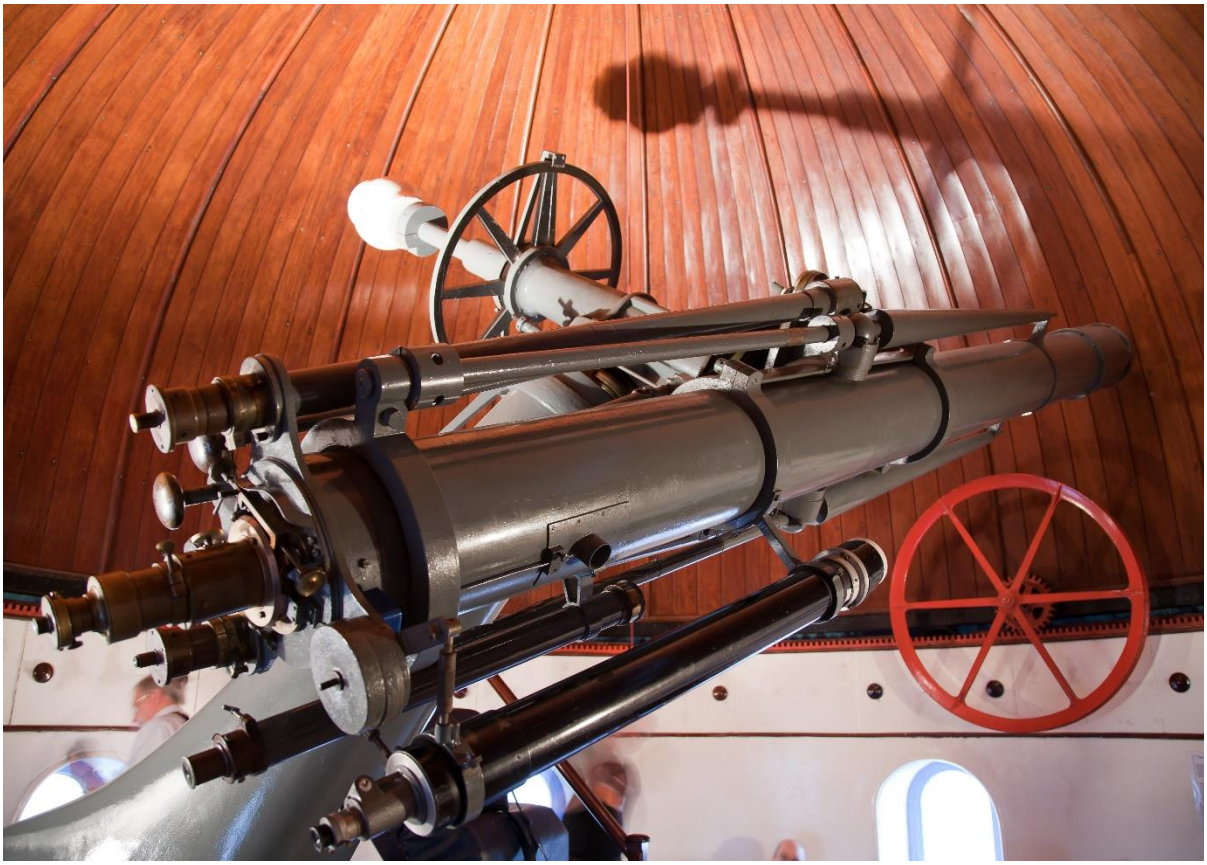
Orwell Astronomical Society (Ipswich)

Tomline Refractor Operating Manual



The Tomline Refractor at Orwell Park

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Document History

Version	Date	Author
Issue 1	August 1996	D B Payne
Issue 2	May 1998	D B Payne
Issue 3	14 December 2001	J M Appleton
Issue 4	23 May 2010	J M Appleton
Issue 5	29 January 2013	J M Appleton
Issue 6	05 July 2024	J M Appleton
Issue 6a	06 July 2024	J M Appleton

1 Introduction

This booklet is a guide to safe operation of the Tomline Refractor at Orwell Park Observatory.

All persons using the Tomline Refractor must adhere to the instructions in this booklet.

2 Safety

Safe and effective operation of the Tomline Refractor requires a degree of skill, knowledge and experience. The Committee of OASI therefore restricts use of the instrument to members of the Society who have demonstrated the necessary skills and are designated authorised operators, and to those acting under the direct supervision of an authorised operator.

The Committee maintains a list, displayed on the noticeboard in the Belvedere room, of authorised operators of the instrument.

The Committee is keen to encourage additional members of the Society to become authorised operators and to use the instrument. Training will be provided for any member who wants to become an authorised operator. The training will take the form of informal coaching by an experienced user, generally over a period of some weeks. Once the member has completed training and demonstrated proficiency in use of the instrument, the Committee will designate him/her an authorised operator and he/she may then use the Tomline Refractor unsupervised according to the guidance in this booklet.

YOU MAY USE THE TOMLINE REFRACTOR ONLY IF THE COMMITTEE OF OASI HAS GRANTED YOU AUTHORITY TO DO SO OR YOU ARE ACTING UNDER THE DIRECT SUPERVISION OF AN AUTHORISED OPERATOR.

FOR SAFETY REASONS, AN AUTHORISED OPERATOR MUST BE PRESENT IN THE EQUATORIAL ROOM WHENEVER THE TOMLINE REFRACTOR IS IN USE.

3 The Tomline Refractor

Figure 1 illustrates the Tomline Refractor. The main components of the instrument are:

- Equatorial mount. This is a huge, cast-iron mount secured to the top of a masonry pillar which extends upwards from the foundations of the observatory to the floor level of the equatorial room. Apart from sharing the foundations, the pillar is isolated from the rest of the fabric of the building, to prevent vibration being transmitted to the telescope. The polar axis of the mount is aligned with the axis of rotation of the Earth, so that rotating the telescope around this axis makes it follow the apparent motion of a star through the sky.
- The telescope tube. The primary function of the telescope tube is to act as a rigid framework holding the 26cm OG (Object Glass) and eyepiece tube in precise alignment relative to one another. It also supports a finder telescope and other accessories.
- Counterweight. This is fitted on the opposite side of the polar axis to the telescope tube. It balances the weight of the telescope tube to ensure smooth rotation of the telescope about its axes.
- Setting circles for RA (Right Ascension) and declination. The declination setting circle is mounted on the declination axis close to the counterweight. The RA setting circle (not shown in the figure) is inscribed on a ring inside the RA drive wheel, at the base of the polar axis, inside the telescope mount. The setting circles indicate the celestial coordinates towards which the telescope is pointing.
- Two periscopes. These provide visibility of the declination setting circle from the eyepiece-end of the telescope. (There are two periscopes so that at least one always has an unobstructed view.) There is no equivalent to view the RA setting circle: to determine the RA of the telescope, the observer must walk from the eyepiece to the base of the polar axis and read the value directly from the RA setting circle.
- A finder telescope. This is a 60mm aperture refracting telescope, optically aligned with the Tomline Refractor, but providing a much wider field of view, enabling the observer to locate the object of interest before engaging a high magnification view in the Tomline Refractor.
- Eyepiece tube. This is a tube of approximately 8cm diameter protruding from the main telescope tube; its end is threaded to accept an eyepiece adapter. Several eyepiece adapters and a wide variety of eyepieces are available (they are stored in the computer room when not in use). A knob fitted to the OG-end of the eyepiece tube provides adjustment of the focus of the telescope.
- RA drive. A small electric motor (not visible in the figure) drives the telescope tube around the polar axis. A hand controller enables adjustment of the speed of the drive so that it precisely compensates for the rotation of the Earth.
- Push-to system. An electronic push-to system (not visible in the figure) provides a precise indication, on the SkySafari astronomy app running on a tablet, of where in the sky the telescope is pointing.

Key optical parameters of the Tomline Refractor are as follows:

Object glass	Merz achromatic doublet dating from 1874, refigured by Horace Dall in 1973 and further overhauled by Es Reid in 2012 and again in 2024.
Clear aperture	258 mm
Focal length	3894 mm
Focal ratio	f15.1

The IAU observatory code for Orwell Park is 582.

Table 1 provides the location of the observatory (sometimes required in reducing astronomical observations).

Coordinate System	**North Lat. (°)**	**East Long. (°)**	**Height above MSL (m)**
WGS-84	52.009807	1.230404	45
IAU 1976	52.010015	1.232187	-528

Table 1. Location of the observatory.

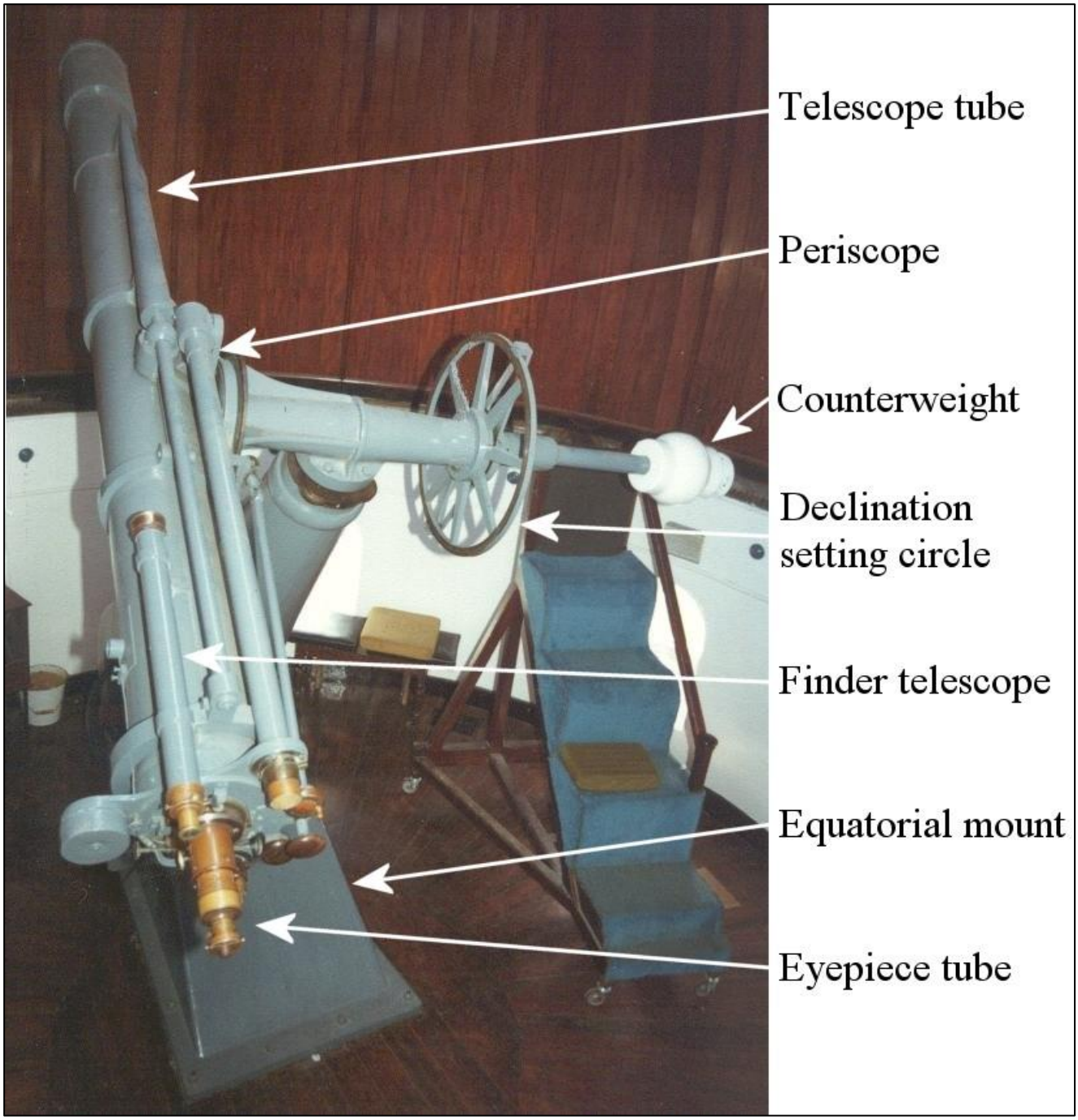
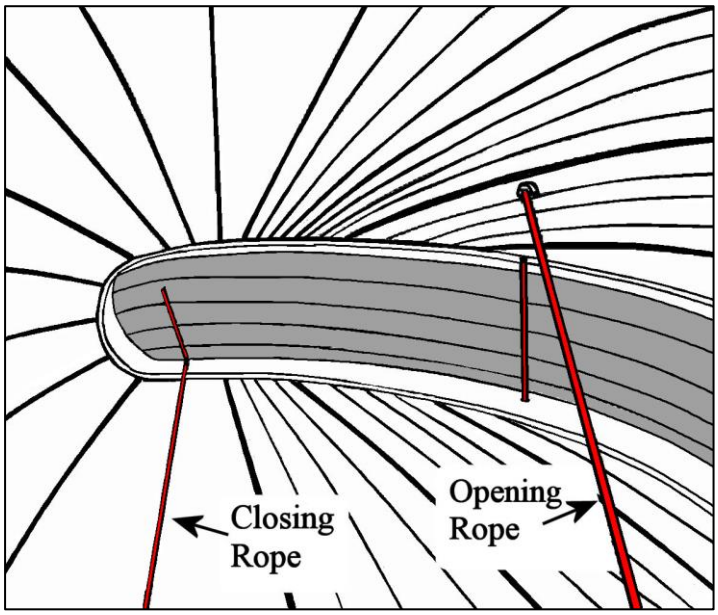


Figure 1. The Tomline Refractor.

4 Dome Shutter

The shutter of the dome is opened and closed by ropes (one for opening, one for closing) and a handle. Two persons (of whom at least one must be an authorised operator) are needed to open or close the shutter – one pulling the appropriate rope and the other operating the handle. Figure 2 illustrates the ropes for opening and closing the shutter and a person at the handle of the shutter.



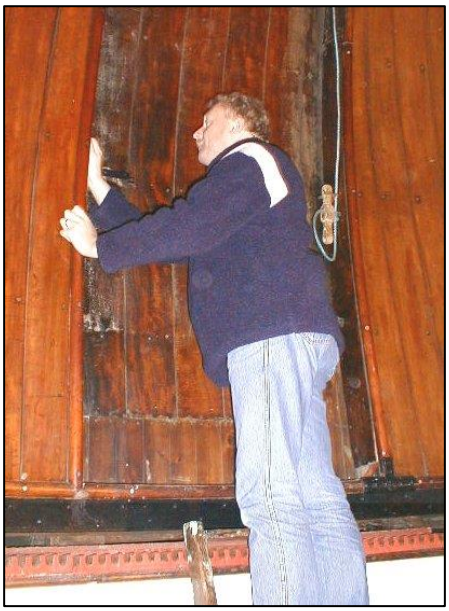


Figure 2. Left: inside of the dome with the ropes for opening and closing the shutter. Right: unlocking the bolt on the dome shutter.

Open and close the shutter **only** when the dome is positioned so that the shutter lies directly above the door to the computer room.

Opening the shutter in adverse weather conditions could result in damage to the shutter, its track or to the copper skirt of the dome. Therefore, open the dome shutter **only** if weather conditions permit. **Do not open the shutter in the following conditions:**

- **high winds,**
- **rain or snow,**
- **ice is present or could form on the shutter track or inside the rainwater gutter of the dome.**

The observatory dome is some 25m above ground level. **Do not** attempt to lean out of the aperture or climb out of it unless you are securely fastened to the structure of the building by a safety harness.

During opening or closing, if the two persons do not successfully coordinate their efforts, there is a risk that the shutter will tilt, and its runner wheels jump out of the lower track. In this eventuality, immediately contact one of the people listed on the notice fixed to the wall of the dome - "Contacts for Emergency Assistance with the Shutter".

The handle on the shutter consists of left and right grips (see figure 3). When the shutter is fully closed, the left grip lies partially between the shutter and the outer skin of the dome; when fully open, both grips lie between the shutter and the outer skin of the dome. Care is therefore required to ensure that hands are not trapped when the shutter approaches either end of its travel.

Access to the handle of the shutter requires use of the dome ladder. Before ascending the ladder, it should be securely propped against the wall of the dome so that the wedges at the top overlap and rest upon the toothed track of the dome (see figure 4). Ensure that the ladder is stable before ascending it.

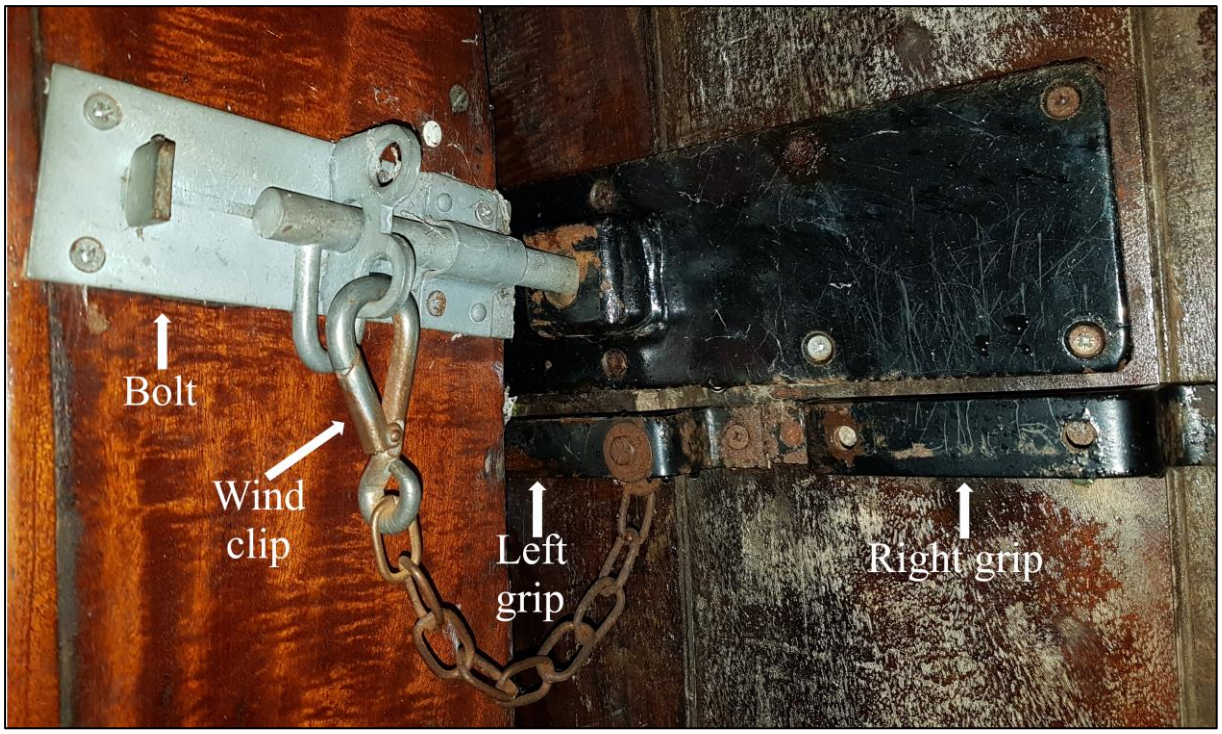


Figure 3. The locking mechanism and handle on the shutter, with the latter in the closed (locked) position. In this position, the left grip of the handle lies partially between the outer skin of the dome and the shutter.

Figure 4. The ladder propped against the wall of the dome (left) and the wedges at the top resting on the toothed track (right).

To open and close the shutter safely, the below procedures should be adopted.

4.1 Opening the Shutter

1. By convention, the person on the ladder oversees the above operation and should take overall responsibility for the entire manoeuvre.
2. Rotate the dome so that the shutter is positioned to the north-east, above the door to the computer room.
3. Position the ladder under the shutter. Climb up the ladder to a height giving easy access to the shutter handle and bolt. Remove the wind clip and open the bolt.
4. Unclip the opening (middle) rope and hand the end of the rope to the second person.
5. Check that the closing (upper) rope cannot become snagged on the telescope or mount.
6. The person on the ladder should grasp the right-hand grip of the handle and smoothly pull the shutter open while the second person pulls on the rope to keep the shutter upright and moving smoothly. Pause when the shutter has reached the mid-position (half-way open).
7. Prior to moving the shutter from the mid-position to fully open, the person on the ladder should reposition his/her stance as necessary.
8. To complete the manoeuvre, the person on the ladder should push on the side of the shutter until it is fully open while the second person pulls on the rope to keep the shutter upright and moving smoothly.
9. After fully opening the shutter, clip the opening (middle) rope to its retaining clips on the dome wall at the shutter opening.

4.2 Closing the Shutter

1. By convention, the person on the ladder oversees the above operation and should take overall responsibility for the entire manoeuvre.
2. Rotate the dome so that the aperture is positioned to the north-east, above the door to the computer room.
3. Position the ladder under the aperture. Climb up the ladder to a height giving easy access to the shutter handle and bolt.
4. Release the opening (middle) rope from its clips and allow it to hang freely.
5. The second person should grasp the closing (upper) rope. If necessary, use the observatory steps to reach the rope.
6. The person on the ladder should grasp the left-hand grip of the handle of the shutter. If necessary, gently edge the shutter slightly closed (by a few cm) until a firm hold of the grip can be achieved.
7. The person on the ladder should now smoothly pull the shutter closed via the left-hand grip while the second person pulls on the rope to keep the shutter upright and moving smoothly. Pause when the shutter has reached the mid-position (half-way closed).
8. Prior to moving the shutter from the mid-position to fully closed, the person on the ladder should reposition his/her stance as necessary.
9. To complete the manoeuvre, the person on the ladder should grasp the right-hand grip of the handle and slide the shutter until it is fully closed while the second person pulls on the rope to keep the shutter upright and moving smoothly.
10. Once the shutter is closed, lock the bolt, re-fasten the wind clip and clip the opening rope back into its retaining clips on the dome wall at the shutter opening.

5 Rotating the Dome

The large red wheel attached to the pinion gear at the base of the dome provides the mechanism to rotate the latter (see figure 5). Operation is self-evident: turn the wheel to rotate the dome. Before turning the wheel, check that there is no risk of the rotating dome trapping hands or clothing. When turning the wheel, take care that it does not collide with the telescope, observatory steps, doors, or other objects. Also be alert to the potential for the closing (top) rope of the shutter to become fouled on the telescope or mount.

Do not rotate the dome if ice has formed in the gutter at its base: the ice may grip the skirt fitted to the exterior of the dome and if the latter is rotated the skirt may become detached.

When rotating the dome, if the wheel may pass a door in the wall, make sure that anyone on the other side of the door is warned not to open it until the wheel has passed safely by.

At the conclusion of an observing session, rotate the dome so that the aperture is positioned to the north-east, over the computer room.

Figure 5. Wheel for rotating the observatory dome.

6 Telescope Covers

Both the Tomline Refractor and finder telescope have covers for their OGs. Figure 6 illustrates removal of the covers prior to an observing session. Only moderate force is required to remove or replace either of the covers.

Replace the covers at the end of each observing session.

Figure 6. Removing the covers from the Tomline Refractor (left) and finder telescope (right).

7 Eyepieces and Focussing

A cover is used to close the eyepiece tube when the Tomline Refractor is not in use. To insert an eyepiece, first unscrew the cover and screw in an eyepiece adaptor. Several eyepiece adaptors are available, accommodating a wide range of eyepieces. The eyepiece pushes into the adaptor and is held in place by a small grub screw which should be tightened by hand. Eyepieces and adaptors are stored in the computer room when not in use.

The magnification provided by an eyepiece in the Tomline Refractor is given by the formula:

3894 / focal length of eyepiece in mm.

Observers most commonly use eyepieces in the range 32mm – 12mm, giving magnifications in the range 122x – 325x. Table 2 lists the magnifications provided by a selection of eyepieces.

Eyepiece focal length (mm)	Magnification (x)
50	78
40	97
32	122
25	156
20	195
15	260
12	325
9	433
6	649

Table 2. Magnifications provided by selected eyepieces.

The eyepiece tube comprises an outer tube carrying within it an inner tube held in position by a ring clip. A large knob on the outer tube controls the focus by moving the tube in or out. If the clip is loosened, it is possible to slide the inner tube in or out of the outer tube to provide more focus adjustment. (A large range of focus adjustment is necessary to accommodate some eyepieces and cameras.) After adjusting the position of the inner tube, re-tighten the ring clip.

Figure 7 illustrates removal of the eyepiece tube cover and the main components of the Tomline Refractor associated with the eyepiece.

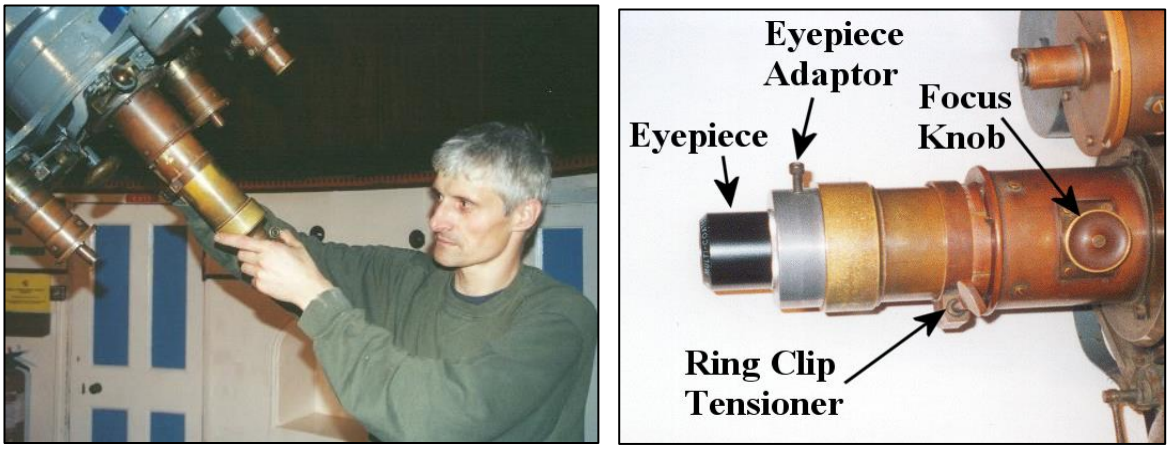


Figure 7. Left: removing the eyepiece tube cover. Right: detail of the eyepiece tube.

8 RA Drive and Speed Control

A stepper motor situated on the east side of the telescope mount provides RA drive. (It supersedes the original mechanical drive mechanism.) The stepper motor drives the telescope via a shaft with a worm wheel which engages with the RA drive wheel. (The worm gear ratio is 1:1440, and the worm gear rotates at a nominal rate 1 RPM to drive the telescope around its polar axis once every 1440 minutes; i.e. once every 24 hours.) This arrangement enables the telescope to track the motion of objects in the night sky.

A mains socket fitted to the telescope mount next to the stepper motor (see figure 8) provides power for the drive. (Note that in addition to the switch on the socket there is an on/off switch mounted on the side of the steel box housing the stepper motor.) At the end of an observing session, switch off at the mains socket the power to the drive motor.

Figure 8. Housing of the stepper motor drive (lower box) and push-to electronics (upper box).

8.1 RA Speed Control

The RA drive motor is preset to the nominal rate necessary for the telescope to track the motion of objects in the heavens. A wireless hand controller (see figure 9) enables adjustment of the rate. Buttons on the hand controller adjust the speed as follows:

- Square: increase speed (up to maximum 110% of nominal).
- Diamond: decrease speed (down to minimum 90% of nominal).
- Square and diamond pressed together and held for 1 second or longer: reset speed to nominal.
- Circle: increase speed to 170% of nominal while button held.
- Triangle: stop drive while button held.

The wireless hand controller is battery powered. In case of apparent failure of the controller, the battery should be checked. A backup, wired hand controller is stored in the eyepiece drawer in the computer room. Plug it into the 25 pin D-connector mounted above the mains cable on the side of the steel box containing the stepper motor. The layout of buttons on the backup hand controller is the same as on the wireless hand controller.

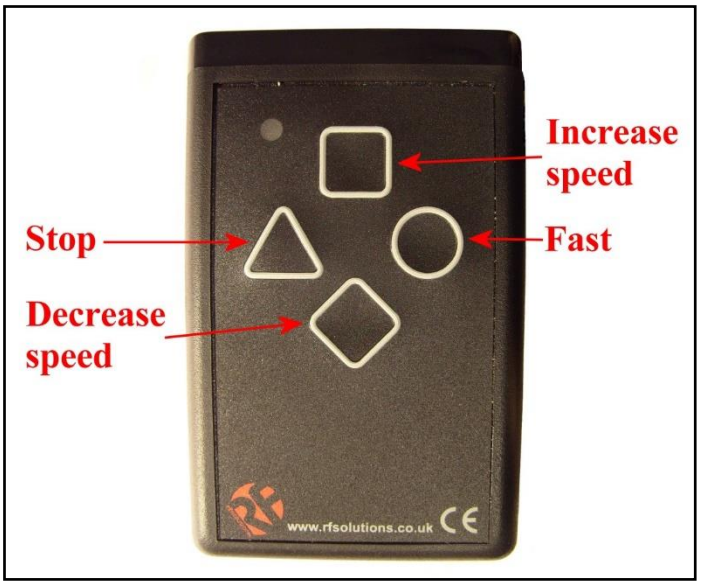


Figure 9. Hand controller for drive speed

8.2 RA Drive

A yellow lever on the west side of the telescope mount provides the means to engage/disengage the RA drive by moving the worm wheel in/out respectively of engagement with the RA drive wheel. The movements of the lever are as follows:

To engage drive: move lever slightly down, to the right then up.

To disengage drive: move lever down, to the left then slightly up.

When closing the observatory, position the lever in the disengaged position.

Figure 10 shows the yellow lever and RA drive wheel and figure 11 is a diagram of the yellow lever and its motion.

An adjustable stop determines the precise position of the worm wheel, when engaged, in relation to the teeth of the RA drive wheel. Do not tamper with this adjustable stop: it is critical to the operation of the drive and should not require adjustment in normal circumstances. Contact a member of the Committee if this stop appears to require adjustment.

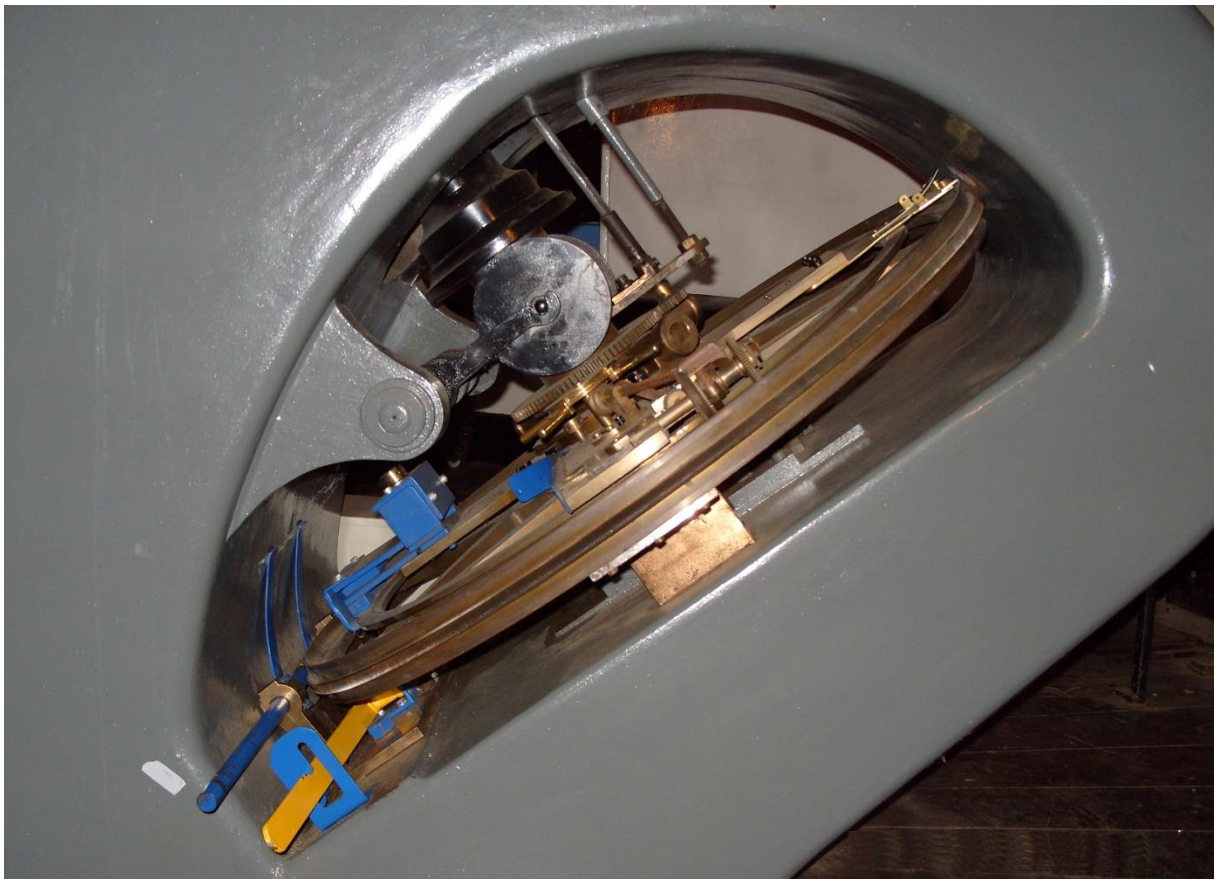


Figure 10. RA drive mechanism. (Yellow lever in disengage position).

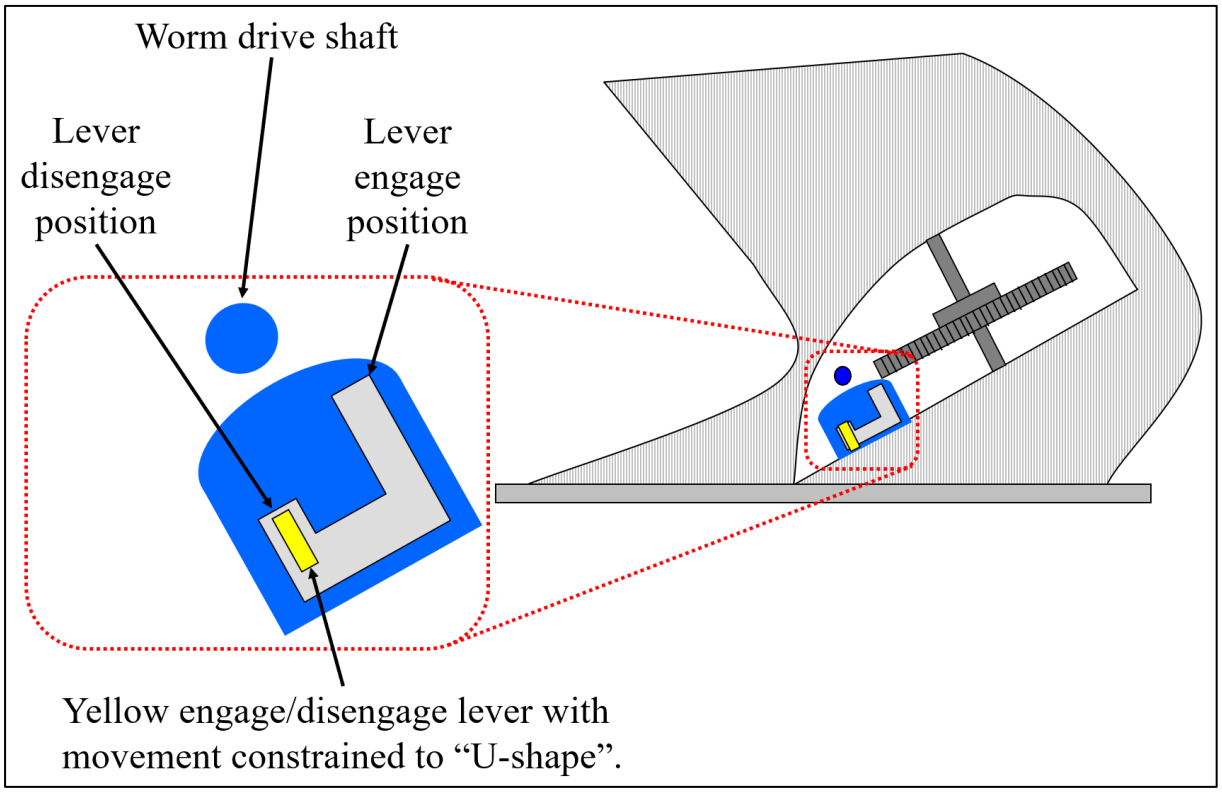


Figure 11. Engage/disengage lever for RA drive mechanism.

8.3 Friction Clutch

A friction clutch (figure 12) on the RA drive wheel transmits torque to the RA axis, but enables the axis to move relative to the drive wheel if the force involved is sufficiently great. The clutch protects teeth on the worm wheel and RA drive wheel from being stripped if too much force is required to turn the telescope.

A brass handle on top of the friction clutch engages and disengages the clutch. Turn the handle anti-clockwise to engage the clutch; clockwise to disengage it. Do not tamper with the two countersunk screws on either side of the handle. The mechanism is preset and should not be adjusted under normal circumstances. If it is necessary to disengage the clutch to set the RA of the telescope (see section 10.1), or if the clutch appears to require adjustment, contact an authorised operator of the telescope or a member of the Committee.

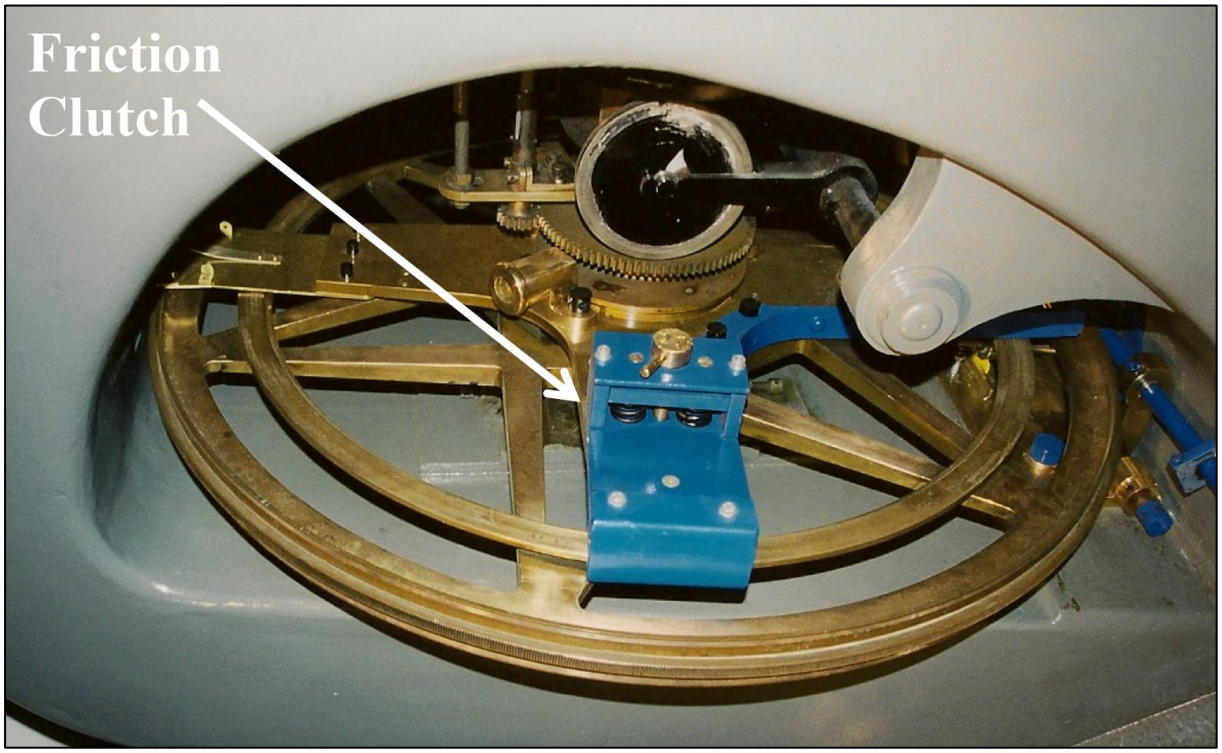


Figure 12. Friction clutch on RA drive wheel.

9 Declination Lock and Declination Adjustment

The declination lock and declination adjustment are accessed from the eyepiece end of the Tomline Refractor (see figure 13). When the declination lock is disengaged, the telescope may be moved freely in declination; when it is engaged, the telescope is essentially fixed in declination, with a limited degree of fine adjustment being provided by the declination adjustment knob.

Note that adjustment of the declination alignment will conflict with use of the push-to system – see Section 11.

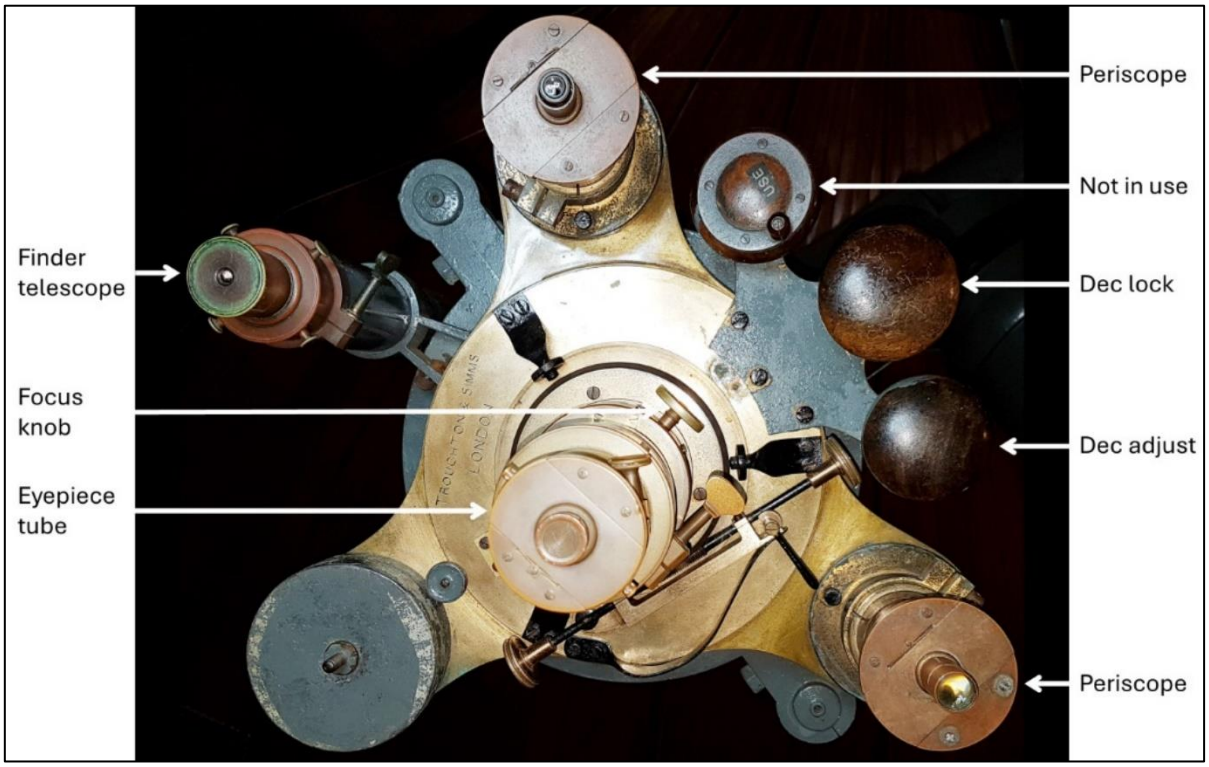


Figure 13. Eyepiece end of the Tomline Refractor showing declination controls.

10 Setting Circles

The Tomline Refractor is fitted with setting circles in RA and declination. The setting circles were used historically to position the telescope and may still be used for that purpose. They are fitted with vernier scales to enable precise positioning. However, the setting circles are nowadays largely of historic interest and their use has been superseded by the push-to system (see Section 11).

10.1 RA

The exact method used historically to set RA on the Tomline Refractor is not known. However, the following method is straightforward and works. It relies on knowledge of local sidereal time (LST), which can be obtained from websites or using tables in the BAA *Handbook*. (LST is equivalent to the RA of an object on the observer's meridian.)

The RA setting circle is inscribed on the outer rim of the RA drive wheel. The setting circle is divided into 24 hours of RA, marked by Roman numerals, and the hours are subdivided into minutes. There are three vernier scales associated with the RA drive wheel. One is fixed, positioned immediately below the wheel, accessible from the west side of the mount. The other two are located above the wheel and are fitted to a structure which rotates with the telescope around the polar axis. Depending on the orientation of the telescope, one or other of the two upper scales may be obscured by the mount. With the telescope pointing due south, the two upper scales are aligned due west and due east; the latter scale reads an additional 12^h of RA relative to the former[1].

Figure 14, photographed from the west side of the telescope mount, shows the RA setting circle and upper vernier scale.

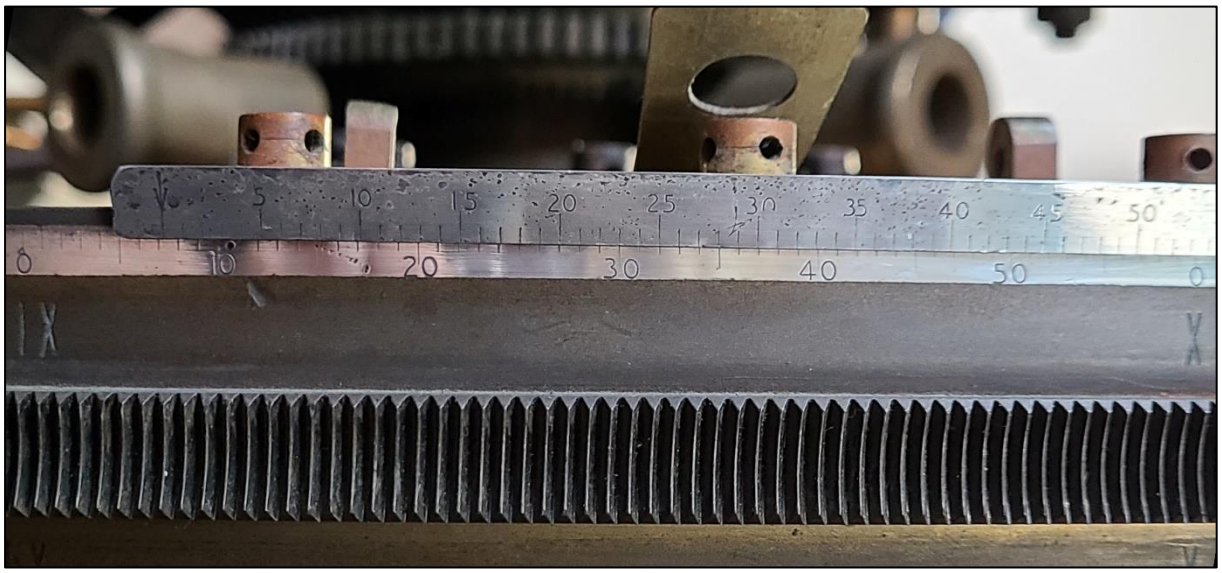


Figure 14. RA setting circle with upper and lower vernier scales.

To set RA, proceed as follows:

1. Switch on the telescope drive motor and ensure that it is set to run at nominal rate (if necessary, reset the speed by simultaneously pressing and holding the *increase speed* and *decrease speed* buttons).
2. Disengage the telescope drive.

[1] Originally, there were two additional vernier scales associated with the RA drive wheel. One additional scale was fixed below the wheel and accessible from the east side of the mount, and an additional scale was fitted to the structure rotating with the telescope around the polar axis, reading RA midway between the readings indicated by the two remaining scales. The two additional vernier scales have been removed and are stored safely and may be refitted if required.

3. Disengage the friction clutch so that the RA setting circle can rotate freely. (Request support from an experienced operator of the telescope or member of the Committee to operate the clutch mechanism.)
4. Working on the west side of the telescope mount, rotate the RA drive wheel until it indicates LST on the lower vernier scale.
5. Re-engage the telescope drive.
6. The worm wheel can only engage to the nearest minute on the RA drive wheel, so engaging the drive will generally cause the RA drive wheel to jump. Use the remote hand controller *fast*/*stop* buttons to correct the time shown on the vernier to current LST.
7. The lower vernier scale now reads LST.
8. Move the telescope until the correct RA is shown on the upper vernier scale. If possible, use the upper vernier scale facing due west when the telescope is aligned due south. If it is necessary to use the other upper vernier scale, subtract 12^h from the RA indicated on the drive wheel.
9. Re-engage the friction clutch.

Points to note about the above:

a) There must be minimal delay between establishing LST and setting the RA drive wheel accurately, or the setting will be incorrect.
b) Once the RA drive wheel is positioned to read LST, the telescope drive should not be disengaged or its speed changed, or steps 1-6 must be repeated.
c) Once the above procedure has been executed successfully, any required further change to the RA of the telescope must be made by disengaging the clutch and physically moving the instrument, not via the remote control for the drive.

10.2 RA Vernier Scales

The RA vernier scales are straightforward to use. Upper and lower scales operate on the same principles, so only the former is explained here.

Figure 15 provides an idealised view of the RA setting circle and vernier scale. The hours on the setting circle are subdivided into minutes. The vernier scale is also divided into minutes of RA, but such that 60^m on the vernier scale correspond to 59^m on the setting circle. Each division on the vernier scale is therefore 1^s ($1/60^{th}$ of a minute) shorter than on the setting circle.

To set RA to a precision of one second, rotate the telescope around its polar axis such that the desired hours and minutes of RA on the setting circle align with the zero arrow on the vernier. If the desired seconds of RA are 0^s, alignment is now complete. Otherwise, further rotate the telescope very slightly such that the marker on the setting circle just after the marker on the vernier scale for the desired seconds of RA comes into exact alignment with the latter.

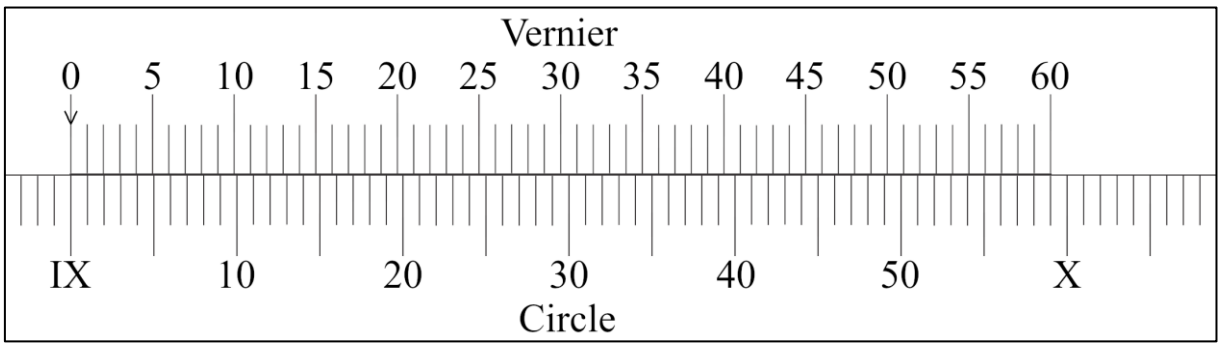


Figure 15. RA setting circle and vernier.

Example: set RA to $9^h\ 7^m\ 24^s$ – see figure 14 and figure 16.

1. Rotate the telescope around its polar axis until IX^h on the setting circle is aligned against the zero arrow on the vernier.
2. Rotate the telescope slightly further until $IX^h\ 7^m$ on the setting circle is aligned against the zero arrow on the vernier.
3. Rotate the telescope very slightly further until the minute marker on the setting circle just after the 24^s marker on the vernier comes into exact alignment with the latter.

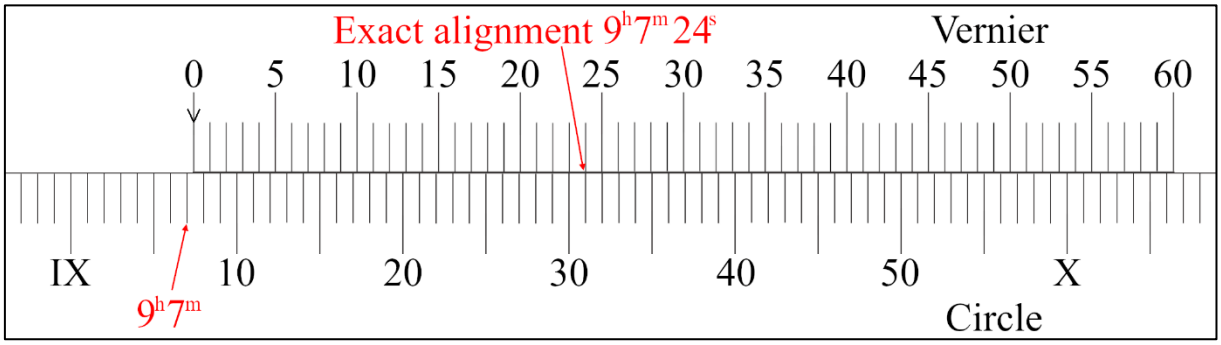


Figure 16. Setting RA to a precision of 1^s.

10.3 Declination

Th declination setting circle is inscribed on a large wheel on the opposite side of the declination axis to the telescope. Two vernier scales are fitted to facilitate precise reading of the circle. These are mounted 180° apart on the outer rim of the circle and rotate about the declination axis with the telescope. With the telescope pointing towards the celestial equator (0° declination), relative to the telescope, one vernier scale lies in the direction of each celestial pole. The setting circle nevertheless reads true declination because the inscribed scale takes account of the relative position of the vernier scales and the telescope.

For the convenience of the operator, two periscopes, accessible from the eyepiece end of the telescope, provide a magnified and re-orientated view of the declination setting circles. The operator can use these in conjunction with the declination adjustment to set the precise declination of the telescope. (Adjustment of declination in this way will conflict with use of the push-to system – see Section 11.)

To facilitate reading the full extent of each vernier scale, the eyepiece end of each periscope may be rotated to align with the tangent to the setting circle (which alters depending on the position of the telescope) and the eyepiece itself slid from side to side across the width of the periscope to move the field of view.

The periscopes are fitted one above and one below the telescope tube thus ensuring that at least one is always un-obscured, whatever the orientation of the latter. In fact, the upper periscope, which is generally more conveniently positioned, may be used when the telescope is pointing towards nearly all parts of the sky; only when observing a relatively small area between the north celestial pole and northern horizon is it necessary to use the lower periscope. There are lights, activated by pushbuttons at the eyepiece end of the telescope, to facilitate viewing the setting circle and vernier scales in the dark.

10.4 Declination Vernier Scales

The declination vernier system is considerably more complex than the RA. Figure 17 shows the setting circle and vernier scale that may be viewed from the upper periscope. Note that the photograph is a “direct” image (not through the periscope) and, because the scales are designed to be read through the periscopes, the numbers on the setting circle appear vertically inverted and those on

the vernier scale laterally inverted. When viewing either declination vernier scale through a periscope, depending on which one and on the orientation of the telescope, either the numbers on the circle are correctly orientated and those on the vernier scale both laterally and vertically inverted, or *vice versa*. For simplicity, the idealised diagrams below cover only the former situation.

Below the declination vernier scales are referred to as *inner* (closer to the setting circle) and *outer* (further from the setting circle). This prevents potential confusion associated with terms such as *upper scale* and *lower scale* which depend on the periscope and vernier in use and the orientation of the telescope.

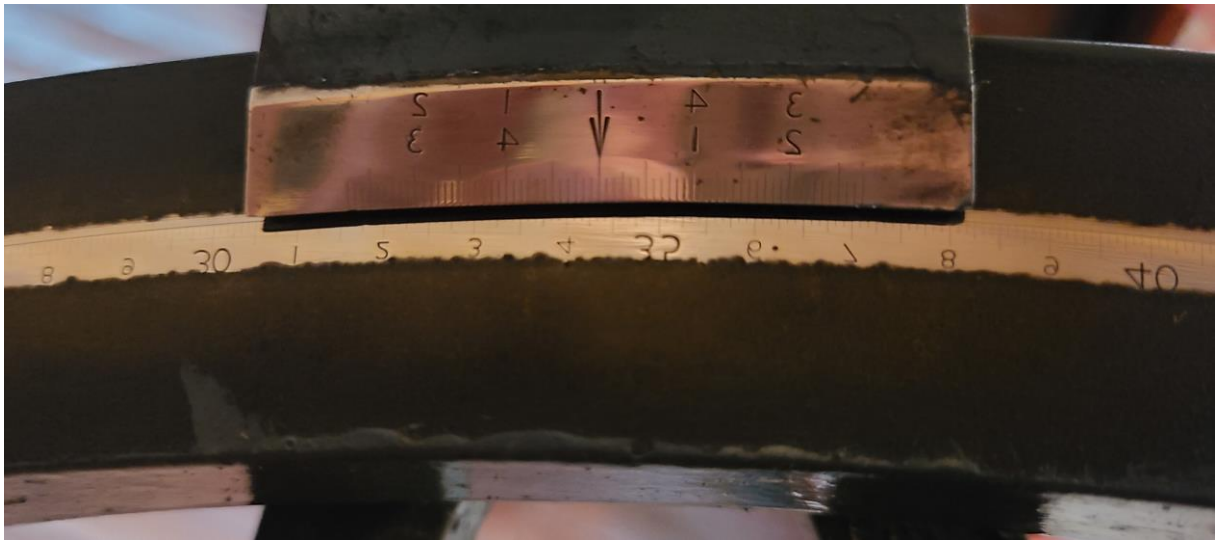


Figure 17. Declination setting circle with vernier scale.

Figure 18 provides an idealised view through a periscope corresponding to figure 17, where numbers on the setting circle are correctly orientated and those on the vernier scale are both laterally and vertically inverted.

The setting circle is inscribed with the range 0° to ±90°. (Decadic and half-decadic degrees are marked in full, but other degrees are marked with only the units value. The degree sign is not used.) Each degree is subdivided into units of one-twelfth, or 5' (minutes of arc). The vernier scale is similarly subdivided and scaled such that 5° 0' on the setting circle corresponds to 4° 55' on the vernier scale.

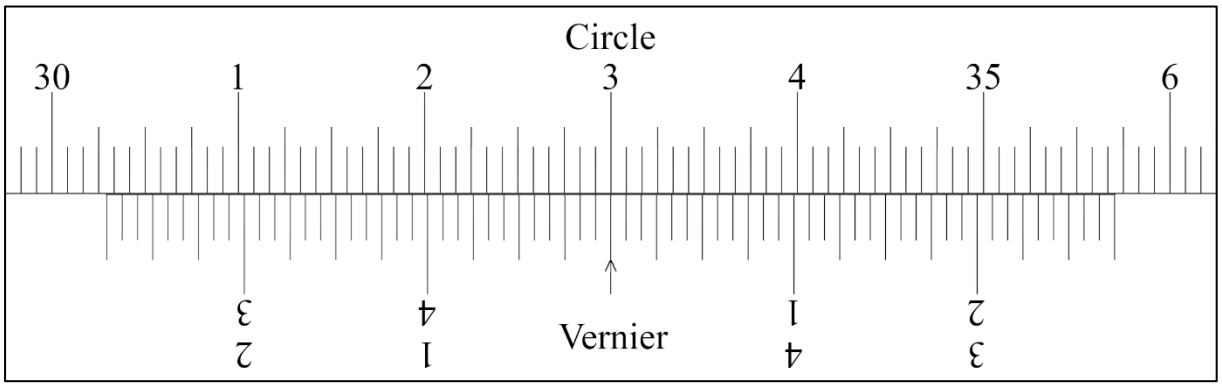


Figure 18. Declination setting circle and "upper" vernier.

The vernier scale facilitates setting declination to a precision of 5" (seconds of arc). Example: set declination to 34° 21' 40" – see figure 17 and figure 19.

4. For setting a declination north of the celestial equator, use the inner vernier scale. In case of a southerly declination, use the outer vernier scale.
5. Rotate the telescope around the declination axis such that the zero arrow of the vernier scale aligns to the 34° marker on the setting circle (the marker 4 between 30 and 35).
6. Advance the telescope slightly further such that the zero arrow of the vernier scale aligns to 34° 20' on the setting circle.
7. Rotate the telescope slightly further still until the number 1 on the inner vernier scale aligns to the mark on the setting circle immediately after it (representing 35° 20').
8. Finally, advance the telescope by a further very small amount such that the 1° 40' marker on the vernier scale comes into alignment with the marker on the setting circle immediately after it ("6", representing 36).

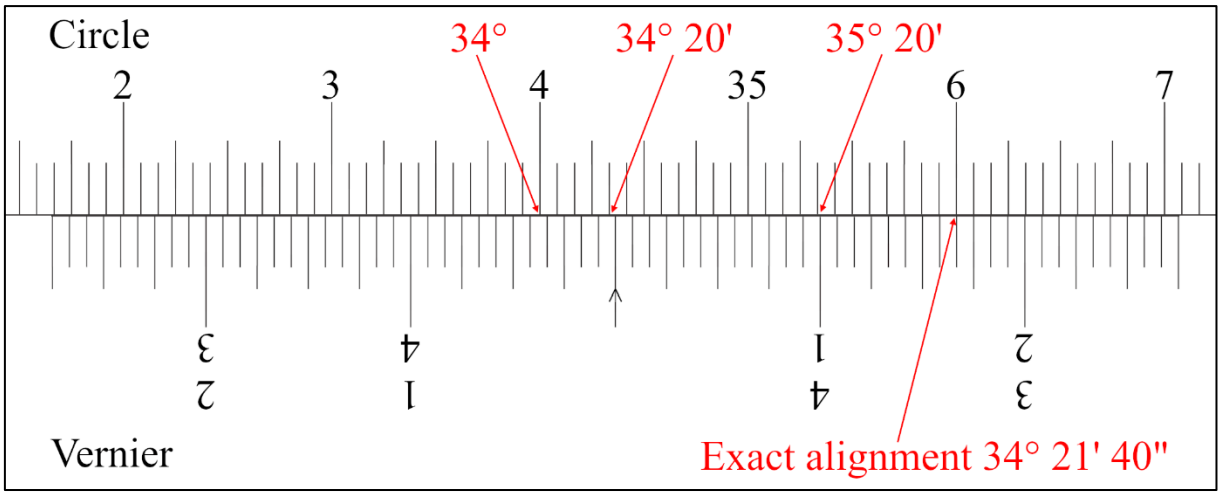


Figure 19. Setting declination to a precision of 5".

11 Push-to System

The setting circles have been superseded by a push-to system which displays on an app, running on a tablet, where the telescope is pointing in the sky. The system enables faint objects to be found with ease.

11.1 Overview

The system consists of shaft encoders fitted to the telescope and a microcontroller which communicates via Wi-Fi to a tablet running the SkySafari sky-mapping app.

A shaft encoder is dedicated to monitoring each of the RA and dec axes of the telescope (figure 20 and figure 21). Each encoder has a 50mm diameter drive wheel attached to its shaft and is mounted such that the drive wheel pushes, by means of a compression spring, against the relevant setting circle of the telescope. Each encoder produces 600 pulses per revolution of its shaft; this number is multiplied by four through the use of two channel quadrature signalling and multiplied again by the ratio of the diameter of the setting circle to the 50mm diameter drive wheel, to give the resulting pulses per revolution of the telescope as 42,679 in RA and 21,638 in dec.

Each encoder is wired through the telescope mount to a plug which connects to a small box fixed to the top of the telescope drive unit (figure 8). The box houses an Espressif ESP32 microcontroller (figure 22) running an Arduino software program which records the number of pulses output by each encoder as the telescope is moved across the sky.

Figure 20. RA shaft encoder.

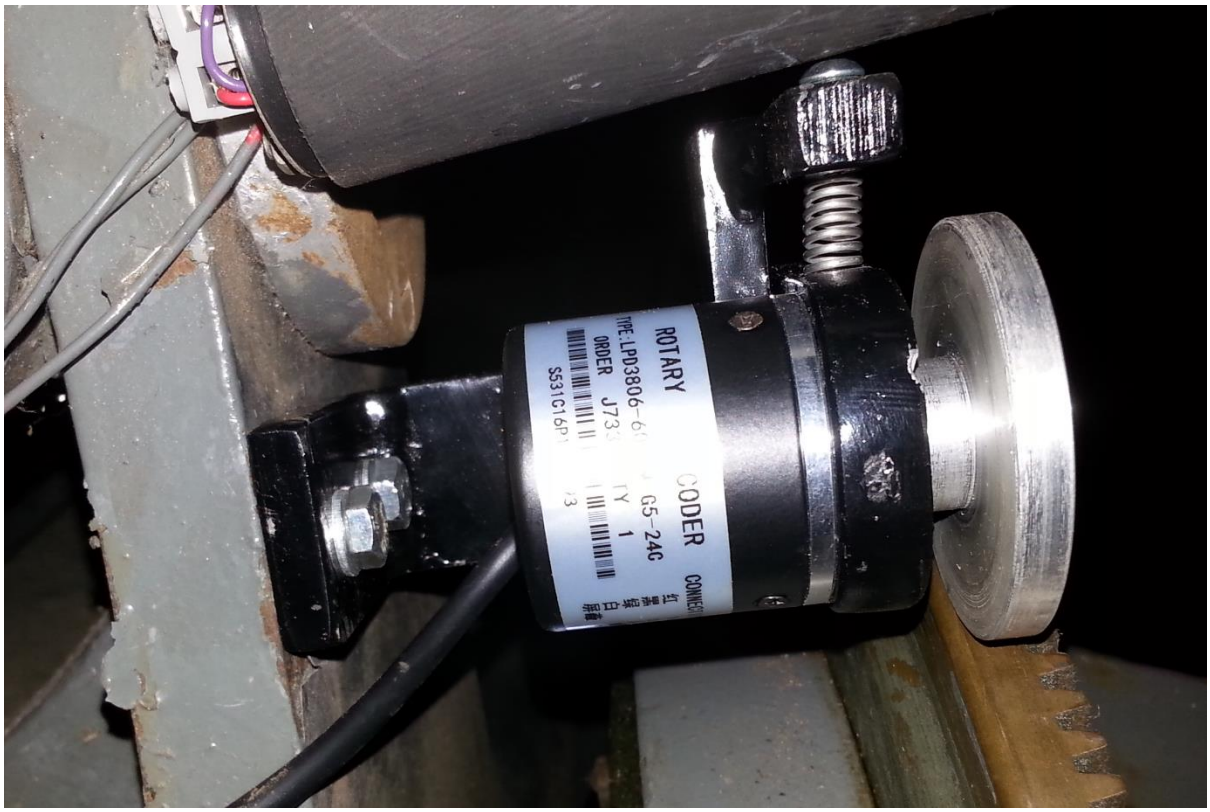


Figure 21. Declination shaft encoder.

The tablet runs the astronomy app SkySafari Pro 6. The app communicates with the ESP32 by means of wi-fi. The app tracks the movement of the telescope by continuously polling the ESP32 for the number of pulses registered by the shaft encoders since the previous poll. The app plots the position of the telescope (RA/dec) by means of a target superimposed on a map of the sky.

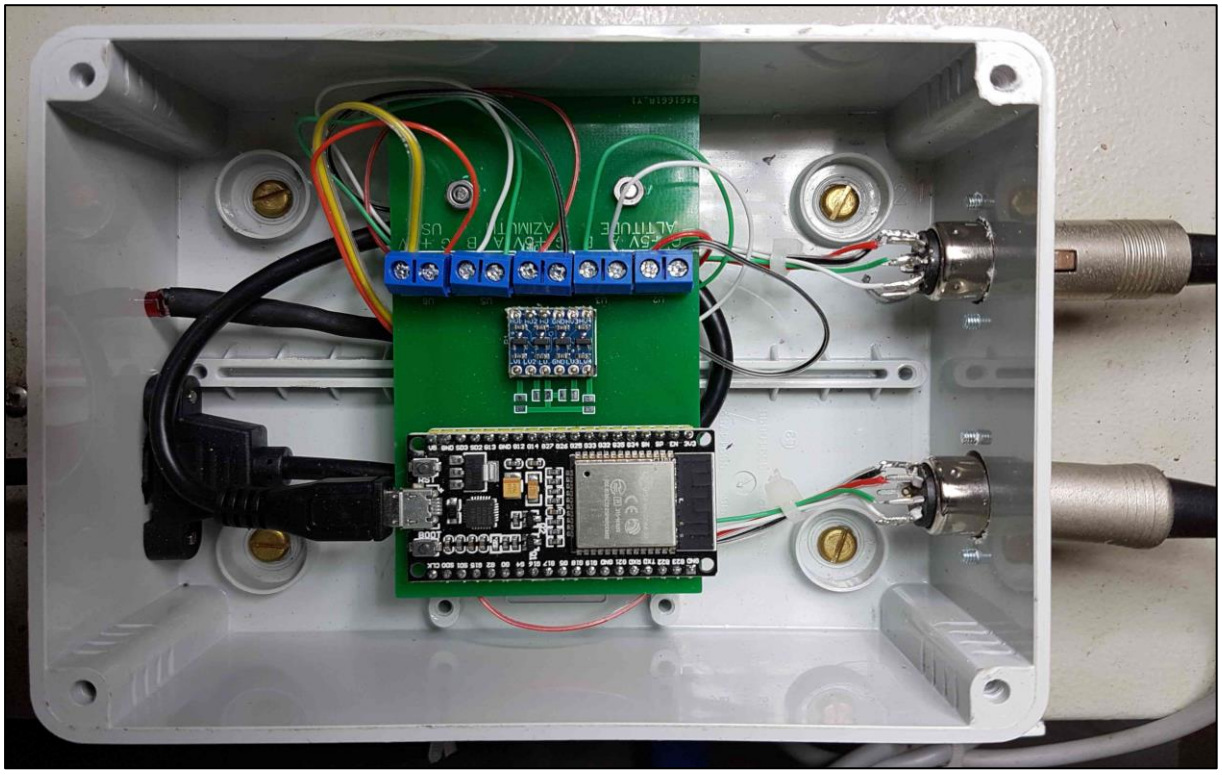


Figure 22. The Espressif ESP32 microcontroller.

Each time the push-to is switched on, SkySafari must be calibrated with the initial position of the telescope. Once calibration is complete, the target on the map of the sky will follow the view in the telescope.

11.2 Initial Alignment

1. Switch on the telescope drive and push-to system. Both are located at the base of the telescope mount, adjacent to mains sockets (figure 8).
2. Turn on the tablet. The on-off switch is a small button on the LHS of the tablet (access is somewhat impeded by the metal security cradle holding the tablet). Hold in the switch until the tablet starts.
3. On the tablet, swipe down from the top of the screen to open the notification panel. The top left icon should be coloured blue and labelled “Tomline No Internet” – if so, this indicates that wi-fi communication has been established between the push-to and the tablet; move to step 4. If not, the appearance will be as figure 23; tap the icon to connect the tablet via wi-fi to the push-to. The icon will turn blue and display the label “Tomline No Internet”. Then move to step 4. NB: the wi-fi password is configured as default data **and must not be changed**.

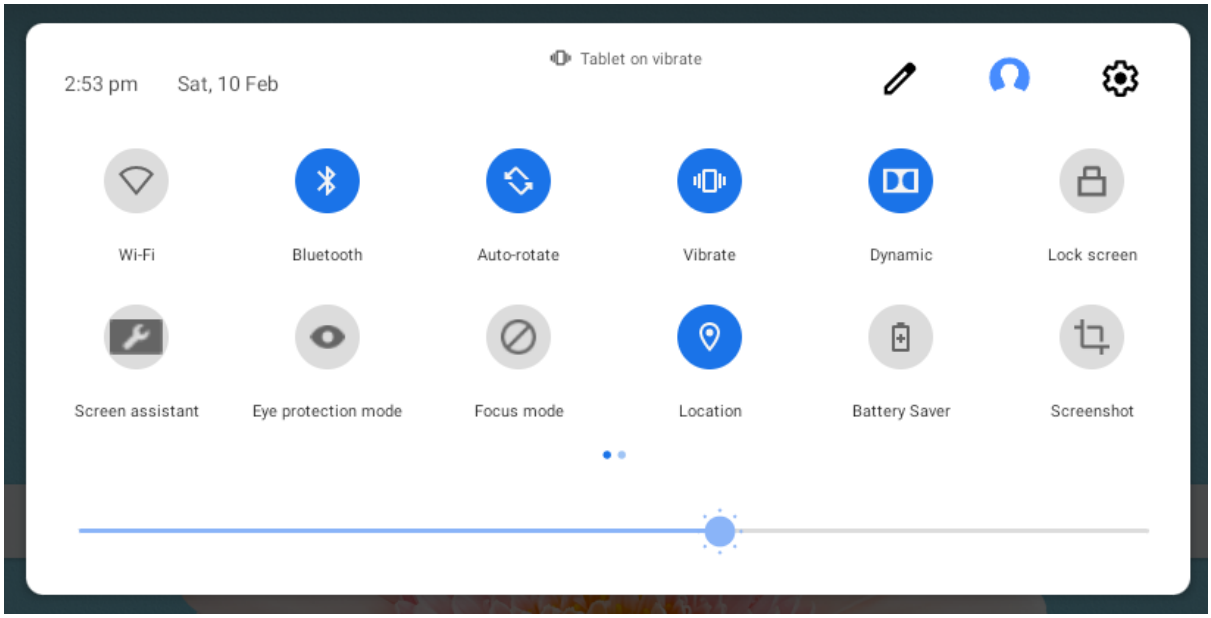


Figure 23. Notification panel on the tablet.

4. Start SkySafari Pro 6 by tapping its icon on the main screen of the tablet.
5. A sky map will appear with a row of symbols at the bottom of the screen.
6. Tap the telescope symbol, labelled “Scope”. This will bring up a ribbon box, the “telescope ribbon”, with four options: Connect, Push To, Align, Lock – see figure 24.
7. Tap <Connect>. The message “Connecting” should appear briefly and the option label should change to “Disconnect”. If “Connecting failed” appears, wait several seconds and tap <Connect> again. It can sometimes take several attempts to establish a connection.

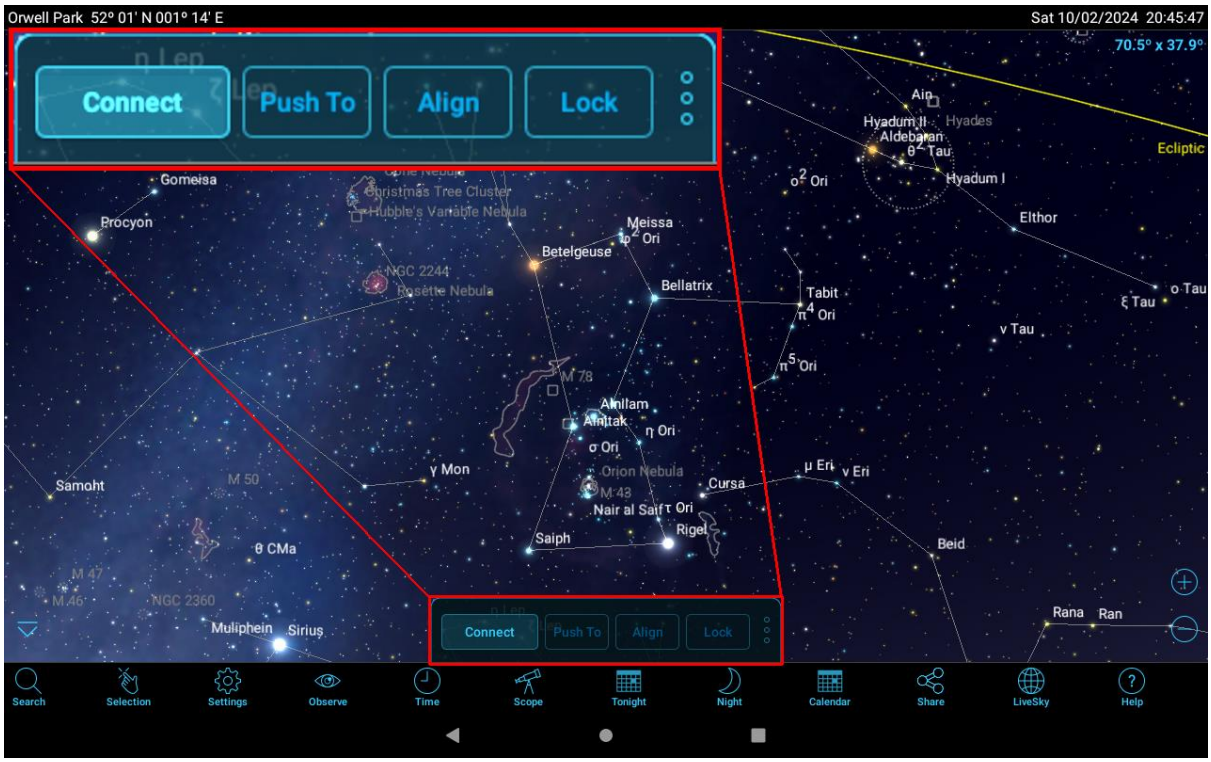


Figure 24. Sky map and telescope ribbon.

8. Find an easy-to-identify-star (Rigel, as an example) in the Tomline Refractor and centre it in the eyepiece. For best results, the star should be in the equatorial zone of the heavens. Engage the telescope drive to track the star.

9. On SkySafari, tap on Rigel and crosshairs will appear centred on the star. If necessary, zoom-in to make it easier to tap the correct star. See figure 25.

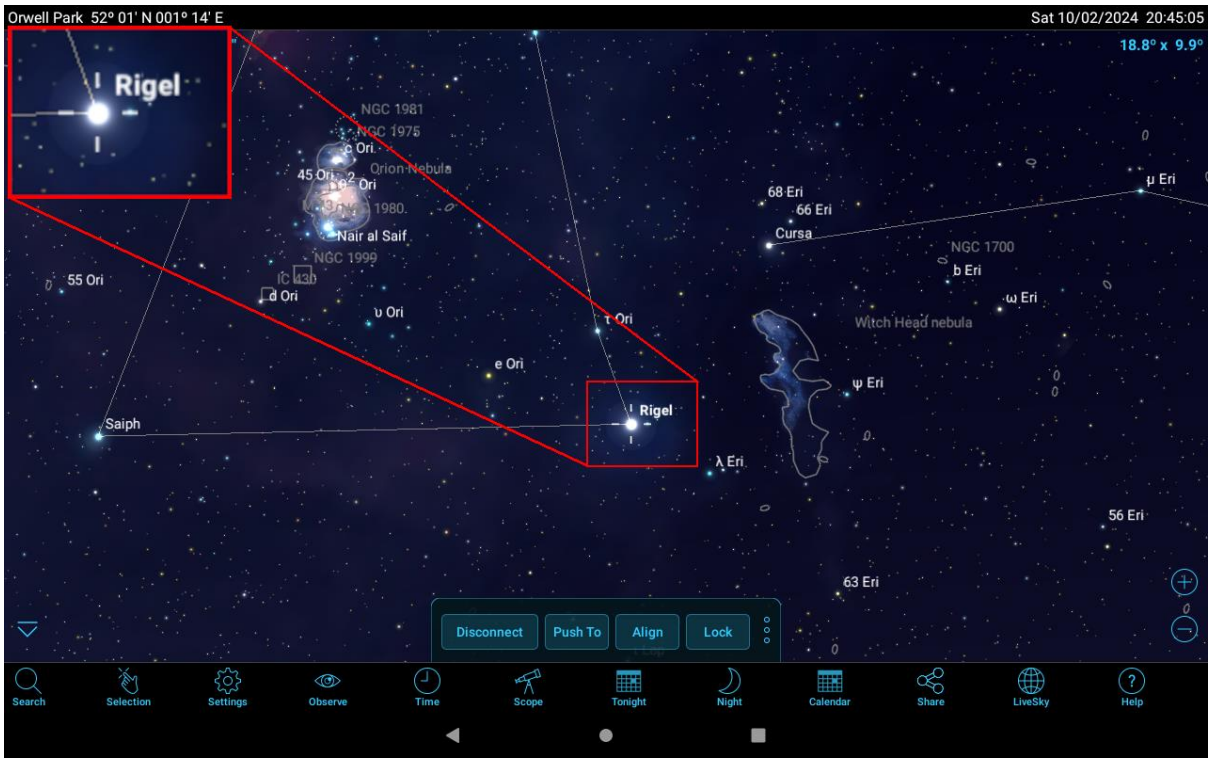


Figure 25. Crosshairs centred on Rigel.

10. Tap <Align> on the telescope ribbon.
11. SkySafari will query: “Are you sure you want to align on Rigel?” Tap <Align>.
12. A target (cross and circles) will appear, centred on Rigel, to indicate where the telescope is pointing in the sky. See figure 26.
13. A one-star alignment is now complete, and the push-to is ready for use. The target on the map of the sky will follow the view in the telescope. If the telescope is moved rapidly, the target may lag behind, but it will eventually catch up! Once alignment is complete, do not use the manual slow-motion dec adjustment on the telescope, or the telescope and target will become misaligned.

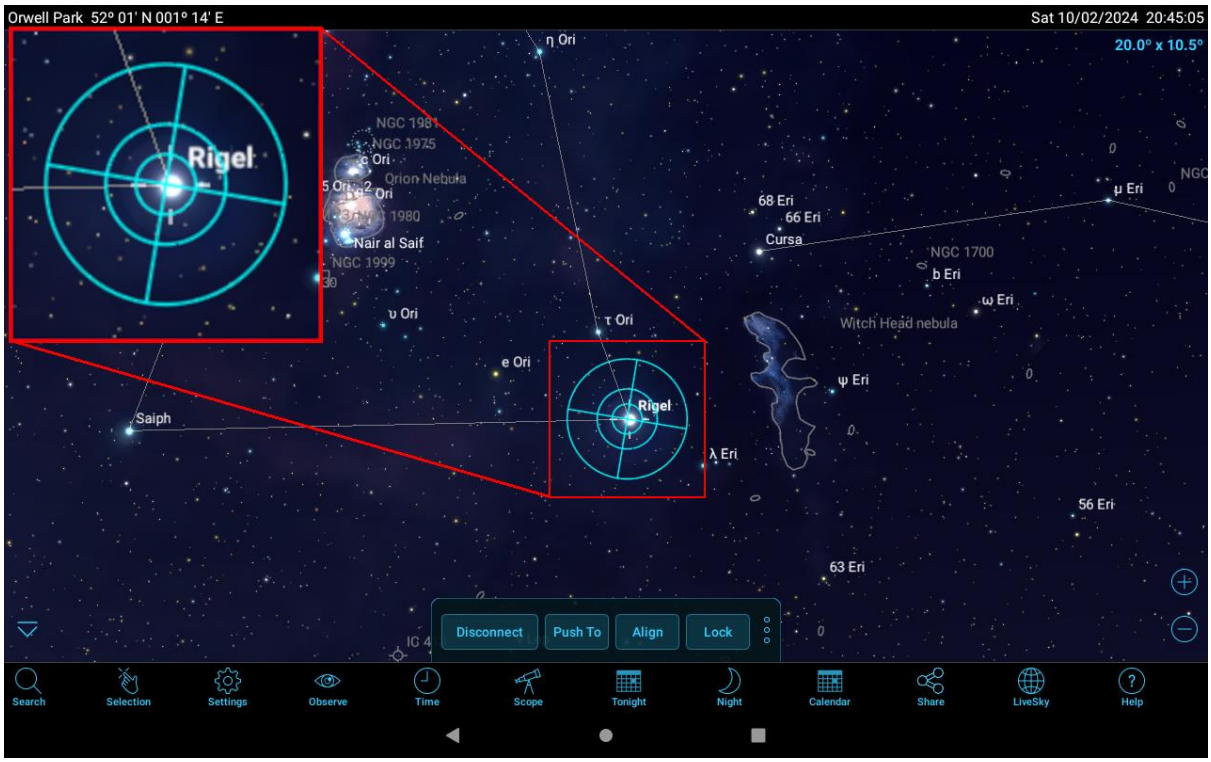


Figure 26. Target indicates where the telescope is pointing.

11.3 In Case of Misalignment

1. If, at any point, the telescope and target become misaligned, repeat steps 8-12. At step 12, tap <Restart Alignment> rather than <Align>.

11.4 Two-Star Alignment – NB: Optional

1. It is possible to repeat the procedure (steps 7-11) to achieve a two-star alignment, which supposedly confers greater accuracy. (In fact, the same procedure can be applied for up to 10 stars.) In practice, multi-star alignment appears to offer limited benefit, and a one-star alignment has proven adequate to date.
2. If undertaking a multi-star alignment, note that the stars must be at least 10° apart from each another or the procedure will fail; a much larger separation, e.g. 90°, is recommended.

11.5 Locating an Object in the Sky

1. Once alignment is complete (one-star or multi-star), to locate an object in the telescope, first find it in SkySafari and tap on it to centre the crosshairs on it. Then tap <Push To> on the telescope ribbon. An arrow will appear showing the direction in which to move the telescope. When the telescope is close to the object, the arrow will disappear, and final approach should be achieved

by moving the telescope slowly to position the target over the object in SkySafari; the object will then be centred in the eyepiece.

11.6 Shutting Down

1. When finished observing, tap the square button < ■ > at the bottom of the screen then tap “Clear all”. Push the power button on the tablet and tap <Power off> on the screen.
2. Turn off mains power to the push-to system and telescope drive.

11.7 Settings For The Tomline Refractor

Should the settings in SkySafari for the push-to system need to be re-entered, they can be found under “settings -> telescope” and are as follows (figure 27).

- ssid – Tomline.
- Password - Ask Martin Cook to reset.
- Scope type - Basic Encoder System.
- Mount type - Equatorial Push-To.
- Connect via WiFi.
- No Auto-Detect SkyFi.
- IP Address 192.168.4.1.
- Port Number 80.
- Readout Rate: 10 per second.

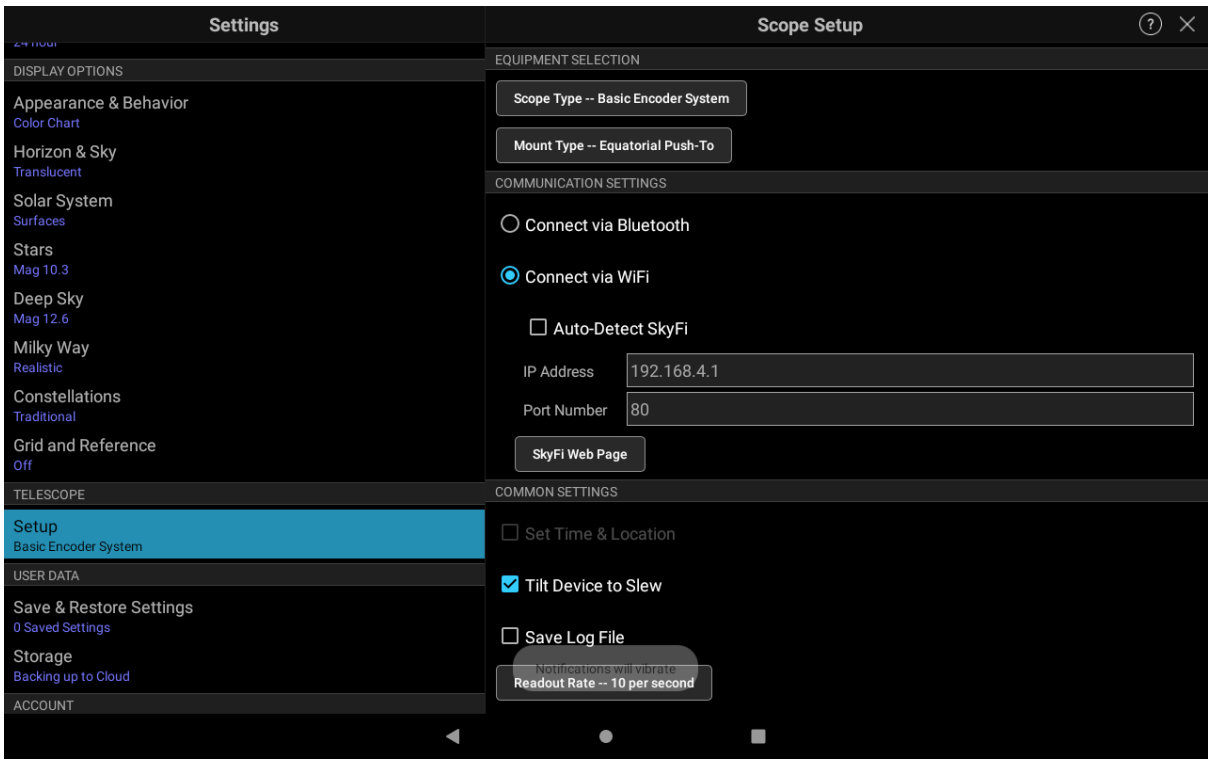


Figure 27. Settings in SkySafari.

12 Solar Observing

NEVER LOOK DIRECTLY AT THE SUN THROUGH AN OPTICAL INSTRUMENT UNLESS IT IS SPECIFICALLY CONSTRUCTED FOR THE PURPOSE AND CERTIFIED TO BE SAFE TO DO SO.

If you wish to use the Tomline Refractor for solar observing, you must use the projection method as follows.

12.1 General safety precautions

1. Two Committee members, experienced in use of the Tomline Refractor for solar projection, must be present in the dome to supervise observing. (One or other may briefly exit e.g. for comfort breaks.)
2. In addition to the two Committee members, personnel in the dome during setting up of equipment and observing should all be members of OASI. No access should be provided to members of the public (i.e. no guests).
3. If members of Orwell Park School ask to be present during solar observing, consider instead offering to provide a dedicated solar observing session for them in the school grounds using telescopes equipped with certified solar filters, rather than the Tomline Refractor. Nevertheless, if they insist on being present during solar observing with the Tomline Refractor, ensure that safety procedures are agreed in advance with the responsible teacher(s).
4. If observing with a group, ensure that all members have been briefed and understand the need to take care. Ensure that members of the group cannot look into the eyepiece of the Tomline Refractor either accidentally or intentionally.
5. Keep the OG cover on the finder telescope throughout the entire observing session.
6. If stepping away from the Tomline Refractor temporarily, move the telescope to the east of the Sun (i.e. behind the Sun in terms of the drive of the telescope) so that the OG is pointing into the dome and not out of the aperture.
7. For best results and for safe observing, use the projection screen holder constructed for the Tomline Refractor (figure 28). Attach the projection screen holder to the telescope and adjust its position as necessary by loosening the mounting blocks and sliding the mounting rods parallel to the optical axis of the telescope. A distance between eyepiece and projection screen of approximately 1 metre is generally satisfactory. When the screen is secure, clip/pin a sheet of white card to it.
8. Use a low power eyepiece so that heat from the Sun will not be too concentrated in the glass elements of the eyepiece. The eyepiece should be an old, un-cemented type, e.g. the 32mm ex-military surplus model.

12.2 Sunshade

It is possible to undertake solar observing without use of a sunshade covering the aperture in the dome to prevent the ingress of stray light. However, stray light entering the dome will result in an image with poor contrast and, to obtain good results, a sunshade should be used. A sunshade was constructed for use during observation of the transits of the inner planets in the early years of the 21st Century. It is stored in the observatory; however, fitting it is a significant undertaking which requires the participation of several personnel and the erection of scaffolding in the dome.

The decision to use or not a sunshade has implications for how the Tomline Refractor should be aligned on the Sun, as below.

Figure 28. Attaching the projection screen to the Tomline Refractor.

12.3 Aligning the Tomline Refractor on the Sun

DO NOT ALIGN THE TELESCOPE BY LOOKING THROUGH THE EYEPIECE OR FINDER TELESCOPE.

Initially, keep the cover on the OG of the Tomline Refractor.

Aligning on the Sun – when using a sunshade

1. Point the Tomline Refractor approximately towards but a little below the Sun.
2. Remove the cover from the OG.

3. Make successive sweeps with the telescope from left to right across the width of the dome aperture, on each sweep slightly increasing the altitude to which the telescope is aimed. Once a portion of the Sun appears on the projection screen, the telescope should then be moved slowly to centre the image on the projection screen.

Aligning on the Sun – no sunshade

1. Align the Tomline Refractor by positioning it to minimise the size of shadow that it casts on the projection screen.
2. Remove the cover from the OG.
3. Finalise alignment of the telescope so that the projected image sits centrally on the projection screen.

12.4 Orientation of the Projected Image

The orientation of the projected solar image is as follows.

- North-south: direct orientation (non-inverted).
- East-west: reversed.

13 Closing the Observatory

When leaving the observatory, make sure that the equatorial room and belvedere room are closed and secured. Use the following checklists.

13.1 Equatorial Room

1. Rotate the dome so that the shutter is positioned to the north-east, above the door to the computer room.
2. Close the shutter, bolt it and attach the wind clip (see Section 4). Clip the opening rope back into its retaining clips on the dome wall at the shutter opening.
3. Disengage the Tomline Refractor RA drive, switch off the RA drive motor at the mains and unlock the declination axis.
4. Switch off the push-to system (if used).
5. Replace the OG cover and the eyepiece tube cover of the Tomline Refractor, and the OG cover of the finder telescope.
6. Position the Tomline Refractor so that the telescope tube is positioned above head height, lying below its RA axis, aligned in an east-west direction.
7. Put away all eyepieces and accessories in the computer room.
8. Ensure that the electric heater in the computer room is plugged in and switched on. Switch off all other electrical equipment.
9. Switch off lights in the transit room and computer room and lock the doors.
10. Switch off the lights in the equatorial room and lock the door.

13.2 Belvedere Room

1. Retrieve any telescopes used on the balconies, shut and lock the balcony doors.
2. Switch off all electrical appliances at the mains, apart from the observatory mobile phone, which should be left on charge.
3. Switch off the lights and lock the door.

13.3 General

1. Complete the observatory logbook to record the names of all people present and details of any observations or other activities undertaken.
2. Ensure that the stairs from the observatory are clear of any obstacles.
3. Make sure no-one remains anywhere in the observatory.
4. Switch off all lights.
5. Lock all doors on exit.

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