Acquiring images and spectra with BFOSC.
A practical user guide

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Version 1.0

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Contents

Abstract

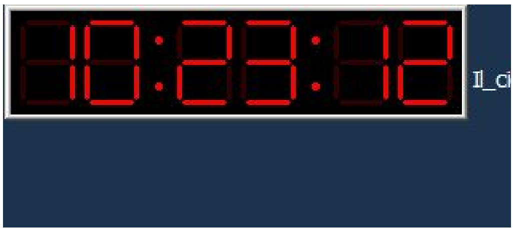
This manual describes the essential procedures to operate with the software packages that control the BFOSC instrument and the main CCD.
The user will find detailed instructions for checking and modifying the Telescope's focus, acquiring full frame and boxed images, acquiring long slit and Echelle spectra and many other procedures.
However, all the informations in this paper requires the knowledge of two others software packages: the telescope pointing user interface and the star guide finder interface, that are described in specific OAS technical reports.
"*BFOSC (Bologna Faint Spectrograph and Camera) Manuale utente*" (Gualandi, R., Merighi, R., 2001, Internal Report) explains in detail the optical characterizatics and performances of the instrument.

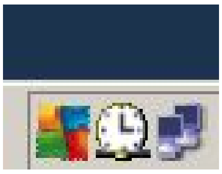
Before starting..

- All the BFOSC electronic needs to be switched on. In contrary case, many error messages will be displayed. This operation, like all those which require intervention on the dome instrumentation, can be performed **only by the technical staff.**

- The pointing software should be running (see the manual), however it is possible to use BFOSC in the modality described in section 2.1 of this guide.

- Pay attention to the desktop of the computer that controls BFOSC: an NTP software synchronizes the computer's internal clock (UT) via network. This time (TM-GPS keyword) is stored in the FITS header. If the NTP synchronization fails, then the clock icon (on the right in the picture below) will have a red cross. In this case the time keyword in the fits header is grabbed from the pointing computer.





- This guide should be used as reference manual for users who take part in the “training” supported by the local technical staff.

- For any kind of technical problems, ask the local staff.

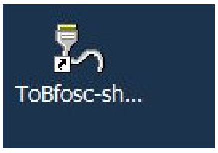
1 Setting up BFOSC applications control

All software packages required to control BFOSC are installed in only one computer.
The applications are:

- “*ToBfosc-schutter*”
- “*Winview*”

1.1 The “BFOSC *panel* ” software

The first package to run is “*ToBfosc-schutter*”. Double click on desktop icon below.



This application controls:

- the optical configurations
- the camera focus value
- the management of the image acquisition

1.2 Initialize BFOSC

The application appears like the picture below.

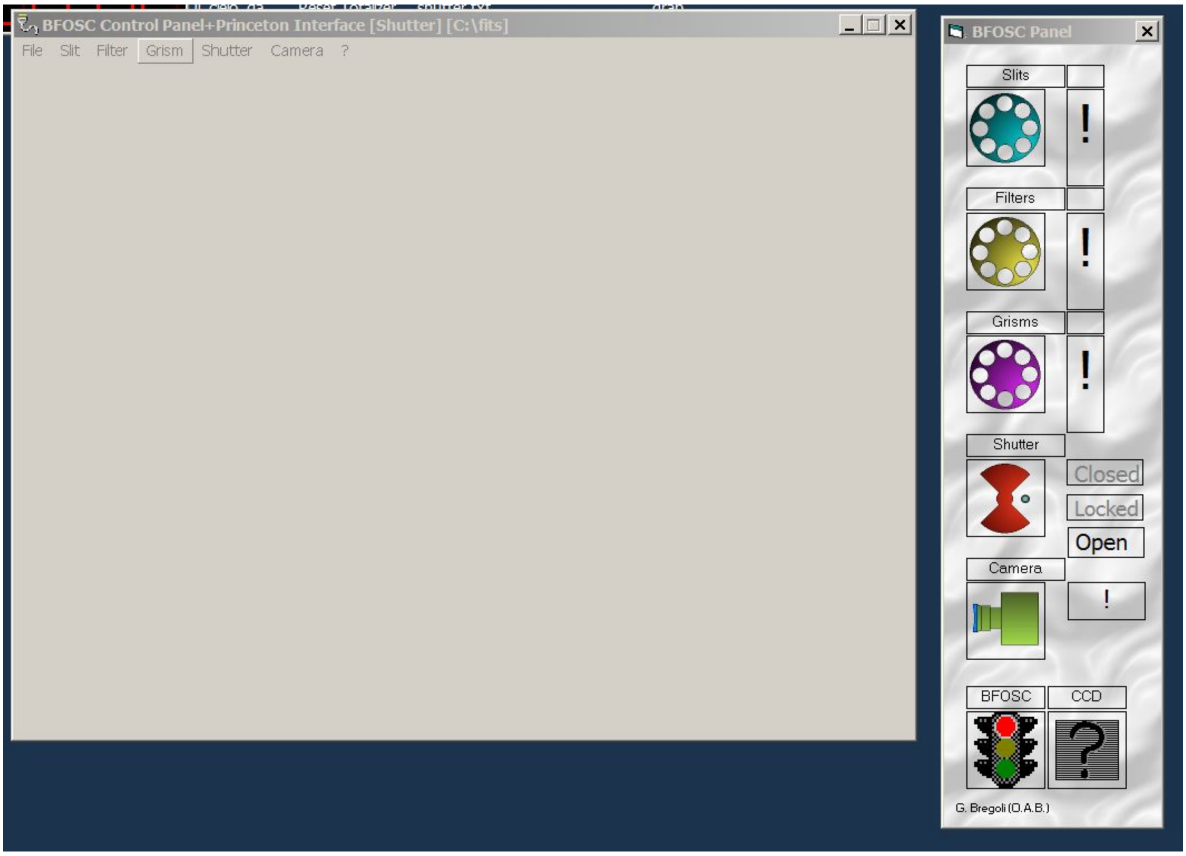


Figure 1

The helpful window is as *Figure 2*. Iconize the other one:

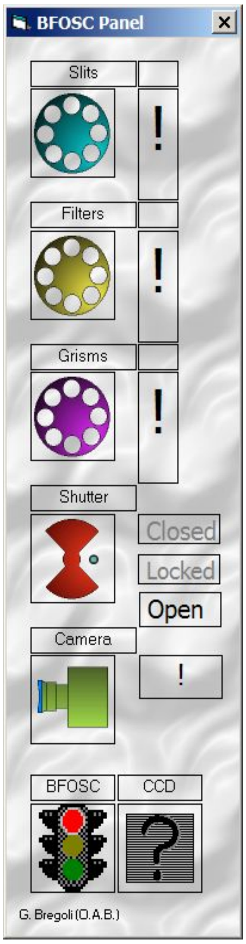


Figure 2

This panel allows to control:

- the wheels where Slits, Filters and Grisms are mounted
- the external shutter
- the focus value of the Camera lens

The exclamation points and the red “traffic light” indicate that BFOSC's electronics are not yet initialized.
Initialize BFOSC by one right click with the mouse on this window and one left click on “*Initialize All*” (*Figure 3*). Do not modify any other settings.

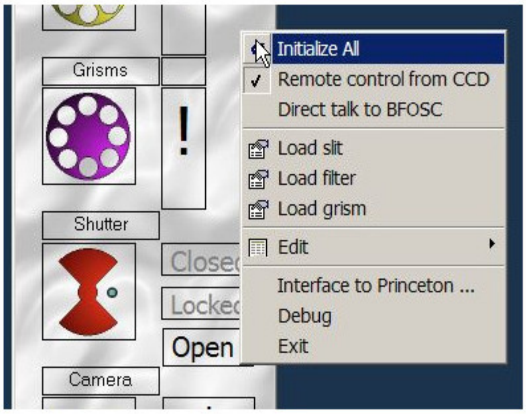


Figure 3

After this command, all the panel symbols are moving and the exclamation points are replaced by the number **-1**, i.e the initializing action is running. This action ends when the "traffic light" color is yellow and the panel looks like *Figure 4*:

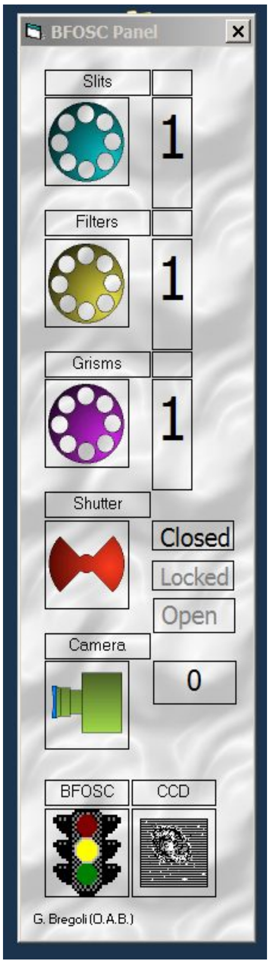


Figure 4

1.3 Set the Camera position

BFOSC is ready and the next step is to change the Camera position to the value **1600**.
Right-click on the green camera shape to open the dialog window (*Figure 5*). Then write "1600" in the text box.

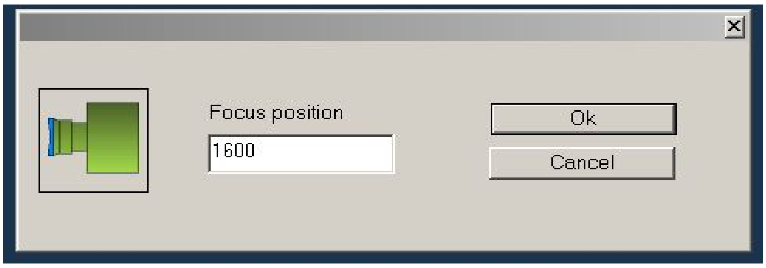


Figure 5

Click "*OK*" and wait for the green "light traffic" color as in *Figure 6.*

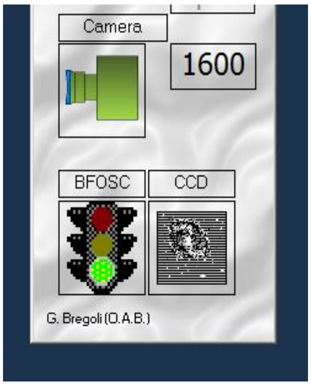


Figure 6

1.4 Open "*Interface to Princeton*" panel control

"*Interface to Princeton*" dialog box allows to send commands to BFOSC. To open this, click on the "*Bfosc panel*", then right click on "*Interface to Princeton ...*" as shown below (*Figure 7*).

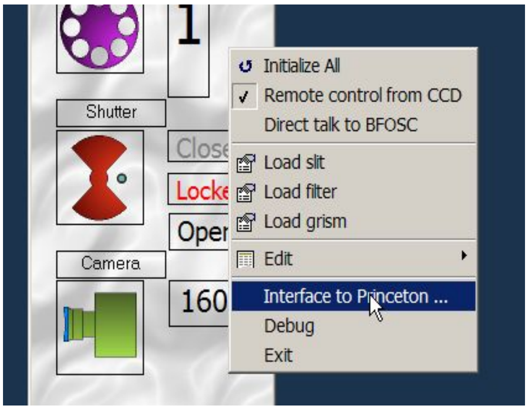


Figure 7

This command will open the window shown below (*Figure 8*). From here we can send all the commands for the acquisition of images.

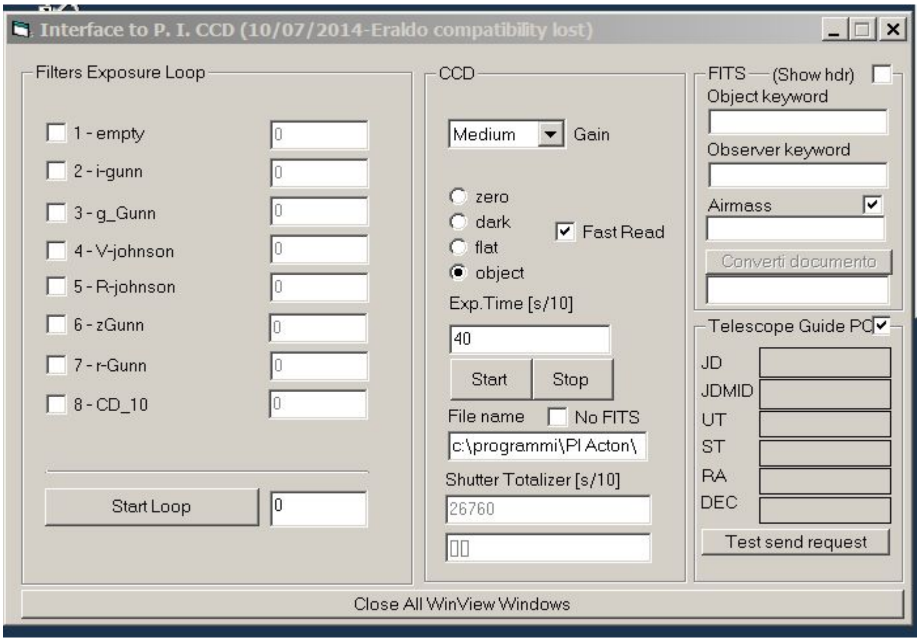


Figure 8

1.5 Open and lock BFOSC internal shutter

This is the last step to complete the BFOSC initialization. The instrument has two shutters; the first (electro-mechanic iris shape shutter) is mounted in front of the main CCD and is normally used for the exposure; the second shutter (blade-shaped and mounted between the filter and grism wheels) is not used and must be locked in open position. Right click on the shutter shape in the "*BFOSC panel*" and select "*Open*" with the left mouse button, then right-click again on the shutter shape and select "*Lock*". The whole sequence of commands is shown in *Figure 9*:

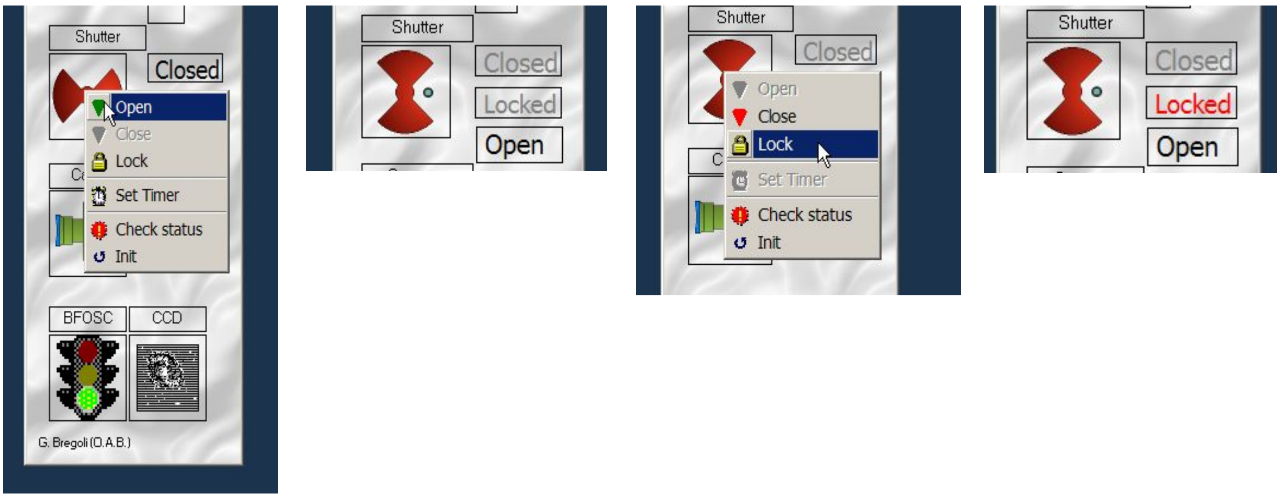


Figure 9

1.6 Change the BFOSC optical configuration

To know the actual Slits, Filters and Grisms mounted on BFOSC, right-click on one of the wheels in “*BFOSC Panel*” and will te current optical configuration will be displayed (*Figure 10*). Then left click on the required Filter or Slit or Grism to turn the wheel. Wait until the green “traffic light” signals that the action is complete.

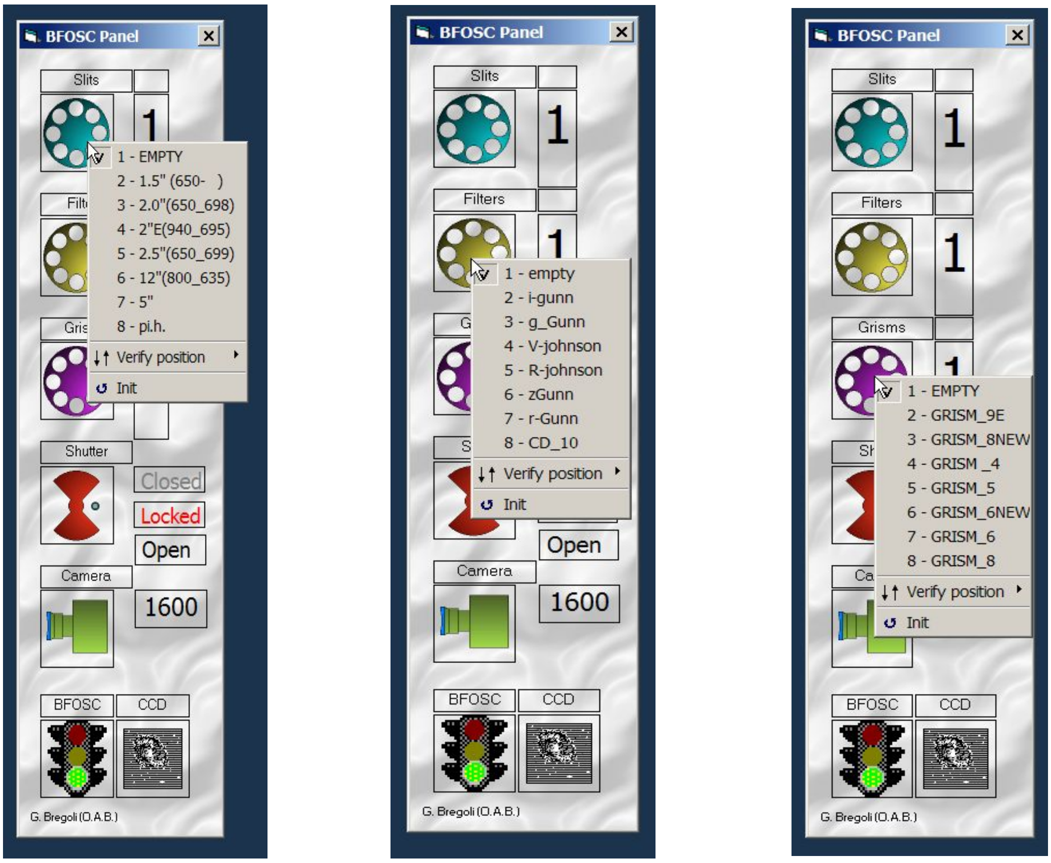


Figure 10

This optical set is not always the same because it depends on the astronomer's request. Only the local technical staff is enabled to physically change the BFOSC optical elements.

1.7 The “*Winview*” software

Double click on the “*Winview*” desktop icon to run the software that display the images taken by the main CCD.

The software appears as in *Figure 11*:

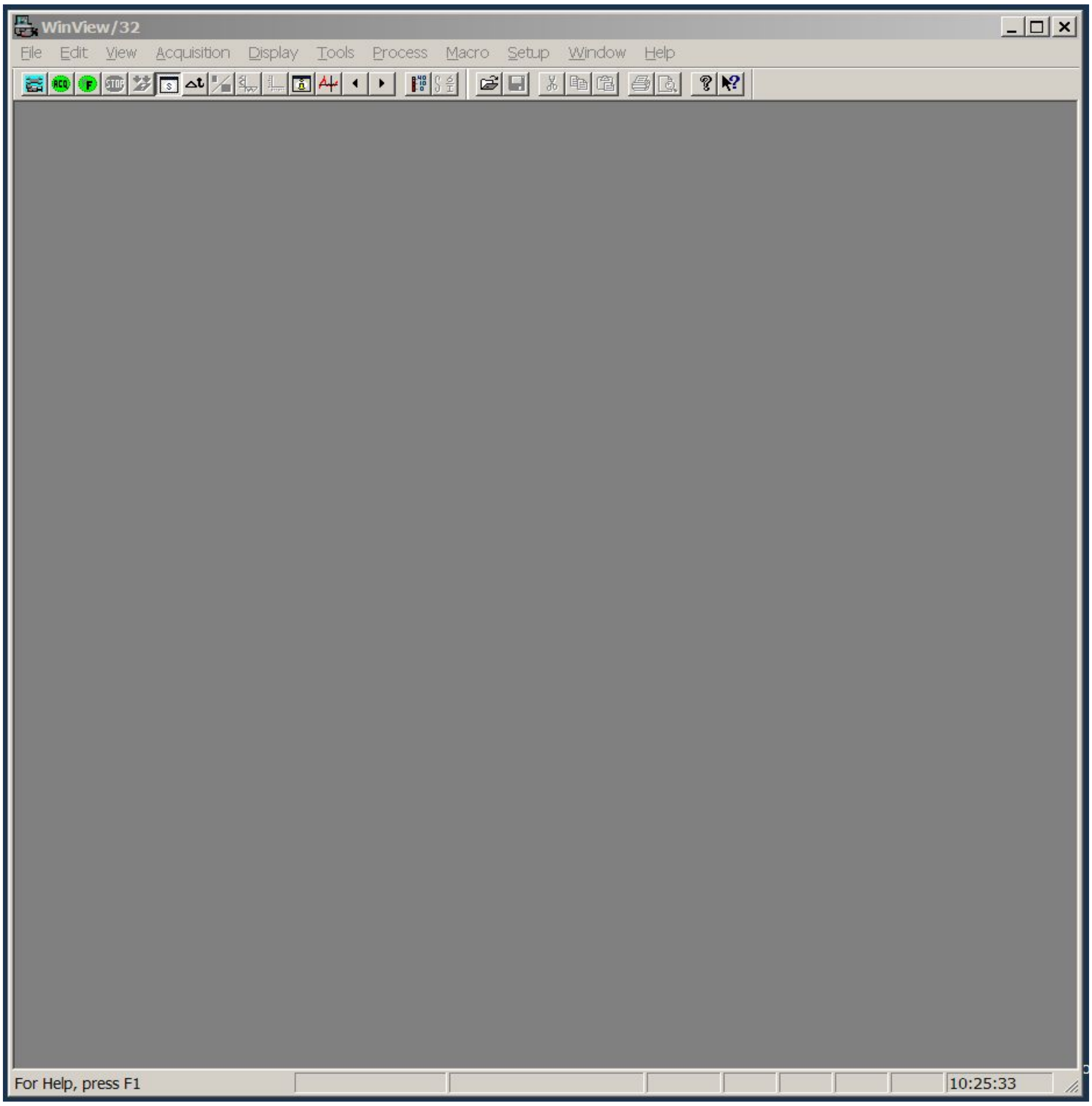


Figure 11

This program permits to:

- check and modify the CCD sensor temperature
- save or not the images on computer disk
- display the statistical data (maximum, minimum and average count) in a box drawn on the image
- change the image color contrast for optimal visualization
- measure the star PSF
- check the time passed from the image acquisition start command
- activate the FOCUS mode to control the Telescope focus and the star's position with respect to the slit
- draw a boxed image to select a smaller CCD readout field
- draw a preliminary plot to display an intensity profile for a long slit spectrum

On the top of the window there are many buttons. Only few of these are helpful for this guide. In *Figure 12* is shown the top – left area of the window and here are explained the functions of 5 main buttons:

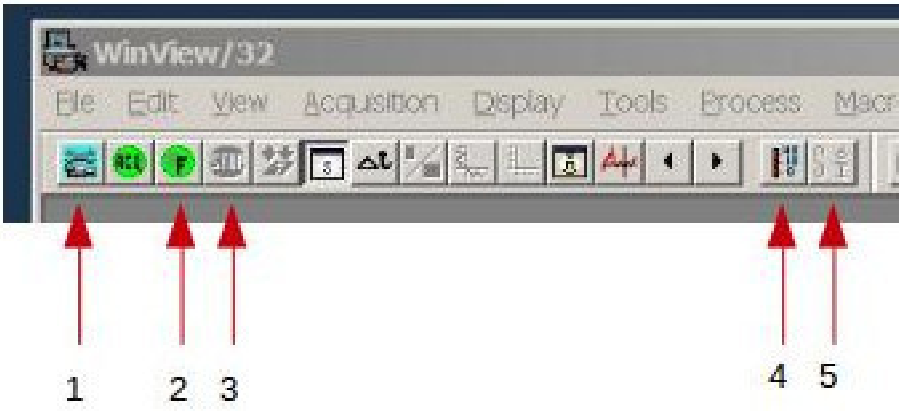


Figure 12

Button 1: “*Experiment Setup*” (save scientific frame on disk, create a box on the full frame)
Button 2, 3: Start and Stop “*Focus*” mode (display a continuous sequence of images without saving on disk)
Button 4: Visualization of CCD sensor temperature
Button 5: Show a numerical statistic on a selected portion of image

On the bottom of the “*Winview*” window the status bar (*Figure 13*) shows:

A : the CCD's working state (STORE or COMPLETED)
B : The time passed from the start acquisition command

Figure 13

1.8 Set the detector's temperature

Press **Button 4** to show the current detector temperature that is usually set at **-91°** (but in poor dewar vacuum conditions it can be higher). A **-25°** temperature detector value means no liquid nitrogen inside dewar.

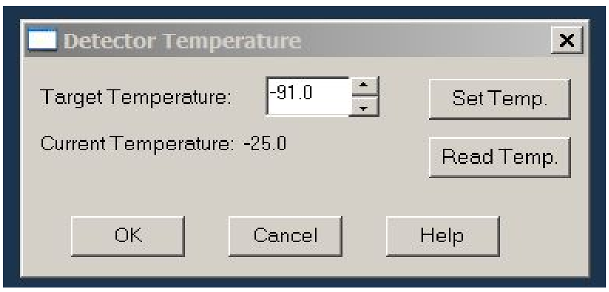


Figure 14

Now all the necessary control programs are opened on the desktop. Adjust the windows to optimize the visualization like in *Figure 15*:

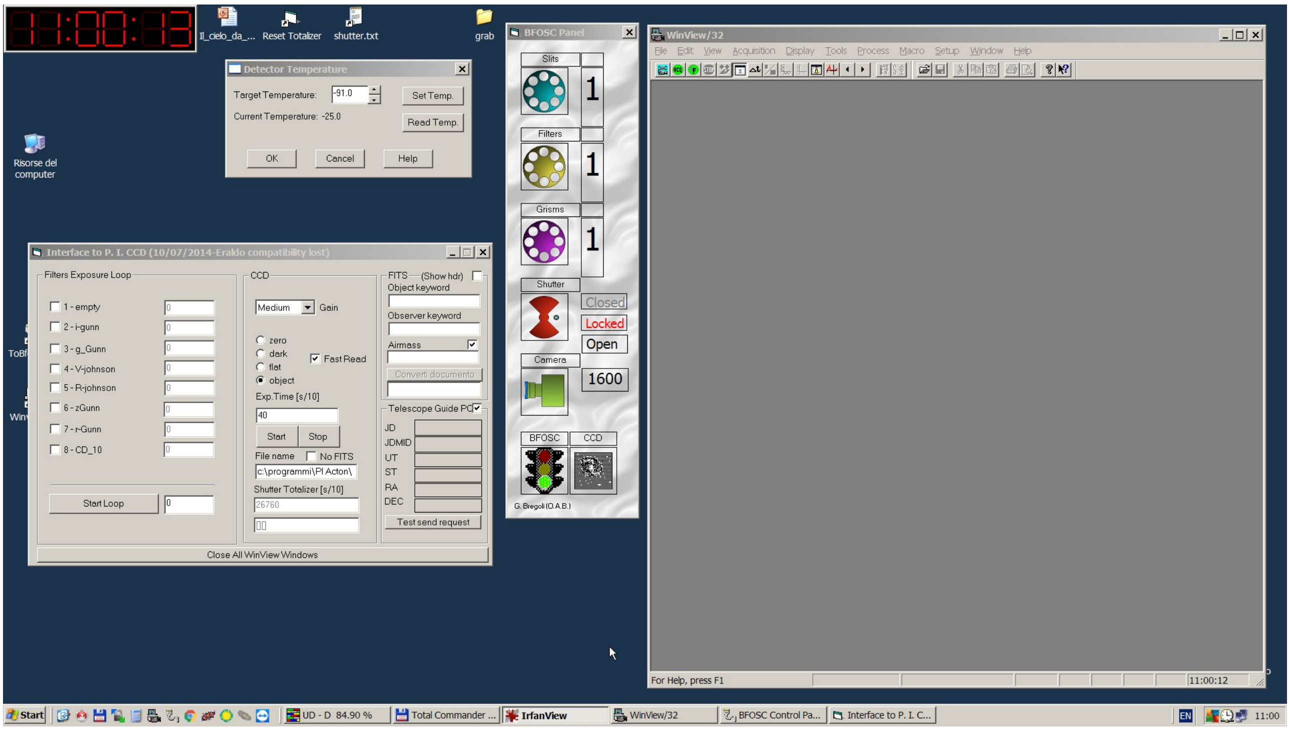
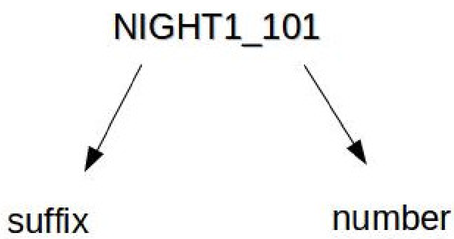


Figure 15

2 Taking an image

First of all we need to decide the name of the data that during the night will be saved on computer's disk. This is not the name of the target but only an identifier that usually is changed night by night. The identifier should be labeled in two parts: a *suffix* and a *number*. This is an example:



The *number* will be automatically incremented by the software every time a new image is acquired if the appropriate saving command is enabled, while the *suffix* remains the same for all the observation run. The *suffix* needs to be changed every new observation night to avoid to overwrite the data.

2.1 Acquire an image and save it (or not) on disk

STEP 1

Look at the **A** circled zone in the "*Princeton Interface*" dialog box (*Figure 16*) and write your *suffix* in the final part of the path (the path is "*C:/Programmi/PI/ Action/Winview/Data/*", **don't modify it**, in this example the suffix is *test_*):

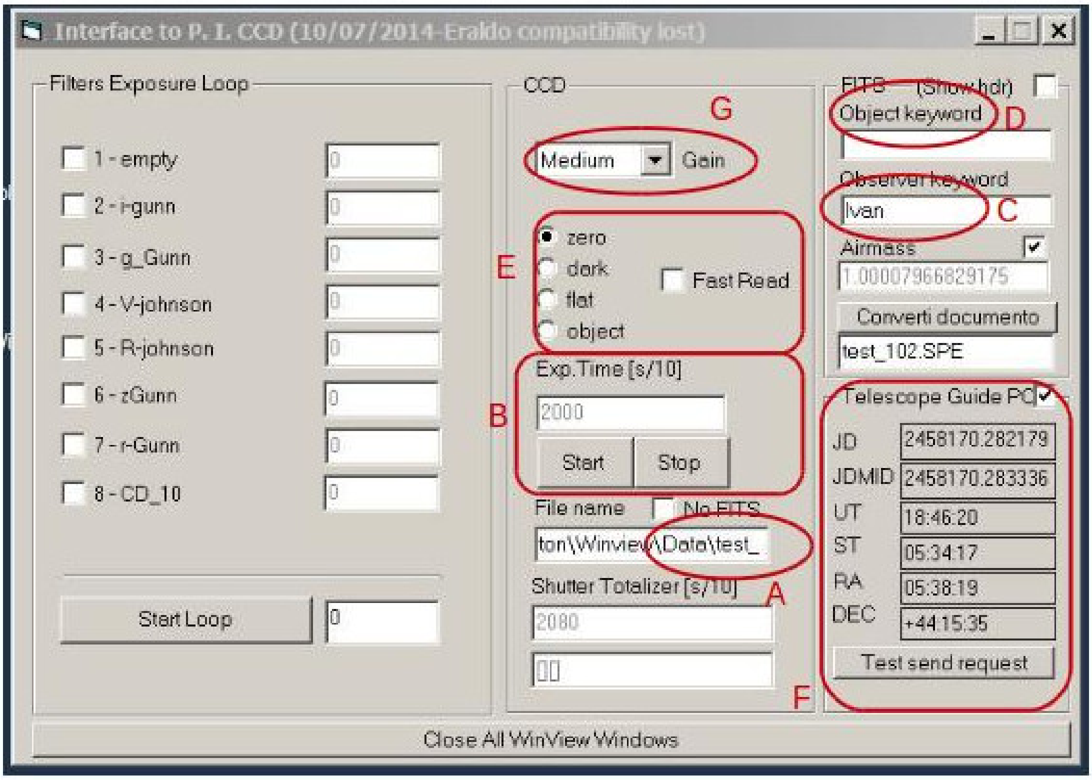


Figure 16

STEP 2

Write the Observer name in the circled **C** "*Observer keyword*". This information is saved in the image fits header (in this example the keyword is *Ivan*)

STEP 3

The **E** circled zone select the kind of image that you desire to take:

- *ZERO* to take a BIAS frame
- *DARK* for the DARK frame
- *FLAT* for a FLAT frame
- *OBJECT* for acquire an image. Only in this case, write your target name in the **D** circled zone (for BIAS and FLAT is not necessary)

All this informations will be stored in the image header.

STEP 4

Also in the **E** circled zone is the "*Fast Read*" check-box. Enabling this means that the read out detector frequency will be at 1MHz, so the full frame read out time will be only 2 seconds instead of 17 seconds (100KHz is the scientific mode). This option is useful for the Telescope focusing activities.

STEP 5
Once you have decided what kind of image to take, inserted the object and name keywords, the *suffix* name and enabled (or not) the “*Fast Read*” mode then you need to decide if you want to take a test image (without saving it) or a scientific image (to be saved).

STEP 6
After defining the *suffix* name, we need to set the start *number* as explained above. To do this, press **Button 1** (see *Figure 12*) to open the "*Experiment setup*" window and enter in "*Data File*" task.

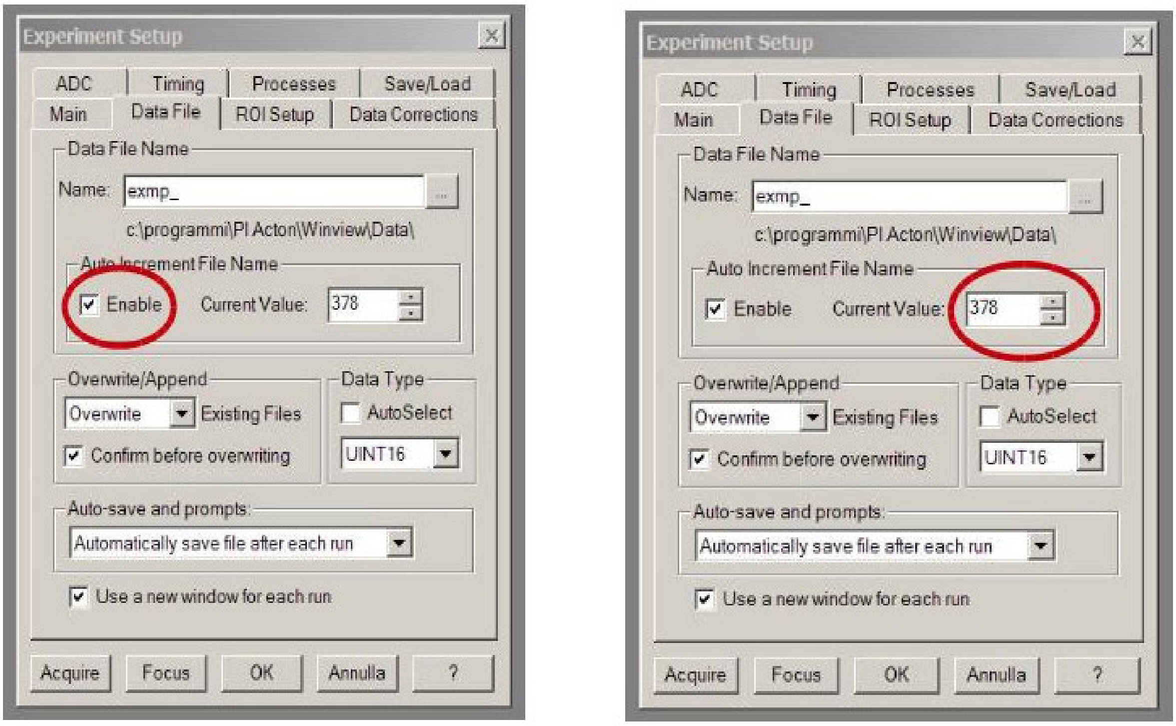


Figure 17

To save every image, check the “*Enable*” label (*Figure 17* left) and change the *number* of the image (*Figure 17* right). Usually the number notation that we use is **101** for the first image of the night.
If the “*Enable*” is not checked then all the images will be only displayed and not saved (this is very useful during the telescope focusing operation and when adjusting the target position on the CCD frame.
The software converts automatically the native binary image format (*.spe)* in standard *.fits.* The local saving folder is **C:/Fits/**.

STEP 7
Now we are ready to start the acquisition. Change the BFOSC optical configuration according to your necessity (see section 1.6). In the circled **B** area (*Figure 16*), set the exposure time expressed in units of 0.1 sec. (e.g.: 600 for a 60 sec integration) and then press the “*Start*” button. The acquisition status is reported in the “*BFOSC panel*” with this marker (*Figure 18*):

Figure 18

The CCD status and elapsed acquisition time will be displayed as in *Figure 13*.
If you are acquiring a test image, without saving on disk, then two messages (*Figure 19*) will appear to warn that the frame in question will be overwritten in the internal memory buffer.

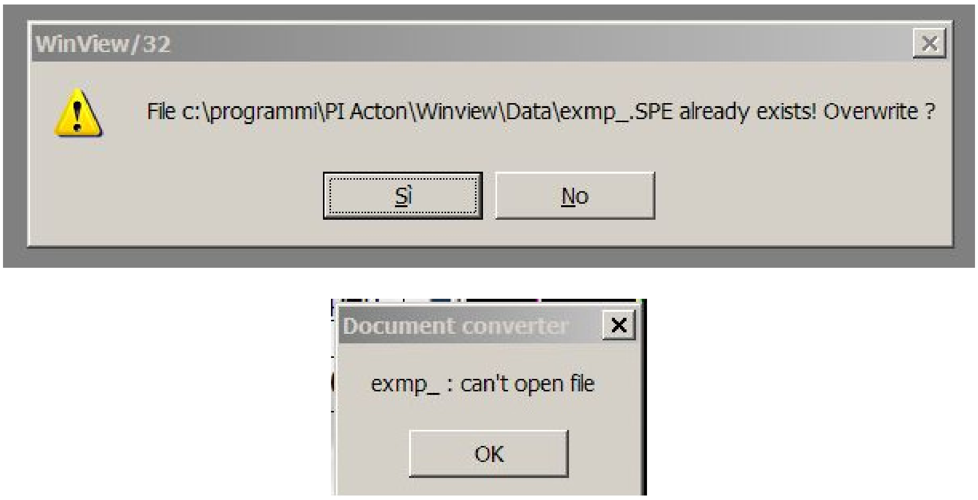


Figure 19

Press “*OK*” in both message boxes. The image will be only displayed in “*Winview*” software window.
The **F** circled zone shows times and Telescope coordinates fed (by RS232 port) from the Telescope pointing user interface. All these data are saved as keywords in the fits header if the “*Telescope Guide*” check box is enabled. Otherwise, no keyword is saved. Disabling this check-box can be useful when the pointing software is off anc you need to take images evenly. In any case, remember to keep it enabled.

2.2 Modify the image gray level contrast

After an exposure, the image displayed on the "*Winview*" window is very dark (*Figure 20*).

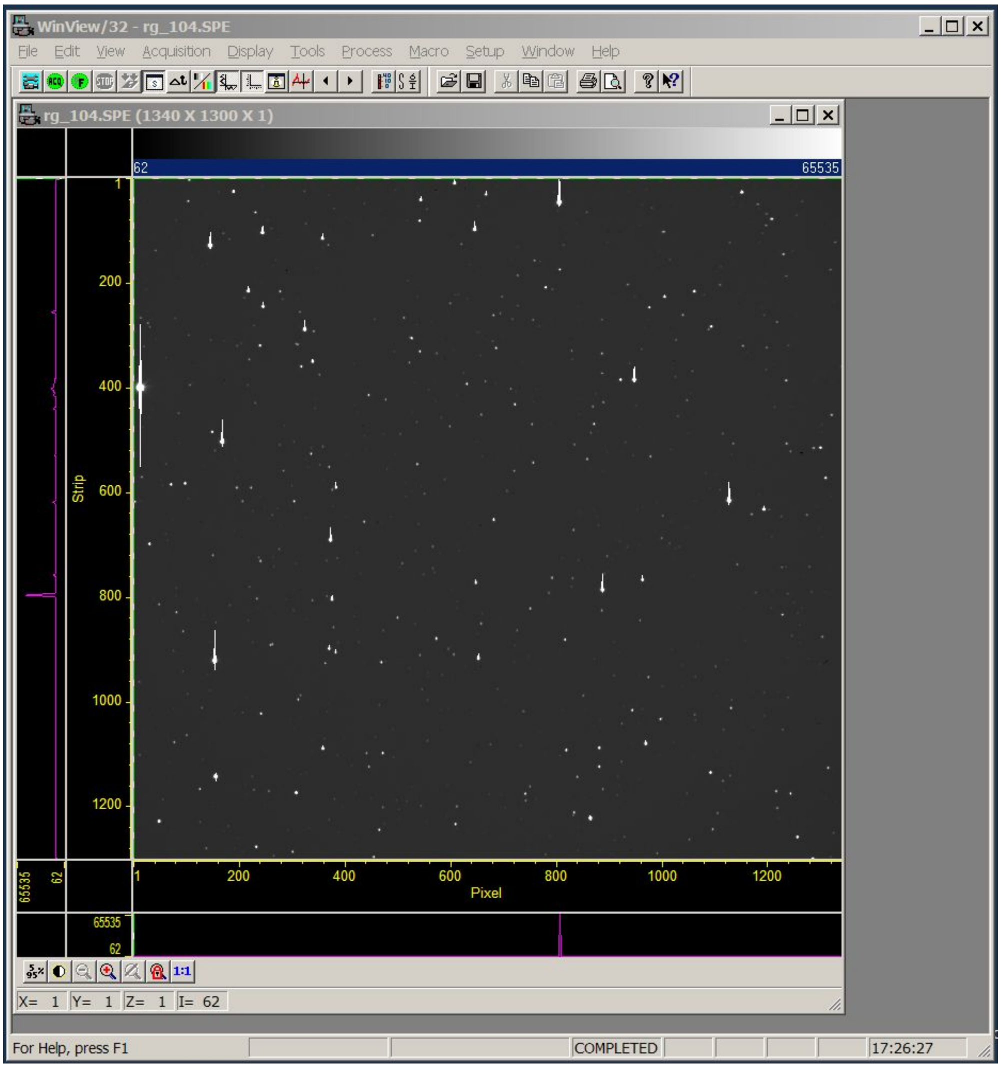


Figure 20

In the lower left-hand corner of the *Winview* window there are some buttons that permit to change the gray contrast level and zoom on the image (*Figure 21*). In particular:

- **Button H** change the contrast with standard gray level values (see *Figure 22*)
- Draw with mouse (left button) a little box on image and then click on **Button I** to dynamically change the gray level contrast
- Draw a box on image and click on **Button L** to zoom the region
- **Button M** to return to the original zoom
- left-click on the image will display the pixel's X,Y coordinates in the N circled zone, and its counts in O (the saturation value is 60000 counts)

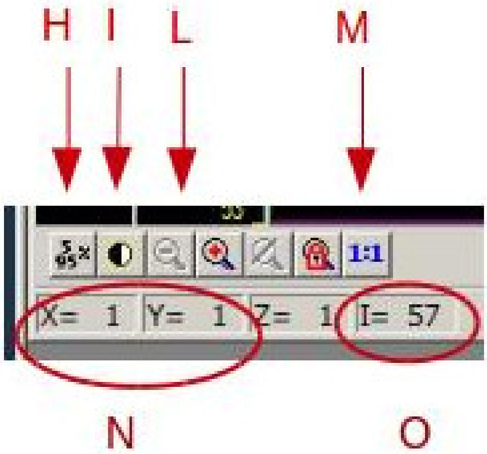


Figure 21

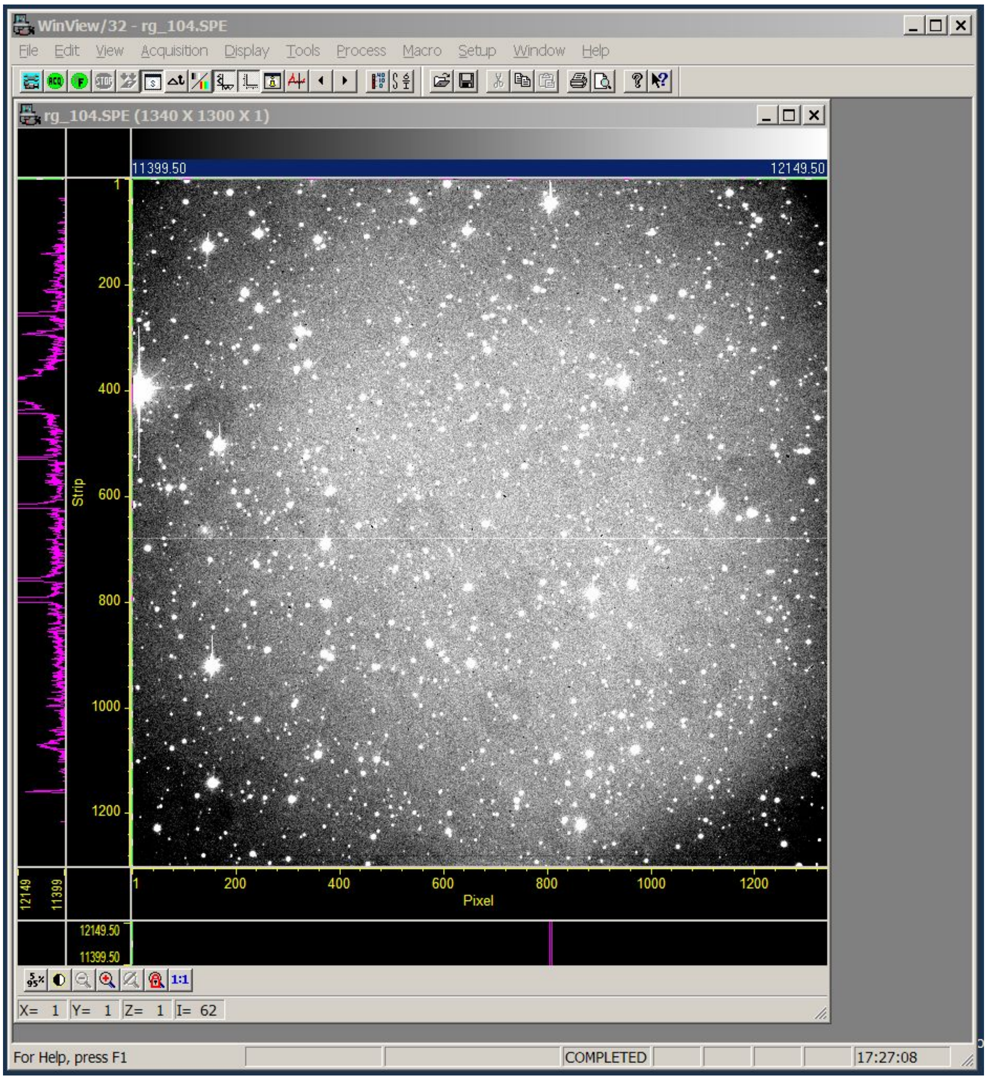


Figure 22

Another way to adjust the image contrast is:

- click on "*Display*" on the menu bar of the "*Winview*" window, and select "*Palette...*" as shown in *Figure 23*.

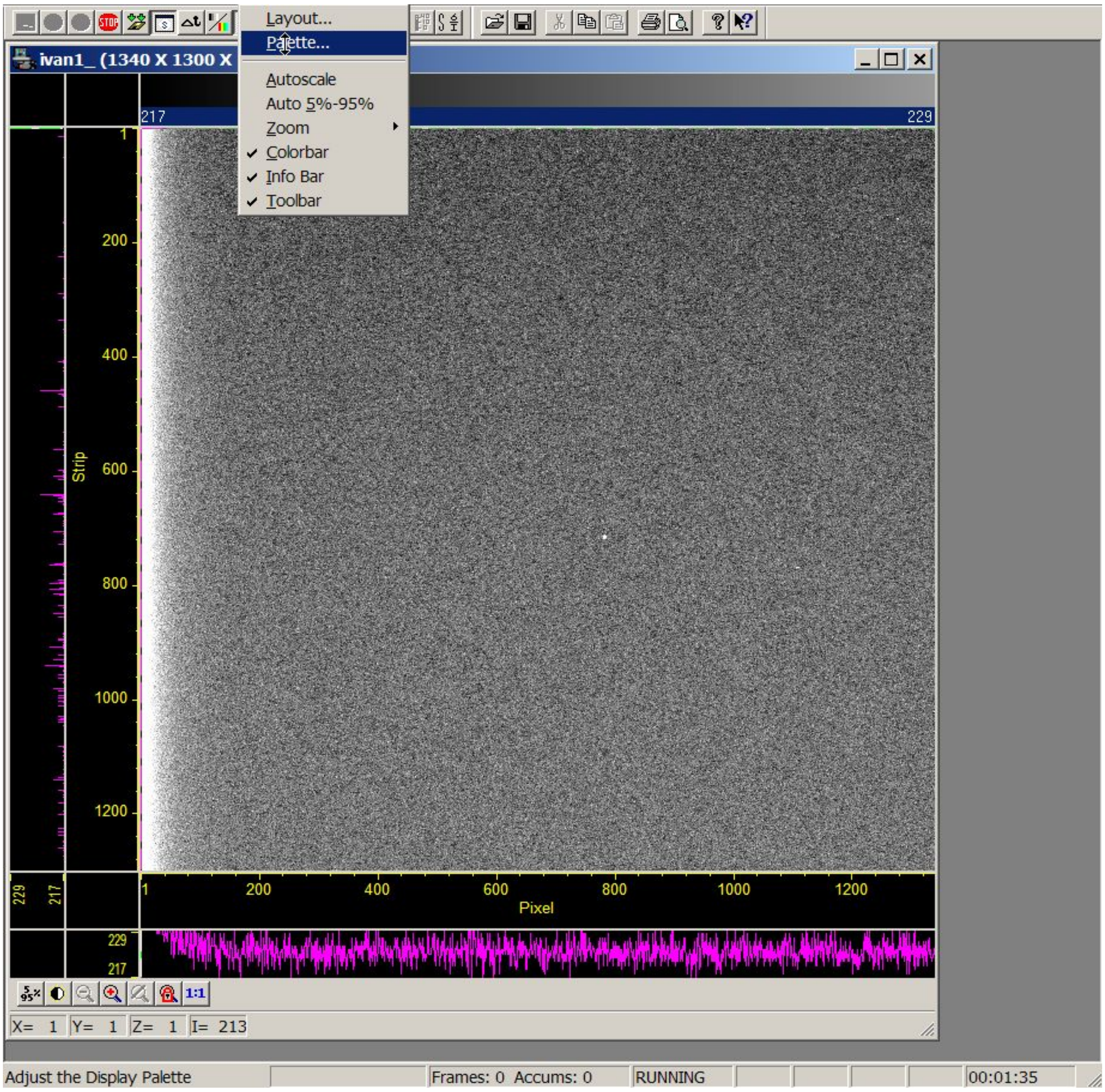


Figure 23

- A new box will appear. Moving the contrast slider, the gray level of the image will change (*Figure 24*).

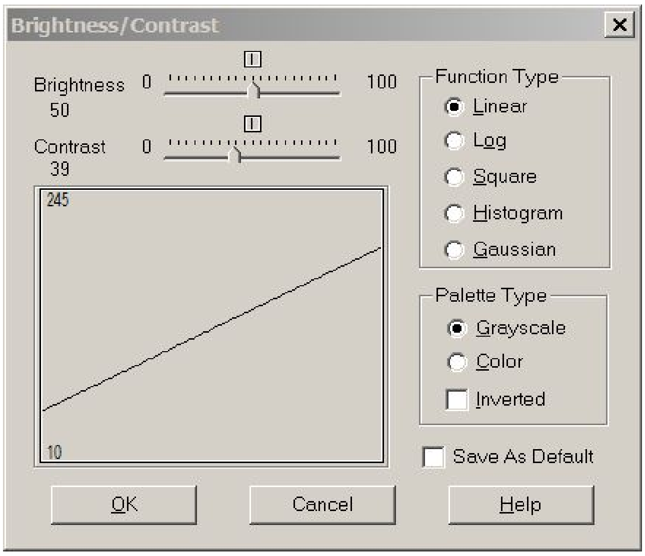


Figure 24

2.3 Statistic on image

Select with mouse a region on the image or a box around the target (*Figure 25*).

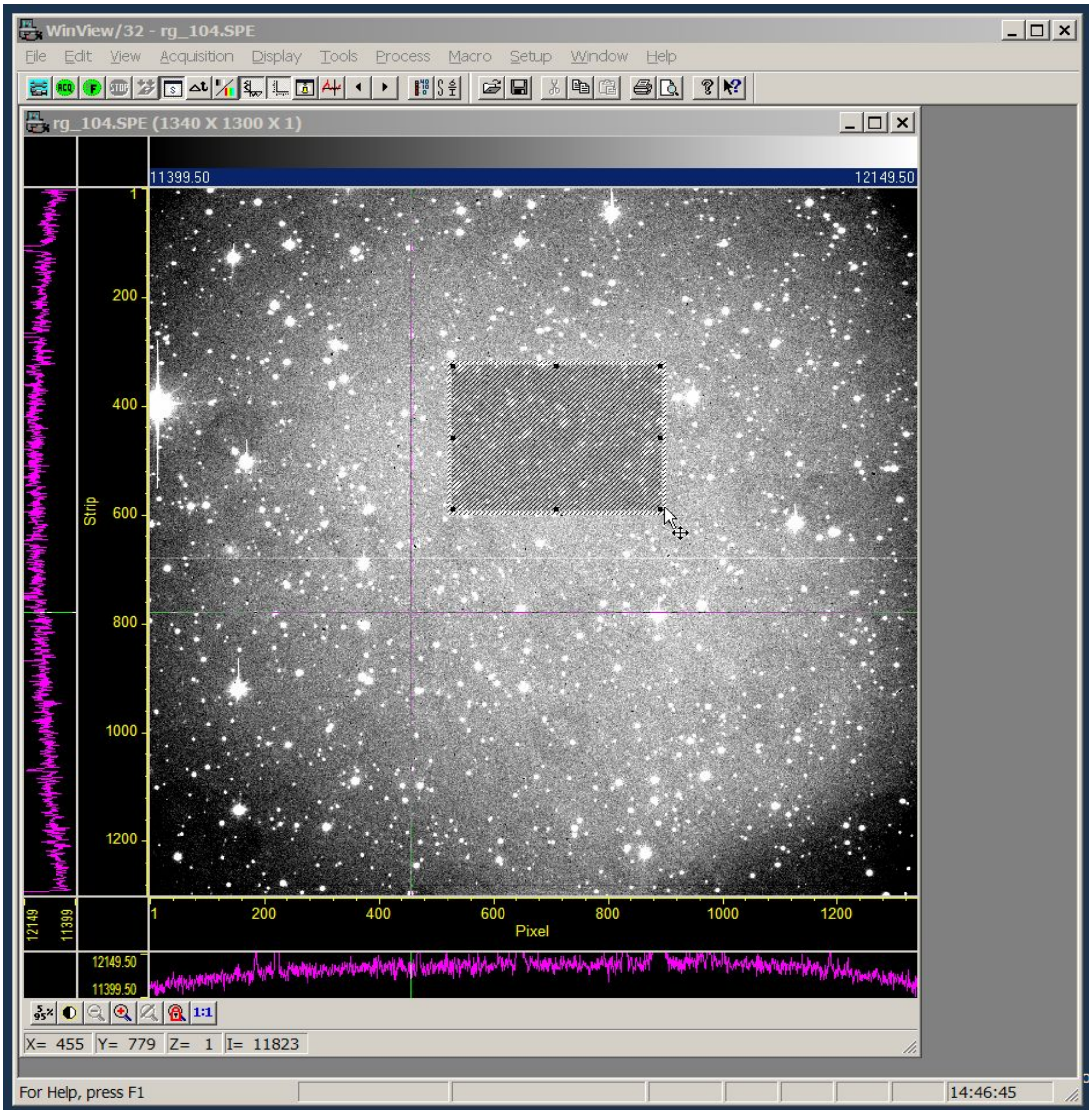


Figure 25

Clicking Winview's **button 5** (*Figure 12*) will display statistical information on the selected area (*Figure 26*).

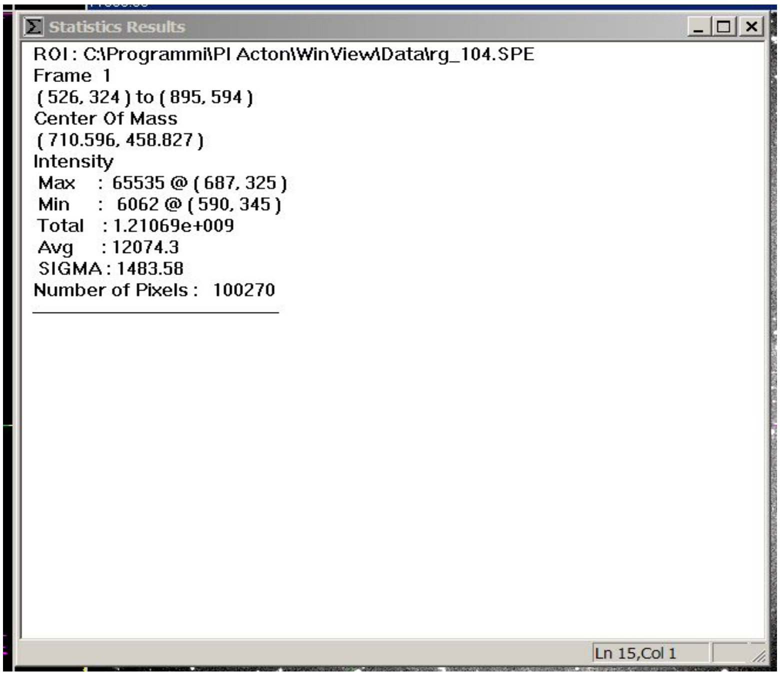


Figure 26

Drawing a small enough box around the target, for example, can show easily if it is saturated. You can close the window without saving it.

2.4 Evaluate the seeing

Make a little box around an isolated and not saturated field star and click on the "*Process*" task in the "*Winview*" panel. Then select "*Cross Section...*" (*Figure 27*).

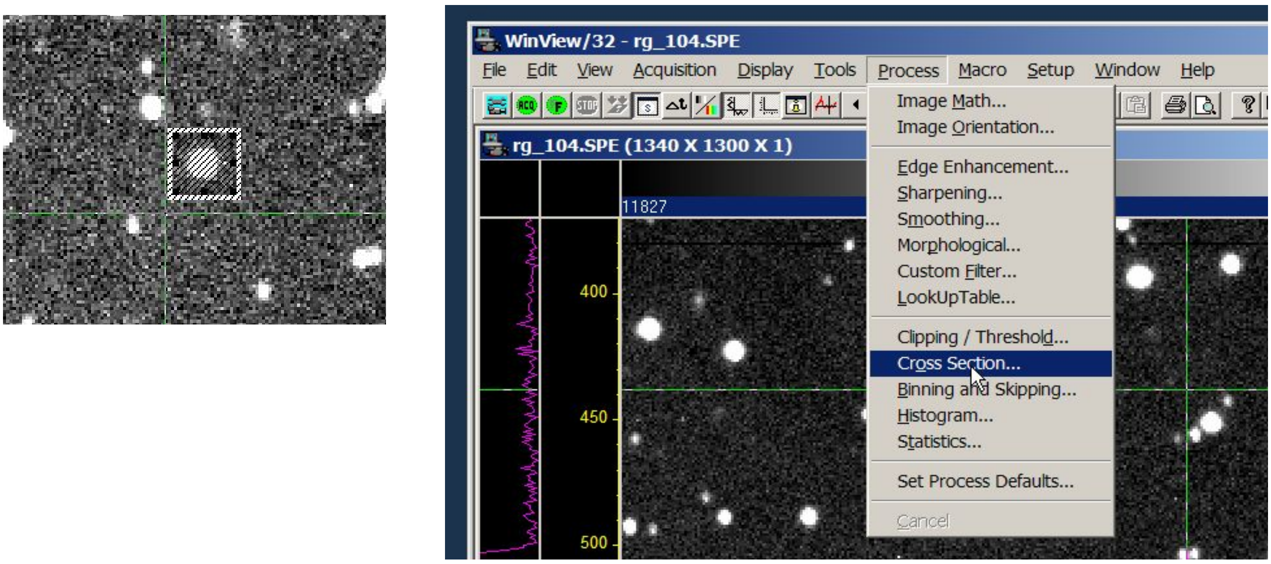


Figure 27

Click respectively on "*Mouse*", "*Apply*" and then "*Close*" in the new window (*Figure 28*).

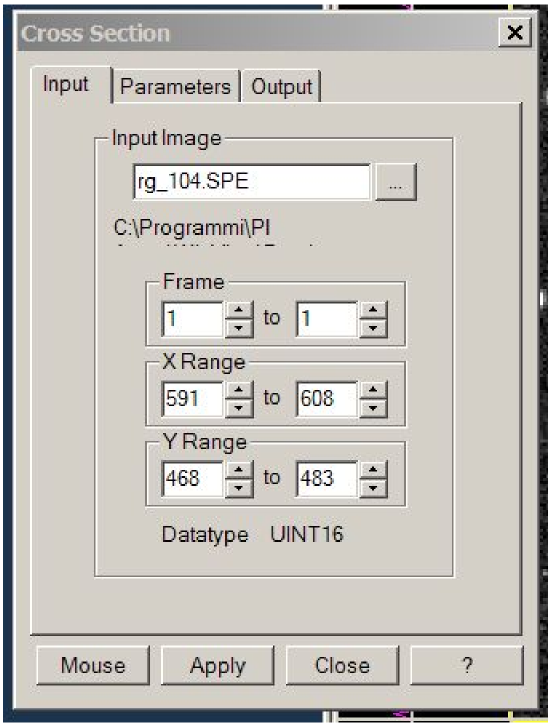


Figure 28

Finally a new graph (*Figure 29*) appears, plotting the flux profile (only for one axis) of the star selected.

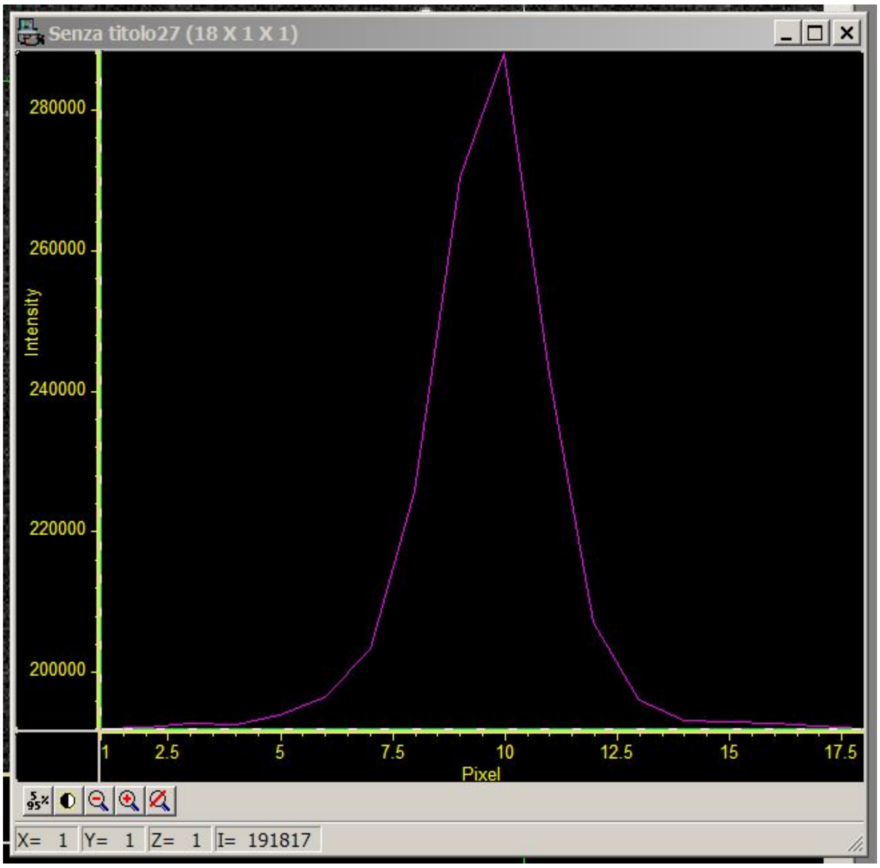


Figure 29

Now it is possible to obtain an estimate of the night seeing by drawing with the mouse a rectangle with the short side coincident with the PSF's FWHM (*Figure 30*) and counting its length in pixels (in this example its value is about 8 pixels). Remember that the CCD pixel scale is 0.57 arcsec/pixel (see *Appendix 1*), so for this example we obtain a seeing of about 0.57(arcsec/px) x 8(px) = 4.5 arcsec

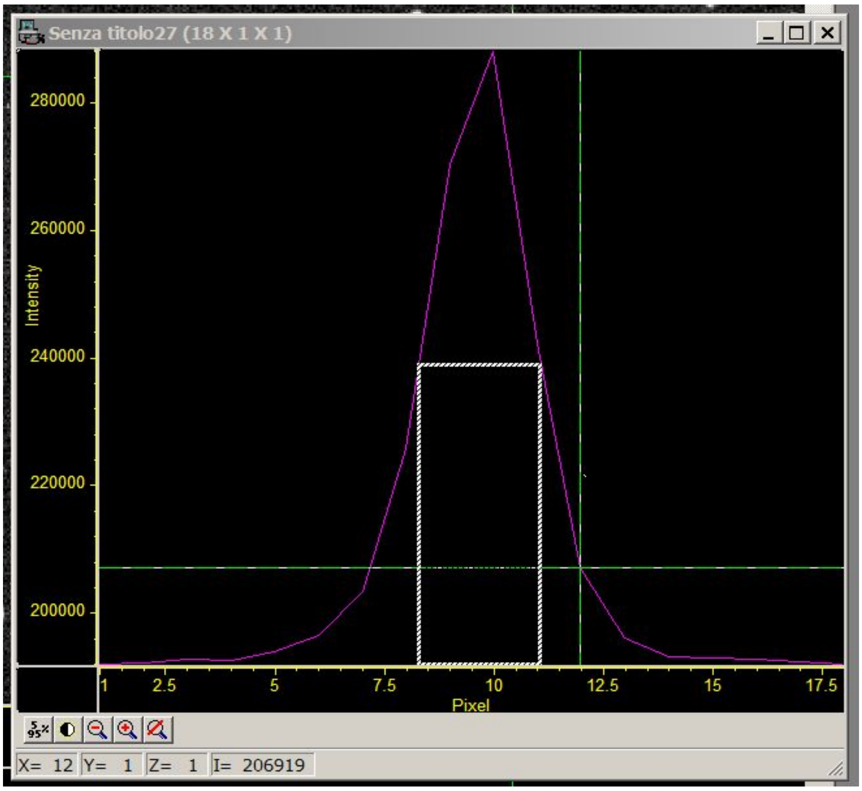


Figure 30

For a more accurate measurement, you need to analyze the image with more specific software (i.e. IRAF).

2.5 Storing a boxed frame. "*ROI Setup*"

Some observation programs require to save on disk only part of the CCD frame, so that the CCD read out time is shorter. To do this, use the mouse to select the desired sectionof the image (as in *Figure 25*) and then press **Button 1** of *Figure 12* ("*Experiment Setup*").
Select the "*ROI Setup*" task (*Figure 31*) and finally press respectively "*Mouse*", "*Store*" and "*OK*".
Click "*OK*" on the message that informs the user of the change of setting (*Figure 32*).
Now the CCD controller will download only the region selected. Open the "*ROI Setup*" again and press "*Full*", "*Store*" and "*OK*" to return to the full frame. Remember to take a note about the XStart, XEnd, YStart, YEnd of the box in "*ROI Setup*" because the full FLAT FIELD and BIAS will be rescaled accordingly.

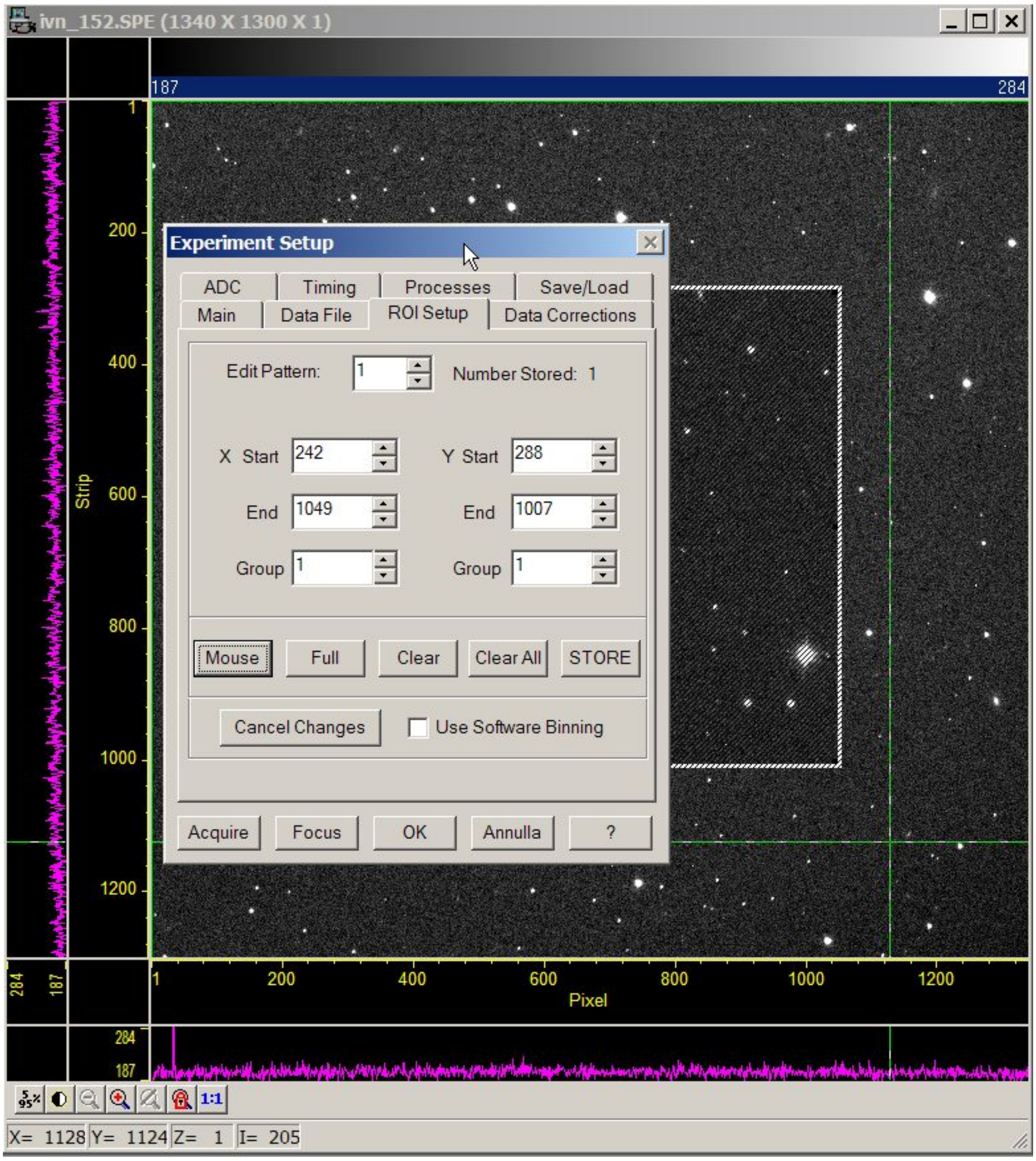


Figure 31

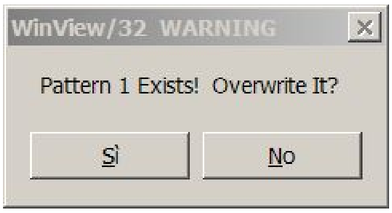


Figure 32

2.6 The "*Focus*" mode

A very useful "*Winview*" facility is the "*Focus*" mode. It is possible to display an infinite sequence of images to examine the CCD image in. We can use it in full frame or in boxed mode. Essentially this is convenient for two reasons:

1. control the star's shape to check the Telescope's focus
2. control the target (X,Y) position on frame to center it inside the slit for spectroscopy

First of all, in both cases, you need to disable the disk storing (see section 2.1, STEP 6) and take one test image of about 3 or 4 seconds of exposure time in fast readout (see section 2.1).
Then, click on **Button 2** (*Figure 12)* to start the "*Focus*" activity. Now, at every exposure time, you will see a new image displayed in "*Winview*" the window. Adjust the image contrast (see section 2.2). Press **Button 3** to stop the series. Use this technique to check the Telescope's focus. *Figure 33* shows the difference between a not focused (left) and focused star (right). There is noautomatic refocusing procedure at this time, so the focus needs to be checked regularly during the night (temperature fluctuations are the main cause of focus variations).

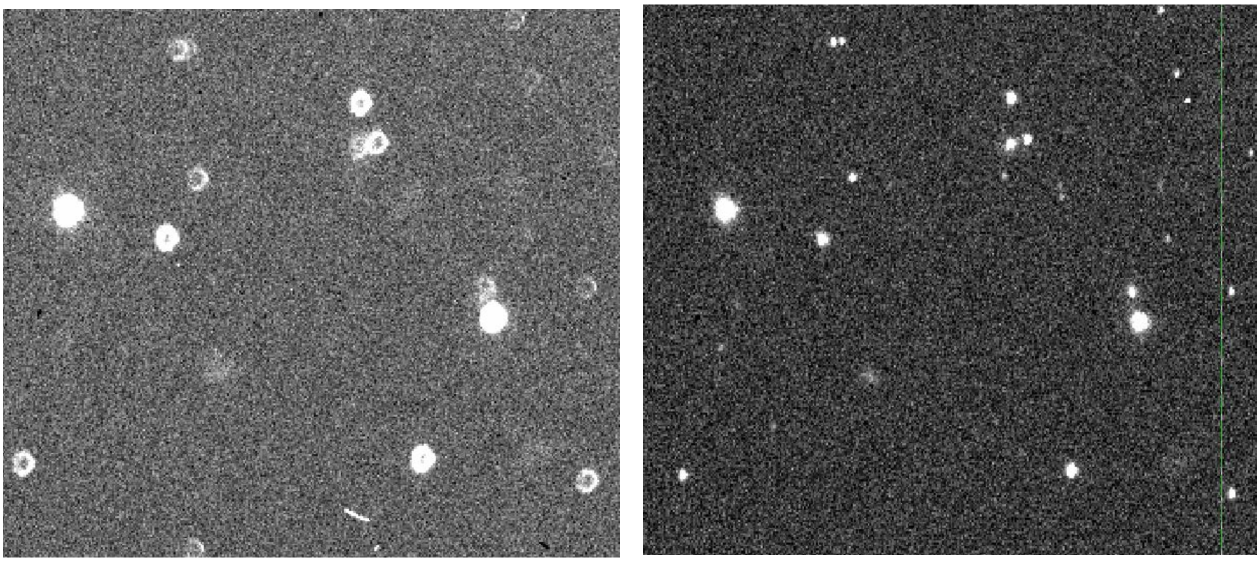


Figure 33

The shape of a focused star is "circular" (for seeing less than 1 arcsecond the PSF is undersampled and the star shape will be not so circular!). To obtain this you need to move properly the Telescope's secondary mirror in two ways: one is using the pointing software interface (see the manual "*Manuale Sistema Puntamento*") and the other one is using the "*manual control box*" in the control room. We use this last method. *Figure 34* shows the "*manual control box*".

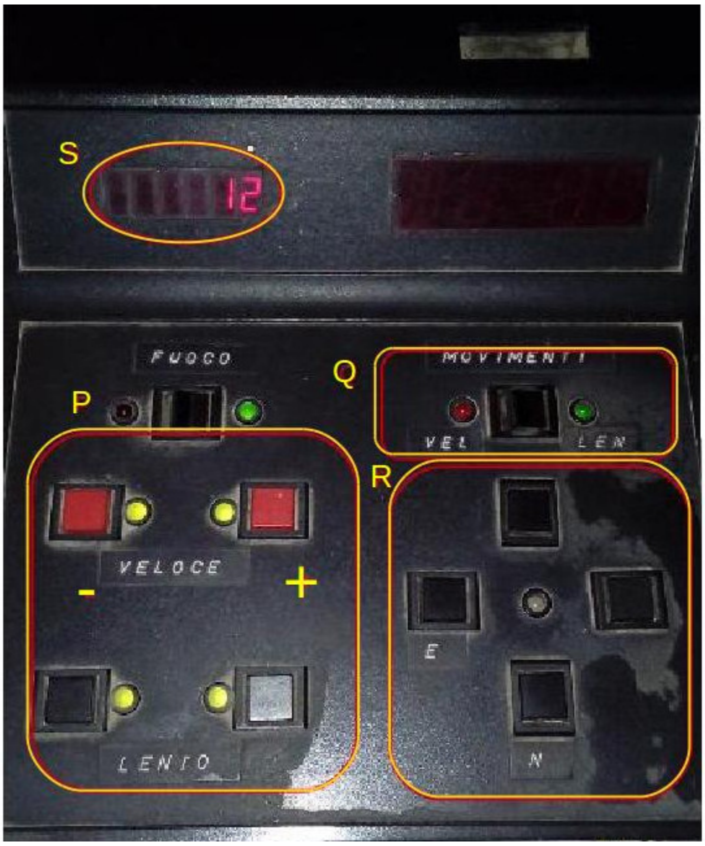


Figure 34

The circled **S** zone displays the (arbirtary) number that indicates the current focus value. Press button **+** or **–** (in the **P** box) to move the secondary mirror and change the focus value. The red buttons (VELOCE) are for the fast movements and the black buttons (LENTO) for the slow movements. With *Focus* mode active any variations of the star shape is easily seen.

Often the Telescope must be moved slowly, to shift te target to a preferred pixel positionon the CCD frame. To do this manually we use the buttons in **R** box (*Figure34*). The switch in the **Q** box sets the Telescope's movements to FAST (red led) or SLOW (green led). The SLOW mode is used to move the Telescope very slowly (arcseconds/sec) to the required position.

When all is ready, remember to keep the switch in the **Q** box on SLOW. This is very important for the best autoguiding performances (see the manual).

3 Taking image series

Many observational programs require the acquisition of several images of the same target in one or more photometric filters. The BFOSC control software permits this operation for the full or boxed frame.

3.1 Activate loop in "*Interface to Princeton*" panel control

When the Telescope is well pointed on the target and all is ok (the focus is good, we have choosen the photometric filter (or filters) and the right exposure time (times), the autoguide is running and the image auto saving mode is enabled), have a look al the "*Interface to Princeton*" panel (*Figure 35*).

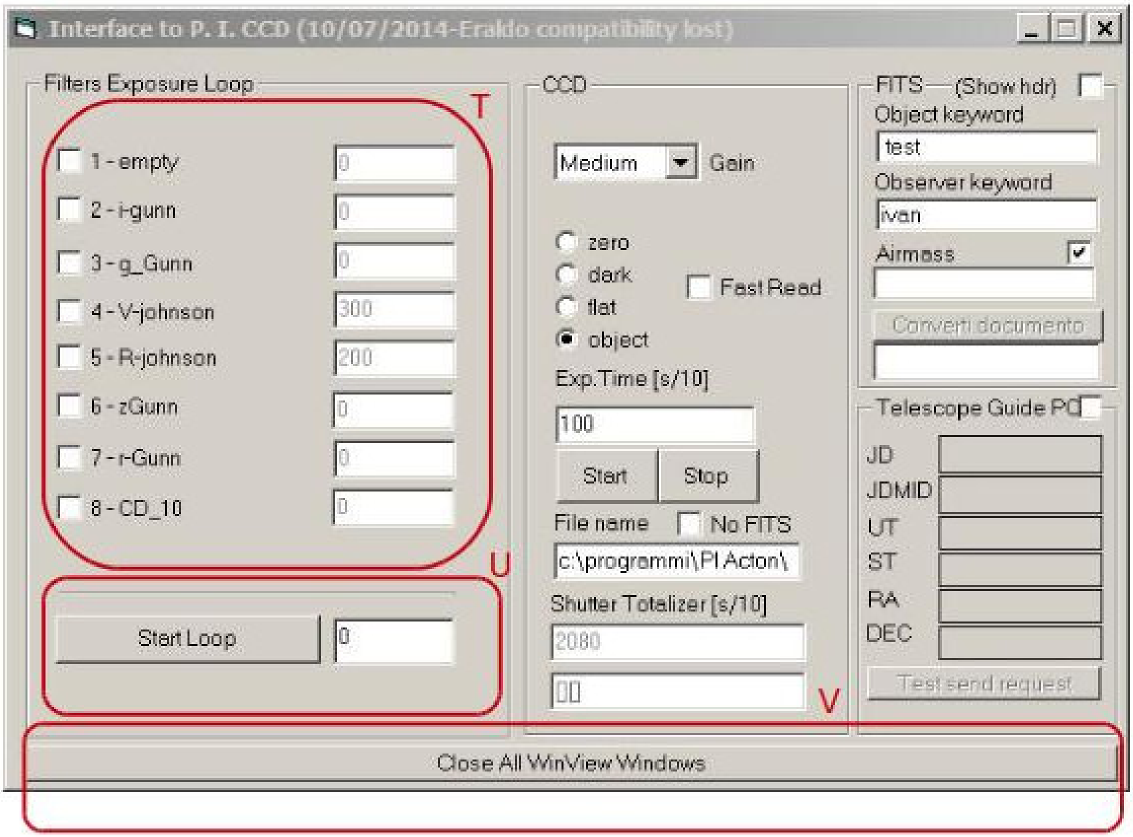


Figure 35

In the **T** red section it is possible to select, with check-boxes, one or more filters (the optical configuration here is the same that you can see as described in section 1.6) and insert, in the corresponding label-box on the right, the exposure time for each filter. The total number of images to take with the chosen optical configuration is inserted in the label box of the **U** section. Press "*Start Loop*" button to begin. A practical example is shown in *Figure 36* where a loop is defined of 10 images V (30 seconds of exposure time) and 10 R images (20 seconds of exposure time). In this example the V and R images will be stored alternately. The first filter that begins the acquisition loop is that with the lower identification number on the filter wheel (in this example it will be the V filter). To stop the loop (this can be done at any time) press the "*Stop Loop*" in the **U** section. If the loop is stopped while the CCD is in acquisition mode, then the current image will be taken correctly.
In case of very long loop (hours of observation), consider that the Telescope's focus will change so it is a good rule to stop the loop (for example every 40 minutes) briefly to check, and adjust it if

required. Also, after taking about 100 consecutive images remember to stop for a moment the acquisition and press the button "*Close All WinView Windows*" in section **V** to clean the video memory buffer.

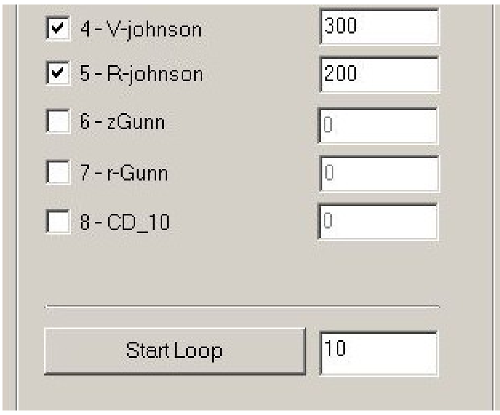


Figure 36

4 Acquire BIAS frames

- Check the detector temperature (section 1.8). Inform the technical staff if its value is not as expected.
- Verify that all the inner dome lights are off.
- The pointing software needs to be running (if not, see section 2.1, STEP 7).

Select (*Figure 37*) in the "*Interface to Princeton*" panel the "*zero*" option and press the "*Start*" button to take one BIAS test image (without save it, see section 2) first to check any abnormalities (intensity gradients, abnormal counts..). Make a box on the image with the mouse, to display the statistics (section 2.3), which should be about 100 counts with standard deviation 1.36.

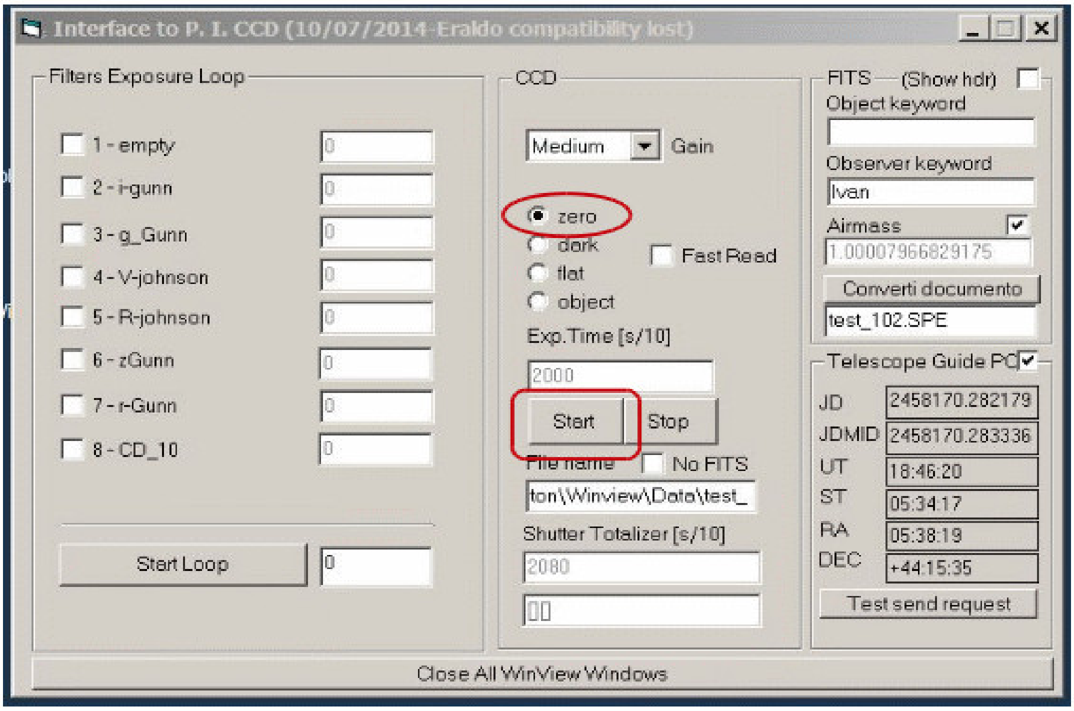


Figure 37

The read out time of a full BIAS frame is 17 seconds. *Figure 38* shows an example of a correct BIAS image. After this test, enable the image storage (section 2.1) and press the "*Start*" button to start the acquisition of one BIAS.

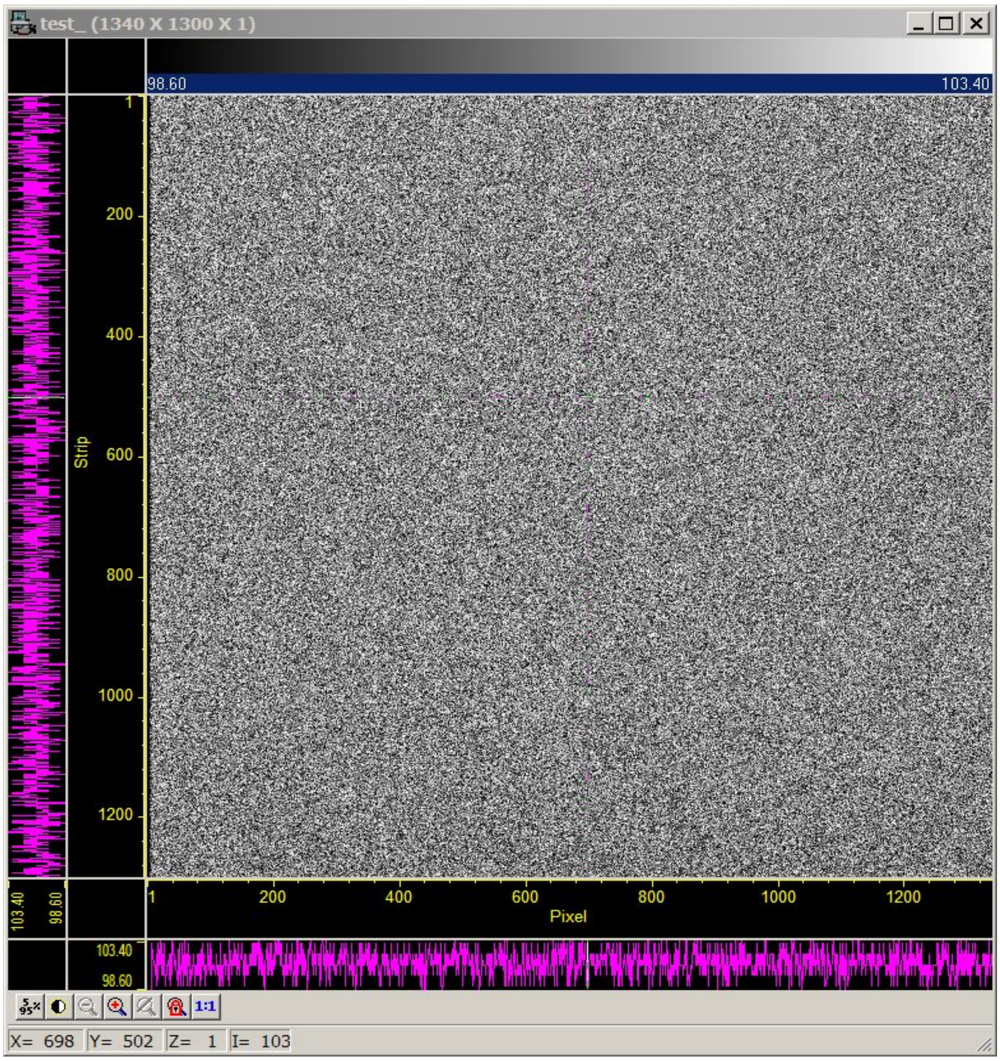


Figure 38

There is also the possibility to acquire automatically a sequence of BIAS images. In "*Interface to Princeton*" randomly select a filter and write 0 in the corresponding exposure time label. Then set up the total number of images and press the "*Start Loop*" button (*Figure 39*, in this example a sequence of 10 bias images has been planned.

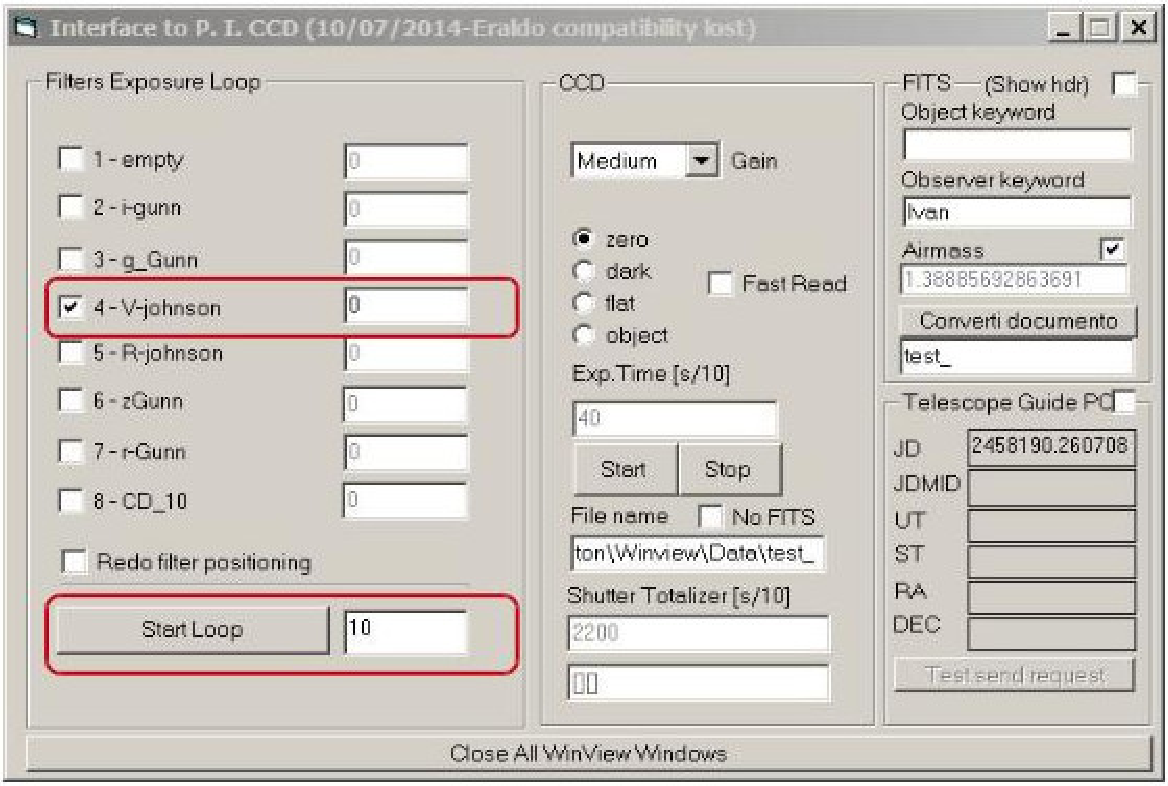


Figure 39

5 Acquire image FLAT FIELD (Dome and Sky) frames

There are two ways to take FLAT FIELD (FF) images: one is SKY FF and the other one is DOME FF. In each way it is necessary to have the knowledge of the pointing system software (see the "Manuale Sistema Puntamento" manual).

5.1 Dome Flat Field

- Point the Telescope at the following coordinates (the precession epoch is not important):

  DEC *-27:00:00*
  RA *current TSL time*

- Rotate the Dome (closed) to *position 51* (remember to stop the sidereal tracking when the Telescope is pointed). In this way we create a uniform screen is in front of the mirror's Telescope and the resultant FF will have no light intensity gradient (any FF acquired with BFOSC is liable to a "vignetting" effect, so it will not be really uniform, especially in the frame's corners (*Figure 40*)
- Select the filter in the "*BFOSC panel*" (see section 1.6)
- Disable the storage image option (see section 2.1) to acquire a test image
- Enable the "*Fast Read*" mode
- From the pointing software (see the manual) switch on the halogen dome lights and take a test image with exposure according to *Table 1*
- Make a box on the new test frame displayed to have a statistical measurement (see section 2.3). Usually the FF average counts should be about 25000. Change the exposure time (but *never under the 3 seconds*) or the dome light intensity to have a custom FF count.
- Once you have the right settings, disable the "*Fast Read*" mode, enable the storage of image

and select the "*flat*" option in the "*Interface to Princeton*" (*Figure 41*). Also from the "*Interface to Princeton*" panel acquire a single FF frame or a sequence (of one or more filters) (see section 3).

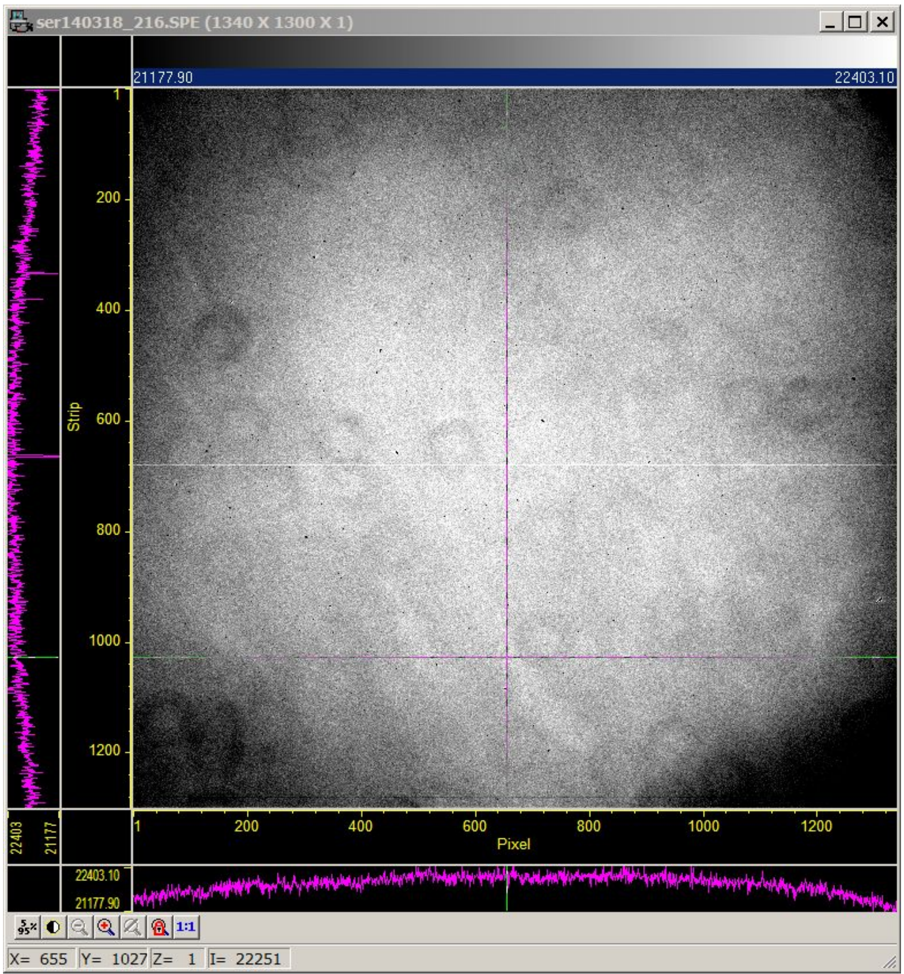


Figure 40

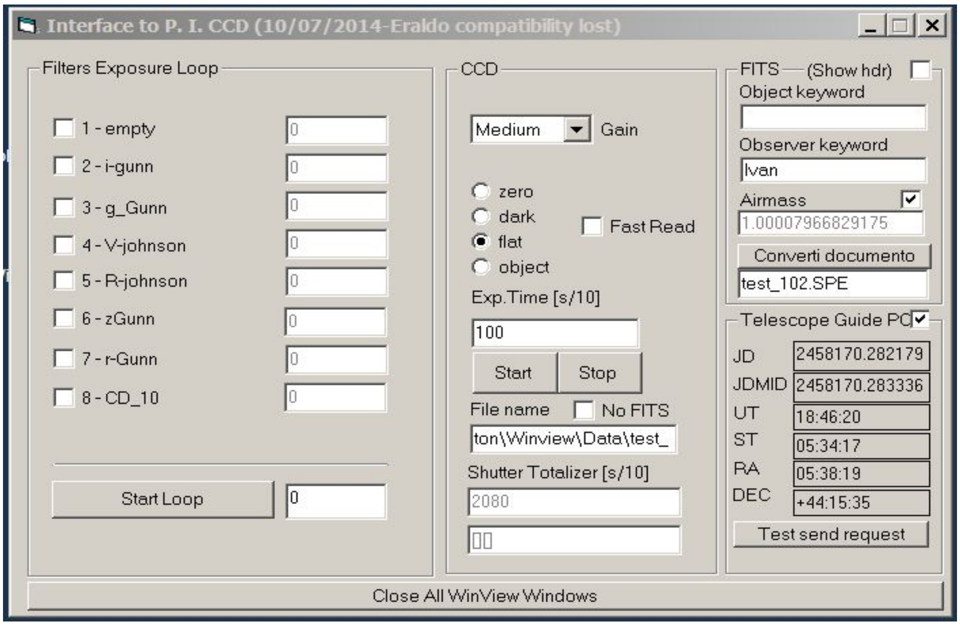


Figure 41

Johnson-Cousin	Aver. Count	Dome Lamp Intensity	Exposure Time (sec)
Flat B	25000	255	3
Flat V	25000	110	4
Flat R	25000	85	4
Flat I	25000	68	4
Thuan-Gunn			
Flat g	25000	120	8
Flat r	25000	80	8
Flat i	25000	70	6
Flat z	25000	70	5

Table 1

5.2 Sky Flat Field

Taking the Sky FF is more complex because typically they must be acquired during the sunrise or sunset time, when the sky background is quite bright again but there are no visible stars. This interval of time is short (especially during the winter), so all the technical operations need to be done very quickly.

- Point the Telescope (see the manual) on a "*Blank Field*", where generally there are few stars. A list of empty fields coordinates are collected in *Table 2*.
- From the "*BFOSC panel*" (see section 1.6), select the appropriate filter. It is a good rule to take FFs in a blue-to-red sequence at sunrise, and red-to-blue at sunset.
- Enable the "*Fast Read*" and select the option "*flat*" from the "*BFOSC panel*". Disable the image storage (section 2.1) and take a test image FF with 3 seconds of exposure time.
- Make a statistical measurement (see section 2.3) on a little box on every test FF image. Continuously acquire test manually, starting from average counts of the frame of about 45000 - 50000.
- At that moment, from the "*BFOSC panel*", disable the "*Fast Read*" mode and enable the image storage. Press the "*Start*" button in the "*BFOSC panel*" to acquire single FF images. Remember to check the average counts every time, because the sky background will be always darker.
- During the sky FF acquisition it is necessary to use the "*dithering*" technique. Every time a sky FF is stored, then move the Telescope in a random way before taking another new image. To do this, on the "*manual control box*" (*Figure 34*, section 2.6), press the switch highlighted in the **Q** red box on the FAST position (red led ON) and stay pressed for about 2 seconds on North direction and East direction concurrently (**R** red box on *Figure 34*).
- Is very difficult to take sky FF for all the photometric filters mounted on BFOSC because the sunset or sunrise time is short. So acquire just 4 or 5 images per filter.
- To compensate the lowering of the sky background it is necessary to increase the exposure time.
- Terminate the sky FF acquisition when the exposure time will be about 20 seconds or the average sky background count become less than 10000.

Name	RA J2000.0	Decl J2000.0

Blank00+07	00:24:00	+07:54:00
Blank01+12	01:21:00	+12:00:00
Blank01+02	01:47:40	+02:20:00
Blank02+13	02:21:00	+13:12:00
Blank03+31	03:33:00	+31:03:00
Blank04+25	04:42:00	+25:33:00
Blank05-02	05:45:00	-02:09:00
Blank06+42	06:51:00	+42:24:00
Blank07+64	07:48:00	+64:30:00
Blank08+37	08:45:00	+37:12:00
Blank09-07	09:12:00	-07:50:50
Blank09+46	09:10:28	+46:26:23
Blank09+66	09:24:00	+66:42:00
Blank10+58	10:24:00	+58:36:00
Blank10+57	10:52:00	+57:36:00
Blank11+51	11:09:00	+51:48:00
Blank12+54	12:21:00	+54:12:00
Blank12+02	12:29:20	+02:01:00
Blank13+29	13:07:00	+29:35:00
Blank13+63	13:21:00	+63:48:00
Blank13+62	13:36:20	+62:14:00
Blank13+05	13:48:20	+05:38:00
Blank14+17	14:12:00	+17:39:00
Blank15+53	15:27:00	+53:45:00
Blank16+55	16:24:30	+55:44:00
Blank16-15	16:50:53	-15:21:45
Blank17+34	17:27:00	+34:03:00
Blank17+66	17:59:40	+66:21:00
Blank19+59	19:15:00	+59:33:00
Blank20-09	20:45:00	-09:06:00
Blank21+11	21:24:00	+11:30:00
Blank21-08	21:29:30	-08:38:00
Blank22-08	22:36:00	-08:33:00
Blank23+11	23:15:50	+11:27:00
Blank23+09	23:39:00	+09:30:00
Blank23+00	23:47:00	+00:57:00

Table 2

6 Acquire long slit spectra

Essentially, the optical BFOSC configuration for long slit spectroscopy is:

SLIT + EMPTY FILTER + GRISM

Figure 42 shows an example for a slit of 2” (position 3 in slits wheel) and Grism 4 (position 4 in grism wheel)). To know the current optical system see section 1.6.

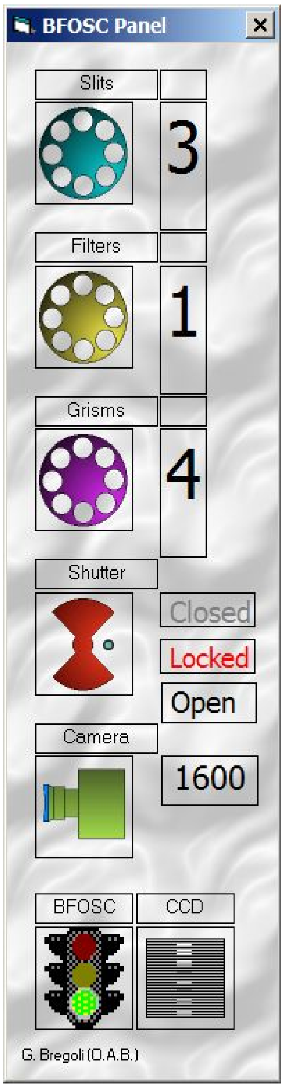


Figure 42

6.1 Center the Target inside the slit and take a spectrum

Briefly, acquiring a spectrum means centering the target inside the slit with very high accuracy, so that the target's photons impact on the selected grism for the light dispersion, with the lowest possible sky background contribution. The most “difficult” operation is centering the object correctly on the slit. If this is not done properly, there will be a loss of light and consequently the spectrum will have a low S/N ratio. Here is the procedure to follow in order to achieve the best result. A real example is the best way to understand it:
Suppose you want to take a spectrum of M66 galaxy's nucleus with the 2” slit and Grism 4. The Telescope is pointed and we have taken a short test image to see the target on the *Winview* display monitor (*Figure 43*). Adjust the image contrast (section 2.2).

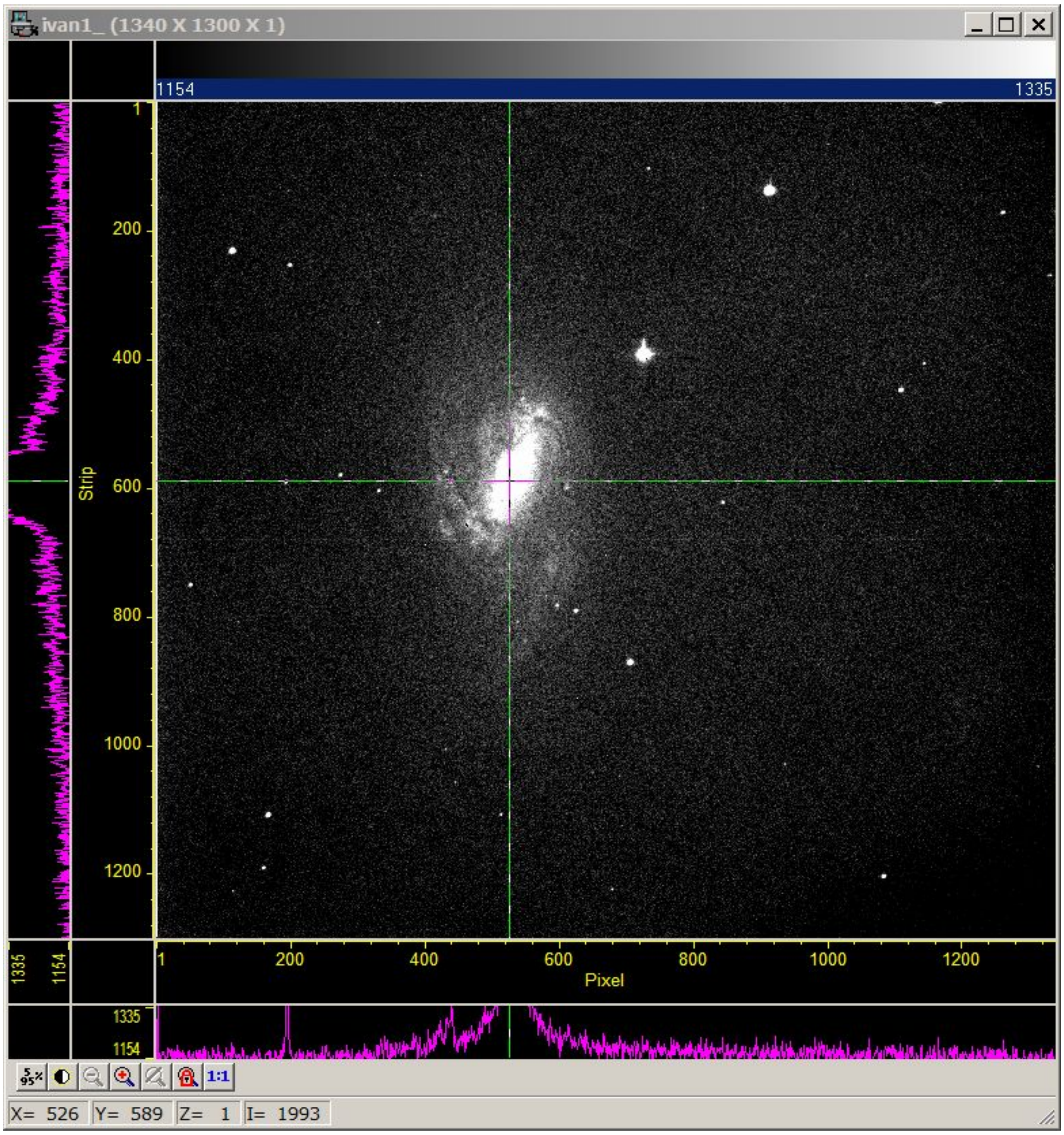


Figure 43

- The first operation is to find the best focus of the Telescope (section 2.6).
- Run the "*Focus*" mode in the *Winview* panel, taking 3 or 4 seconds of exposure time (section 2.6).
- Click with the mouse on the galaxy nucleus. A green cross is displayed and take a note of the target position in pixel (***Xt,Yt***). These coordinates are shown in the lower left-hand corner of the *Winview* display. For this example (***Xt,Yt***) is (526,589) (*Figure 43*).
- Then, always with "*Focus*" mode active, change the BFOSC configuration from the "*BFOSC Panel*" to insert the 2" slit (*Figure 44*). We are now watching the sky through the slit. This step is necessary to know the slit position in pixel (***Xs,Ys***) on the *Winview* display.
- *Figure 45* shows the image of the 2" slit. Draw a box on the slit as in *Figure 46*, and zoom on it (*Figure 47*).
- Now press the left mouse button on the slit's center and take a note of the position (***Xs,Ys***) (*Figure 47*). For this example the center is at coordinates (609,640). The slits are all oriented in the East West direction so the most important position is ***Ys***.

Figure 44

- From the "*BFOSC panel*" remove the slit and set the empty hole (position 1) to see the entire field of view.
- We know now the target and slit pixel coordinates and now we will move the Telescope in order that the galaxy nucleus will be on the same slit pixel value. The *Focus* mode helps considerably in this operation because we see in "real time" the target shift on the CCD frame.
- Use the *manual control box* (see section 2.6) or the pointing software (see manual) to move the Telescope.
- Take the green cross fixed on the slit position, this helps to have a visual reference. In *Figure 48 left* is described the initial condition and in the *right* the final when the M66 nucleus is overlapped on the 2" slit position. Is very important to be accurate in this step.
- When we are near the correct final position, we can start to find a guide star (see manual).
- When the galaxy nucleus is on the slit position, from the "*BFOSC panel*" insert the 2" slit and verify that the target is really inside it as in *Figure 49*.
- Activate the guide software (see the manual). Be sure that the Telescope speed movement switch on "*manual control box*" is positioned on SLOW (see section 2.6).
- Now stop the *Focus* mode and configure BFOSC with 2" slit and Grism 4
- Enable the storage image (see section 2.1) and disable the "*Fast Read*" from the "*BFOSC panel*".

- Set the exposure time and the object name in the “*Interface to Princeton*” (see section 2.1). For this example we have chosen 5 minutes of exposure time.
- Then press the “*Start*” button in “*Interface to Princeton*” to take the spectrum.

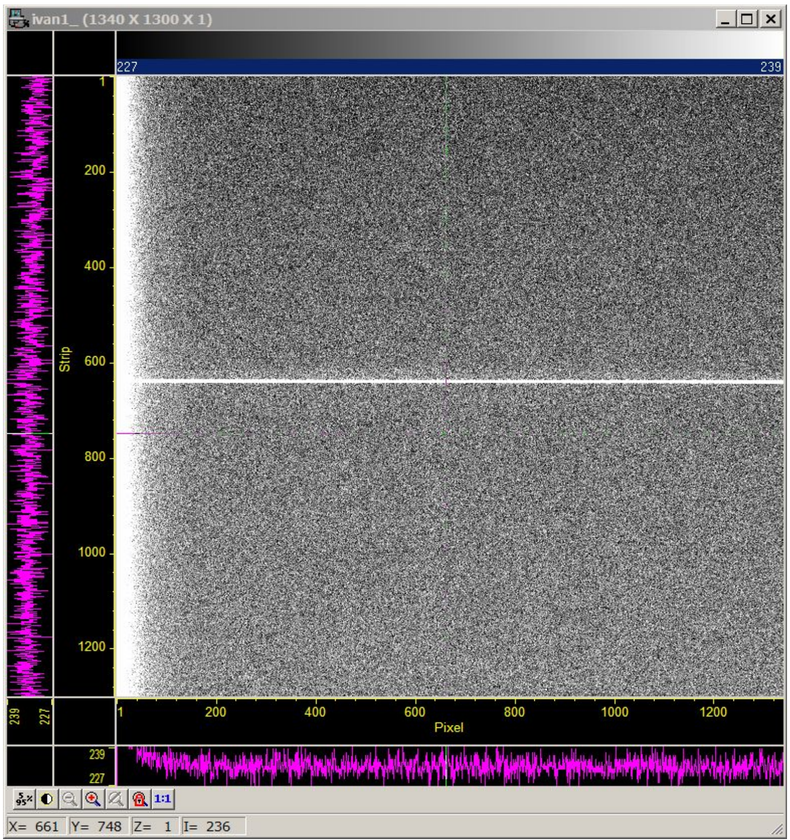


Figure 45

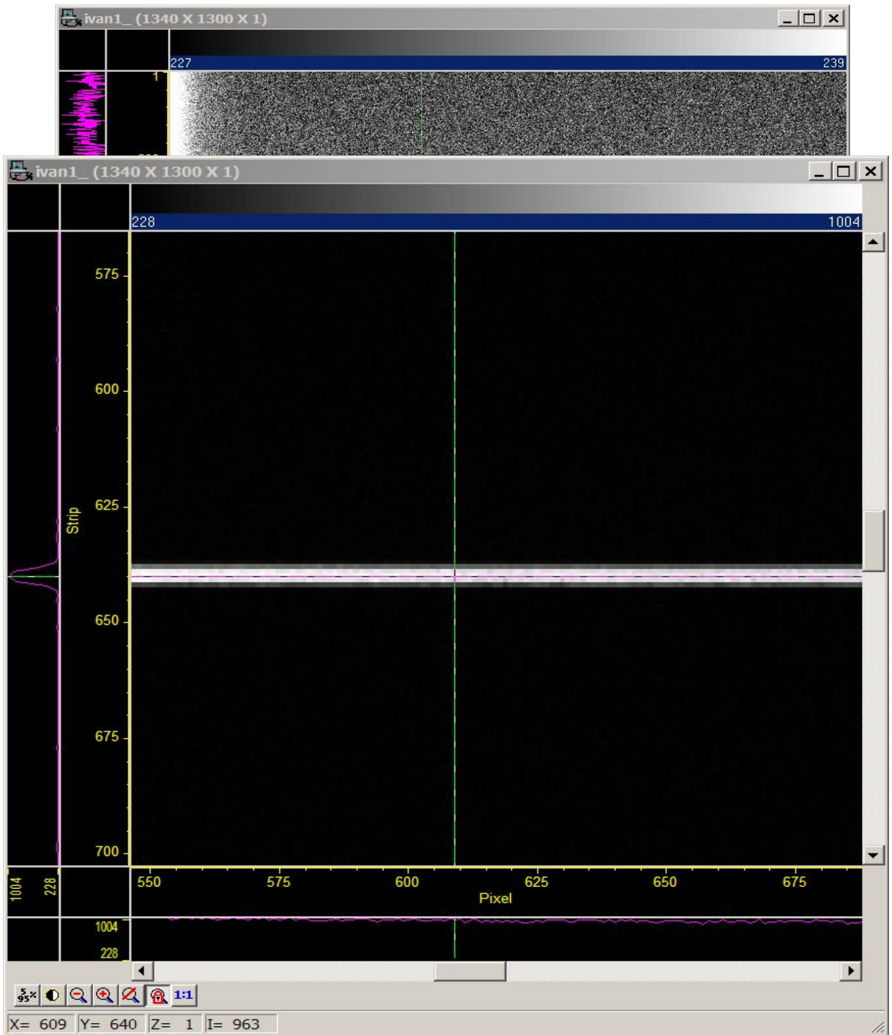


Figure 46

Figure 47

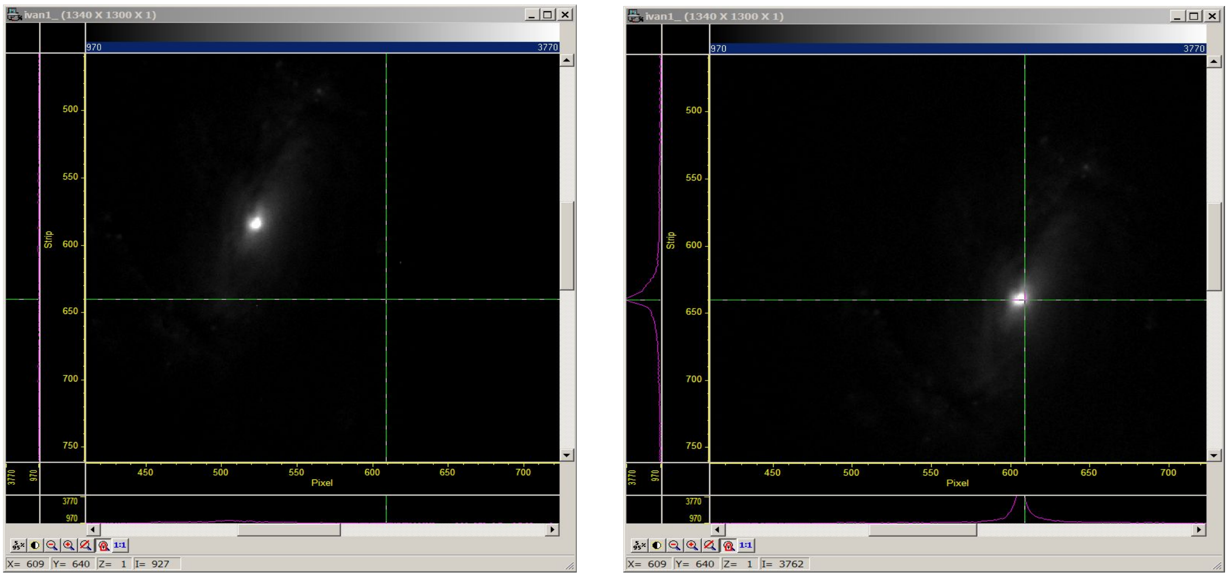


Figure 48

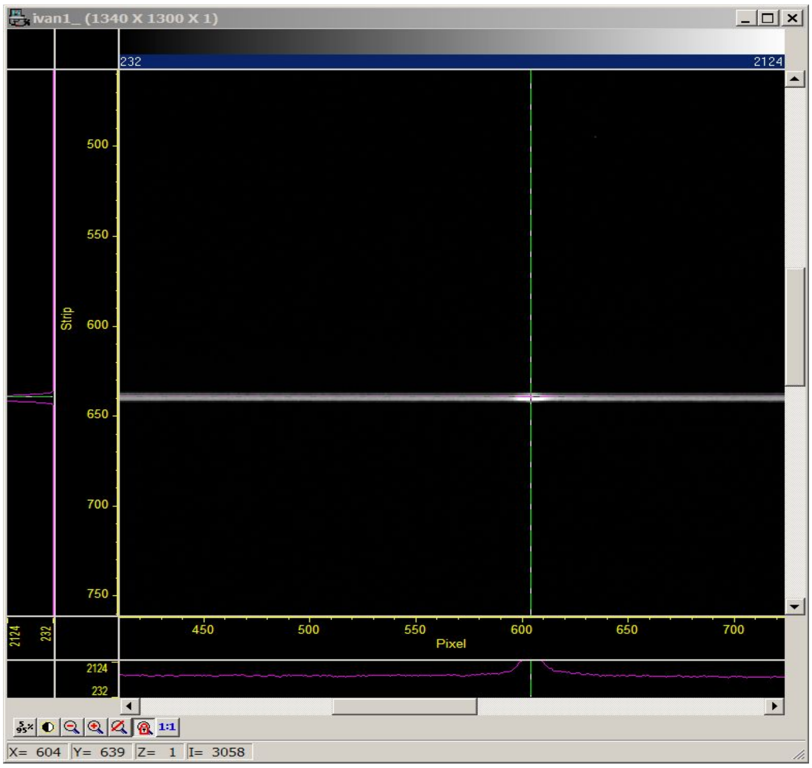


Figure 49

Figure 50 shows the resultant spectrum of M66. The light is dispersed in the vertical direction. The blue part is on top of the CCD frame.

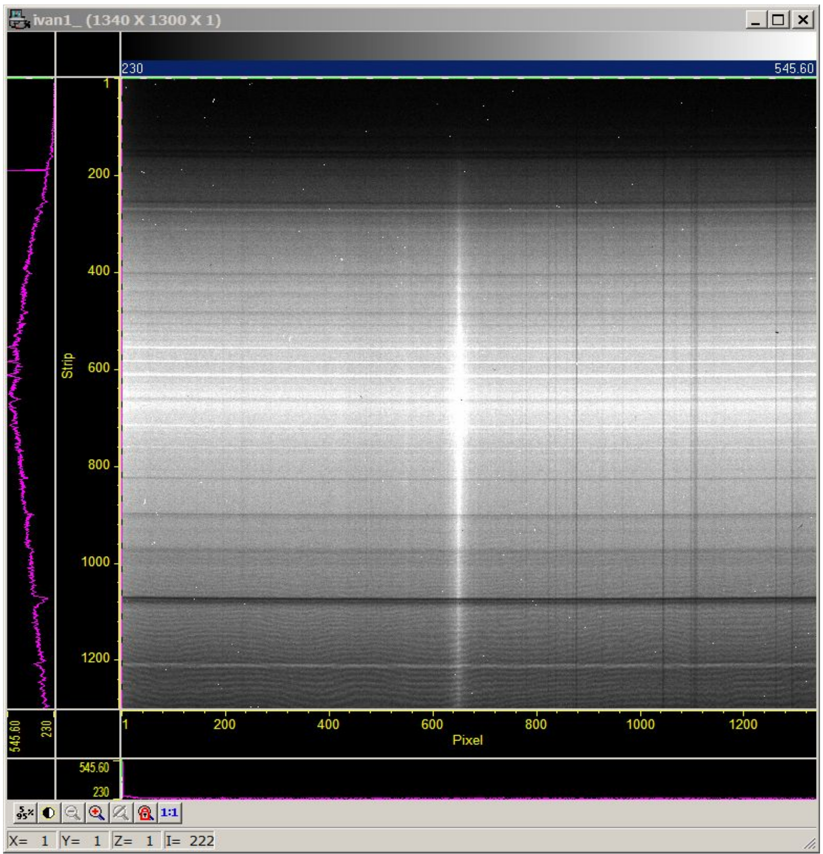


Figure 50

The horizontal bright and dark lines on the frame are due to sky emission.

6.2 The calibration lamp spectrum

After every scientific spectrum is saved, a calibration lamp (HeAr excited gas) spectrum should be acquired because the inside BFOSC optical mount is subject to some mechanical flexure, of the order of 1 pixel.

- Use the same BFOSC optical configuration (SLIT+GRISM) used for the target.
- From the pointing software (see the manual) insert the HeAr calibration lamp.
- Use *Table 3* to select the correct exposure time (depending on grism and slit) and write it in "*Interface to Princeton*" panel.
- Write manually in the "*Object*" Keyword of "*Interface to Princeton*" the lamp notation (for example: *M66_lamp*).
- Press the "*Start*" button in "*Interface to Princeton*" to start the acquisition.
- **REMEMBER to switch off the lamp (from pointing software) after any exposure**.

An example of lamp spectrum is in *Figure 51*. Here we have used the same optical configuration of the previous example of the M66 galaxy (2" SLIT + GRISM 4) with an exposure time of 4 seconds.

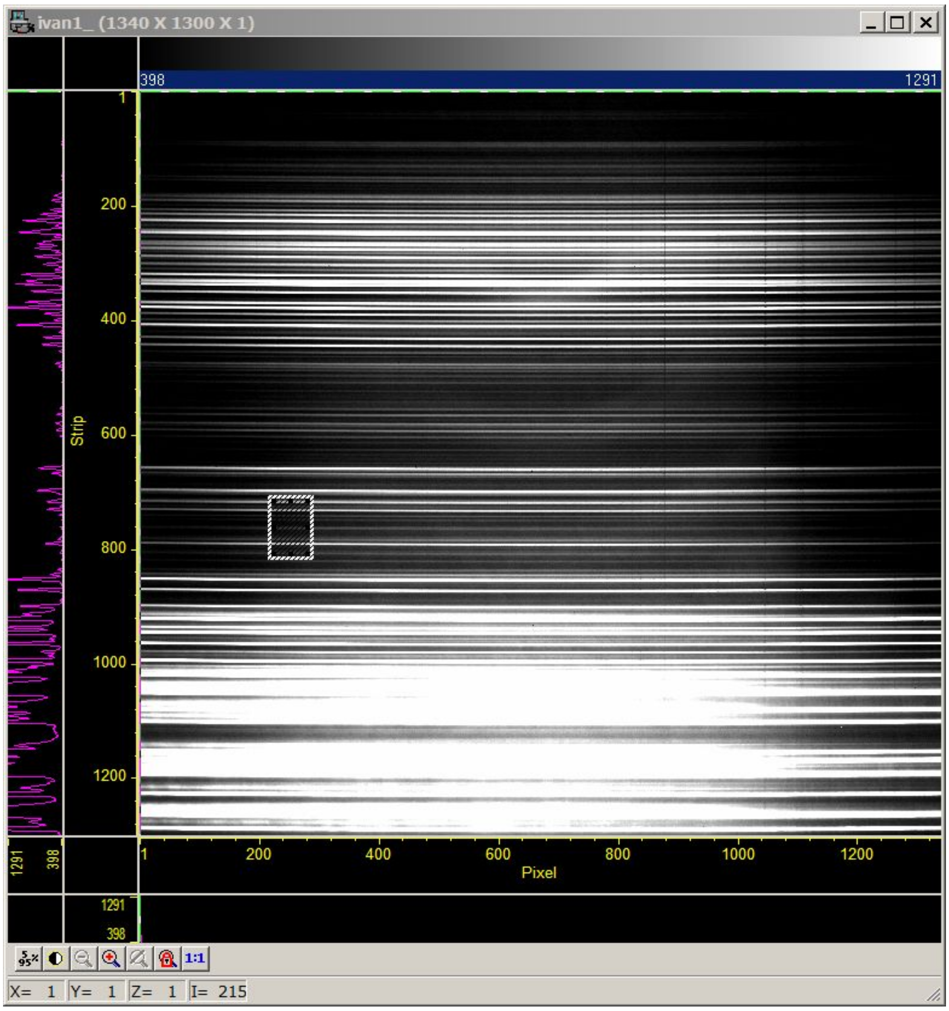


Figure 51

6.3 Examine "on the fly" the spectrum intensity profile

The *Winview* software permits to display in a 2D graph (pixels vs counts) the flux inside a mouse drown box. This view does not have a "scientific" relevance because the plot is essential with no subtraction of the sky contribution, but sometimes it can be useful. For instance we refer to the previous example of the M66 galaxy spectrum (*Figure 50*).

- With the mouse, draw a tight box around the vertical target light dispersion and long as the entire frame (*Figure 52*).
- Press "*Process*" in the "*Winview*" software menu and then "*Cross Section...*" (*Figure 53*).

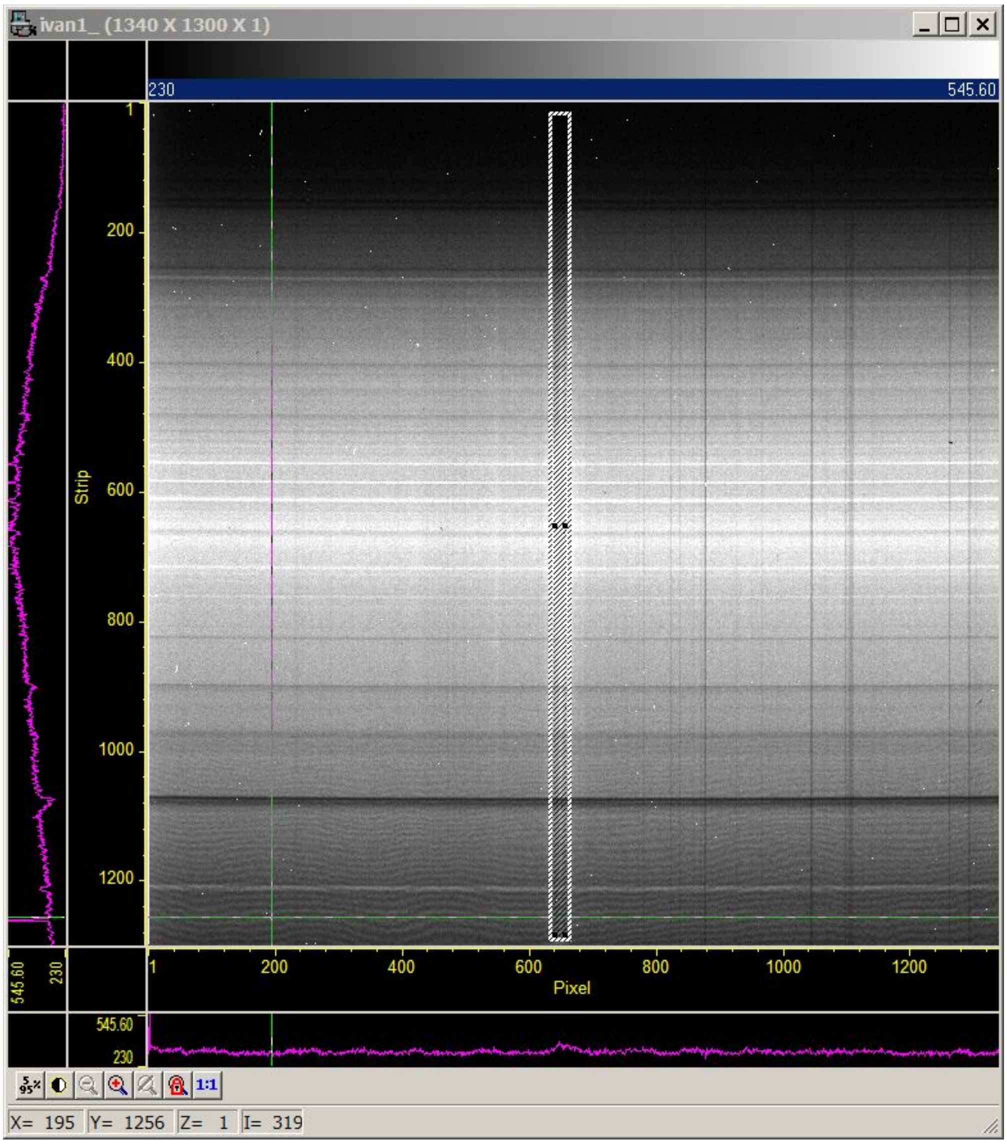


Figure 52

- This command opens a new window (*Figure 54*) which stores the length and width in pixels of the box drawn in *Figure 52*. Now simply press the "*Mouse*", "*Apply*" and "*Close*" buttons.
- The plot of the 2D spectrum will be displayed as in *Figure 55*. You can close it without saving.

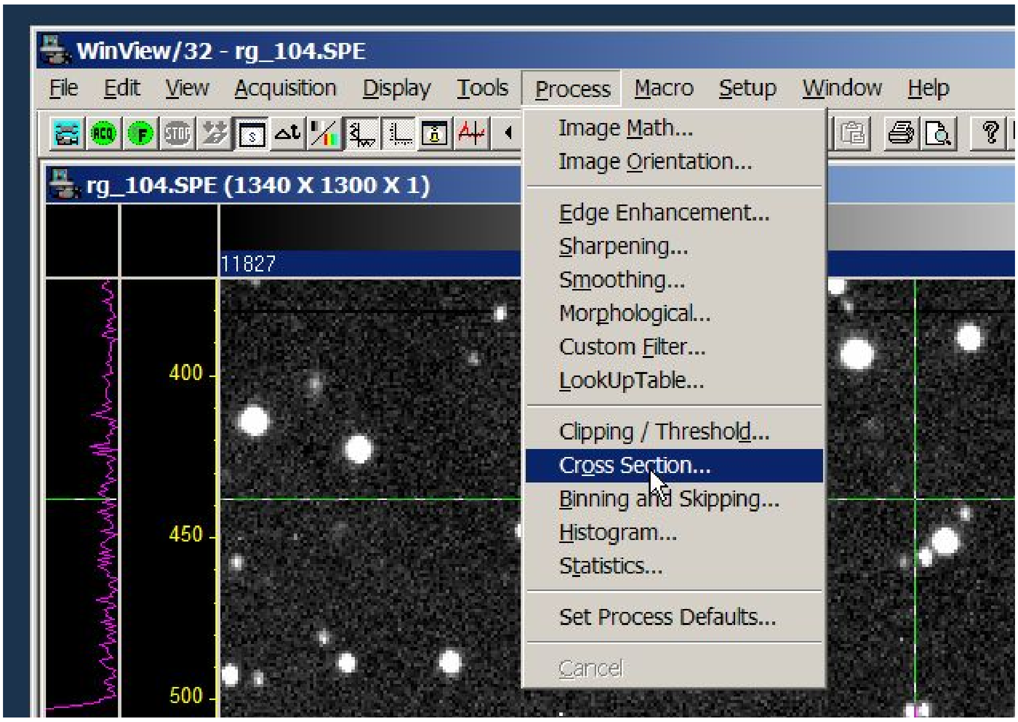


Figure 53

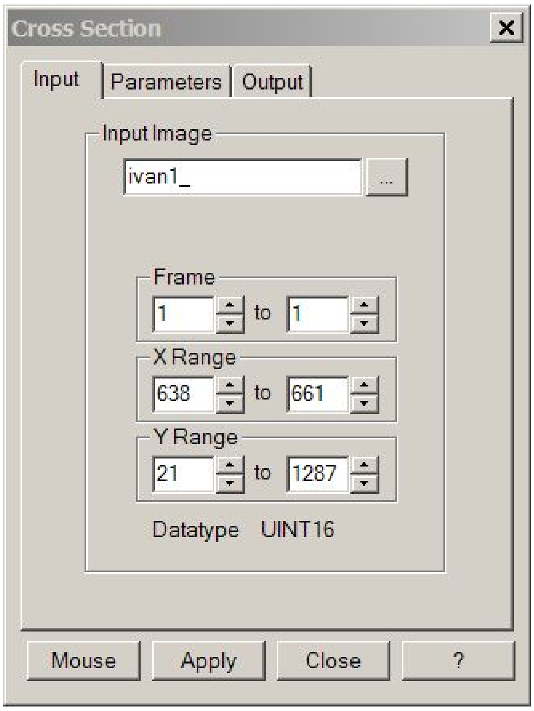


Figure 54

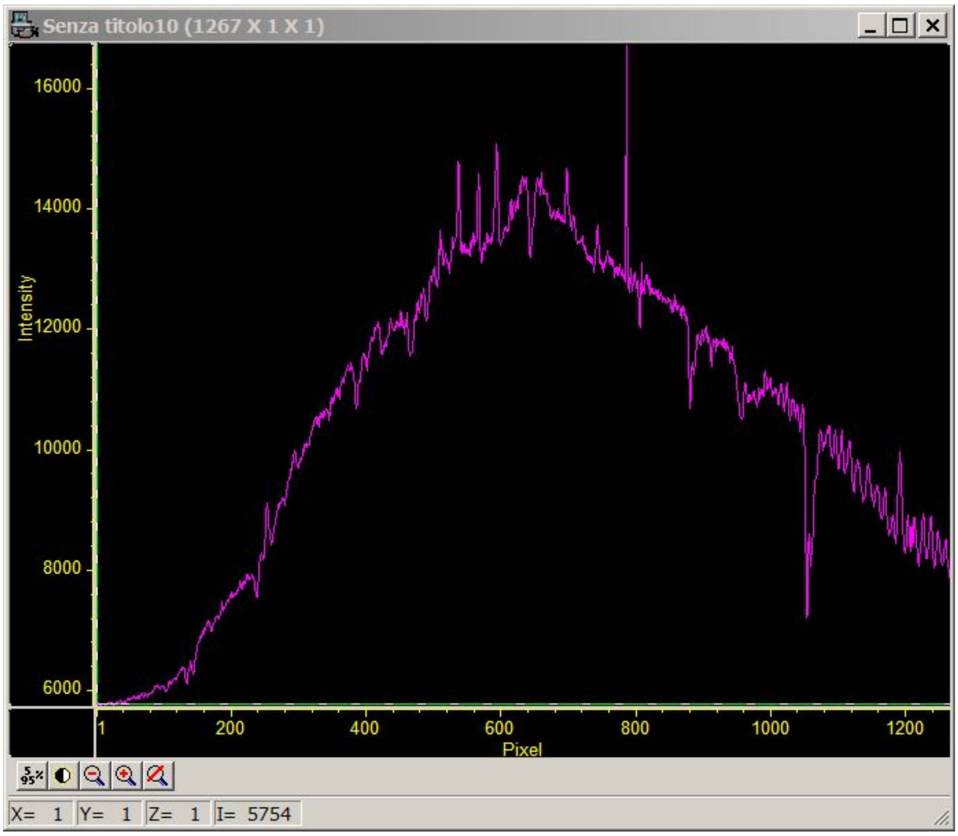


Figure 55

HeAr lamp Exposure Time

Optical Configuration	Exposure Time (sec)
Grism 3 / 2”	30
Grism 4 / 2”	4
Grism 5 / 2”	6
Grism 6 / 2”	50
Grism 7 / 2”	30
Grism 8 / 2”	5
Grism 9E + CD10	30

Table 3

6.4 FLAT FIELD for spectra

To take in account the effect of different CCD + GRISM system sensitivity, the FLAT FIELD (FF) must be acquired using the same optical configuration for the target's spectrum. Referring again to the previous M66 example (remember that we have taken a spectrum with GRISM 4 + 2" SLIT), the FF needs to be obtained in the same conditions (*Figure 56* shows the FF used for the M66 spectrum). Practically:

- Switch the BFOSC wheels to your correct configuration (SLIT + GRISM).
- From the pointing software (see the manual) power on the Dome light to the 255 value and move Telescope and Dome to the same position for the image FF (see section 5.1, for spectrum calibration we use only dome FF).
- Use the "*Fast Read*" from "*BFOSC panel*" and set the "*Winview*" software for not saving mode (see section 2.1).
- Take a test image , for example of 10 seconds, and inspect the image counts statistic (see section 2.3). On the basis of this result, rescale the exposure time to have about 15000 – 20000 counts.
- When the right exposure time is found, remove the "*Fast Read*" and set the "*Winview*" software in saving mode.
- Enable the "*Flat*" option in "*Interface to Princeton*" (see section 5).
- Take a single FF shot or series (see section 3).

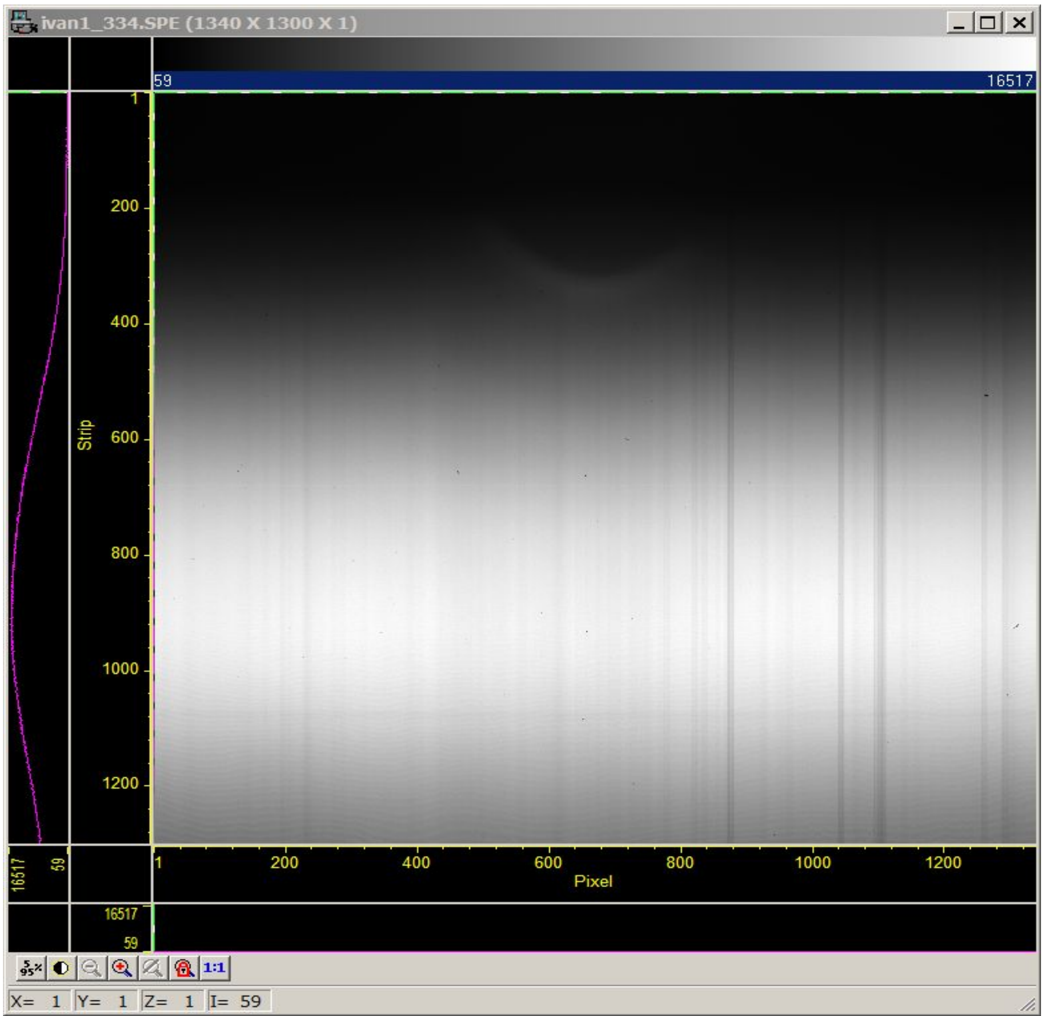


Figure 56

7 Acquire Echelle spectra

For this kind of high resolution spectra, the optical BFOSC configuration must be (example in *Figure 57*):

Slit Wheel ---------> slit 2"E

Filter Wheel ---------> CD 10 (Cross Disperser)

Grism Wheel ---------> grism 9E

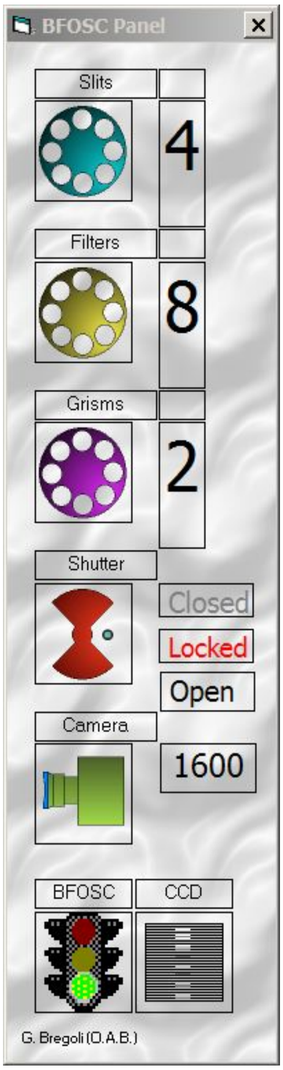
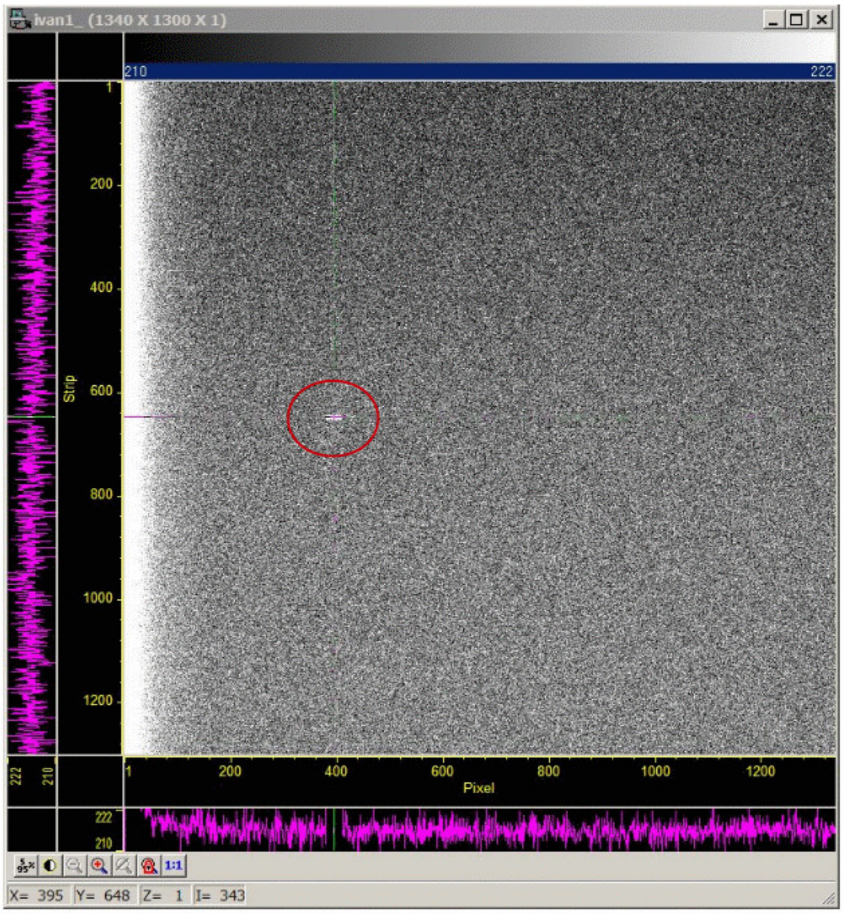


Figure 57

The slit for Echelle (*Figure 58*) is very short and shifted with respect to the long slit (*Figure 45*) . The fixed position in pixel of the Echelle slit center is (***Xe,Ye***) = (394, 649). So the procedures for acquiring Echelle spectra is exactly the same for the long slit described in section 6 with the difference that we have to move the target in the (***Xe,Ye***) position. An example of spectrum is showed in *Figure 59*.

Also the procedure for the acquisition of calibration lamp spectrum and FF (see *Table 3* for the exposure time) is identical for the long slit with the only difference of using now the new optical configuration. Examples of lamp and FF spectra are in *Figure 60* and *Figure 61* respectively.


ivan1_ (1340 X 1300 X 1)
Strip
Pixel
X= 395 Y= 648 Z= 1 I= 343

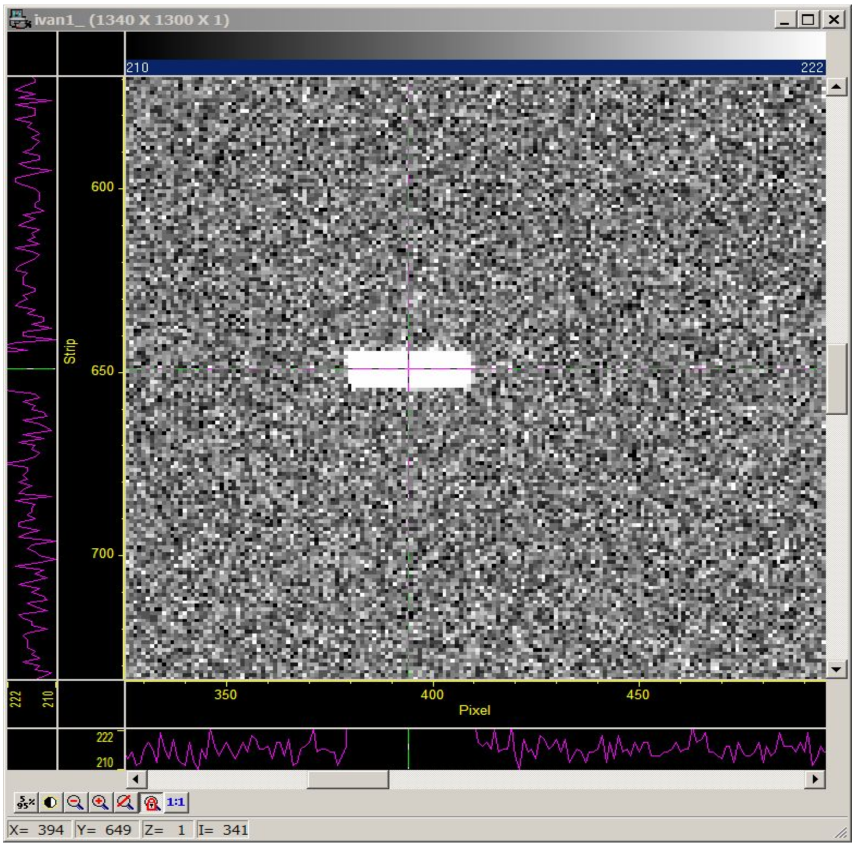

ivan1_ (1340 X 1300 X 1)
Strip
Pixel
X= 394 Y= 649 Z= 1 I= 341

Figure 58

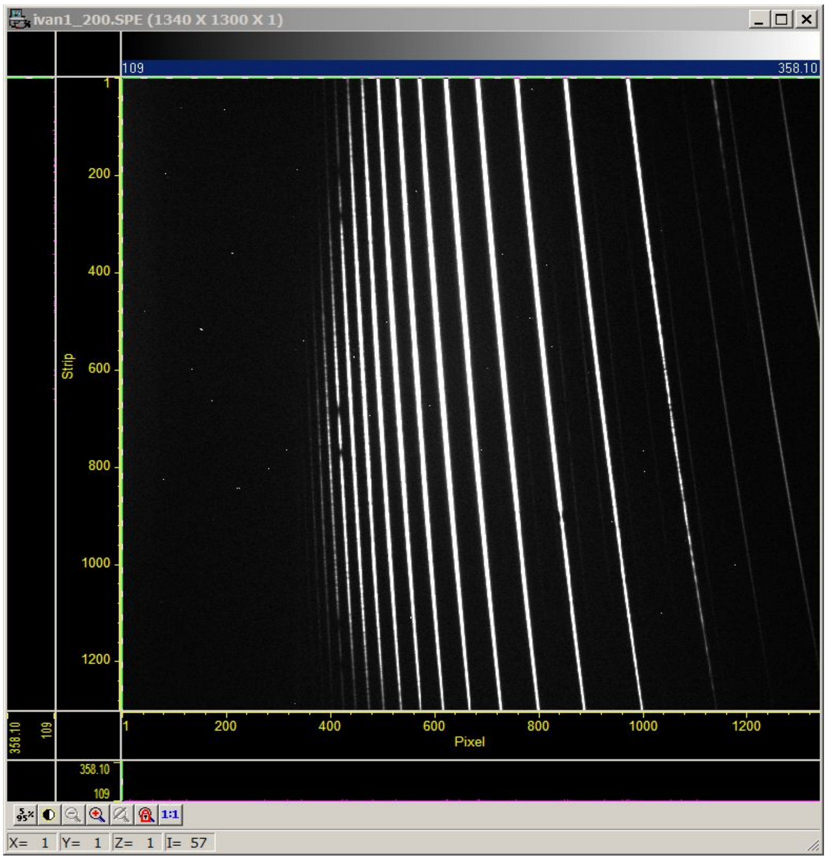


Figure 59

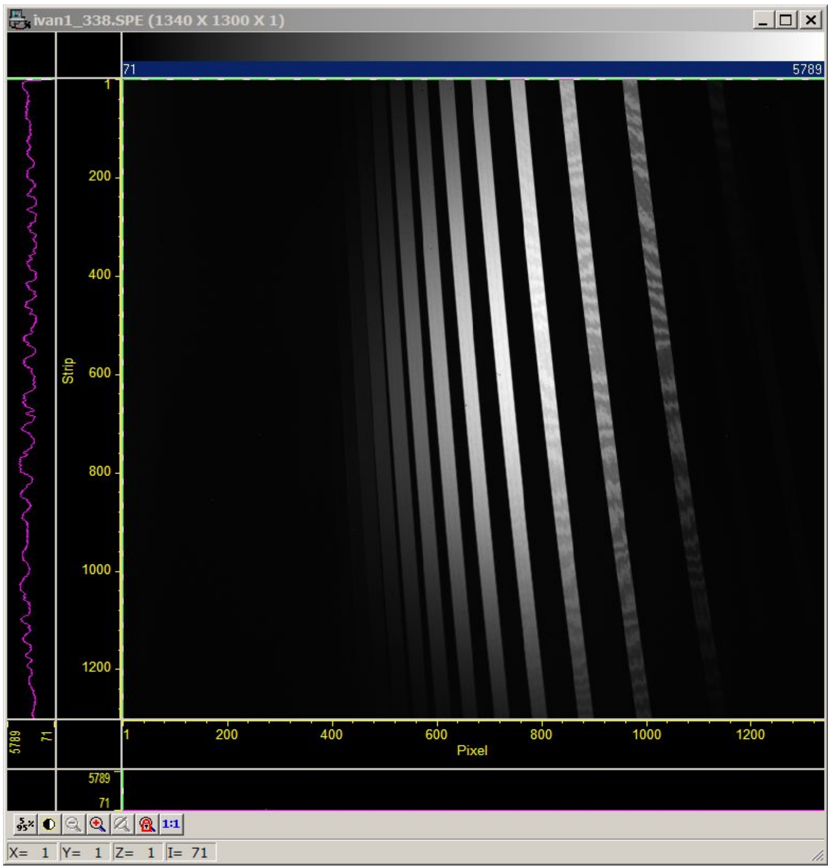


Figure 60

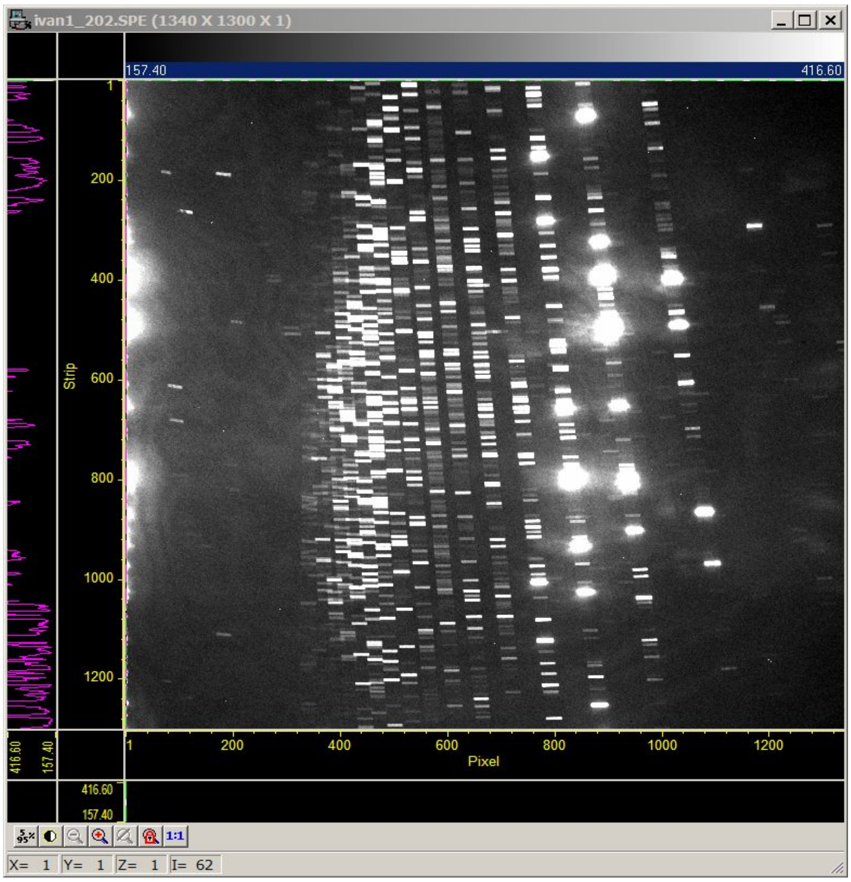


Figure 61

9 The image FITS header

All the keywords that appear in FITS header, are coming in part from "*Interface to Princeton*" and in part from the pointing user interface software (an example is in *Figure 62*).
In particular, from the first one all values are obtained from BFOSC computer control (the time is synchronized by a NTP server):

TM-GPS	Current time
OBSERVER	Observer keyword from "*Interface to Princeton*" panel
OBJECT	Oject keyword from "*Interface to Princeton*" panel
APERTNR	Slit number from "*Interface to Princeton*" panel
FILTERS, FILTERNR, GRISMNR	Filter, Grism from "*Inteface to Princeton*" panel

and from the last one, the keywords are from the pointing user inerface:

DATE-OBS, DATE, UT, JDMID, ST	current observation date and time
RA, DEC	these are the precessed and modeled Telescope's coordinates. The CCD field is not astrometrized.
TM-START, TM-END	UT start and UT end exposure

```
--------------------------------------------------------------------------------------------------------------------
SIMPLE  =                    T /
BITPIX  =                   16 /
NAXIS   =                    2 /
NAXIS1  =                  704 / Number of columns
NAXIS2  =                  592 / Number of rows
BZERO   =                32768 / Unsigned short
BSCALE  =                    1 /
DATE-OBS= '2017-10-23'         / Date of data acquisition
DATE    = '2017-10-23'         / Date file was written
UT      = '18:08:15'           / UT at start exposure
EXPTIME =                120.0 / Exposure time in seconds
TM-GPS  =              65296.6 / 18:08:17.0
TM-START=              65294.8 / 18:08:15.0 measurement start time (UT)
TM-END  =              65414.8 / 18:10:15.0 measurement end time (UT
RA      = '19:35:43'           / Telescope pos. R.A. (  x:xx:xx)
DEC     = '+36:50:15'          / Telescope pos. Dec. ( xx:xx:xx)
POSTN-RA= '19:35:43'           / Telescope pos. R.A. (  x:xx:xx)
POSTN-DE= '+36:50:15'          / Telescope pos. Dec. ( xx:xx:xx)
TELESCOP= 'Mt. Orzale 152 cm. Telescope'
EPOCH   =                  0.0 /
INSTRUME= 'BFOSC   '
ORIGIN  = 'Bologna Astronomical Observatory'
IMAGETYP= 'object'
DETNAME = 'EEV 1300x1340B [NEW] '
OBSERVER= 'Bruni'
OBJECT  = ' wts-2'
APERTNR =                    1 / EMPTY
FILTERS =                    7 / r-Gunn
FILTRNR =                    7 / r-Gunn
GRISMNR =                    1 / EMPTY
JDMID   =        2458050.25642 / Julian date at middle exposure
AIRMASS =             1.051881 / Airmass at start time
ST      = '21:02:58'           / Sideral time at start exposure
COMMENT   'Gain Medium'
END
--------------------------------------------------------------------------------------------------------------------
```

Figure 62

10 Known problems and how to fix them

The electronics and the control softwares are quite stable, and very rarely malfunction. We report here the most frequent problems:

- especially during long (hours) loop photometrical observations, it can happen that the acquisition is interrupted in an abnormal way without a warning message. To restore the system, close and restart "*Winview*" software and "*BFOSC panel*".
- Very rarely some images are downloaded as completely "black", with zero counts. In this case, it is necessary to reboot the BFOSC electronic (ask the technical staff for this operation) and close / restart the "*Winview*" and "*BFOSC panel*" applications.

Please inform the local staff of other problems not listed here.

Appendix 1

BFOSC + P.I. Versarray 1300B CCD

Optical Configuration

CCD FOV:	13' x 13'
Pixel Matrix:	1340 x 1300
CCD Linear Size:	26.8 mm x 26 mm
Pixel Size:	20 um x 20 um
Pixel Scale:	0.57 arcsec/pixel
BFOSC Equivalent Focal Ratio:	f/4.7
BFOSC Equivalent Focal Lenght:	7212 mm
M1 Diameter:	1520 mm
Cassegrain Focal Ratio:	f/8
Cassegrain Focal Lenght:	12160 mm

CCD Performances

RON:	1.7 e (@100 Khz)	3.6 e (@1MHz)		
Gain (@100KHz):	2.22 (Mid)	1.12 (Hi)	4.4 (Low)	e/ADU
Saturation:	60000 ADU			
FWC:	117 Ke @ mid Gain			
Dynamic Range:	16Bit			
Dark Current:	< 1e /px/hr @-91°			