

# UNIVERSITY COLLEGE LONDON

University of London Observatory

PHAS1130 Practical Astronomy 1112.1

## Introduction to the Celestron Telescope

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### 1 Introduction

The Celestron telescope at ULO (C14) is a 14-inch Schmidt-Cassegrain optical tube assembly on a ‘Paramount’ semi-robotic, German-equatorial mount. The telescope is controlled with *The Sky* software, with monitors available in the dome and the control room.

The telescope is equipped with a CCD camera, with built-in filter wheel and autoguiders. A mirror at the breech end can be adjusted to direct light to an eyepiece for direct visual observing, to a video camera, or to the CCD camera. The accuracy of the telescope drive system, and the availability of autoguiding, means that the system is capable of obtaining good-quality, long-exposure images of the sky.

The telescope is used by students mainly for CCD imaging of stars, asteroids, clusters, nebulae, galaxies, *etc.*. The C14 has also been used extensively in recent years in photometric monitoring campaigns of transiting extrasolar planets.

### 2 Telescope and CCD specifications

<b>Telescope specifications</b>	
Aperture:	350 mm (14 inches)
Focal ratio:	f/12
Focal length:	4270 mm
Image scale at f/12:	48.1 arcsecs/mm
<b>STL-6303E imager chip</b>	
Physical size:	27.7 × 18.5 mm
Array size:	3072 × 2048 9- $\mu$ m pixels
Field of view at f/12:	22.2 × 14.8 arcminutes
Image scale at f/12:	(1 × 1 binning) 0.43 arcsecs/pixel
	(2 × 2) 0.86 arcsecs/pixel
	(3 × 3) 1.30 arcsecs/pixel
<b>TC-237H autoguiding chip</b>	
Physical size:	4.9 × 3.7 mm
Array size:	657 × 495 7.4- $\mu$ m pixels
Field of view at f/12:	3.9 × 3.0 arcminutes
Image scale at f/12:	(1 × 1 binning) 0.35 arcsecs/pixel

### 3 Safety matters

- **Take particular care when working in darkness in the dome**, and beware of the platform stairs and other trip hazards. Torches are provided in the domes.
- **All telescope slews should be operated by an observer in the dome.** If the telescope were to be moved to point below the horizon, the telescope tube could collide with the rails of the observing platform or the telescope guard rail.
- **All observers should stand clear of the telescope and guard rail** to avoid risk of collision with the telescope body, the counterweight, and the CCD camera.
- **When you start a telescope slew, notify the other observers present, and watch the telescope while slewing.**
- **A slew is aborted by pressing the space bar.** The slew can also be stopped by moving the joystick control *in both axes*.
- Observe the slew closely when the CCD camera and Van Slyke assembly are moving near the guard rails — they should not be able to collide, but you should monitor and be ready to intervene.
- The telescope is on a German mount, and reverses when slewing to a target on the opposite side of the meridian; particular care should be taken to monitor the telescope during such slews. The telescope system knows when it needs to reverse, and will do so automatically when commanded to slew.
- Damage or serious malfunction should be reported immediately to the technician on duty. Minor problems or glitches should be recorded on the left-hand pages of the telescope log-book, kept in the control room, for attention of the technical staff.

### 4 Dome operation

Information for demonstrators on dome opening and closing, and slewing and tracking, is given in §11.

#### 4.1 Dome opening and closing

The opening and closing of the dome is managed by the technicians and demonstrators, and should not be attempted by students.

However, some specific points relating to the dome opening and closing should be noted by students:

1. Whenever the dome shutter is opened or closed, the telescope must be covered or moved to a position where dislodged grit and dirt cannot fall onto the telescope objective lens. At the beginning of the night, leave the telescope covers on until the dome is fully open. At the end of the night, cover the telescope first before the dome is closed.
2. Power to the dome shutter is provided by slip rings which are mounted inside the skirt of the dome: these are electrified, and students should avoid touching them, for obvious reasons (you can't really get your fingers in if you tried, but better to be aware).

Students will be shown how to remove and replace the C14 telescope cover.

## 4.2 Dome slewing and tracking

Under manual control, the dome can be rotated using the handset attached to the pillar or on the South wall, or in the control room.

The dome can also be controlled by software to slave the dome slot to the telescope position, for slewing and tracking. When the dome is slaved to track the telescope, it should not be rotated manually.

The demonstrator can advise students on whether to implement dome tracking in any given situation.

## 5 Preparing to observe — in the control room

At the beginning of the training/observing session, all observers should sign in the log-book in the control room, on the right-hand pages. The date, time of start and end of session, names of all observers and staff, and weather conditions should be recorded in the log book, as well as other relevant information (targets observed, CCD temperature, *etc.*)

### 5.1 Operation of *The Sky*

For student training and observing, the telescope should already be booted up and initialized with *The Sky* software, ready to observe.

The control interface of *The Sky* can be accessed from the monitor in the dome or the control room. Move the mouse to select the current display.

For observing, the CCDSOft package used to control the CCD camera should have been started, and connected to the CCD (you may still have to adjust the CCD temperature setting and the focus).

### 5.2 Checking the view of the sky

At the beginning of the observing session, it is convenient to use the monitor in the control room to check the current view of the sky. The default is a wide-field view of the sky looking south (Fig. 1).

You can check the position of the objects you plan to observe:

- When the telescope is connected, the current telescope position is shown by a circular, white, ‘crosshair’ symbol, and the sky view is displayed for the current time (and updated every few minutes).
- The local meridian is indicated by a pink stripe.
- The actual horizon limits (including adjacent buildings) are shown in block green. The limit to the South is due to the dome flap, and is about  $-10^\circ$  in declination.
- The RA and Dec can be read from the reference lines (just — the labels are quite faint); the RA and Dec of the mouse cursor is displayed in the taskbar at the bottom.

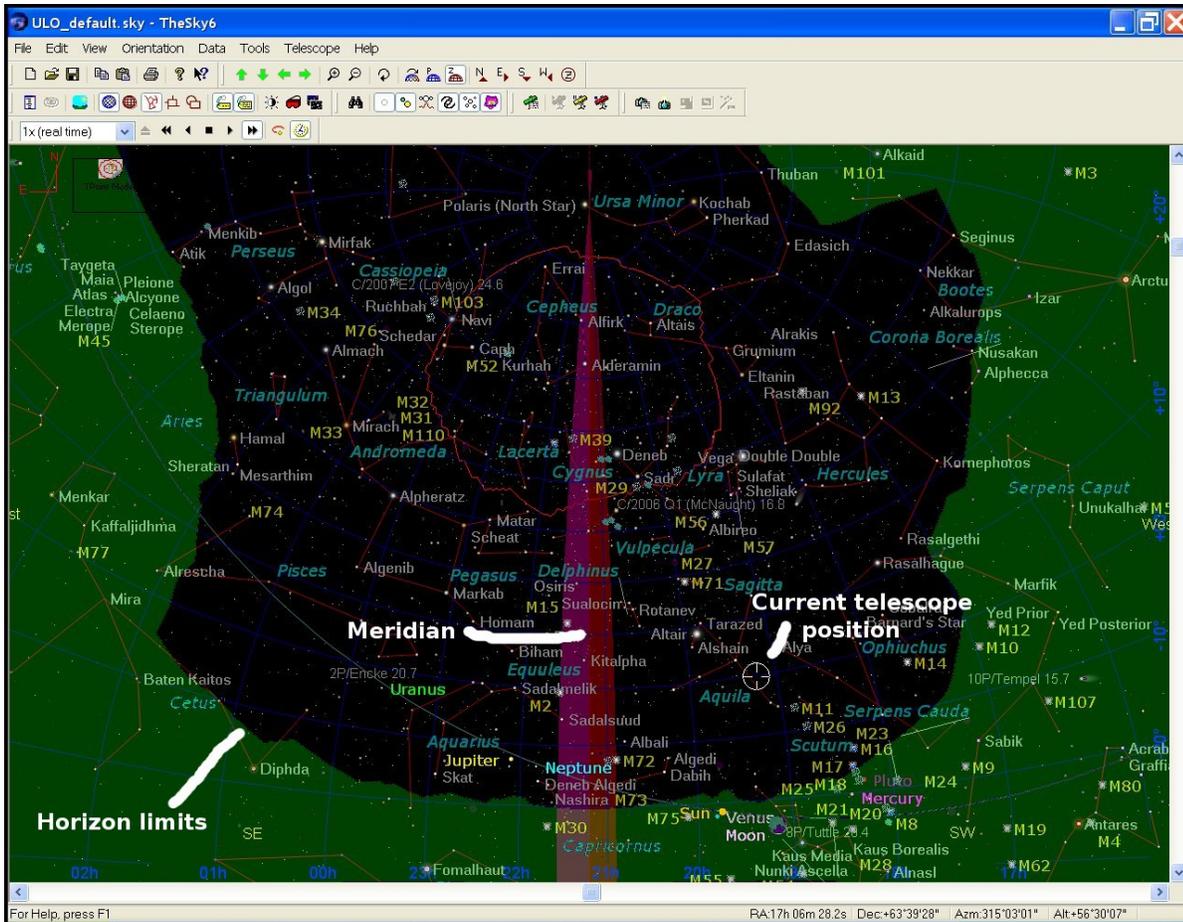


Figure 1: Appearance of the *The Sky* default display

### 5.3 Date and time

To show the calendar/clock window (if not already displayed), select **Data**→**Time**.

The date, time, and sidereal time are displayed in the desktop status bar (the sidereal-time display is provided by a different software program).

If the telescope is connected (as is usually the case), you can only view the sky for the current time. When the telescope is not connected, you can preview the appearance of the sky at other dates/times.

### 5.4 Changing the display field (zooming)

**When the telescope is connected, the system will only let you view a field which includes the current telescope position.** It will reset to the telescope-centred field if you try to view or zoom a region which excludes the current position.

The field shown on the display can be changed or zoomed in several ways:

- **Z** on keyboard: zenith up, looking South, wide-field view.
- Keyboard shortcuts:
  - Ctrl-W**: show wide-field view;
  - Ctrl-T**: show telescope field (smallest field), including the ‘footprint’ of the CCD

detector on the sky;  
You may also wish to use:  
**Ctrl-E**: show naked-eye field;  
**Ctrl-B**: show binocular field;

- To zoom:  
**Click and drag** around current telescope position, then click inside the drawn box to zoom; **PgUp**: zooms out;  
**PgDn**: zooms in;  
**The mouse wheel** also zooms in or out.
- The arrow keys scroll the display left/right and up/down.

## 5.5 Field orientation

On the toolbar, there are buttons which control the field orientation; these are used most often when comparing a CCD image with the field displayed.

- **P**: pole up  
**Z**: zenith up  
**rotate tool**: allows free rotation

## 5.6 Finding targets

When a new target is selected, a red ‘target’ symbol shows its location on the sky.

An Object Information window displays information about the selected target, including its RA and Dec.

There are several different ways to find and select a new target or position (you can practise this in the control room, but **do not slew** the telescope yet!):

1. If you can identify the target on the display, click on the target.
2. If you know the name of the target (*e.g.*, M51), click on the binocular ‘search’ icon, and enter the target name. [The long (!) drop-down lists can be cumbersome to navigate.]
  - **Find**: will display the position of the new object;
  - **Centre and Frame**: will only work if the telescope is already pointing at the target, or is not connected (since it tries to zoom the display on the chosen target).
3. If you know only the target co-ordinates, select **Orientation** → **Move To** and enter them. Make sure you specify the correct epoch! Note that you cannot preview the target location — this option will only slew the telescope.

## 6 Telescope operation — in the dome

### 6.1 Telescope tracking

Telescope tracking is enabled by default.

[The most precise tracking, essential for CCD imaging, includes a so-called periodic error correction (PEC); this is also enabled by default. The telescope is driven by a worm gear, which has a period of rotation of a few minutes. PEC means that the periodic residual errors in the worm gear have been modelled, and corrections are applied in real time.]

### 6.2 Manual operation

For manual control of the telescope position, there is a joystick stored in a cradle on the side of the telescope pier. Avoid pressing the button on top (located just where it *can* be accidentally pressed!) — a double-click will send the telescope back to its ‘home’ position (which will be inconvenient, at least).

### 6.3 Visual or CCD?

The Van Slyke breech-end assembly incorporates a mirror for directing light to an eyepiece, or it can be withdrawn from the light path for CCD imaging. To adjust between the two positions, loosen the two nylon screws slightly, and carefully push/pull the mirror into position, *bracing* the whole assembly with your other hand.

#### 6.3.1 Visual observing

The Van Slyke mirror must be IN for observations at the eyepiece. Remove the eyepiece cover and store. Make sure that the eyepiece cover is replaced at the end of the session, or before moving to CCD imaging (§7).

To focus at the eyepiece, **ONLY** use the Robofocus remote-control handset. This allows the correct focus for the CCD to be recovered quickly at any time.

To use the Robofocus, press and hold one of the red buttons while observing the star image. If the focus does not improve, reverse direction by pressing and holding the other red button on the controls (it’s a bit slow, so you may need to be patient).

#### 6.3.2 CCD imaging

The 40-mm eyepiece with extension tube is parfocal with the CCD: this can be used to achieve an approximate CCD focus. (Note: the EAST C14 has an independent focuser, so this is not true.)

The Van Slyke mirror must be OUT for CCD imaging. Replace the eyepiece cover to avoid light leaks.

### 6.4 RA and Dec display

To obtain a large, full-screen display of the RA and Dec of the current telescope position, select Telescope→Digital setting circles.

## 6.5 Slewing to a target

Find a target using one of the methods in §5.6 above.

- Remember that the spacebar interrupts a slew.
- To start the slew, click the green telescope icon (mouse hover='Slew') shown at the bottom of this window. Watch the telescope while it is slewing, so you can interrupt it if there is a problem.
- The telescope knows when it needs to reverse to complete a slew (see §6.6 below), and will do so when necessary.

## 6.6 Observing limits

The C14 is on a German equatorial mount (like the Fry and the Radcliffe). This makes it difficult or impossible for the telescope to slew to objects in the east(west) of the sky when the telescope itself is east(west) of the pier. Also, when the tube is west of the pier, the telescope cannot track west of the meridian more than 20 minutes in hour angle.

A  $\pm 20$ -minute limit in hour angle either side of the meridian is indicated by the red/pink zone in the meridian line on screen.

The telescope system knows when to reverse when slewing, but note the following:

- Built-in switches protect the telescope from slewing or tracking into the pier. If the telescope drives into the limit, the joystick may need to be used to slew the telescope out of the limit again, before repositioning.
- Reversing: If a target which has crossed the meridian is to continue to be observed, the telescope must be reversed by re-selecting and slewing to the target.
- After reversing, the field on the CCD camera will be inverted relative to its previous orientation (see §8.3).

## 7 Checks for CCD observing

Detailed notes on CCD operations, including focussing, are documented elsewhere. Students will become familiar with the software used for CCD operations during the practical ‘Use of a CCD Camera’.

### 7.1 Checks before leaving the dome

When observing with the CCD, there are several checks you should make before you leave the dome to observe from the control room:

- Check the telescope will not collide with anything.
- The Van Slyke mirror should be OUT.
- The eyepiece cover should be ON.
- Dome slot positioned correctly (check by eye).
- The dome monitor should be OFF.
- The lights should be OFF.
- The blackout blind should be drawn.
- Keep the control-room door closed (to keep the heat in — for your benefit, and the telescope’s!).

### 7.2 Viewing the dome slot from the control room

Double-click the Philips VRecord icon on the desktop to show the webcam view of the dome slot. You will need to check the telescope/dome alignment from the dome itself and then review the displayed image to ascertain the correct position of the dome slot relative to the ‘markers’ attached to the telescope: the exact alignment of the markers with the dome slot depends on the dome azimuth.

With the webcam view, the dome rotation can be adjusted from the control room. It is worth re-checking the alignment occasionally in the dome itself.

[Note that when the object is E of the meridian, the view is inverted — in the VRecord menu, select **Options**→**Video properties** and check the **Mirror image** box so that the dome still moves left or right on the display when ‘L’ or ‘R’ is pressed on the dome rotation.]

## 8 Notes for clear-night CCD observing

The detail of managing the CCD during observing will not be provided during telescope training, but on a clear night, since it requires a real sky to make it meaningful. However, you may wish to read through the following notes in advance (some of it will be familiar from the ‘Use of a CCD’ exercise).

## 8.1 Taking CCD images

Enter in the log (or on the charts provided) the details of every image taken and autosaved (image number, exposure time, filter, ...). Also, include the information for the session — weather, observers, CCD temperature, *etc.*

Select the **Take Image** tab.

This tab allows you to set image exposure times, choose filter, and specify a single exposure or a series.

Make sure the Imager CCD is selected.

- Exposure times of up to 10–15 minutes or so are usually not trailed. For longer exposures, you may wish to consider autoguiding, or taking a series of shorter exposures which can be aligned and co-added later on.
- Binning by  $2 \times 2$  pixels (0.86 arcsecs/pixel) is adequate for most applications.
- Saturation occurs when the maximum counts is greater than about 50000 ADU, so make sure that the maximum count is always less than about 45000 ADU for science exposures.

To take an image:

1. Set the exposure time.
2. Select the filter.
3. Set the image type to **Light**. (Note that the image type selected here also controls the type of exposure taken in the **Focus Tools** tab.)
4. The **Light** option permits autodark subtraction. Autodark subtraction is useful for ‘quick look’ images where the highest quality is not required, or for focussing. For the best results, do not select Autodark subtraction — acquire darks during the daytime.
5. When the exposure time and filter are correctly set, set the number of exposures required in the **Series of:** drop-down menu. Then click **Take Image** or **Take Series**.

N.B. The filter-wheel rotation does not always complete before the exposure is started, when moving by more than one filter position. To get around this, take a short exposure first to allow the filter wheel to locate correctly, before starting a long exposure. (It may be convenient to switch briefly to the **Focus Tools** tab to do this.)

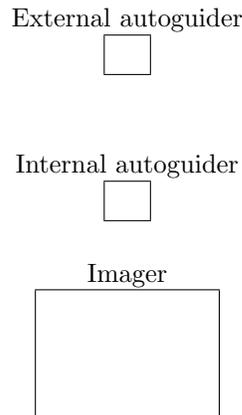
## 8.2 Checking the CCD field

To compare the CCDSoft field with the display from *The Sky*, select the pole-up view (P on the toolbar in *The Sky*) and use **Ctrl-T** to zoom. The field orientation is shown in the top left (but see below for how to match this to the CCDSoft image orientation).

The field of the CCD on the sky is shown as a large red rectangle enclosed in a circle (the circle doesn’t really mean anything here). Smaller boxes show the positions of the two autoguiding chips. Hence the projected ‘footprint’ of the CCD camera chips on the sky should look as shown in Fig. 2.

The position of the CCD window can be moved by selecting the red frame (click on the line) and then dragging the orange spot in the centre to reposition it.

Figure 2: The CCD imager and autoguiding chip arrangement



### 8.3 CCD field orientation

The CCDSOFT-image field orientation depends on which side of the meridian the target is, as shown below. A laminated card is provided in the control room to remind the observer.

CCD field orientation when:																			
object West of meridian (telescope east of pier)	object East of meridian (telescope west of pier)																		
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If the object is east of the meridian, the default field orientation of *The Sky* will need to be inverted to match the orientation of the CCDSOFT image:

- Click on the rotate tool (a clockwise-pointing arrow) on *The Sky* toolbar. A North direction indicator will appear on the display: drag the ‘N’ round by 180 degrees to invert the display of *The Sky*. Then click on the rotate tool again to remove it.
- The red CCD frames will now be inverted: click on the red line, then drag the orange spot to rotate the frames back by 180 degrees.
- When the orientation of *The Sky* is correctly matched to the CCDSOFT image data, the two autoguiding frames should be *above* the imager frame.

### 8.4 Centring the target on the CCD

The telescope faithfully acquires the target on the chip — barring serious pointing problems — but the telescope pointing may be offset slightly from the centre of the CCD chip, or a target may need to be re-centred once acquired.

This can be done from the control room by nudging the telescope position using *The Sky*. Select Telescope→Motion Controls to display a windows with NSEW direction

buttons. The motion should be to **Move** (not ‘Jog’), and the rate set to no greater than, say, 16× (to avoid overshooting). When the NSEW buttons are clicked, the telescope-position symbol will move.

N.B. When the object is east of the meridian, the field of *The Sky* should be rotated to invert, as noted above. However, the NSEW buttons do not then correspond to motion in those directions on the sky (*i.e.*, clicking N actually moves the telescope S!) — but you can trust the telescope-position symbol *always* to display the true position on the sky.

## 9 Notes for clear-night visual observing

The Van Slyke mirror must be IN for observations at the eyepiece. Remove the eyepiece cover and store. Make sure that the eyepiece cover is replaced at the end of the session, or before moving to CCD imaging (§7). The 40-mm eyepiece with extension tube is parfocal with the CCD: this can be used to achieve an approximate focus.

### 9.1 Focus

To focus at the eyepiece, **ONLY** use the Robofocus remote control. Do not attempt to refocus using the telescope main focus mechanism. This allows the correct focus for the CCD to be recovered quickly at any time.

To use the Robofocus, press and hold one of the red buttons while observing the star image. Reverse direction if necessary by pressing and holding the other red button on the controls.

### 9.2 Field diameter

The field of any given eyepiece can be determined displaying the RA and Dec of the current telescope position (§6.4) while observing a bright star in the field. Move the star to one edge of the field using the joystick so that it will pass through the field diameter when setting in Dec only. Read the telescope Dec co-ordinates with the star positioned at each edge of the field, and take the difference for the angular field.

### 9.3 Field orientation

To check the field orientation visually, you will need to display the RA and Dec of the current telescope position (§6.4) and then watch the monitor to establish which joystick directions correspond to which directions on the sky. Then observe the target through the eyepiece and nudge the joystick to move the telescope, say, *south*, then *west*: the target’s apparent motion is then *north* and *east*.

## 10 Notes on Telescope Tracking [for demonstrators]

### 10.1 Tracking

Telescope tracking is enabled by default.

The most precise tracking, essential for CCD imaging, requires the PEC (periodic error correction) to be enabled.

The tracking can be turned off, *e.g.*, for taking sky flat fields — but don't forget to turn it on again!

**To enable/disable PEC:** select Telescope→Options→PEC→Enable.

**To disable/enable tracking:** select Telescope→Options→Tracking.

### 10.2 Tracking a moving target

The telescope can be set to track a moving target, such as a comet, or the Moon. In the object information window, select the CHECK tab. The telescope will then track to follow the object at the rates given.

It is important to remember to reset the tracking rates when a new target is observed. This can be done by selecting any star and performing the same procedure to set the sidereal tracking rate and zero the tracking in declination.

## 11 Notes on dome operation [for demonstrators]

### 11.1 Dome opening and closing

To open or close the dome, use the ACE dome software. Before running the ACE dome software, check whether *Automadome* is running, and if it is, you must exit it cleanly.

The *Automadome* software supplied for use with *The Sky* has a bug whereby it will not release the dome-control port unless it is exited cleanly. To close *Automadome*, you must exit two windows:

- select Dome→Link→Terminate within the dome-control window in *The Sky*, then File→Exit;
- then do the same within the *Automadome* window, running in the background.

In the ACE dome software:

1. Click **Connect** to connect to the dome.
2. Check the status of the shutter door and flap: click on the appropriate icon to select the dome state you require (fully open/shutter only open/fully closed).
3. You may interrupt the dome opening or closing by clicking the **STOP** button (big X).
4. To send the dome to its home position (azimuth 110°), click **Home**.
5. To park (due North), click **Park**.
6. When dome adjustment is complete, click **Disconnect**, then exit the software.

## 11.2 Dome slewing and tracking

There are two distinct modes of dome operation:

1. Dome slewing: a telescope slew will cause to the dome to move to the new position;
2. Dome tracking: the dome will slave to track the current telescope position.

To start *Automadome*, for slewing, press the 'D' key on the keyboard. Then select **Dome→Link→Establish**; confirm that **Dome→Coupled** is checked with a tick.

There are two software scripts on the desktop to start and stop the dome tracking, called, helpfully: **Start Dome Tracking** and **Stop Dome Tracking**.

There are some awkward limitations of the dome tracking due to the German mount when the telescope is pointing close to the meridian, and it may be easier to turn dome tracking off and rotate the dome manually using the handset control.

It is usually convenient to enable the dome slew, even if autodome tracking is not used.

## 12 Training Check List

On completion of training, the student should be able to do the following:

1. describe basic safety considerations when working in the dome;
2. describe the safe and correct procedure for protecting the telescope when the telescope dome is opened or closed;
3. focus at the eyepiece with the Robofocus handset;
4. adjust the Van Slyke mirror smoothly;
5. read the current position of the telescope in equatorial coordinates (display with Telescope→Digital Setting Circles);
6. read the current sidereal time;
7. estimate roughly where an object of given RA and DEC should be at a known sidereal time;
8. find and slew safely to a given target by searching the object database (explain whether the telescope will need to reverse);
9. interrupt a slew;
10. zoom the field on *The Sky*— *e.g.*, to show the zenith view and the telescope field;
11. perform initial telescope checks before observing from the control room.

All students will be examined individually and are expected to demonstrate basic competence in operating the telescopes.