Data analysis and graph plotting using Excel spreadsheets

Although MaxIm DL is ideal for processing CCD images and performing aperture photometry, most of the projects require you to perform calculations using the measurements you have made. You may also need to plot graphs of the processed data which are not possible within MaxIm DL. In SXR208 you will use Excel spreadsheets.

You may already be familiar with the use of spreadsheets and have used Excel. In this section we present only a summary of those parts of Excel which are required to complete the projects.

There are often several methods of performing the same task: through a menu, by a shortcut key or by clicking on a button. We will usually just describe the menu method.

7.1 Getting started

- To start Excel, click on the Excel icon on the desktop or open Excel from the *Start* menu on the bottom toolbar of the desktop (it can be found in the *Programs* menu).

A screen similar to that shown in Figure 7.1 will appear.

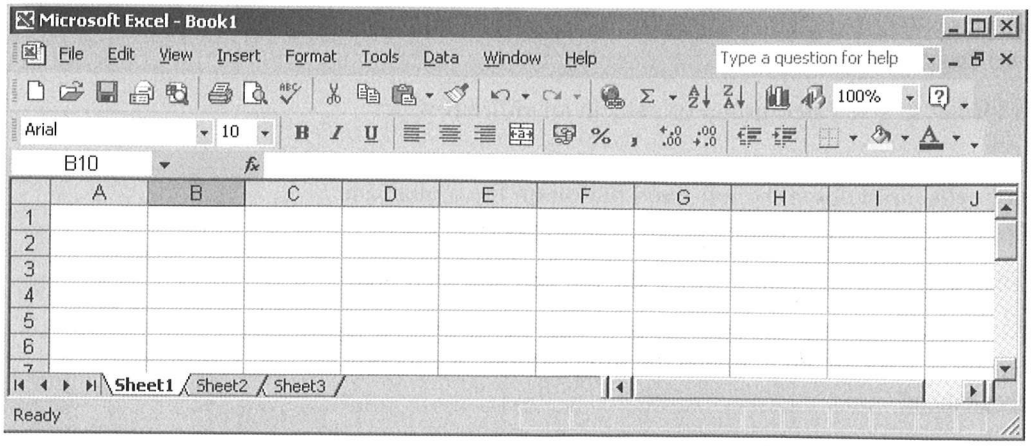

Figure 7.1 A blank Excel spreadsheet.

7.1.1 Spreadsheet structure

The main menus are found along the top of the page; the small icons underneath are toolbar icons, most of which provide shortcuts to menu items. The exact toolbar icons present will depend on how the display has been set up.

Along the bottom of the screen you will see some tabs labelled *Sheet1, Sheet2,* etc. and some arrow buttons. The tabs indicate separate *worksheets.* You can move between worksheets by clicking on the tabs.

The main part of the spreadsheet consists of a grid of *cells* identified by their row number down the left-hand side and column letter along the top.

In this manual we indicate the *contents* of a cell in the spreadsheet by a box: 3.29.

If you are not sure how to accomplish a particular task using the spreadsheet, remember that Excel has built-in help information under the *Help* menu item. In general however, you will find it quicker and easier to ask another student or a tutor for help.

- If you make a mistake at some point, you can usually undo what you just did by clicking on the *Undo* button, on the toolbar or *Undo ...* in the *Edit* menu. You can do this several times to undo a sequence of steps.
- Don't forget to save your work regularly in your own clearly named folder on the PC but remember that you can't *Undo* past the last *Save*. To save a document use the *Save* or *Save As* entries in the *File* menu.

7.1.2 Automatic formatting

One of the default settings in the spreadsheet software causes the first letter of any entry to be capitalized as well as automatically 'correcting' some characters or spelling. You may find this annoying if you want to enter lowercase first characters. You can disable this as follows:

- Click on *Options* in the *Tools* menu, then the *AutoCorrect Options* box under the *Spelling* tab. Under the *AutoCorrect* tab, de-select all the boxes that are ticked to disable the autocorrect functions. Click *OK* in each window to close.

7.1.3 Formatting the worksheet

If you want to change the width of columns or the depth of rows to accommodate the information contained in them:

- Use the *Format Row* or *Format Column* commands in the *Format* menu.

- Alternatively, click on the line separating the rows or columns in the grey bar around the edge and drag it along.

If you want to apply a format to a selected group of cells in an entire row or column:

- To select a group of cells, hold down the left-hand button on the mouse and drag the cursor across several cells (called *dragging*, see Section 7.2.2).
- To select all the filled cells in a column, click on the top cell and then press CTRL, SHIFT and the ↓ key.
- To select an entire row or column, click inside the grey column or row box at the edge of the spreadsheet.
- To select an entire table, press CTRL, SHIFT and END keys.
- Use the *Cells* command in the *Format* menu or the formatting icons on the toolbar (e.g. for font, size, bold, italic, cell colour, font colour...).
- To clear the contents of selected cells, use the *Clear* command in the *Edit* menu.
- To delete entire rows or columns select the row or column and use the *Delete* command in the *Edit* menu or press the DELETE key.
- Deleting individual cells or groups of cells is not recommended!

7.2 Data entry and spreadsheet formulae

7.2.1 Entering data and formulae from the keyboard

You can enter text, numbers or formulae into cells.

- To enter text or numbers, just type directly into a cell. For scientific notation type 5.4e-3 to represent 5.4×10^{-3}.
- To enter formulae type = followed by the formula you require. For example, entering = A1 + 4 in cell A2 will result in adding 4 to whatever value is in cell A1. When you type =, some extra icons will appear in the toolbar. Press the ENTER key or click the tick (which appears green on screen) to complete your function (the answer will appear in the cell). Alternatively, clicking the cross (which appears red on screen) will cancel your entry or changes you have made.

In the formula above, A1 is called a *cell reference* and represents the value contained in that cell.

When you click on a cell, notice that the box immediately above the column letters (A, B, C, etc.) shows either the value of the cell, or the operation that is performed to produce the value on the spreadsheet. In Figure 7.2 this reads =A1+A2. This box is called the *input line*. The input line always contains what you originally typed in, whether it is a number or a formula, whereas the spreadsheet will always convert equations to numbers within the cell.

If any value in a cell is changed then any other cells which include that cell entry within their formula will be automatically updated.

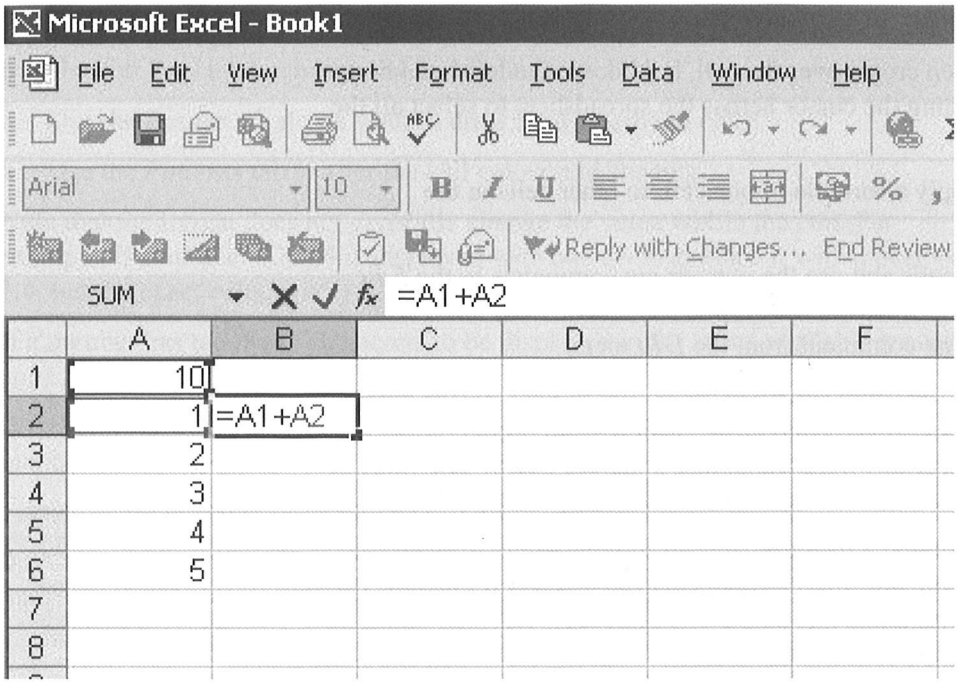

Figure 7.2 Entering a simple function in the spreadsheet.

If you want to enter a formula you need to remember the basic rules for arithmetic.

- The order for arithmetic operations to be performed is: ^ (to the power of), followed by * and / (multiply and divide), followed by + and – (add and subtract). For example, when entering a number such as $5^{2/5}$ you will get the wrong answer if you enter =5^2/5 since this represents $5^2/5$. The correct formula is =5^(2/5). Alternatively, you could write =5^0.4. If in doubt always use brackets to separate different parts of a formula and check your answers.
- There are many built-in functions you can use. They are listed in the toolbar (to the left of the red cross and green tick) when you type = in a cell. Useful examples are:

  =SUM e.g. =SUM(A1:A10) gives the sum of cells A1,A2,...A10.

  =AVERAGE e.g. =AVERAGE(A1:A3,A5:A10) gives the average of the values in cells A1 to A3 and A5 to A10.

  =STDEV e.g. =STDEV(A1:F1) gives the standard deviation of the values in cells A1, B1,...F1.

  =INT e.g. =INT(A5) gives the integer part of the number in cell A5.

  =EXP e.g. =EXP(A5) gives e to the power of the number in cell A5.

  =SIN e.g. =SIN(A5) gives the sine of the number (in radians) in cell A5.

  =LOG e.g. =LOG(A5,n) gives the logarithm to the base n of the number in cell A5. If n is not specified it defaults to 10.

  =LOG10 e.g. =LOG10(A5) gives the logarithm to the base 10 of the number in cell A5.

Instead of typing cell addresses in a function you can, after typing =, click in any cell and the cell address will appear in the function.

7.2.2 Dragging

If you click on a cell it shows a bold border with a small square in the lower right-hand corner.

To select several cells at once:

- Place the cursor (an open cross) over the cell, hold down the left-hand button on the mouse while sliding the cursor across the spreadsheet to select all the cells required.

To copy the contents, or apply a formula in one cell, to other cells in the spreadsheet:

- Either: Select a cell or cells and use the *copy* or *cut* commands in the *Edit* menu then click on the destination cell (top left if several cells have been copied) and use the *Paste* command from the *Edit* menu.
- Or: Place the cursor on the small square in the corner of the cell (the cursor will change into a narrow cross). Hold down the left-hand button on the mouse and drag the cursor down a column and/or across a row. The value or the formula will be copied to all the cells you have dragged over.
- Note that if you drag or copy a formula, the cell references are regarded as relative to the selected cell and will automatically be updated in the new cells. For example, if cell B2 contains the simple formula =A1+A2 then dragging it to cell B3 will update the formula to =A2+A3 .

If you wish to drag a formula without updating the cell references:

- You must specify the cell reference using the $ character before its column letter and row number. E.g. if, in the example above, you wish to add the contents of cell A1 to each of the other cells in column A: Type the formula =$A$1+A2 in cell B2. Click the small black square and drag the formula down column B. Cell B3 will now contain =$A$1+A3.
- If you wish to fix the row but allow a column to vary when dragging or copying then place the $ symbol before the row number only. If you wish to fix the column but allow a row to vary when dragging or copying then place the $ symbol before the column letter only.

Be careful when dragging, or copying and pasting, formulae that you are aware of the result.

7.2.3 Entering data from files

- To open a file click on *Open* in the *File* menu. The *Open* window will appear, and you can select the folder and open a file by double-clicking on the icons within it. It is possible to open files containing data or text even if they are not Excel files. Make sure you select *All files* in the *File of Type* field so that you can see the files.
- To open the *comma separated variable* (.csv) files you have saved during your observations, simply click on the file in the window. (Some other types of files need a more complex process before Excel can open them.) The data from the .csv file will appear in a new Excel spreadsheet.
- To paste the data into your working spreadsheet select the cells you require and use the *Copy* and *Paste* commands from the *Edit* menu.

7.2.4 Formatting cells

When you enter data or text into a cell, Excel will try to assign a particular format to that cell. You can change the formatting of the selected cells:

- Click the *Cells* command in the *Format* menu. You will see the *Format Cells* window shown in Figure 7.3.
- Use the *Number* tab to select the style of display of the number.

- Use the *Alignment* tab to determine how the text is aligned within a cell.
- Use the *Font* tab to change the font in the cell.
- Use the *Border* tab if you want to draw borders around cells.
- Use the *Patterns* tab to alter the cell colour and shading.

Note that the format does not generally change the value within the cell. For example, if a number 1.3824 is displayed with one decimal place it will appear as 1.4, but the exact value is still stored and used in any calculation or formula.

If a number has too many characters to be displayed in the space available it may appear as ### on the display, but the value will be retained.

Be careful with data/time and text formats as they may give strange results when numbers are entered.

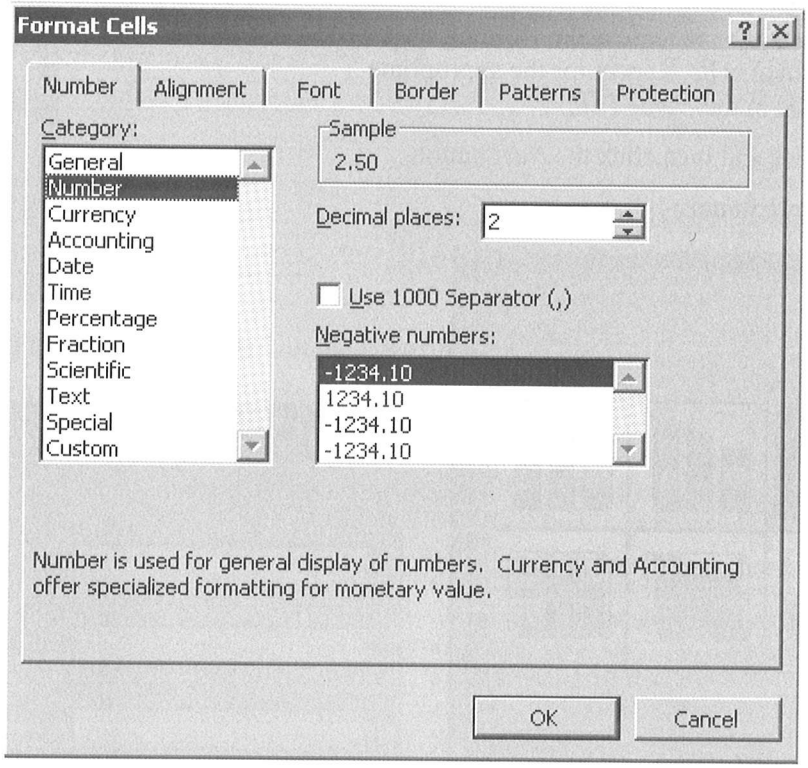

Figure 7.3 The *Format Cells* window.

7.3 Plotting graphs

The SXR208 projects require you to plot graphs to display your reduced data.

In this manual we will show you how to draw and format a scatter plot. (Although Excel allows you to draw a wide range of different styles of graph, they are not required for SXR208.)

7.3.1 Drawing the graph

There are several ways to select data and draw a scatter plot. The following method is not the quickest but can cope with data in a variety of formats:

- Select the *Chart* command from the *Insert* menu. The first screen of the *Chart Wizard* will appear (Figure 7.4).
- Select the *XY (Scatter)* option, then the first entry from the *Chart sub-type* choices. Click the *Next* button.

- The second screen of the *Chart Wizard* will appear. Click the *Series* tab. Figure 7.5 shows the completed screen together with a spreadsheet with demonstration data for a light curve showing magnitude vs. time for three objects.

Each set of X-Y data (in this case X is time and Y is magnitude) forms a *series*. In this example there are 3 series corresponding to the three targets. The data for each series together with a title need to be entered.

- The chart wizard may try to select the data for you (it did in this example). If you are happy with what is chosen click *Next*. If you don't like what it has chosen you can delete any series by selecting it and clicking the *Remove* button.
- To change a series, select it (to enter a new series click the *Add* button), and click on the icon next to the *X-Values* field. Select the range of X values (e.g. A7 to A14) by dragging, and click the icon again. Holding the CTRL key down allows you to select additional cells. Repeat for the appropriate *Y-Values* field and type or select a title in the *Name* field.
- Repeat this process for each data series and then click the *Next* button.

Note that the data series can be in rows or columns.

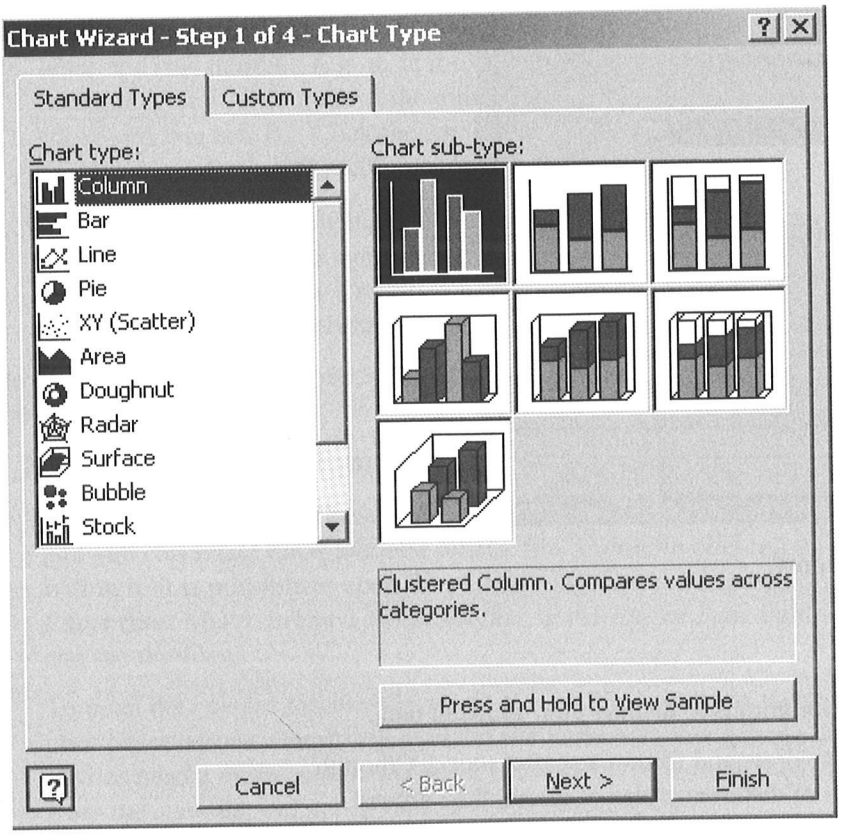

Figure 7.4 Step 1 of the *Chart Wizard.*

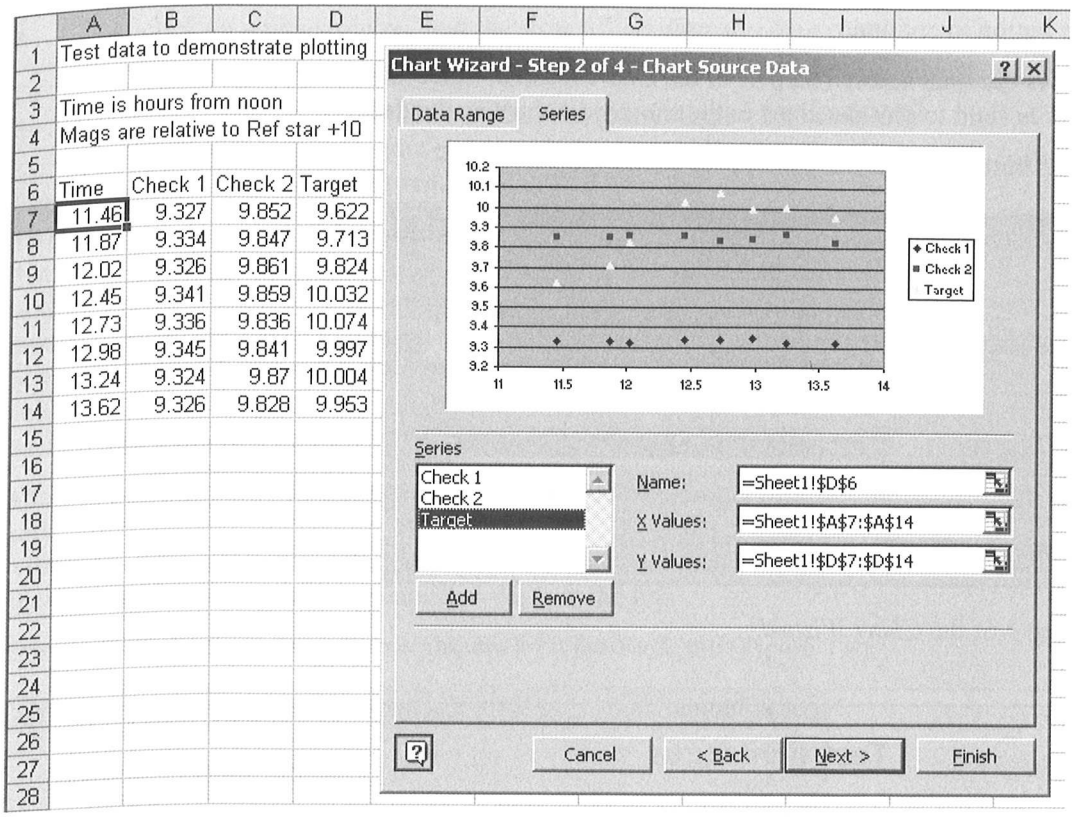

Figure 7.5 Step 2 of the *Chart Wizard.*

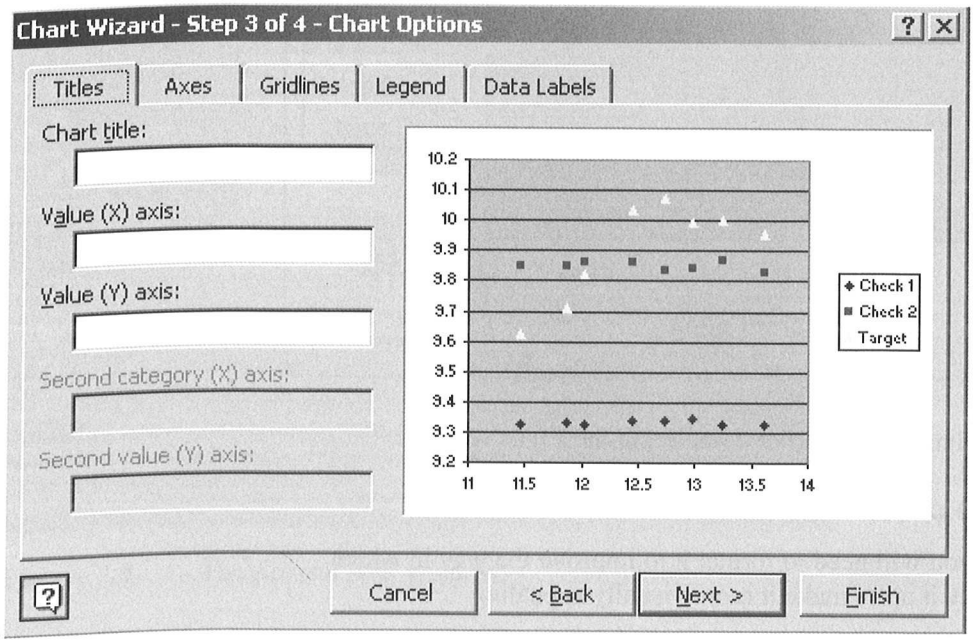

Figure 7.6 Step 3 of the *Chart Wizard.*

- Figure 7.6 shows Step 3 of the *Chart Wizard.*
- Enter a Title, X and Y axis labels in the *Chart title*, *Value (X) axis*: and *Value (Y) axis:* fields respectively.
- Click the *Gridlines* tab and add or remove them as you require. You can do this later (Section 7.3.2) if you are unsure what you want now.
- Click the *Legend* tab and use the controls to remove or re-position the legend (key to symbols). You can do this later if you wish.

- Click the *Next* button to continue.
- Figure 7.7 shows the final screen (Step 4) of the *Chart Wizard*. Select *Sheet 1* in the *As object in* field to plot the chart in the same worksheet as the data.
- Click the *Finish* button. The chart will appear as in Figure 7.8.

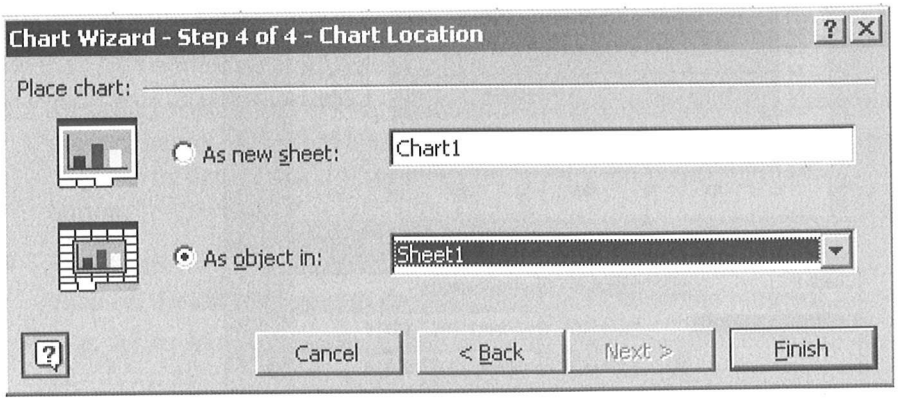

Figure 7.7 Step 4 of the *Chart Wizard*.

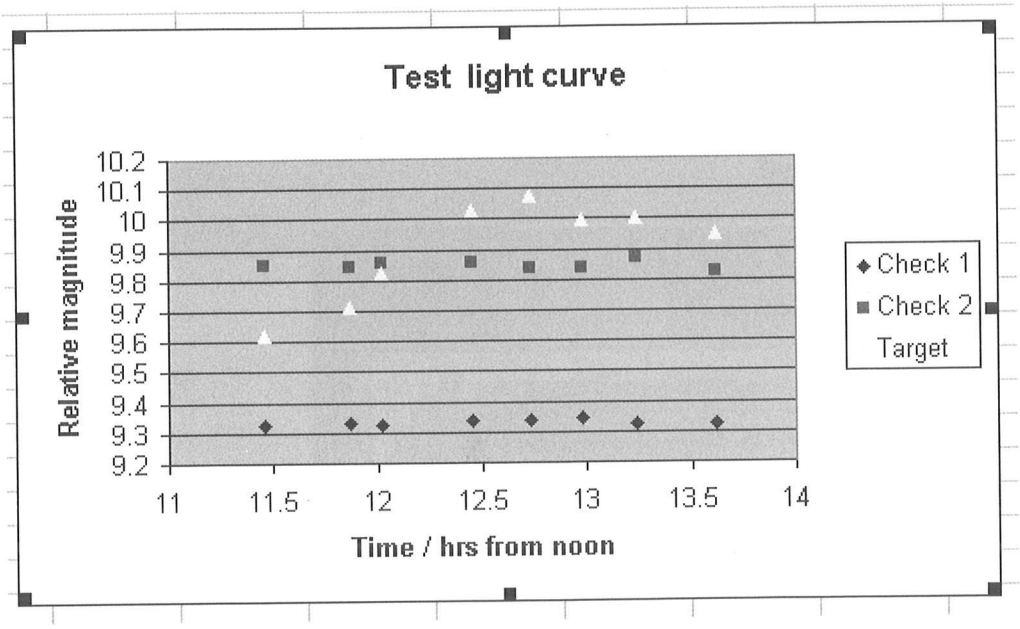

Figure 7.8 The chart immediately after completing the *Chart Wizard*.

7.3.2 Formatting the chart

Having created the chart, you will need to format it to improve the way in which it displays the data, and tidy it up to make it more visually appealing.

In order to make changes, an item must be selected: there are two different levels of selection.

- Place the cursor over the item and single-click. The region or object will be highlighted in some way, and where appropriate, 'handles' will appear to allow you to move or resize it (these can be seen in Figure 7.8).
- Place the cursor over the item and double-click: When appropriate a window will open with options you can adjust.

The first thing that you are likely to want to do is to resize the chart to make it larger.

- Single-click on a blank region near the edge of the chart to select the chart area. Drag one of the corner selection handles as required.
- To change the size of the plot area within the chart, single-click inside the plot region (avoiding axes, data points, grid lines etc.). Drag one of the selection handles to resize as required.

To change other aspects of the appearance of the chart you will need to make sure that the chart is selected. You can change the formatting of just about any element of the graph by double-clicking on the part you want to change. As you move the mouse pointer over the chart a small label will appear telling you which item will be modified (you may need to be quite precise with the mouse to select the item you want). In this way you can change the colour of the plotline, add or remove background shading, gridlines and so on.

There is one aspect of this chart that does not satisfy the normal astronomical convention for plotting magnitudes. The magnitude scale has the brightest objects with the most negative magnitudes. Spreadsheet plotting routines automatically show the axes with the largest numerical value at the top.

Double-click over the *Value Y axis* and click on the *Scale* tab (Figure 7.9).

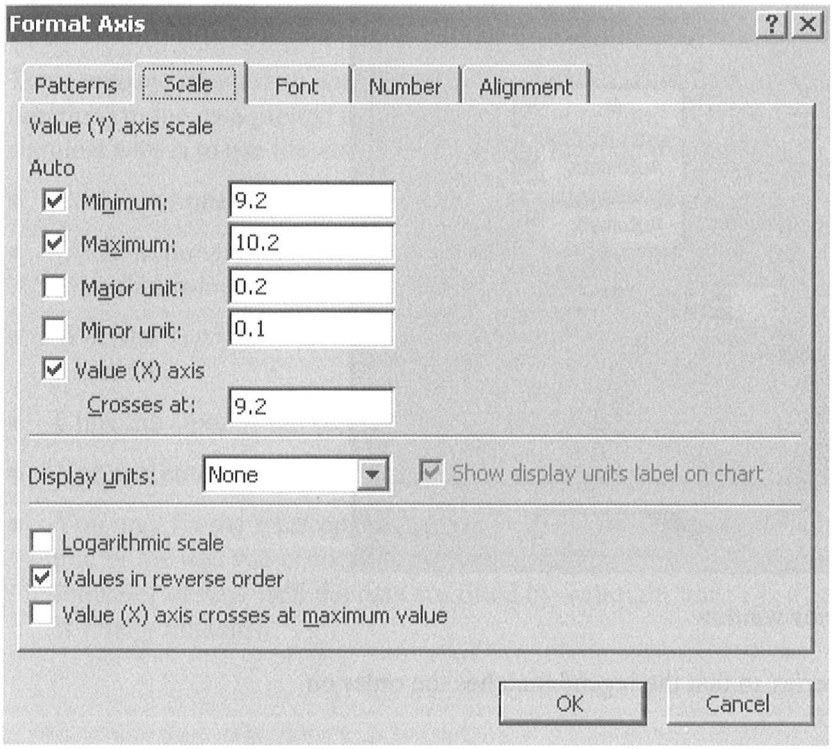

Figure 7.9 The *Format Axis* window.

- Click the *Values in reverse order* tick box to on.
- You can also change the range of the axes (*Minimum* and *Maximum*), the interval between labels and gridlines (*Major unit*) and interval between minor tick marks if shown (*Minor unit*). The tick marks can be set in the *Patterns* tab. The font size and style can be changed in the *Font* tab. The number style can be changed in the *Number* tab. The label alignment can be changed in the *Alignment* tab. When you have finished, click *OK*.
- Similar cosmetic changes can be made separately on the X-axis.

Other cosmetic changes that are desirable are

- Turning the grey background to white: Hold the cursor over the *Plot area* part of the chart and double-click to select the white box in the resulting window.
- Turning off the gridlines: Select the chart and open the *Chart Options* command from the *Chart* menu. The resultant window is identical to that shown in Figure 7.6.

The default symbols used by Excel do not reproduce well. If you want to plot your graphs in black and white, you will need to change the symbols:

- Double-click over one of the data points. Click on the *Patterns* tab. The *Format Data Series* window (Figure 7.10) will open. You can change the style and colour of the symbols. (You can also draw lines between the points or switch off symbols, although that is not required in this example.)

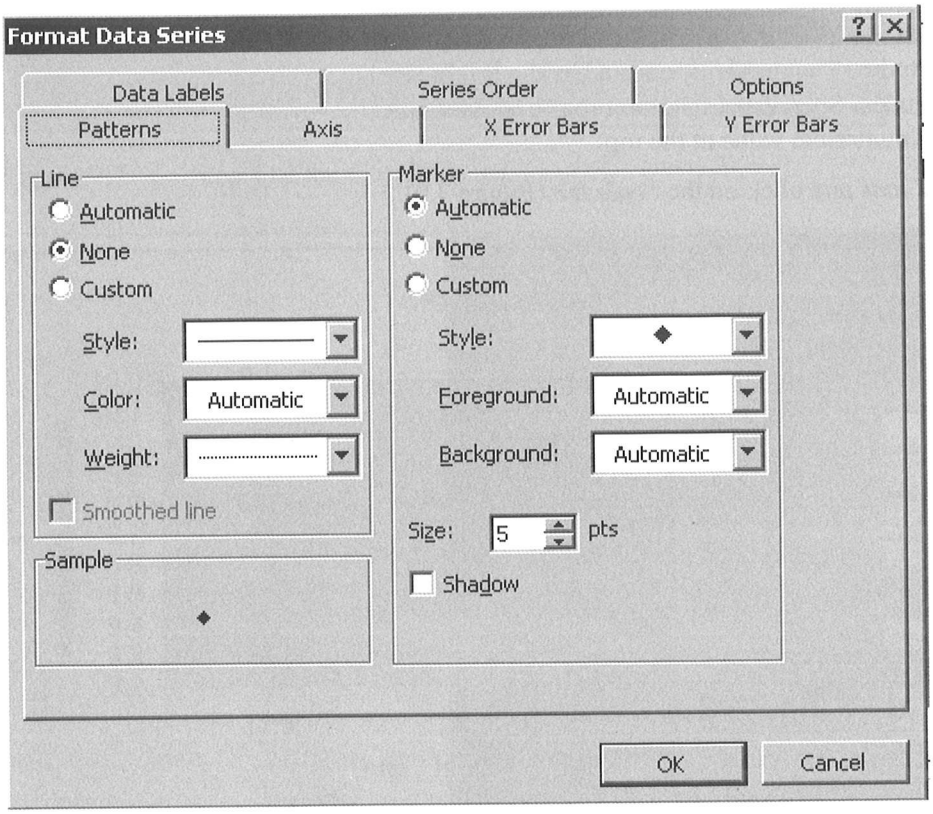

Figure 7.10 The *Format Data Series* window.

- You can change the order of the series so that the legend matches the order on the plot using the *Series Order* tab.
- The *X Error Bars* and *Y Error Bars* tabs can be used to plot error bars on the graph. You can select either defined constant values for the whole series or read them from the Excel spreadsheet in the same way as the series were entered. (In this example there are no uncertainties in the spreadsheet. They are indicated by the scatter in the check star data.)

The reformatted example chart is shown in Figure 7.11.

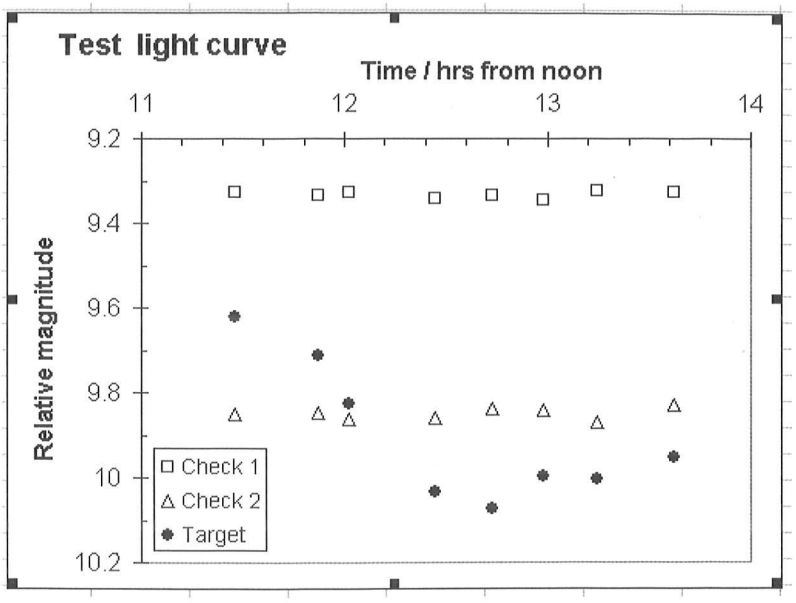

Figure 7.11 The chart after reformatting.

7.3.3 Best-fit line

There are several ways to use Excel to determine the best-fit straight line (or other function) to the data plotted in a graph using the method of least squares. The simplest way is to use the *Add Trendline* command on data plotted on a chart:

- Click over one of the symbols to select the data series to be fitted.
- Click on the *Add Trendline* command in the *Chart* menu to open the *Add Trendline* window (Figure 7.12).
- With the *Type* tab selected, click on the top-left image, which represents a linear fit.
- Click the *Options* tab (Figure 7.13).
- You can enter your own title for the best-fit line in the *Trendline name* field.
- You may fix the intercept of the line on the X-axis, display the equation and/or the regression coefficient (a value between 0 and 1 which is an indicator of how well the data are fitted by a straight line: 1 is a perfect fit, 0 is totally random).

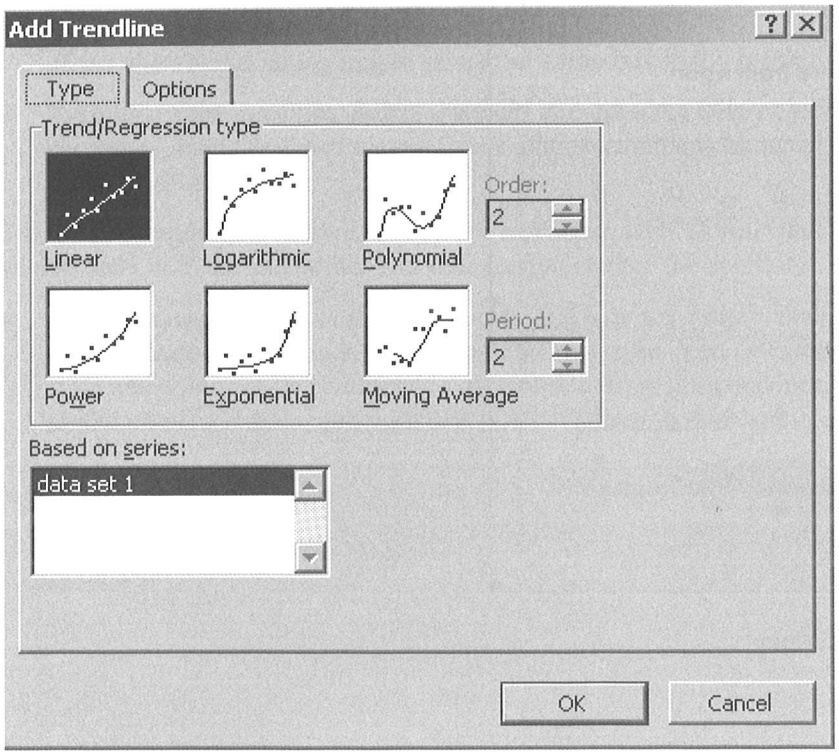

Figure 7.12 The *Add Trendline* window with the *Type* tab selected.

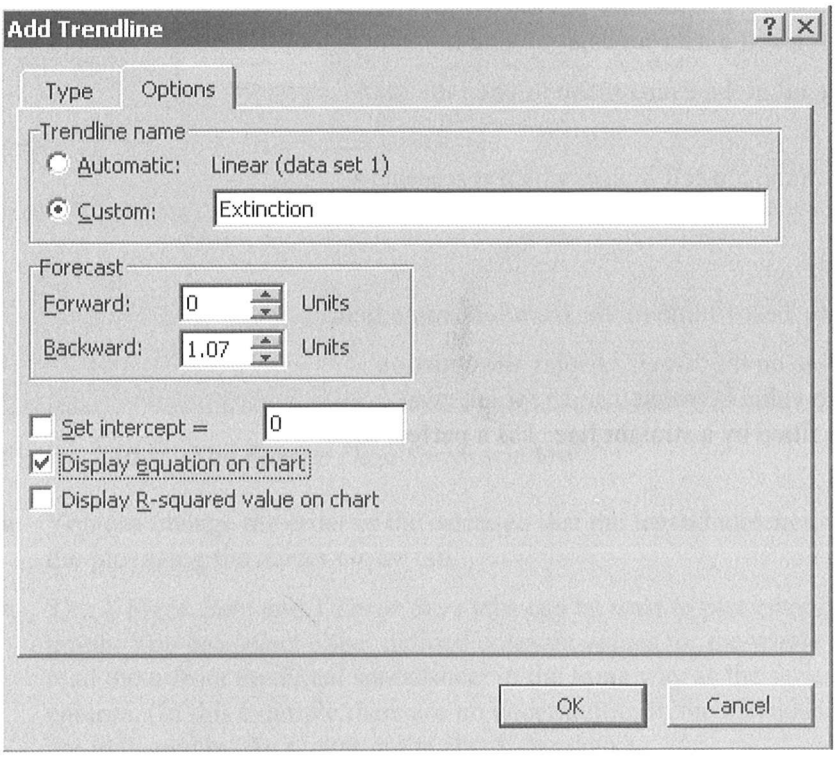

Figure 7.13 The *Add Trendline* window with the *Options* tab selected.

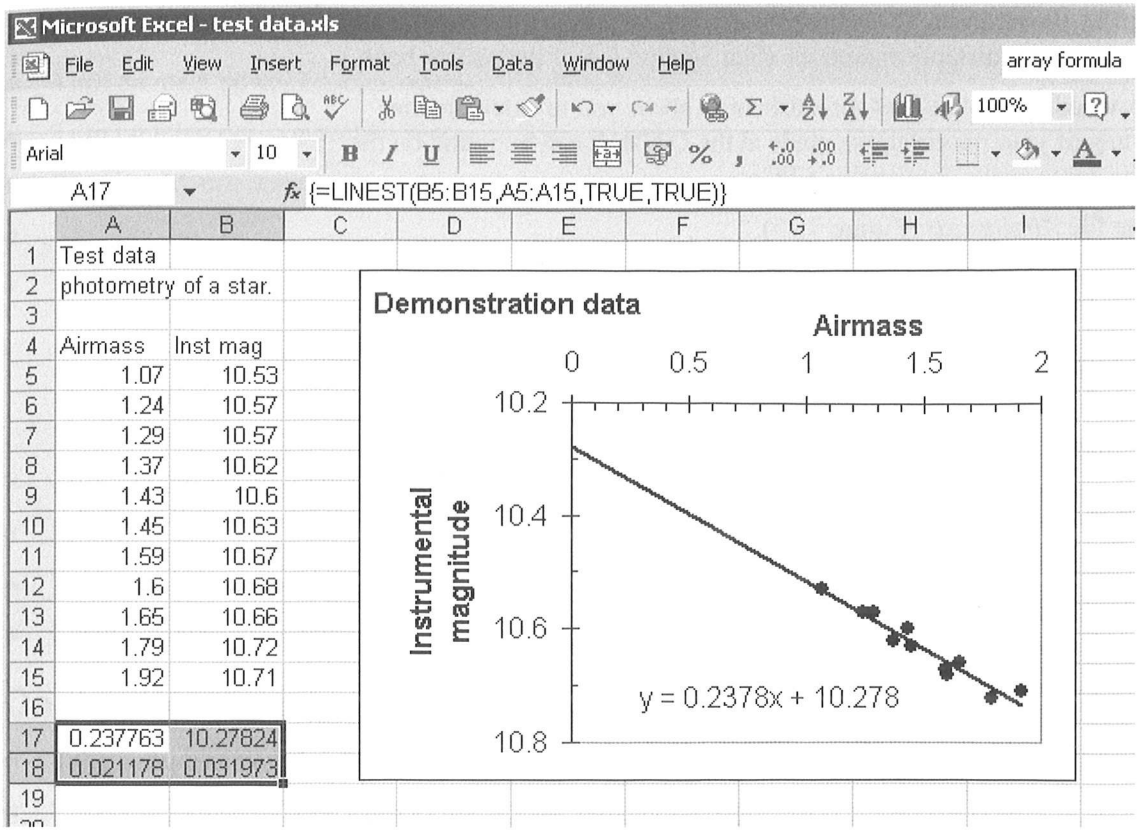

Figure 7.14 Chart showing result of fitting a trendline to the data in columns A and B.

- The best-fit line will be plotted between the first and last X values. If you wish to extend the line (e.g. when plotting an extinction curve to find the magnitude at airmass = 0 as shown in the example) use the *Forecast* fields.
- Click *OK* and the trendline and any selected captions will appear on the chart (Figure 7.14). The style of the equation or the line can be changed by double-clicking on an item and using the options which appear.

This method does not give uncertainties in the gradient or intercept. If you want numerical values then you can use one of the built-in functions in Excel.

- Highlight four cells (2 columns wide and 2 rows deep).
- Type in the formula =LINEST(known y's,known x's,TRUE,TRUE) where known y's and known x's are the range of cells containing the data. In the example shown in Figure 7.14 the formula is: =LINEST(B5:B15,A5:A15,TRUE,TRUE)
- Press CTRL SHFT and ENTER simultaneously.
- The array of four cells will contain the slope and intercept on the top row and the uncertainties in these values in the row below. In the example the best-fit straight line is $y = (0.24 \pm 0.02)x + (10.28 \pm 0.03)$.

This command can be used to produce further statistics and fit more complex equations that do not concern us here (see the *Help* menu for more details).

7.4 Airmass calculation spreadsheet

The atmosphere absorbs a fraction of the light arriving from a star. The amount that is absorbed depends on the atmospheric conditions, the wavelength and the thickness of atmosphere through which the light passes. The last of these is

characterized by the airmass. The airmass is 1 when viewing at the zenith and increases as the zenith distance increases. (See Section 6.4 of the course book.)

We have provided a simple Excel spreadsheet to allow you to calculate the airmass for any of your observations made at the OAM. It can be found on the laptops in the dome or the data analysis PCs.

- Open the file *Airmass.xls* (Figure 7.15).
- Enter the local date and local time in the white cells. Take care to ensure that the correction to UT is correct for the chosen date.
- Enter the right ascension and declination of the star in the appropriate white cells.
- The calculated airmass will appear in the (yellow) box.

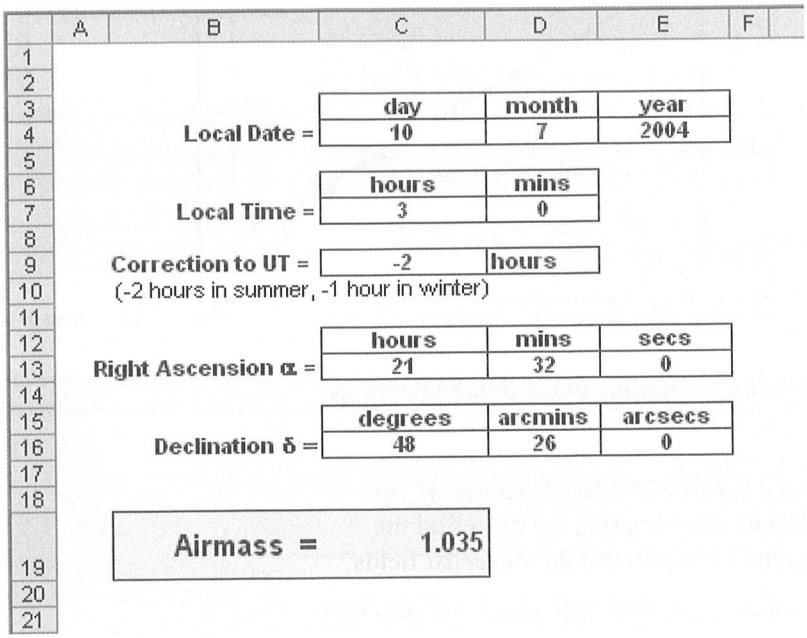

Figure 7.15 The airmass calculation spreadsheet.

7.5 Saving and printing results

There is a printer available in the laboratory for printing your final output.

You should only print the final results, tables/graphs that you may include in your final report. Note: demand will be high at the end of the night. Please keep printing to a minimum.

You can, if you wish, copy your Excel files, and any data you require, onto a CD-ROM for you to take home.

Appendix 1: Quick observing guide for CCD photometry

Remember to follow Health and Safety guidelines at all times.

Starting up

- Open the dome (Section 2.1.1).
- Remove telescope covers.

- Ensure all electrical connections are correct (Sections 2.2.3 and 4.1).
- Turn on main power on telescope pier (Section 2.2.3).
- Turn on telescope controller (Section 2.2.3).
- Plug in and turn on laptop.
- Start MaxIm DL.
- Set up CCD camera (Section 4.2.2).
  Connect MaxIm DL to camera.
  Switch on cooler and check/adjust temperature.
  Check filter-wheel settings.
  Adjust orientation of frame readout if required (Section 4.2.3).
- Turn Maxim DL to night-vision mode when required (Section 3.3.6).
- Fill in the headers on the observing log sheet (Section 4.3.1).
- Set up any pre-determined observation sequences (Section 4.2.6).
- Ensure camera has cooled to correct temperature before you start taking data.

Calibration frames

- Take a sequence of bias frames (Sections 4.3.2 and 4.2.6).
- Take a sequence of dark frames (Sections 4.3.2 and 4.2.6).
- Take flat-field frames in each filter (Section 4.3.3):
  Set up the illumination lamp and flat-field screen.
  Select desired filter and take test exposures using Expose (Section 4.2.4).
  Take a sequence of flat-field frames (Section 4.2.6).
  Repeat for each filter required.
- Fill in the observing log as you go along.

Making observations

- Check declination limits in place on telescope (Section 2.2.2).
- Identify a suitable bright star and set up telescope pointing (Section 2.4.3 or 2.5.3).
- Focus telescope (Sections 2.4.8 or 2.5.8 and 4.2.5).
- Find your target (if it is faint you will need to move to a bright star nearby and synchronize positions) and centre it on CCD (Section 2.4.7 or 2.5.7).
- Ensure dome is positioned correctly.
- Make the required observations using the *Sequence* command (Section 4.2.6).
- Take dark frames at periods during the night.
- Fill in the observing log as you go along.
- Check periodically that there is no condensation on the corrector plate. Use the hair dryer provided to remove it (do not touch the optics).

Transferring data

- Use the USB memory stick to save data in blocks of 50 files (Section 4.3.1).
- Make a note in the observation log.

Closing down

- Park the telescope (Section 2.4.9 or 2.5.9).
- Turn off telescope computer controller (Section 2.2.3).
- Replace telescope covers.
- Warm up the CCD, switch the cooler off and disconnect the camera (Section 4.2.2).
- Ensure your observing log is complete.
- Close down MaxIm DL.
- Shut down and un-plug laptop.
- Turn off main power on telescope pier (Section 2.2.3).
- Close the dome (Section 2.1.1).

Appendix 2: Quick observing guide for spectroscopy

Remember to follow Health and Safety guidelines at all times.

Starting up

- Open the dome (Section 2.1.1).
- Remove telescope covers.
- Ensure all electrical connections are correct (Sections 2.2.3 and 4.1).
- Turn on main power on telescope pier (Section 2.2.3).
- Turn on telescope controller (Section 2.2.3).
- Plug in and turn on laptop.
- Start MaxIm DL for the data CCD.
- Connect MaxIm DL to camera.

  Switch on cooler and check/adjust temperature.

  Turn on slit viewing webcam software (consult tutor).
- Turn MaxIm DL to night-vision mode when required (Section 3.3.6).
- Fill in the headers on the observing log sheet (Section 4.3.1).

Calibration

- With the spectrograph off the telescope, use a hollow-cathode lamp. Check the data CCD focus and rotation.
- Obtain a hollow-cathode spectrum to establish wavelength calibration (Section 5).
- Check the focus and orientation of the slit-viewing CCD.
- Fill in the observing log as you go along.

Making observations

- Check declination limits in place on telescope (Section 2.2.2).

- Identify a suitable bright star.
- Focus telescope on slit (Sections 2.4.8 or 2.5.8 and 4.2.5).
- Find your target and centre it on the slit (Section 2.4.7 or 2.5.7).
- Ensure dome is positioned correctly.
- Make the required observations.
- Fill in the observing log as you go along.
- Check periodically that there is no condensation on the corrector plate. Use the hair dryer provided to remove it (do not touch the optics).

Transferring data

- Use the USB memory stick to save data in blocks of 50 files (Section 4.3.1).
- Make a note in the observation log.

Closing down

- Park the telescope (Section 2.4.9 or 2.5.9).
- Turn off telescope computer controller (Section 2.2.3).
- Replace telescope covers.
- Warm up the CCDs, switch the coolers off and disconnect the cameras (Section 4.2.2).
- Ensure your observing log is complete.
- Close down MaxIm DL.
- Shut down and un-plug laptop.
- Turn off main power on telescope pier (Section 2.2.3).
- Close the dome (Section 2.1.1).

Appendix 3: Bright star list

This list contains all stars in the *Named* list under the *Stars* option of the *Object* menu in the Autostar II controller. The corresponding numbers for stars in the LX200 star catalogue are provided. Note that the list occupies all of page 62 and part of page 63.

The Names and Designations in italics are never accessible at altitudes above 20° from the OAM.

Name	Designation	LX200 Star catalogue No.	*RA*	*dec*	*V*
Alpheratz	α And	1	00h 08min	+29° 06′	2.1
Algenib	γ Peg	3	00h 13min	+15° 12′	2.8
Ankaa	*α Phe*	5	00h 26min	–42° 18′	2.4
Shedir	α Cas	7	00h 41min	+56° 33′	2.2
Diphda	β Cet	8	00h 44min	–17° 59′	2.0
Mirach	β And	11	01h 10min	+35° 37′	2.1
Achernar	*α Eri*	13	01h 38min	–57° 14′	0.4
Almaak	γ And	16	02h 04min	+42° 21′	2.1
Hamal	α Ari	17	02h 07min	+23° 28′	2.0
Polaris	α UMi	19	02h 15min	+89° 17′	2.0
Acamar	*θ Eri*	21	02h 58min	–40° 19′	2.9
Algol	β Per	24	03h 08min	+40° 58′	2.1v
Mirphak	α Per	25	03h 24min	+49° 52′	1.8
Alcyone	ε Tau	27	03h 48min	+27° 06′	2.8
Aldebaran	α Tau	33	04h 36min	+16° 31′	0.9
Rigel	β Ori	41	05h 15min	–08° 12′	0.2
Capella	α Aur	42	05h 17min	+46° 00′	0.1
Bellatrix	γ Ori	44	05h 25min	+06° 21′	1.3
Alnath	β Tau	45	05h 26min	+28° 37′	1.6
Nihal	β Lep	46	05h 28min	–20° 46′	2.8
Mintaka	δ Ori	47	05h 32min	–00° 19′	2.3
Arneb	α Lep	48	05h 33imn	–17° 49′	2.6
Alnilam	ε Ori	50	05h 36min	–01° 12′	1.7
Saiph	κ Ori	54	05h 48min	–09° 40′	2.1
Betelgeuse	α Ori	56	05h 55min	+07° 25′	0.4
Canopus	*α Car*	63	06h 24min	–52° 42′	–0.6
Alhena	γ Gem	64	06h 38min	+16° 24′	1.9
Sirius	α CMa	67	06h 45min	–16° 43′	–1.4
Adara	ε CMa	70	06h 59min	–28° 58′	1.5
Procyon	α CMi	80	07h 39min	+05° 14′	0.4
Pollux	β Gem	81	07h 45min	+28° 02′	1.2
Alphard	α Hya	95	09h 28min	–08° 39′	2.0
Regulus	α Leo	100	10h 09min	+11° 58′	1.4
Merak	β UMa	108	11h 02min	+56° 23′	2.3
Dubhe	α UMa	109	11h 04min	+61° 45′	1.8
Denebola	β Leo	114	11h 49min	+14° 34′	2.1
Phad	γ UMa	115	11h 54min	+53° 41′	2.4
Megrez	δ UMa	119	12h 16min	+57° 01′	3.3
Acrux	*α Cru*	121	12h 27min	–63° 06′	0.8
Alioth	ε UMa	132	12h 54min	+55° 58′	1.8
Cor Caroli	α CVn	133	12h 56min	+38° 19′	2.9
Vindemiatrix	ε Vir	134	13h 02min	+10° 58′	2.8
Alcor		137	13h 24min	+54° 55′	4.0
Mizar	ζ UMa	137	13h 24min	+54° 55′	2.2
Spica	α Vir	138	13h 25min	–11° 10′	1.0
Alkaid	η UMa	140	13h 48min	+49° 19′	1.9
Thuban	α Dra		14h 04min	+64° 21′	3.7
Hadar	*β Cen*	144	14h 04min	–60° 24′	0.6
Arcturus	α Boo	147	14h 16min	+19° 11′	–0.1
Rigel Kentaurus	*α Cen*	150	14h 40min	–60° 51′	0.0
Izar	ε Boo	154	14h 47min	+27° 04′	2.3
Kocab	β UMi	156	14h 51min	+74° 10′	2.1
Alphekka	α CrB	165	15h 36min	+26° 43′	2.2

Unukalhai	α Ser	167	15h 54min	+06° 25′	2.6
Antares	α Sco	177	16h 30min	–26° 26′	1.1
Ras Algethi	α Her	190	17h 15min	+14° 23′	2.8
Shaula	*λ Sco*	199	17h 34min	–37° 07′	1.6
Rasalhague	α Oph	200	17h 35min	+12° 33′	2.1
Etamin	γ Dra	206	17h 57min	+51° 29′	2.2
Kaus Australis	*ε Sgr*	212	18h 24min	–34° 23′	1.8
Vega	α Lyr	214	18h 37min	+38° 47′	0.0
Nunki	σ Sgr	216	18h 55min	–26° 18′	2.0
Albireo	β Cyg	223	19h 31min	+27° 58′	3.0
Tarazed	γ Aql	225	19h 46min	+10° 37′	2.7
Altair	α Aql	226	19h 51min	+08° 52′	0.8
Alshain	β Aql		19h 56min	+06° 25′	3.7
Deneb	α Cyg	232	20h 42min	+45° 17′	1.3
Enif	ε Peg	238	21h 44min	+09° 53′	2.4
Sadalmelik	α Aqr	241	22h 06min	–00° 19′	3.0
Alnair	*α Gru*	242	22h 08min	–46° 58′	1.7
Fomalhaut	α PsA	247	22h 58min	–29° 38′	1.2
Scheat	β Peg	248	23h 04min	+28° 05′	2.4
Markab	α Peg	249	23h 05min	+15° 12′	2.5