Observations with SOFIN at the NOT

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Contents

1   Before the run

- Install the spectrograph on the telescope (Sect. 7.1).

- Prepare your catalog by connecting to `ssh obs1@elena.not.iac.es` in the `/home/catalogue` directory. Load the catalog to the TCS (Telescope Control System) by pressing ⏎`Cat` button and typing `read catalog-name`. To erase the existing catalog in TCS memory type `erase y`.

- Balance the telescope by `c-w-h 0.9` when the telescope is in the idle mode. Change the altitude to `alt 45` and check the balance by displaying a status page `show 3` and inspecting the current of the two motors.

- Change the default settings for the telescope:

  - Focus of the telescope by `foc-pos 22700` (polarimetry mode).
  - Focus of the guide camera by `tv-foc 520`.
  - Telescope offset step size in arcsec by `o-s 0.5 0.5`.
  - Guide probe step size by `p-s-s 0.2 0.2`.
  - Preset rotator angle `i-p-a -90`
  - Disable guide camera focus correction `man-tv-foc`
  - Disable auto position of guide probe `a-p-o`

The dynamic settings can be also quickly changed with the global script from `verushka.not.iac.es` (or `tessa`) by typing `tcs.setup-tel-sofin` which is useful when changing between another instrument (e.g. FIES).

2 The SOFIN control program

2.1 Before observations

Open a terminal on `tessa`, `staff-cr`, or `florence` and type `vncviewer sofin:1`, which opens desktop on the sofin control computer located in the electronics room. No password is required for `vncviewer`.

If the connection is refused, restart `vncserver` with the command `ssh sofin@sofin .vnc/x11vnc`

In the `vncviewer` window open terminal from top left `Activities` menu and type `sofin` in the terminal to start the control program (Fig. 3).

It may happen that the vncviewer in full screen mode is not responding either the keyboard keystrokes or mouse buttons, in this case, type from `florence` terminal or any other computer `ssh obs@tessa killall vncviewer` and then restart it `vncviewer sofin:1` from terminal in `tessa`.

Alternatively, one can start the control program over `ssh` from `tessa` terminal by `ssh -X sofin@sofin` then type `sofin` to start the application.

The control program can be closed by clicking on the `x` close button on the window title bar. It can be also gracefully closed by typing `Ctrl-C` on the terminal opened by the control program. To kill the application type `Ctrl-\`.

After switching the CAMAC power on and plugging the spectrograph power cable to the telescope adapter, initialize the instrument from the `Calibration` tab. Once it is completed and no error messages seen on the popup window, preset the spectral region, e.g. '5498 & 6302 LF5' for spectropolarimetry, by selecting it from the table of spectral regions. Select `Loral polarimetry` CCD setup from the table.

2.2 During observations

Select the object and programme PI from the tables and start the exposure (Fig. 3). The `Stop` button is used for prematurely stop of exposure: it will read the CCD and continue the sequence. The `Abort` button stops the sequence and will not read the CCD. The exposure time can be edited while exposing as well the number of exposures. In circular polarization mode, the number of exposures should be two (2) for the two angles of the quarter-wave retarder 0 and 90°. To repeat a series of two polarimetric exposures, specify the number of cycles. Each science exposure is made with the ThAr spectrum taken before and after each exposure, though for bright stars with short integration the calibration can be taken after 2–3 exposures. A very long exposures should be never made with SOFIN as the flexure effects on the Cassegrain adapter may affect the échelle image quality: a good idea is to make exposures no longer than 15–20 min.

The photon counter shows the instantaneous rate per second and the average value since the beginning of exposure. The cumulative values shows how many counts is collected in thousands and what amount is expected at the end of exposure. The exposure length can be set with the required number of counts in thousands to be collected in the `Total counts` edit field.

After each exposure put the red marker box around the image one polarized spectral order and press `Enter` to display the spectrum. Put the red marker box on the top of the spectrum and drag it down to the bias overscan level, then click on the sunny sun toolbar button to calculate the signal/noise and save it to the FITS header which will then be shown in the browser table (it simply uses the height of the marker box in ADUs and the CCD gain factor).

The Loral CCD has a limited dynamic range, so that the maximal number of ADUs per one pixel allowed is 5000 above the bias overscan with a significant deviation from CCD linearity above this limit. With a nominal seeing

of $1''$ with FWHM of one cross-dispersion profile in 6.5 pixels (camera 2 has $0.153''$/pixel) and the gain factor $g = 5.9\,e^-$/ADU, the maximal allowed signal/noise of the extracted spectrum in one polarized order per pixel is limited to 450 ($\sqrt{\sqrt{\pi} \times \text{FWHM} \times 0.6 \times \text{ADU} \times g}$). For a seeing of $0.5''$, the limited signal/noise is 320. Refer to Fig. 7 to estimate the exposure time.

Make up the observing blocks schedule from the table of observing targets with `Alt-B` in the `View` menu bar. The target is added with `Alt-O` to the scheduler and its observing parameters can be edited with `F4` and moved up and down in time by arrow buttons on the blue toolbar. The CCD readout time is 1.5 min and the overhead time for pointing the telescope and start guiding is about 3–5 min.

3 During observations

3.1 Opening the telescope

- Reset the security system and power-on `po-on y`.
- Open upper hatch by `o-u-h`. Wait while it is opened to proceed. Open side ports meanwhile.
- Open mirror cover by `o-m-c y`.
- Open lower hatch by `o-l-h`.
- Switch guide camera on by `tv-on`.
- Set rotator to automatic mode by `rot-auto`.

3.2 Making exposure

- Enter catalog menu `Cat` and select object in the catalog by pressing `1` or `7` on the keypad.
- Preset to the object with the `6` key. This will point the telescope to the star and set the rotator angle chosen according to `i-p-a -90` so that the slit height is oriented to zenith along the atmospheric dispersion.
- Optionally change the guide camera filter with `tv-fil g, b, r, y, o` depending on the brightness of the guide star. Filter letters stand for gray, blue, red, yellow, and open.
- Change the motion mode with `5` to `Telescope RA/Dec` and use `Alt-arrows` to move the star onto the slit.
- Check the telescope focus and if necessary change it with `foc-del` followed by the relative increment, say, +100, or –200 with respect to the default focus value. The command `foc-del 0` resets the focus to the default value. Changing the telescope focus requires correction of the guide camera with `tv-foc` followed by the absolute value of the new focus.
- Change the motion mode with `5` to `Star box` and use `Alt-arrows` to move the guider box onto the guide star. Change the guider box size with `s-b-q 20`.
- Change the motion mode with `5` to `Background box` and use `Alt-arrows` to move the guider background box closer/away to the guider box. Change the box size with `b-b-q 10`.
- Start autoguider `ag-rel`.
- Start integration of the star.
- Make a fine correction of the star on the slit: select with `5` motion mode to `Guide probe` and use `Alt-arrows` to move the guide probe in small steps. Horizontal keys move the star along the slit height, and vertical keys move the slit to the star.
- Stop autoguider by `ag-off` once the object exposure is finished followed by comparison spectrum and flat field exposures. To change to a new object start over at the beginning of this section.
- Use `!` key to clean the TCS error message line, ans `Quit` button to erase the command typed.

3.3 Summary of the commands to make exposure

1. Select object in catalog menu `Cat` with `1` and `7`

2. Preset with `6`

3. Wait to see the star on the slit

4. `tv-fil g b r y o` optionally

5. Motion mode `5` to `Telescope RA/Dec` and set the star on to the slit with the **Alt-arrow** keys

6. Motion mode `5` to `Star box` and set the box on the guide star with the **Alt-arrow** keys (Fig. 5)

7. `ag-rel`

8. Start exposure

9. Motion mode `5` to `Guide probe` and correct the star on the slit with the **Alt-arrow** keys
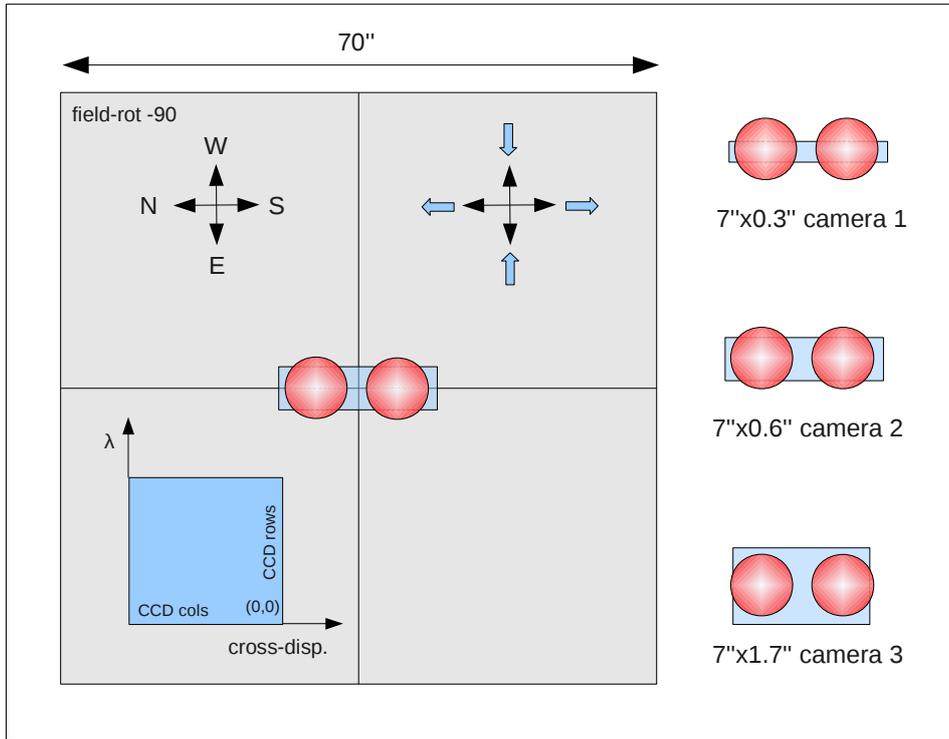
10. `ag-off`

Figure 1: Layout of the slit viewing camera. With the paralactic angle `field-rot -90` for the linear polarimetric mode, the telescope motion in RA and Dec is aligned to the slit orientation. For any field orientation, the guide probe motion moves the star with arrows keys as indicated, i.e. left/right moves the star on the slit, but up/down moves the slit (Fig. 5).
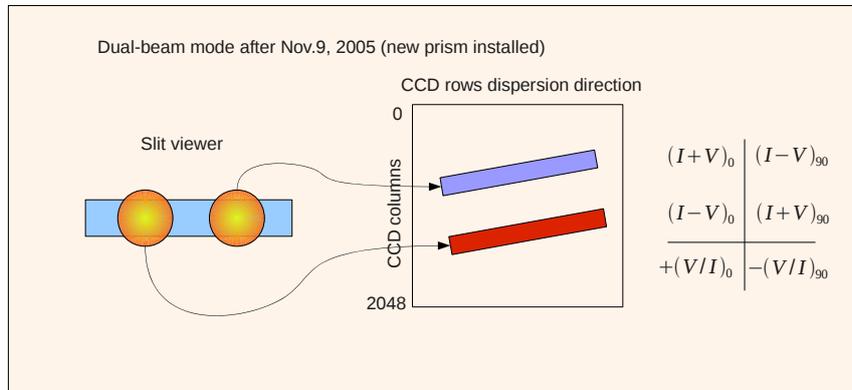

Figure 2: Designation of the polarized beams on the échelle image and as they seen on the slit viewing camera.

3.4 Closing the telescope

- Close the shutter of the slit viewing camera by clicking on the radio button in the control program.

- Switch the telescope guide camera off by typing `tv-off`.

- Put telescope to zenith position by typing `zenith`.

- Close lower hatch by `c-l-h`.

- Close mirror cover by `c-m-c`.

- Park the building in `Start/Stop` menu with 4.

- Close upper hatch by `c-u-h`. Wait while it is closed to proceed. Close side ports meanwhile.

- Type `po-off y`.

- And submit End-of-Night (or End-of-Run) report at the NOT home page.

4   Other modes and notes

4.1   Observations with the Stokesmeter

- Stokesmeter is on-axis

  – Focus of the telescope `foc-pos 22700`.

  – Focus of the guide camera `tv-foc 520`.

  – For the linear polarization mode set the paralactic angle to $-90°$ by typing `field-rot -90` and preset telescope with $\boxed{4}$, so that the slit are oriented to the north pole, i.e. by moving the telescope in declination, the two polarized beams are moving along the slit height. For the circular polarization, the orientation of the slit which is aligned along calcite beamsplitter is irrelevant.

  – Use the Loral CCD binning factor 1 in columns, in order to the two closely spaced beams are well sampled in cross-dispersion direction.

- Stokesmeter is off-axis with integral light mode

  – Focus of the telescope `foc-pos 22500`.

  – Focus of the guide camera `tv-foc 470`.

4.2   Scaling factors of the spectrograph

The scaling factors of the CCD pixels in cross-dispersion direction are:

Camera	pixel, μm	M	arcsec/pixel
2	15.0	0.716	0.153
3	15.0	0.249	0.353

These numbers can be used for measurement of seeing by estimating the width of cross-dispersion profile of an échelle order.

In the cross-dispersion direction the magnification factor is $M = f_{\mathrm{cam}}/f_{\mathrm{col}}$ and the projected slit height p related to the entrance slit height w as $p = M\,w$. The scaling factor $(F/206265)$ of the telescope is $1'' = 136.5\,\mu$m for the focal length $F = 28160\,$mm.

The magnification factor M_λ in the dispersion direction is $M_\lambda = f_{\mathrm{cam}}/f_{\mathrm{col}} \cdot \cos\alpha/\cos\beta$. where f_{cam} and f_{col} are the focal length of the camera and collimator, α and β are the incident and diffracted angles on the échelle. The later ratio is the échelle magnification factor equals to 0.7546 at blaze.

The following table gives the approximate slit heights in cross-dispersion for optical cameras. The slit height is set by the mark on the handle in hour minutes (15^{m} is $90°$). The slit decker is closed when rotating anti-clockwise, to open it rotate clockwise.

Camera	Handle	pixels	arcsec
2 Stokesmeter	55^{m}	63	9.6″
3 Stokesmeter	45^{m}	21	7.8″
2 integral light	35^{m}	25	3.8″
3 integral light	30^{m}	3	2.0″

4.3 Focus of the optical cameras

Positions of the best focus for optical cameras obtained at different air temperatures:

Camera	Filter	Temp, C	Focus
2	no	12	46
2	yes	12	51
3	no	8	22

With the increase of air temperature by 4C, the focus of the camera 2 should be decreased by 1 large division of the focussing ring.

5 Manual adjustment of the image

The step size of the échelle and prism stepping motors in CCD pixels. The shift in rows corresponds to the turn of the échelle, the shift in columns - to the cross-dispersion prism.

Camera	100 rows	100 columns
2	147	112
3	430	
1		534

6 Solution to the problems

6.1 No star is seen on the SOFIN slit viewing camera

- It is cloudy: check outside.

- Lower hatch is closed and the zenith distance of the target is more than 55°: open it with `o-l-h`.

- Mirror cover is closed: open it with `o-m-c`.

- Slit viewing camera power supply is off: switch on the upper button on the power supply. *Do not change any settings on the power supply: it may damage the camera.* The gauge should show the voltage of 12V.

- Slit viewing camera shutter is closed or the gain is too low: check the camera panel in the control program.

- Check the coordinates of the target.

- Check that the adapter CCD probe or the guide probe are not obscuring the beam. Otherwise, park the CCD probe with `c-p-p` or the guide probe with `g-p-pa`.

- Check that the brightness and contrast knobs of the slit viewing camera TV monitor are at maximum.

- The star is out of the slit viewing camera field of view which is $70''$: try to preset to the star once more.

  If there is still no star, try `g-p-c y` to move the guide probe to the center to view the star on the telescope guide camera (field of view is $100''$). Move the star to the center of the guide camera by moving the telescope in `RA/Dec` in $\boxed{5}$ mode and park the guide probe with `g-p-pa`. The target star should appear in the center of the slit viewing camera.

  This may occur due to an error in the pointing model of the telescope at specific locations: to store the offsets use `per-off-adopt y`, to reset the offsets use `per-off-reset y`.

  If this does not help, then try to preset to the nearest FK5 star and repeat the procedure.

- Possible malfunction of the light beam switch in front of the slit: change it to FF and then back to Star in the control program.

- The Stokesmeter is moving or stalled and obscures the beam: check that one of the two LEDs named `KV1` (off-axis) and `KV2` (on-axis) on the CAMAC module called `SHIFTER` is on, which indicates that the Stokesmeter is on or off axis.

- Something was forgotten to be removed on the front flange of the spectrograph during installation on to the telescope.

6.2 No guide star is seen on the telescope guide camera

- Check that the camera is on by typing `tv-on`.

- Change to the appropriate filter `tv-fil g b r y o`.

- Try to pickup another guide star.

7 Handling the SOFIN spectrograph

7.1 Before the run

7.1.1 In the dome

- Remove black cover from the spectrograph and the dust cover from the front panel.

- Start pumping CCD dewar until the pressure gauge reads 10^{-7} bar after 4-7 hours.

- Fill the CCD dewar with liquid nitrogen. Re-filling of the dewar should be done before observations and after in the morning, i.e. every 12 hours.

- Turn the telescope power on `po-on y` and put the rotator angle to zero position `ro-po 0`. Install the spectrograph on the telescope (Fig. 4). The spectrograph is oriented so that the CCD camera and its controller are faced to the entrance door, i.e. along north-south axis of the dome. *Watch the cables while operating with the red fork lift.* Put the red fork lift on the right side of the spectrograph yellow carriage. Insert the wooden plates between the forks and the yellow carriage. Lift the spectrograph, adjust the holes, and use the blue bolts with spacers to mount. *Watch that the CCD dewar pressure gauge connector and the vacuum valve are not touching the yellow carriage.*

- Plug in the power cable of the spectrograph and CCD controller to the telescope power sockets.

7.1.2 In the electronics room

- Remove the top metal protection cover plate atop of the CAMAC crate. Put on the power of the CAMAC crate with the switch located at the lower-left part of its front panel (Fig. 5).

- Switch on the High Voltage Power Supply 1200V for the photon counter atop of the control computer. It takes *at least half a day* to get it into the working regime.

- Switch on the power for the slit viewing camera power supply 12V situated atop of the control computer.

- Check that the black coaxial cable from the slit viewing camera is plugged to the TV monitor input connector. The monitor is situated to the left of the TCS console in the control room. Switch the monitor power on.

7.2 During the run

- Adjust the slit viewing camera filter settings in the control program depending on the brightness of the object. Too bright star can *permanently damage* a very expensive intensified CCD (which is on a loan from the NOT): in this case immediately switch the shutter of the camera in the control program, adjust the gain, and select the gray filter.

- The CCD camera should be re-filled with liquid nitrogen before, and at the end of each the night. The CCD should never be re-filled while it is exposed: this will lead to a significant drift of the spectral lines. The CCD temperature set point is 173K.

- To switch between two optical cameras currently installed, the following steps have to be done:

  1. Flip the cross-dispersion prism by rotating the handle at the prism to the direction indicated by the labels above it (Fig. 4).
  2. Switch off the power of the CCD controller. Disconnect all five electrical cables from the CCD dewar (not on the CCD controller). Do not disconnect the orange digital data signal fibers.
  3. Release the three steel screws with handles by making one turn around (Fig. 5). Release one slanted radial black hard-stop screw with the handle until it goes inside the bayonet connector flange. Turn the dewar anti-clockwise and pull it out. *Do not use screwdriver for this operation: everything should be done by hand. Do not turn the stopper screw with the flat handle, since it will change the CCD adjustment.*
  4. Install the CCD dewar on the other optical camera in reverse order by inserting it into the slots of the bayonet connector and turning it clockwise, then turn the slanted black hard-stop screw until it locks against the slanted cut of the connector and tighten it by hand. Tighten the three steel screws with handles on the side of the bayonet connector to push the dewar against the optical camera.
  5. Dismount CCD controller with two screws and install it on the other side. Check again that the CCD controller is still off and plug in all five cables from the controller to the CCD dewar. After that switch the CCD controller power on.
  6. Adjust the slit decker height: open the slit hatch and turn the handle clockwise to open the slit decker according to Tab. 4.2 (e.g. 55 min for camera 2).

7.3 After the run

- Exit from the SOFIN control program and close its vnc connection.

7.3.1 In the dome

- Unplug the spectrograph and CCD controller power cables and dismount the spectrograph. *Watch that the CCD dewar pressure gauge connector and the vacuum valve are not touching the yellow carriage.*

- Install the dust cover atop of the Stokesmeter.

- Install the black plastic cover hood atop of the spectrograph and tie it around with the rope.

7.3.2   In the electronics room

- Switch off the power supply 12V for the slit viewing camera atop of the control computer.

- Switch off the High Voltage Power Supply 1200V (black box) for the photon counter atop of the control computer.

- Switch off the CAMAC crate and cover it with the metal protection plate.

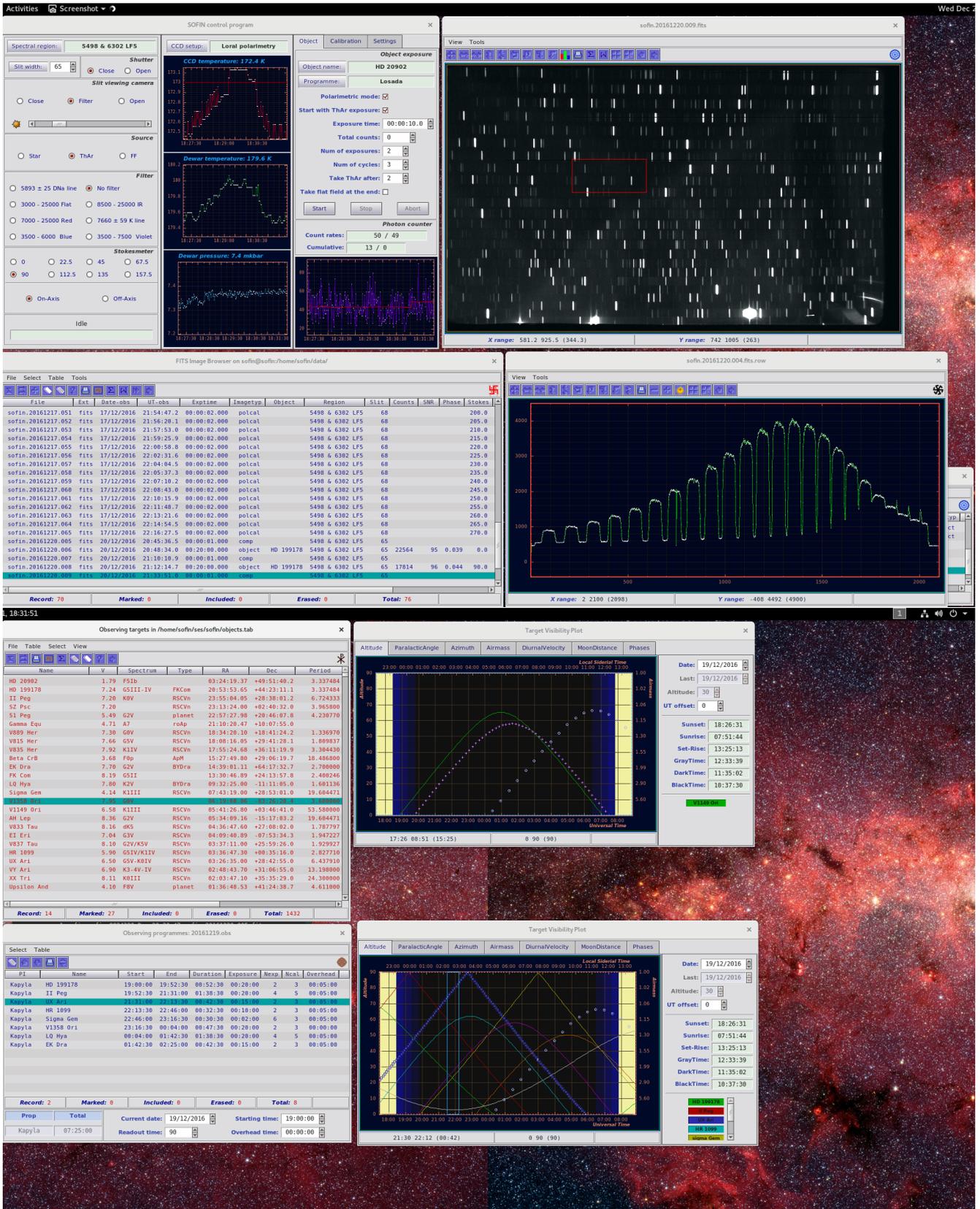- Keep the control computer running without switching it off.

Figure 3: The SOFIN control program running over vncviewer on double screen in `tessa`.

Figure 4: Shown spectrograph in the storage position with the cover removed and the Loral CCD controller with permanently connected electronics cables (top row). Location of the fork lift when mounted on the telescope with the rotator at `rot-pos` 0 (middle row). SOFIN mounted with `rot-pos` -90 (lower row). The location of the cross-dispersion prism flipping knob is seen.

Figure 5: The five connecting cables to the CCD dewar (top row). The CAMAC crate and the two power supplies atop of the control computer (middle row). The slit decker location with the slit hatch removed and the two polarized beams from a star as seen on the slit viewing camera (bottom row).
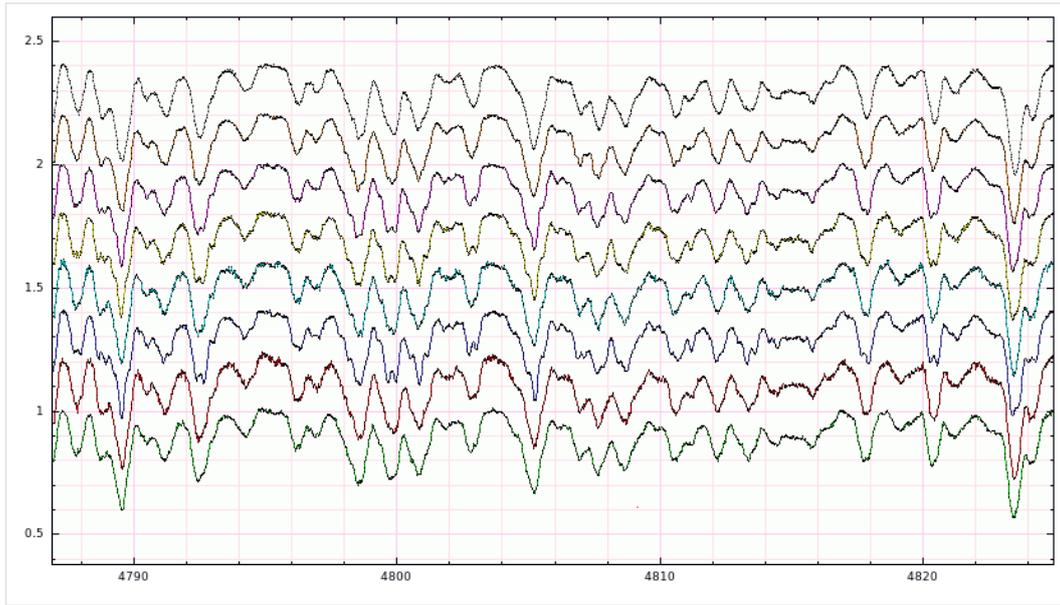
Figure 6: A typical spectra taken with camera 2 ($R = 80\,000$) in the extracted order 47 of II Peg. The signal/nose is ranging between 100 and 300 with exposure time of 20 min. A series of two or three exposures is taken for each spectrum.
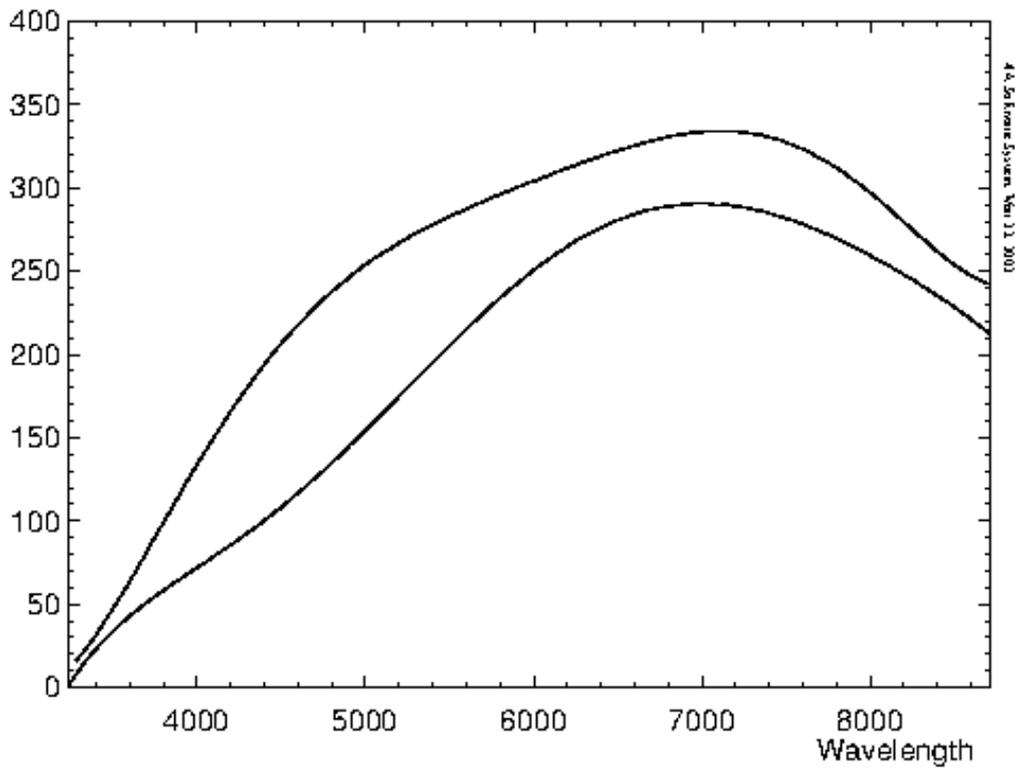

Figure 7: The measured signal/noise ratio of a star of 7th magnitude witch has a flat energy distribution. The upper curve is for the Loral CCD, and the lower is for EEV7. The signal/noise ratio is measured per one CCD pixel (The Loral pixel is 1.5 times smaller than EEV7), in zenith, per 10 min of exposure time, and with no light losses on the slit. For the seeing image of $1''$, a typical light loss is about 50% for the slit which provides the maximal resolution.