The Ekar Schmidt 67/91 Telescope – User Manual

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Technical Report n. 27

December 2017

Document available at: http://www.oapd.inaf.it/
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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

The 67/91 Schmidt telescope is the largest instrument of this type in Italy. It was officially commissioned in 1966, when it was located in the Pennar Observation Station, near the Galileo telescope; in 1991 the telescope was moved to mount Ekar near the Copernicus telescope, in order to take advantage of the higher altitude and lower light pollution. The dome is not a traditional one: it is octagonal in shape for an easier mechanical assembling and was originally designed to test the proposed solution for the Telescopio Nazionale Galileo (TNG). Recently (2017) the telescope has been considerably refurbished (new CCD camera, new filters, autoguider) and it can now be remotely controlled.

2 Main Telescope characteristics

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

- Longitude: E11° 34' 07.772"
- Latitude: N45° 50' 58.000"
- Height: 1369.9m a.m.s.l.

The telescope is a classical Schmidt reflector with an equatorial fork mount; light is collected at the prime focus and the CCD cameras, located inside the tube, can be moved for focusing.

- Spherical mirror: 910 mm diameter in Schott Duran-50 glass
- Correcting plate: 670 mm diameter in Schott UBK7 glass
- Focal length: 2150 mm (f/3.2, 96 arcsec/mm)

3 Focal plane instrumentation

The technical data of the main imaging camera are:

- ON-Semiconductor KAF-16803 (active area: 4096×4096 pixels, prescan: 30 pixels)
- CCD scale: 0.87 arcsec/pixel (unbinned)
- Pixel size: 9 μm
- FOV: 59 x 59 arcmin
- Full well capacity: 100 ke-
- Dark current: 0.01 e-/pixel/sec at -30°C
- A/D Converter: 16 bits
- A/D Gain: 1.6 e-/ADU
- Readout noise: 10 e-
- Full frame readout time: 22 sec
- Multistage Peltier cooler (max ΔT -60°C from the CCD heatsink temperature)
- Filters wheel with B and V Johnson-Bessel, u g r i Sloan filters; it is possible to work without filter as well
- Minimum exposure time with electromechanical shutter: 0.2 sec
The technical data of the autoguider imaging camera are:

- Sony IMX-174M (active area: 1920 × 1200 pixels)
- CCD scale: 0.56 arcsec/pixel (unbinned)
- Pixel size: 5.87 μm
- FOV: 18 × 11.2 arcmin
- The camera is mounted on a linear positioner that permits to adjust the focus independently from the main CCD camera focus
- Minimum exposure time: 50 μsec

4 Telescope performance

The typical pointing error of the telescope is less than 2 arcmin. The resolution of the encoders is 0.45 arcsec.

The telescope can be manually moved at three different speeds:

- Large: 1 degree/sec
- Medium: 2 arcmin/sec
- Micro: 12 arcsec/sec
- Differential guiding: up to 7200 arcsec/h

The maximum excursion of the medium/micro declination drive is ±4°.

5 Tracking and guiding

The telescope is in sidereal tracking when Micro or Medium movements are inserted.
5.1 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 guide star becomes less than 500 ADU 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.

6 Image quality

The typical natural seeing at Mount Ekar is under 1.5 arcsec. Stellar images with FWHM < 1.0 arcsec are not uncommon. 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. The whole Schmidt focal plane seen by the CCD is free of aberrations.

7 Ekar weather stations

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/. 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

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.
8  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 dome if the weather conditions are unsafe.

8.1  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 94%, the dome must be closed.

⚠️ In case of wind gust over 15 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.

8.2  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 12 degrees. 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.

This limit is imposed to avoid permanent damage to the wiring loom of the telescope. Moreover, there is a mechanical lock stopping the telescope in case it accidentally reaches an hour angle of ±12h. The lock can be disengaged only by the technician on the following morning.

8.3 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.

9 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 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 remotely controls PUNTAMENTO-SCH, which is the PC with the Schmidt Relay Control, the TPS (Telescope Pointing System) and the Guider run. The PC located on the left remotely
controls STRUMENTI-SCH, which is the PC where the software for the acquisition of data run (see figure 4).

![Figure 4: Schmidt Control Room: the monitor on the left displays the PUNTAMENTO-SCH desktop, the two monitors on the right display the STRUMENTI-SCH desktop.](image)

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

- Click on DVRemote icon on PC PUNTAMENTO-SCH and switch on the microphone (figure 5).
- Click on the Strumenti.rdp icon to connect to the remote desktop of PCSTRUMENTI-SCH
- Click on the PUNTAMENTO.rdp icon to connect to the remote desktop of PUNTAMENTO-SCH
- On PUNTAMENTO-SCH click on the “Relay Control” icon (figure 6).
- From the Relay Control window:
  - Switch on the top ring camera and dome lights
  - Switch on the CCD (CCD+Focus)
- On STRUMENTI-SCH click on the “Schmidt CCD” icon
- From the CCD Control window:
  - Click the *connect CCD* button
  - Start the cooling of the CCD:
    - start with a set temp of -35°C
    - after 15min, when the temperature is stabilized, check the power percentage next to the temperature: if the power is lower than 90%, you can select a lower CCD set temperature
    - remember that the maximum \( \Delta T \) between the CCD and the camera heatsink (“HS temp” on the control software) is -60°C
Figure 5: DVR remote software interface

Figure 6: Schmidt CCD Control software

⚠️ Caution: watch out for any objects (ladder, mechanical devices, etc...) in the dome preventing the telescope and the dome from moving freely!
On PUNTAMENTO-SCH:

- Click on the TPS icon to open the TPS software (telescope pointing system and the dome movement).
- On the menu bar, select Setting → Telescope Power → Power on
- As soon as the outside temperature is equal or lower than the dome temperature (check this on the Ekar meteo webpage), Select Dome → Open to open the dome shutter (remember to deactivate the dome tracking as the dome shutter must be opened and closed with the dome at rest)
- Turn on the dome and telescope tracking by pushing the appropriate buttons on the TPS keypad.

![Schmidt 67/91 - TPS](image)

*Figure 1: System setting to switch-on the telescope movements*

The telescope is now ready.

⚠️ If the dome temperature is lower than +5°C, please wait 10 min before moving the telescope.

- Click on the Guider icon to start the Autoguider and focusing software
- If not already initialized, press the initialize button to initialize the focusing system of the guider CCD: the nominal focus position of the guider CCD is 4.70mm when the main CCD is correctly focused with the V filter
- The focus position range is between 0mm and 9mm
- Increasing the focus position move the camera focus from extrafocal to intrafocal
10 Selection of the target and pointing

From the top-left menu of the TPS, select **Pointing → Select Object**: the select target windows appear as in figure 8.

10.1.1 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.

10.1.2 Stars

When ticking on the **Star** field you will be asked to select a constellation from a list of the 88 official ones. Then, you will be asked to select one particular star from the Bayer or Flamsteed catalogues.

10.1.3 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.

10.1.4 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

10.1.5 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 push **Go to Target** on the Keypad (see figure 7): the telescope will automatically move to the target coordinates. At the end of the pointing procedure, if not already enabled, the tracking will start.
By using the “Guide 9.1” software it is possible to display a chart of the field pointed by the telescope (main CCD camera and guider CCD, see figure 9), press F12 on the keyboard to update the displayed field.
11 Image acquisition, Focusing and Guiding

11.1.1 Image Acquisition

- insert your name and program in the Observer and Program fields of the CCD Control software
- remember to select the appropriate binning factor in the selection field
- you can enable several rows to take a sequence of images with different exposure times and filters
- for each row insert the object’s name and tick the Save checkbox only if you want the image to be archived (all the images will be written on the PCSTRUMENTI-SCH pc, but the unsaved images are not archived and will be deleted on the following day by the technicians)
- The last image taken by the CCD camera will be displayed in the DS9 window
- To download the images, just connect to the shared folder at \147.162.193.231 ("tonight" folder). During the night, almost in real time, the saved images are transferred and archived in the national database in Trieste.

11.1.2 Focusing

- The nominal focus position of the main CCD is 29.400mm when it is focused with the V filter
- The focus position range is between 0mm and 60mm
- Increasing the focus position move the camera focus from extrafocal to intrafocal
- Use the CCD Control software to take a test image: for example with filter R, exposure: 1 second, binning 4×4
- Open the focus aid window by clicking the Focus key on the CCD Control software
- On the test image look for a well exposed star (a mag. 9 star is ideal if the test image was taken as suggested)
- In the Focus window press Grab coords and click on the selected star in the image displayed on DS9
- Press Start in the Focus window
- Check if the star looks well exposed, otherwise change the exposure time (best exposure time range is between 1 and 3 seconds)
- On the Autoguider software, change the value in the Main Focuser window (typically a few tenths are sufficient, remember that the intrinsic optical focus tolerance is ±0.014mm) and press Move Focus until the FWHM is minimized.
- Press STOP in the Focus window
- When the star PSF is pointlike, press autofocus in the Focus window to start an automated focusing procedure (remember to stop the guider if the autoguiding is enabled)
- At the end of the autofocus procedure, check that the star is correctly focused

![Focus](image_url)  
*Figure 11: Focus aid windows*

### 11.1.3 Autoguiding

To put the telescope in guide mode using the Autoguider CCD:

- Click on Expose or Video to check if a suitable guide star is present
- If the star appears out of focus, try to adjust it, using the Guider Focuser controls (remember that the Guider focuser movement do not alter the main CCD focus while the Main focuser movement changes also the guider focus)
- If the star is faint try to increase the exposure time and/or the camera gain
- If the dark noise is too strong, click Dark to take a dark image (which it will be automatically subtracted from the other images) with the same exposure time and gain of the following images. Remember that the Guider camera is not equipped with a
mechanical shutter, you need to close the dome or manually turn the dome in front of the telescope before taking the dark image

- Select a star for guiding and press Guide in Guide Control. Differential tracking is also available.

![Figure 12: Guider control software and Relay software](image)

### 11.1.4 Measuring the seeing

- To measure the FWHM of a star on an image already opened in the DS9, select Utilities on the CCD control menu bar → Seeing Meas.
- On the Seeing Meas. window click Add Star and click on a well exposed star in the image displayed on DS9

### 11.1.5 Plate solving of the images

- To apply the astrometric solution on an image, click on Image Astrometry and a window will be opened, choose and click on 'last image', 'last scratch' or 'open an image'; the astrometric solution will be automatically applied on the selected image. The new file (named *.wcs.fits) will be saved in the pc STRUMENTI-SCH, C:\Tonight\WCS directory.

### 11.1.6 Taking flat fields

Activate the dome tracking and point the telescope with TPS by selecting menu Pointing → Flat position. Switch on the Flat Field light or the Dim light by pressing the appropriate buttons in Relay Control.

Indicative exposition times in binning 1 × 1 are:
- Filter u: Sky Flat only
– filter B: 25s Flat Field + Dim light
– filter g: 6s Flat Field light
– filter V: 4s Flat Field light
– filter r: 10s Dim light
– filter i: 8s Dim light
– white light: 3s Dim light

### 12 During the night

If the “spider” temperature varies more than 5°C, check the telescope focus. If the orientation of the telescope changes remarkably, check the telescope focus. Remember that, if the dome is open and oriented southward, switching on the dome lights or the flat field lights can disturb the Copernicus telescope observations.

### 13 End of night: shutdown of the system

On the pointing PC:

- Activate the dome tracking and park the telescope with TPS: 
  `Pointing → Park`.
-⚠️ Once the dome is definitively stopped, close it by selecting `Dome → Close`.
- Switch off the telescope power, on the TPS menu `Setting → Telescope Power → Power off`.
  On the bottom-right of the TPS window, the notice `Soft Power Off` will appear.
- Close the TPS, the Autoguider software, Guide 9.1

On the CCD control PC:

- Warm up the CCD by pressing `Warm Up CCD` in CCD Control
- Wait at least 20 minutes
- When the CCD temperature and the Heat Sink temperature (HS Temp) are similar, click on `Disconnect CCD`
- Close the CCD Control software and the DS9
- Disconnect the remote desktop

Again on the pointing PC:

- Switch off the CCD from the Relay Control by pressing `CCD+focus`
- From Relay Control, switch-off all the lights and the top ring camera.
- Close the Relay Control software and disconnect the remote desktop.

**!!! DO NOT FORGET TO FILL IN THE NIGHT REPORT !!!**
The observer must fill in the night report at the end of each night. From www.oapd.inaf.it, go to “Asiago Site”, “Telescope and Instrumentation” and click on the “Night Report” link. 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.

14 How to reduce the Schmidt CCD images

The images generated by the CCD Control software are standard compressed FITS 3.0 (Flexible Image Transport System) files.

To uncompress them, you need to use a utility called Funpack which can be found here: https://heasarc.gsfc.nasa.gov/docs/software/fitsio/fitsio.html

All the images, if taken without windowing, include an overscan region located at the top.

All the pixels in the rows with DS9 coordinates Y between 4122 and 4128 can be averaged to obtain the image offset value (about 780ADU).

The overscan and trim area in IRAF notation (which is also included in the image header) is:

BIASSEC = [*,4122:4128]
DATASEC = [*,1:4097]

These keywords can be automatically used under IRAF by CCDPROC task, remember to set, under CCDPROC, the parameters:

\[
\begin{align*}
\text{readaxi} & = \text{column} \\
\text{biassec} & = \text{image} \\
\text{trimsec} & = \text{image}
\end{align*}
\]

Because the response of the main CCD camera is not perfectly linear, all images, after the application of the offset and bias corrections, must be relinearized to achieve the maximum photometric precision.
To relinearize:

- Correct all ‘flat’, ‘dark’ and ‘object’ images for overscan offset and bias
- Apply the relinearization polynomial:

\[
Corrected\ ADU = ADU - 3.0946 \cdot 10^{-6} \, ADU^2 + 3.2273 \cdot 10^{-11} \, ADU^3
\]

To relinearize under IRAF, after applying the overscan and bias corrections as described before, use the IRLINCOR task with the following parameters:

- Coeff1 = 1.0
- Coeff2 = -0.10140076
- Coeff3 = 0.034650755

The relinearized images will have a gain of 1.80 e⁻/ADU and the saturation point at 56000 ADU.
15 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 DS9 shows only completely white images

Assuming that the image is not completely saturated, close and reopen the DS9 software. Check that there is only one DS9 started at a time.

The dome azimuth seems to be wrong

Using the TPS keypad, turn the dome from South East to South West to reset the azimuth encoder.

The dome doesn’t turn when the telescope is manually moved

The selected target is “Park” or “Flat Field”: please select another target (e.g. a star) and check if the “dome tracking” is enabled.

We thank dr. E. Artusi for the linguistic revision of the present manual.