

## Telescope User Instructions

This document contains important information about using the astronomical observatory on the roof of the Physics Building. To use the observatory, you **must** have attended a safety briefing for the current academic year. By signing the briefing register you agree to abide by the safety rules and instructions in this document. Failure to do so will result in your access to the observatory being withdrawn.

### Safety Rules

- Only individuals who have attended a safety briefing (and signed the register) are allowed to operate the telescope and access the observatory outside normal working hours. Others may only visit the observatory out of hours with the permission of the observatory director or other member of academic staff. In such cases, guests must be informed of these safety rules and remain under the supervision of an experienced observatory user.
- The observatory is a hazardous place, especially at night. To minimize risks to yourself and others you must:
  - Never work in the observatory alone – if you have an accident, there will be no-one to get help. Always work in pairs or small groups.
  - Carry a mobile phone with you – put the numbers below in your contacts.
    - In an emergency, call 0115 951 8888 (the campus equivalent to 999).
    - In less urgent cases, security may be contacted on 0115 951 13013.
  - Set the sign on the door to show that you are working in the dome. This is important for fire safety.
  - Don't get locked out on the roof! Make sure you take the roof door key with you.
  - Do not go onto the roof beyond the railed area and the path to the railed area.
  - Be careful when climbing the steps to the raised area of the roof.
  - Take care when entering the observatory; there is a step and reduced door height.
  - Be careful moving around in the dome. There are plenty of cables and objects to trip over, which is especially easy to do in the dark.
  - Carry a torch and use it when necessary.
  - Wear suitable warm clothing.
  - If you see an intruder in the building DO NOT confront them – contact security.
  - Comply with School rules for out-of-hours access to the building.
- The telescope, its mount and associated equipment are expensive and delicate. In order to protect them from damage and ensure continued access for all, you must:
  - Be aware whenever the telescope is moving to a new target. Ensure it does not collide with anything (including its own mount) or snag any cables. Pressing any arrow key on the handset will immediately stop the telescope.
  - Try to keep dust and damp off the telescope. Open the dome before you take the covers off the lenses, and put them back on before you close the dome. Leave the telescope covered up when the dome is closed (in case of leaks).
  - Do not open the dome in poor weather (wet or excessively windy) – close the dome if conditions deteriorate.
  - Do not leave the dome open unattended if there is a risk of rain.
  - Take care of the roof door and dome keys. Return them to the key safe when you have finished observing.
  - Fill in the observatory log with times, names of all attendees, objects observed and any problems encountered.
- Never point the telescope anywhere near the sun. Doing so will damage the telescope in a fraction of a second, and could cause irreversible damage to your eyesight.
- Make sure the building is locked and the alarm is set when leaving out of normal hours.
- You should also read and understand the School Emergency Procedures. These are distributed at briefings and displayed inside the observatory.

## Observatory Access

Trained users will be issued with a code for the key-safe by the door to the roof, where the observatory keys are kept. The keys must be put back in the safe after each session and must not leave the Physics building. Keys on the blue fob are for the main lock on the roof door and the telescope dome; keys on the green fob are for the bottom lock on the roof door. Take both sets with you – the bottom lock is sometimes locked by security. Always remember to indicate that you are working in the observatory by using the magnetic sign on the roof door (for security and safety reasons). Enter your names and the time in the observing log by the key box.

Undergraduates undertaking projects on the telescopes will be given appropriate training as part of their introduction to the project. PhysSoc members and other individuals wishing to use the telescopes must attend an official safety briefing. All users must sign the safety briefing register to indicate they have received the requisite training.

**Note that students observing as part of their project have priority over all others.** However, project students are encouraged to accommodate other telescope users where possible.

Attending a telescope safety briefing and signing the register entitles you to use the observatory without supervision, but does not entitle you to supervise others who have not yet attended a safety briefing. That entitlement may be granted upon successfully demonstrating that you have gained sufficient experience of safe working.

Failure to work in a safe manner or misuse of the observatory equipment may lead to your entitlement to use the telescope being immediately withdrawn.

## Building Access / Out of Hours Working

Students who have signed a safety briefing register are permitted to use the observatory outside normal working hours, provided they adhere to the rules and guidelines. Several days after you have signed the safety briefing register, you will be able to enter the Physics Building out-of-hours using your University card. You may only enter the building out-of-hours in order to access the observatory.

Outside normal working hours the building alarm is set. Entering with a key card, and leaving the same way, does not activate the alarm. However, using other exits, including on to the roof, will set off the alarm. If the alarm is set, you must first unset it, by entering the code into the keypad on the wall by the door. Then set it again and exit while the warning noise sounds. On re-entering from the roof, you should open the door then enter the code into the keypad, while the warning noise sounds. You should then rearm the alarm by entering the code again.

Even if the alarm is not set when you exit on to the roof, it may have been armed by the time you re-enter to the building. You must therefore ensure you have the alarm code with you before accessing the building and roof out-of-hours.

The alarm code will be changed each academic year, and potentially at other times – if so you will be notified. If you inadvertently trigger the alarm, phone security and let them know.

## Observing

This guide sets out the procedures involved in carrying out an observing session on the telescope. It describes the preliminary steps, such as the alignment and focussing of the telescope, observational procedures, including usage of the CCD camera, and the processing of the resulting images. The material is roughly in the order in which the procedures will usually be performed.

Some of the material below is labelled **Advanced**. If you are observing relatively bright sources for fun, or just becoming acquainted with the observatory, these more involved techniques may be skipped. Users undertaking projects or observing faint targets should take careful note of the more detailed instructions.

## Preparation

Once inside the dome:

- Turn on all of the four power sockets (two on the wall and two on the telescope pillar), the dome-rotation unit (if in use), the computer screens and (if necessary) boot the computer.
- Open the upper dome slit, leaving the handle pointing up to avoid it hitting the power supply. Open the lower section of the dome.
- Take the cover off the telescope and remove the dust caps from the telescope and finder.
- Turn on the telescope mount drive.

Following this sequence reduces the risk of getting dust or water on the telescope optics, and means you do not need to handle the telescope after it has been turned on.

## Getting Started

After turning the telescope mount on, look at the handset. It will either ask you (1) if you want to 'wake up' the telescope (if the previous user hibernated the mount, as recommended), or (2) to carry out an alignment.

During these initial stages, the handset will also ask you to confirm the time. The telescope is linked to a GPS unit which provides an accurate time and location. However, **you must be patient and wait (for up to a minute) for the GPS to link up and display the correct time on the handset.** Do not manually adjust the time. It is vital that the telescope is set at the correct time, otherwise the telescope pointing will be inaccurate. The time is displayed as UTC (UK local time in winter, one hour behind in summer).

If the telescope has been hibernated prior to you 'waking' it up, it should already be aligned. If it was not hibernated, you can simply select 'Last Alignment' from the list of possible calibrations; this should recall the prior alignment. If you have trouble with inaccurate pointing, check the handset time is correct. If it is, you may need to perform an alignment calibration (see below).

## Using an eyepiece

The telescope is often used with a CCD camera. However, for observing bright objects it can be easier, and more satisfying, to collect the photons with your own eye. To enable this, it is usual for a 'flip-box' to be installed between the telescope and the camera. This contains a moveable mirror which, when lowered, diverts light into an eyepiece. If the flip-box is not installed, then it is possible to remove the camera from the back of the telescope and replace it with a large diagonal mirror and eyepiece. Please contact the observatory director in advance if you wish to do this. It is essential to store any removed equipment safely.

## Acquiring Targets

There are several ways to point the telescope at a target: using the various object lists available on the handset, manually entering RA and Dec coordinates on the handset, or using software on the PC, i.e. *Control* or *Starry Night* (see below). If correctly aligned, the telescope mount should place the requested position in the field of view of the CCD or eyepiece. If not, and the target is bright enough to see in the finderscope, it may be manually centred using the direction buttons on the handset. The speed at which the telescope moves is controlled by pressing the 'motor speed' button and then a number: 1 is slowest, 9 is fastest. Once at the centre of the finderscope crosshairs the target should be within the field-of-view of the CCD or eyepiece. However, if the finderscope is misaligned, then it may be necessary to search for the target by driving the telescope around in a small pattern.

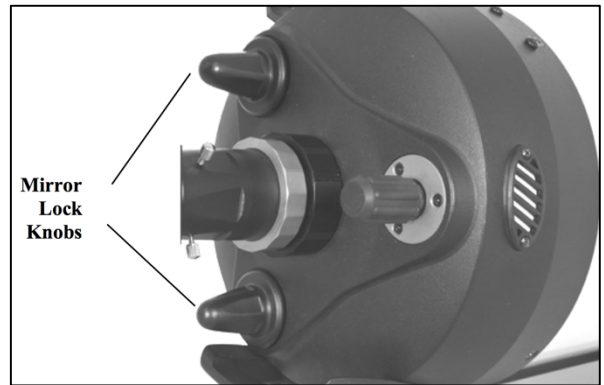
The dome aperture must be positioned such that the telescope can see the sky. If the motor unit is available use that, otherwise you may need to (firmly, but carefully) rotate the dome by hand.

**Advanced:** To ensure that faint objects are located on the CCD, for long-exposure imaging, some extra steps are advisable. Firstly, you should ensure you have a good pointing alignment. Then, you can do a 'Precise GoTo' using the handset (see p. 26 of the manual). This involves first centring the telescope on a star near the target (automatically selected by the handset). The telescope then only needs to make a small, and therefore accurate, offset to the target location. To avoid disappointment, it is very wise to inspect your images as you take them to ensure they contain your target and are of sufficient depth and quality.

## Focusing the Telescope

If you are using the eyepiece, focussing is simply a matter of adjusting the focus to give a clear image in the eyepiece. If you are using the CCD, or if the telescope appears to be very out of focus, you should focus on a bright star before going to your target of interest.

On the back of the main telescope tube there are three knobs: the two similar ones are the mirror locks and the other is the focus adjuster. Before focusing the mirror lock knobs must be loosened. Then, the focus may be varied by carefully turning the focus knob. When focusing is complete you must tighten the mirror lock knobs again.



It may take some time to get clear focus, but this will be essential to your observations. It is important to be patient, as turning the focus knob too quickly could result in passing over the ideal focus. Unfocused stars typically appear as 'donuts' of light. Turn the focus knob to reduce the size of these donuts until they resemble compact points.

Only move the focus knob by small amounts (fractions of a revolution) at a time, leaving time for vibrations to dissipate before judging the focus. Note that occasionally the telescope is focussed on terrestrial targets (e.g. during open days), so stars may sometimes be very out of focus: increase the exposure time and look for large, faint donuts.

**Advanced:** If you intend to use the CCD camera, you should perform the focus on the CCD. This is easiest if you set *Control* to take continuous images, in which case a new image is read out every few seconds. Ensure the exposure time is short enough that the star is not saturated. To achieve an optimal focus a Bahtinov mask may be placed over the front of the telescope. This produces a star-like pattern: adjust the focus until it is symmetrical.

## Using the CCD Camera

**Advanced:** *this section may be skipped by users who only intend to observe using an eyepiece.*

If the flip-box is installed, ensure its mirror is fixed in the up position, such that light can pass through to the camera. Otherwise, your images will be blank!

Images are obtained, processed, saved and displayed using custom software called *Control* on the dome PC. Images are displayed in *DS9*, which *Control* communicates with via *TOPCAT*. Therefore, you must start these programmes in the following order: 1) *TOPCAT*, 2) *DS9*, 3) *Control*. You may minimise *TOPCAT*, and it is convenient to move *DS9* to the second screen.

*Control* has a fairly simple interface, with buttons for typical tasks and sensible defaults. For optimal images, both cosmetically and for science use, you should obtain a new set of calibration images each night (see below). However, on start-up *Control* will load the most recent calibrations it can find, which will often be good enough for casual users.

To take an image of an astronomical object, enter the desired exposure time and number of exposures, then click the 'Take science images' button. Exposure times should be from one hundredth of a second for a very bright star or planet, to 30 seconds for faint sources.

For convenience, there is also a 'Take acquisition image' button for use when initially finding your target. This behaves very similarly to the 'Take science images' button, but only takes a single image, and names the saved image differently.

*Control* will save the raw image and display it in the left panel of *DS9*. It also performs an automatic processing of the image, using the latest set of calibration images, separates the three colour filters, saves these images and displays a colour image in the right panel of *DS9*.

All images are saved to a folder for each night, linked from the desktop. These are given a filename constructed from the date and time the exposure was started, the type of image ('flat', 'sci', etc.) and, for the processed images, the filter ('r', 'g' or 'b'). A colour jpeg image is also automatically produced and saved in the same place. Note that performing your own careful processing of the raw images may produce better results than the automatic routines. A document describing the steps for a manual data reduction with *AstroImageJ* is available on the observatory web page.

It is sometimes useful to take repeated images, during alignment and focusing. To achieve this, click the 'Take continuous images' button. Click 'Abort' to stop taking images. These images are not saved to disk.

For each 'acquisition' or 'science' image, *Control* will attempt to independently determine the location of the image on the sky, by comparing with star catalogues. If this is successful, the position will be displayed in the interface. The coordinate system will also be written to the processed images, allowing coordinates to be checked in *DS9*. This can be useful for checking the telescope pointing and ensuring that faint targets are in field-of-view.

The telescope can typically track accurately for ~30 seconds, after which images will start to become trailed (i.e. stars will have extended shapes, instead of being circular points). To obtain a deeper image there are several options: (1) take multiple, shorter exposures then shift and combine these using dedicated software, or (2) train the periodic error correction or use the auto-guider and active optics unit (see the manuals and consult the observatory director if you wish to try this).

Ensure you keep a careful log of all your observations, including observation time, image number, exposure time, target name, weather conditions and any other relevant notes. Avoid wasting time when you could be obtaining data, but do take time to check that your images contain your target and are of sufficient quality otherwise you will be disappointed the next day. Better to have some useable data than lots of unusable data.

## Transferring data

**Advanced:** *this section may be skipped by users who only intend to observe using an eyepiece.*

To backup all images taken, if it is not already running, please start *WinSCP* and log in to pppzsb2 (the default). Start the 'synchronize folders' tool (again the defaults should be correct). This will copy everything to another server, which makes the files accessible online via Dropbox. A link will be shared following your safety briefing. You may also like to transfer images via USB stick.

## Alignment Calibration

**Advanced:** *If the instructions are adhered to, there should be no need to recalibrate the telescope pointing. However, if you are sure that the telescope is not aligned, and are sufficiently confident at identifying stars, then you may carry out the following procedure (also see the mount manual).*

Choose a '2 star' alignment from the options presented upon switching the mount on.

The first step in the re-alignment process is for the telescope to locate the switch positions (approximately pointing at Polaris). The handset then lists suggestions for the first alignment star. Once selected (the first is usually the best option), the scope will move to point at that star, based on its current alignment. Usually the relevant star will be close to the centre of the finder scope. If not, the handset time may be wrong, or the previous alignment attempt may have been incorrect. You should then centre the star using the arrow keys on the keypad, first in the finder scope, then in the eyepiece or CCD field of view (see the CCD operating instructions above). To change the speed the telescope moves at, press the 'motor speed' button on the handset followed by a number 1-9. 1 selects the slowest speed, while 9 is the fastest.

If the star does not look like a compact point, but more like a light donut with a dark centre, the telescope needs focussing (see above), before continuing with the alignment procedure.

Once you have aligned the first star, press 'enter' then 'align' on the handset. You will now be instructed to choose another star; simply repeat the procedure you carried out for the first star.

Once the 2 stars have been aligned, the handset gives the opportunity to add 'calibration stars', to further improve the pointing accuracy. Adding several calibration stars is advisable, but not necessary for casual observers. The procedure for adding these stars is identical to that above.

It is also possible to replace alignment and calibration stars without cycling the mount power and performing a full alignment. See the mount manual for details.

Under no circumstances should you adjust the physical alignment of the mount (i.e. performing a polar align, adjusting the various knobs on the mount) without consulting the observatory director.



## Calibration Images

**Advanced:** If you are observing with the CCD camera you should obtain some special images with which to calibrate your target images.

**Dark/bias frames:** These are used to subtract the signal in the CCD images that is present even when no light is incident on the detector. To obtain them, put the telescope cover on and click the 'Take bias images' button in *Control*. This will take a set of images and then combine them to create a master bias image for use in calibrating subsequent images.

**Flat-fields:** These are used to correct for variation in pixel sensitivity and the presence of dust and other contamination on the optics. To obtain them, put the telescope point the telescope at a blank patch of sky at twilight and click the 'Take flat images' button in *Control*. This will take an initial exposure and then calculate the exposure time required so that the image has sufficient counts (~25,000) but is not saturated. It will then take a set of exposures and create a master flat calibration image. It should be a fairly uniform grey with faint, darker 'donut' shapes visible due to out-of-focus dust. If you cannot obtain sky flats, images of an evenly illuminated part of the observatory dome may suffice.

## Additional software

*Starry Night*, *ECU* and *Stellarium* are accessible from the PC desktop. These are planetarium programs useful for identifying suitable targets. *Starry Night* and *ECU* can communicate with the mount to point the telescope at a target.

## Further information

The telescope website contains further information, including manuals, specific details about the telescope, reduction scripts, analysis software and links to other useful resources.

See <http://www.nottingham.ac.uk/astronomy/observatory.php>

## A Typical CCD Observing Session

- Arrive at the telescope around sunset and follow the startup procedure.
- Take set of bias frames.
- Take set of flat-fields (may not be perfect if focussing required later).
- When first stars become visible, check pointing alignment by acquiring one.
- Check focus on this star, adjust focus if necessary.
- If focus adjusted and still light enough, take another set of (dithered) flat-fields.
- Perform pointing alignment if required.
- Acquire first target (using handset or PC, possibly first synching on a nearby bright star).
- Take science exposures (check for depth and trailing, use a variety of exposure times).
- While waiting for exposures, examine previous images to check data quality.
- Acquire next target, and continue as before.
- When observations are complete, follow the shutdown procedure.

## Ending your Observing Session

When you have finished you need to leave the observatory in a safe condition. Essentially just do what you did at the start, but in reverse. Hibernating the telescope maintains the best alignment.

- Backup your observations to a USB key, external drive or university storage space.
- Shut down the computer.
- Slew the telescope to its home position (e.g. using Menu → Utilities → Home → Goto).
- **Hibernate** the telescope: select Menu → Utilities → Hibernate.
- Turn off the telescope drive.
- Put the lens covers back on the main telescope and on the finder.
- Put the plastic cover over the telescope.
- Close the upper and lower dome shutters.
- Turn off all the power. In particular, remember to turn off the dome rotation unit, the two sockets on the telescope pillar, the two sockets by the computer.
- Lock the dome and return the keys to the key safe.