The 1.82m Copernico Telescope – User Manual
L. Tomasella, S. Benetti, V. Chiomento, A. Frigo, G. Martorana, M. Rebeschini, L. Traverso, M. Fiaschi

Technical Report n. 26
September 2017

Document available at: http://www.oapd.inaf.it/
**NB:** It is mandatory that publications based on Ekar-Asiago proprietary or archive observations shall have in a footnote on the first page of the article or in the Acknowledgments section the following citation:

“Based on observations collected at Copernicus (or/and Schmidt) telescope(s) (Asiago, Italy) of the INAF - Osservatorio Astronomico di Padova.”

1 Introduction

In 2014-2015 the 182cm Copernicus telescope, the principal instrument at the observing station of Mount Ekar, underwent several major changes. In particular, the change of the AFOSC (Asiago Faint Objects Spectroscopic Camera) detector and the fine-tuning of the remote control of the telescope triggered an update of all the control systems of both the telescope and the instruments. This manual includes instructions on the new control software of the telescope, in addition to the main information on the telescope and instruments (as already included in previous manuals; a complete list of technical reports is available on the web, see [www.oapd.inaf.it](http://www.oapd.inaf.it), Asiago Site menu). See *AFOSC User Manual* by Tomasella et al. for instructions on the Asiago Faint Object Spectrograph and Camera (AFOSC) and its control software.

On November 1997, the observatory at Mount Ekar has been dedicated to professor Leonida Rosino (Treviso, 19 September 1915 – Padova, 31 July 1997).
2 Main Telescope characteristics

The telescope is located at the top of Mount Ekar at the following coordinates:

Longitude: E11° 34' 08.397"
Latitude: N45° 50' 54.894"
Height: 1376.2m a.m.s.l.

Its construction was completed in 1973.

The telescope is a classical Cassegrain reflector with an equatorial fork mount. The secondary mirror can be moved on 5 axis for focusing and optical alignment. The following table lists the basic optomechanical parameters of the telescope (from Barbieri & Galazzi 1973):

<table>
<thead>
<tr>
<th>M1</th>
<th>M2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total mass: 1500 kg</td>
<td>Total mass: 67.4 kg</td>
</tr>
<tr>
<td>Diameter: 1820 mm</td>
<td>Diameter: 580 mm</td>
</tr>
<tr>
<td>Thickness (external ring): 300 mm</td>
<td>Clear diameter: 566 mm</td>
</tr>
<tr>
<td>Central hole diameter: 383 mm</td>
<td>Thickness (external ring): 110.3 mm</td>
</tr>
<tr>
<td>Conic constant: -1</td>
<td>Conic constant: -3.943</td>
</tr>
<tr>
<td>Curvature radius: 10786 mm</td>
<td>Curvature radius: 4594.8 mm</td>
</tr>
<tr>
<td></td>
<td>Telescope equivalent focal length: 16315.5 mm</td>
</tr>
</tbody>
</table>
3 Instrumentation


Both instruments are mounted at the Cassegrain focus of the telescope. AFOSC is usually offered during dark and grey times and the Echelle spectrograph during bright time.

Figure 1: The Echelle high-resolution spectrograph

Figure 2: The AFOSC imager and spectrograph
4 The rotator-adapter

The Rotator Adapter represents the interface between the telescope and the instrumentation. Furthermore, it hosts the guide probe and the calibration arm. The rotator adapter can be rotated at any angle, thus it allows to observe an object at any position angle. A 90 degrees rotation is performed in 20 seconds. The accuracy of the positioning is within 1 arcmin. The rotation, the guide probe and the calibration arm can be controlled from AFOSC+CCD or the Echelle+CCD control software.

4.1 The guide probe

The guide probe is the system carrying the guide camera. A folding mirror at 45 degrees with respect to the optical axis of the telescope redirects the beam towards the guide camera on the rotator adapter plane. The probe can be moved along two axes, covering a rectangular area around the optical axis of the telescope (46x28 arcmin). When the calibration arm is inserted, the probe is parked in a corner.

4.2 The calibration arm

The lamps for the wavelength calibration are attached to the integrating sphere to ensure the homogeneity of the beam. The integrating sphere is positioned below the rotator adapter. The optical system of the calibration arm consists of the following elements:

- The light from the integrating sphere is directed towards the calibration arm by a folding mirror
- A lens (focal length 8 cm) transforms the beam in f/9 (as that of the telescope)
- A folding mirror redirects the beam toward AFOSC

When a calibration sequence is completed, the calibration arm is parked in a position far from the telescope optical axis.
5 The Guider Cameras

As explained previously, two instruments are available at the Copernicus telescope: AFOSC and Echelle spectrograph. Each instrument has a dedicated guider camera and software.

With **AFOSC**, the Auto-Guiding is performed by using a star outside the instrument’s field of view. A folding mirror inside the rotator adapter redirects the light towards the guide camera. The useful areas are to the left and to the right sides of the scientific field. The total travel of the probe is 46 arcmin on the X axis and 28 arcmin on the Y axis. The repeatability in positioning a star in the guide camera’s focal plane is about 0.1 arcsec.

The main characteristics of the guide camera are listed below:

- Sony IMX-174M CMOS sensor
- Pixel scale: 0.296 arcsec/pixel (binned 4×4)
- Field of View: 2.4×1.5 arcmin
- Limiting magnitude: 17 (3 sec. exposure at maximum gain)

The whole field of view of the guide camera is useful for guiding, being free of strong optical aberrations. The image orientation of the guide camera is North up and East left. The procedure to find the guide star is described in the AFOSC manual.

With **Echelle**, a Proxitronic intensified camera sees the telescope field-of-view reflected by the slit, with these main characteristics:

- Field of View: 3.0×2.2 arcmin
- Limiting magnitude: 18 (10 sec. integration with high gain)
6 Telescope Performances

6.1 Pointing

The typical pointing error of the telescope is less than 1 arcmin thanks to a pointing model. The resolution of the encoders is 4.364 arcsec. Therefore, it is not possible to point the telescope with a better precision than this using only the encoders.

6.2 Movements

The telescope can be manually moved at three different speeds:

- Large: 1 degree/s
- Medium: 2 arcmin/s
- Micro: 2 arcsec/s

The pointing is performed by moving the telescope using the TPS Telescope Pointing System, which is explained in Sec. 14.1.

7 Tracking and guiding

The telescope is set automatically in tracking mode when MICRO or MEDIUM movements are inserted. The telescope is also allowed to work with differential tracking. Tracking performances make auto-guiding mandatory for exposure times longer than 1 minute in typical working conditions. The Guider software for AFOSC and Echelle are explained in Sec. 16.

7.1 Autoguiding

The autoguiding procedure is performed by a dedicated software (Autoguider) and based on the calculation of the centroid of a star seen by the guide camera. If the flux from the guiding star becomes less than a predetermined threshold over the background (for example, for the onset of clouds), the autoguider stops sending corrections. Once the guide star is detected again, the software takes as reference the previous position, so there will be no shifts of the science-target on the detector.

8 Image quality

The Typical natural seeing at Mount Ekar is under 1.5 arcsec. This natural seeing of the site is measured frequently on images taken with the Schmidt 67/91 telescope, where the internal temperature of the dome is always in thermal equilibrium with the outside temperature.

On the sky quality monitor webpage (see Sec. 9) there is a link to an external webpage showing an astronomical seeing forecast:

Pay attention mainly to the columns labelled “seeing index” (1 and 2), “Jet stream” and “Bad layers (K/100m)”: if any of these columns is not green, the natural seeing will probably not be good.

Stellar images with FWHM under 1 arcsec can be obtained with Copernicus telescope if the main mirror is in thermal equilibrium with the outside temperature. Opening the windows (this can be done remotely from the “Copernicus Relay Control”, see Sec. 11) at sunset can help to improve the quality of the images.
9 Ekar weather station and weather limits

The Ekar weather stations are located one in the balcony of the telescope building (direction SW) and one in the field between the Copernicus and Schmidt domes. A set of temperature and humidity sensors monitor the conditions in different points of the dome and of the telescope. Meteorological conditions are continuously updated on the page [http://www.oapd.inaf.it/meteo/](http://www.oapd.inaf.it/meteo/).

Links to plots showing the weather evolution of the last 12 hours, last 30 min and webcams to see the sky conditions are also available. Another weather station located in the field outside the dome, gives the sky quality: **clear**, i.e. without clouds; **haze**, i.e. partially covered; **overcast**, i.e. totally covered. This weather station has also a rain sensor. Meteorological conditions from this station are shown on the page: [http://meteo.astro.unipd.it/weather/meteoLC.php](http://meteo.astro.unipd.it/weather/meteoLC.php)

Outside conditions, in particular humidity, sky quality and wind speed, must be controlled throughout the night. There are some weather limits for the observations (see the following chapter) and the observers must know that all the weather sensors data are recorded and cross-correlated with the temporal data of the observations. The TPS reports the critical weather data for the safety of the telescope, i.e. wind speed, humidity and sky quality.

10 Constraints for observations

The observer is responsible for the safety of the telescope and the instrumentation: they must observe the following rules and must monitor the weather stations and webcams throughout the night: they must immediately close the mirror and the dome if the weather conditions are unsafe.
10.1 Weather limits

The TPS control software prevents the observer from opening the dome if the weather conditions are not safe and automatically closes the dome if the limits are exceeded. When the outside humidity exceeds 92%, the dome must be closed.

⚠️ In case of wind gust over 12 m/s the dome has to be closed immediately. If the sky quality is poor (haze) the dome must be closed.

⚠️ It is also forbidden to open the dome if there is snow on it: the technical team must first inspect the dome to certify that it is safe to open it.

10.2 Telescope mechanical limits

⚠️ It is not possible to automatically point targets with elevation above the horizon lower than 20 degrees.

This limit is imposed to avoid permanent misalignments of the telescope optics. Moreover, there is a mechanical lock stopping the telescope in case it accidentally reaches an elevation lower than 10 degrees above the horizon. The lock can be disengaged only by the technician on the following morning.

It is not possible to automatically point targets with a declination over +88°.

⚠️ Do not point the telescope in antimeridian position (i.e. using the keypad, do not move the telescope past +90° of declination: the control system cannot manage the telescope movements in this position).

⚠️ It is not possible to automatically point targets with an hour angle over +11h 30m or under -11h 30m.

There are no position limits in hour angle. However, it is not possible to do more than 1.25 turns in a given direction. If the limits are reached, a mechanical lock stops the movement, and the system can be unlocked only by the technical staff.

10.3 Software safeties

Some safety watchdog timers are enabled during the observations. If the connection between the dome controller and the TPS software is lost for more than 5 min, the dome shutter will be automatically closed.

If the connection of the remote desktop is lost for more than 10 min, the dome shutter will be automatically closed and the telescope stopped.

If the telescope elevation is lower than 15°, the tracking will be stopped.
11 Starting the system

Observers must arrive well in advance at Asiago Astrophysical Observatory, and must be trained by the technical staff or by the local astronomers before starting the observing run.

The telescope is remotely controlled from the control room located in the main building of the Astrophysical Observatory in Asiago (Pennar), Dep. of Physics and Astronomy, University of Padova (scientific control room). A secondary control room, which can be used for educational activities with groups of students, is located in the Galileo telescope building (educational control room). The observer must work from the main building at Pennar, by opening remote connections with the telescope’s system (prepared by the technical staff during daytime). Two computers located in the scientific control room (having 2 screens each) are dedicated to the remote control. For security reasons only few network connections are allowed from these computers, so the observer must use other devices to navigate the web.

These local PCs are always switched on: do not shut them down.

The use of the educational control room must be authorised by the Observatory Director.

Inside the scientific control room, the PC located on the left controls remotely STRUMENTI-T182, which is the pc where the software for the acquisition of data runs (AFOSC+CCD or Echelle+CCD). The PC located on the right controls remotely PUNTAMENTO-T182, which is the pc where the Copernicus Relay Control, the TPS (Telescope Pointing System, explained in Sec. 14.1) and the Guider (Sec. 16) run.

Here the list of operations, to follow step by step, to initialize the system:

1. First of all, to see the telescope and the dome aperture on webcams, from the PC on the right, click on “DVRemote” and select the address: 147.162.193.209

2. Four frames show the dome webcams. Turn on the microphone by clicking on the speaker symbol:

3. From the PC located on the right: click on the “Puntamento T182” icon to connect remotely to PUNTAMENTO-T182.

4. A browser will be opened showing the technical staff check list, reporting useful information about the system status; you can also access it at the address: www.oapd.inaf.it/checklist
5. From the PC located on the left: click on “Strumenti T182” to remotely connect to STRUMENTI-T182.

6. If the technical staff has already initialised the system the observer can skip the following steps and start to work.

7. On PUNTAMENTO-T182: start “Relay Controller” and, when opened, click on:

   - “Instrumentation+CCD Power” to switch on the instruments on the telescope flange
   - “CCTV” to switch on all the webcams
   - “Guide Cam AFOSC” only if AFOSC is installed

   Caution: If Echelle is installed: do not switch on the “Guide Cam Echelle” at this point!

8. On PUNTAMENTO-T182: start “TPS” and “AFOSC Guider” or “Echelle Guider” depending on the installed instrument.


10. When “AFOSC+CCD” or “Echelle+CCD” is open, connect the CCD and start the CCD cooling (see AFOSC or Echelle Manual for more information on these software)


   Caution: watch out for any objects (ladder, mechanical devices, etc...) in the dome preventing the telescope and the dome from moving freely!
12. On “Copernicus Relay Control”: click on “Start system” to power the telescope and wait until the TPS shows the telescope's coordinates.

13. Click on “Start M1” (the top ring camera is switched on) and the telescope is ready to be moved.

14. About 40 sec after starting the system, M2 is automatically switched ON.

15. On “AFOSC+CCD” (or “Echelle+CCD”): from “Utilities” and “Telescope Focus” manually insert z = 7 mm (or 20 mm when using Echelle) as a starting point for the focus (then the focusing will be done on the sky with a real star, see the AFOSC or Echelle User Manual).
12 At the end of the night

1. On “AFOSC+CCD” or “Echelle+CCD”: warm up the CCD.

!!! NB: wait the end of the ramp before disconnecting the CCD and switching off the system (it takes about 20 minutes) to avoid damage to the CCD sensor!!

When the ramp is complete the message “end of controlled warming ramp” is displayed in the log window. At this point disconnect the CCD

2. On “TPS” menu: park the telescope by clicking on “Telescope” and “Park”. The mirror will be closed as well.

3. On “TPS” menu: close the dome by clicking on “Dome” and “Close”.

!!! NB: Look at the top ring camera to make sure that the dome is completely closed !!!

4. On “Copernicus Relay Control”: click on “STOP M1” and then “Stop System”

5. Close the Guider software and Switch off the “Guider Cam AFOSC” if still powered.

6. On “Copernicus Relay Control”: only when the warming ramp of the CCD has ended, click on “Instrumentation+CCD Power” to switch off the instrumentation on the telescope flange.

!!! NB: only after switching off the instrumentation power, is the system protected from lightening, so the observer must go through all these steps !!!

7. Switch off the dome light and “CCTV”.

8. On **PUNTAMENTO-T182**: close “Copernicus Relay Control”, “TPS”. Close the remote connection to PUNTAMENTO-T182

9. On **STRUMENTI-T182**: close “AFOSC+CCD” or “Echelle+CCD” and “DS9”. Close the remote connection to STRUMENTI-T182

10. Close “DVRemote”

11. Fill in the **Night Report** form

The observer must fill in the night report at the end of each night: from [www.oapd.inaf.it](http://www.oapd.inaf.it), go to “Asiago Site”, “Telescope and Instrumentation” and click on the “Night Report” link. You can open it directly from this address: [www.oapd.inaf.it/nightreport](http://www.oapd.inaf.it/nightreport)

This is essential for the technical staff to promptly resolve technical problems occurred during the night. In addition, the data on sky conditions will be used for the annual statistic.

!!! DO NOT FORGET TO FILL IN THE NIGHT REPORT !!!
13 Focusing the telescope

The focusing of the telescope is performed by moving the secondary mirror along the Z axis. The secondary mirror can also be decentered and tilted to correct the coma, however this is done only by the technical staff in a particular situation (for optical alignment). The determination of the best focus can be performed by comparison of several images of point sources obtained at different focus positions. With AFOSC we suggest to use the pyramid focus procedure, which is fast and accurate, cf. AFOSC User Manual for details. The theoretical Z axis tolerance is ±12µm to keep the PSF diameter within the Airy disc.

14 Using the telescope

14.1 TPS Telescope Pointing System

The TPS software controls the telescope pointing and the dome movement. It is installed in PUNTAMENTO-T182 and is started by clicking on the TPS icon on the desktop. This also opens a Keypad from which it is possible to start the telescope tracking and Dome tracking, to manually change the movement of the telescope (fast, medium, slow), to manually move the telescope and to rotate the dome, to go to the target after selection and to stop the telescope for emergency.
The TPS menu (up, left), allows to open/close the mirror, reset gear alarms, move the telescope in park/flat position, open/close the dome, stop the dome, point the target.

The main window of TPS shows three data columns: the central column displays the current telescope position (HA, RA and Dec, telescope elevation above horizon and azimuth, atmospheric refraction, airmass, parallactic angle (ParA) and flange position in order to have the parallactic angle (PAfl), dome position and the engaged gear.

The right column lists the current Julian date, date, universal time, local sidereal time, coordinates epoch, the type of connection (always remote for the observer, could be local for the technical staff), critical weather conditions (wind speed, humidity from balcony and from field, sky quality) and dome/mirror status (open/close).

The left column displays the selected target coordinates, as inserted using “Select the telescope target” window, which is opened from TPS menu, “Pointing”, “Select object”:

14.2 Selection of the target and pointing

There are five procedures for the selection of the target.
From the top-left menu of the TPS, select Pointing → Select Object: the select target window appears as in figure.

14.2.1 Simbad
By ticking on the Simbad field, you use the online Simbad Astronomical Database to get the target coordinates by identifier. CDS or SAO servers can also be selected.

Write the name of your target using the standard designations of astronomical objects: i.e. Vega, HD 172167, M31, MCG+02-60-010, then click the Search button. In a few seconds, the target's coordinates will appear in the RA and Dec fields. Click the OK button and the target’s name and coordinates are displayed in the left column of the TPS principal window.

14.2.2 Stars
When ticking on the Star field you will be asked to select a constellation from a list of the 88 official constellations. Then, you will be asked to select one particular star from the Bayer or Flamsteed catalogues.
14.2.3 Object and Planets
The TPS provides the Messier, NGC, IC and PGC catalogues: tick the right catalogue first, then write the number of your object and click the Load button. The planet’s name can be selected from the dedicated menu.

14.2.4 Coordinates
This option allows to insert manually the coordinates (RA, Dec) of the target. It is possible to use different formats.
The following data format are allowed and equivalent:
12h15m46s, +31°10'25"
12h15.77m, +31°10.42'
12.2627h, 31.17361°
12:15:46, +31:10:25
12 15 46, +31 10 25

14.2.5 Custom list
The option Custom can be used if the observer has prepared in advance a file containing the objects' coordinates for the night (ask the technician for more information on how to proceed).

⚠ Check once again the status of the telescope and dome by carefully looking at the internal cameras, then, from the TPS menu, click on Pointing, Go to Target: the telescope will automatically move to the selected target coordinates.

In addition, it is possible to point the target by clicking the button “Go to Target” on the keypad.

At the end of the pointing procedure, the telescope tracking will start automatically if the tracking button on the keypad is switched on (the button will become green). In addition, the dome will reach the position and track the telescope if the “Dome tracking” in active (button green).
15 The autoguiding software

The autoguide software allows to grab images from AFOSC or Echelle guider camera. It can be started from PUNTAMENTO-T182, by clicking the appropriate icon on the desktop.

The AFOSC autoguide software

The Echelle autoguide software

When started, both Guiders have three boxes that allow the control of the principal functions of the software:
Exposure control box

This box allows to take an image from which to choose the guide star. The available options are:

- The exposure time (in seconds)
- **The Object Name** field allows to add an object name to the fits image header, if you decide to save it.
- Click the **Expose** button to take one single image with the inserted exposure time.
- Click **Video** to start a sequence of images, each with the inserted exposure time, which will be stopped only if you click the STOP button.

**Only on the AFOSC guider:**

The Gain horizontal slider cursor allows to increase the sensitivity of the Guider camera. There is a set of options that allows to modify the focus of the guider camera:

You can move the camera focus from 0mm to 10mm (nominal position is 2.5mm), then write the required focus position in the box and click the **GO** button.

The **Initialize** button permits to reset the position in case the controller loses it.

**Only on the Echelle guider:**

The two horizontal sliders cursors allow to increase the sensitivity of the Guider camera:

- The Video cursor changes the electronic gain of the Guider camera.
- The MCP cursor changes the gain of photomultiplier tube of the Guider camera.

It would be better to increase the Video gain rather than the MCP gain, because the photomultiplier tube can be damaged if stricken by a bright source when operated at high gain.

A group of options allow to choose the CCD video integration time.

Guide control box

- the X and Y fields show the initial coordinates of the guide star in the image.
- **Box size** shows the dimension of the image used for guiding.
- **Exp time** displays the exposure time in seconds for the guiding image.

The **START Guide** and **STOP Guide** buttons allow to start and to stop the autoguiding.

The large window on the right of the Start Guide button shows the statistics of the autoguiding with the following six columns of data:

- Displacement (arcsec) on the X axis from the initial star position.
- Displacement (arcsec) on the Y axis from the initial star position.
- Star FWHM (arcsec), X axis
- Star FWHM (arcsec), Y axis
- Star flux (ADU), calculated from stellar PSF fitting.
- Star flux (ADU), measured on the brightest pixel.
The button **Clear List** will delete all the statistical data.

By ticking on **No Guide** the autoguiding command will not be sent to the telescope. If you are in Echelle mode, the **on Slit** option allows to guide on the star on the slit.

### Stretch box

This box allows to change the cuts of images. The image display can be adjusted by changing the low cursor for black and hi cursor for white.

### Guiding on a field star (AFOSC and Echelle)

- Take an exposure by clicking on the **Expose** button.
- Click with the left mouse button on the star selected for autoguiding.
- If the selected star is too faint or too bright, change the parameters that control the camera sensibility.
- Select a good exposition time (about 3 sec) in the Guide Control box.
- Click on **Start Guide**.
- The flux values displayed on column 5 should be higher than 100 for the AFOSC guider and 400 for the Echelle Guider and those displayed on column 6 lower than 65000 for AFOSC and 16000 for Echelle.

It is possible to find a good star for autoguiding with AFOSC by using the “AFOSC+CCD” software to move the guider probe, cf. AFOSC User Manual for details.
Guiding with the star on slit (Echelle only)

- Take an exposure by clicking on the **Expose** button.
- Check if the star is inside the slit.
- Click with the left mouse button on the point of the slit where you would like to keep your star.
- Tick on **on Slit** and **No Guide** button.
- Click on **Start Guide**.
- Control the camera’s sensibility so that you can see very well the star’s wings above and under the slit; make sure that the sky is under 7000 ADU. You can set the lower cursor in the stretch box around 7000 ADU (first label over 8192) and hi cursor the lower half (over 8192).
- If the star is very faint or if it is saturate, change the parameters that control the camera’s sensibility, not the exposure time.
- Click on **Stop Guide**.
- Tick **No Guide**.
- Select an exposure time around 3 sec in the **Guide Control box**.
- Click on **Start guide**.

16 Troubleshooting

If you see any unexpected behaviour of the instrumentation, write a note on the night report form including the time, date and context in which the problem occurred and the status of the instrumentation.

**The software requires a username and password to run**

All the softwares available to the observer use the username: *** and password: ***

**The AFOSC Guider shows corrupted/partial images**

Leaving the “Guider Cam AFOSC” powered, close and reopen the AFOSC guider software.

**Cannot connect to the Remote Desktops**

If the direct network link between Pennar and Ekar station does not work, try to use the icons labelled “Backup network - …” to start the remote desktop sessions. In the DVRRemote software, select 193.206.244.244 as DVR address.