IAC80 @ OT

CARONTE

Detector features
and
Interface user guide

By Enol Matilla and David Nespral

Ver. February 2024 by David Nespral

The aim of these series of user guides is to help the observer in some specific tasks related to the telescopes and instruments available at the Observatorios de Canarias (OCAN). The information is provided in a clear and simple manner, and is illustrated with screenshots to make the manual easier to use.

In particular, here, the user will find the following tasks:

1. The detector and its characterization

    1.1 Linearity

    1.2 Darks

    1.3 The Photon Transfer Curve (PTC)

2. Graphical User Interface:

    CARONTE

    2.1 Initialization and configuration of camera parameters
    2.2 Focusing the telescope
    2.3 Images acquisition

    CALIBRATION IMAGES

    2.4 Dome Flats
    2.5 Sky Flats
    2.6 Bias
    2.7 Darks

    MACROS

1. The detector and its characterization

The detector is a SONY medium format IMX461 sensor, 44*33 mm, **102 Megapixel**, back-illuminated, 16bit ADC. 11736 (H) x 8808 (V) pixels of **3.76 micron/pixel** each, equivalent to **0.0811 ´´/pixel** in IAC80. The FoV in the IAC80 telescope is **15.9 x 12 arcmin**.

There is a readout mode with two gain (0 and 60) enabled. The main features are given by:

MODE 1: readout time (s):

Gain 0

Gain	0.779 e-/ADU
Full Well (FW)	50891.168 e-
RON (e-)	3.683 e-
RON (ADU)	4.730 ADU
Dynamic Range (FW/RON)	13816.171

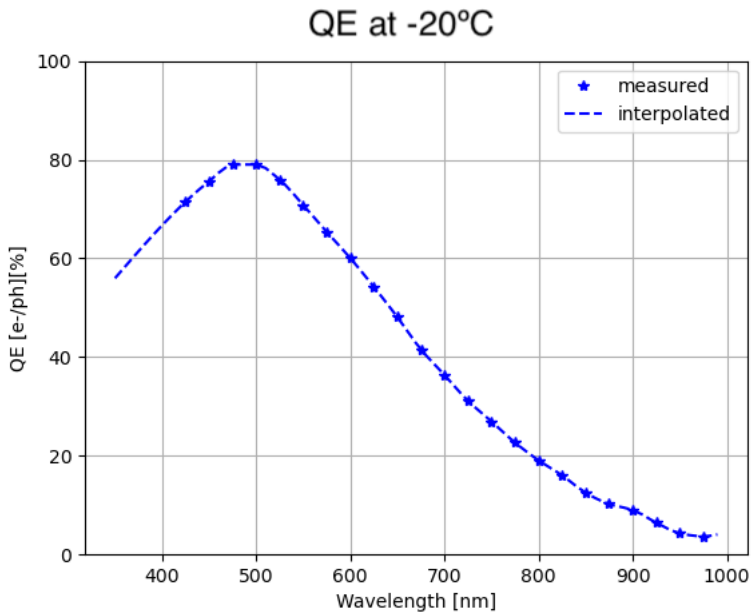
Gain 60

Gain	0.309 e-/ADU
Full Well (FW)	20221.177 e-
RON (e-)	1.698 e-
RON (ADU)	5.487 ADU
Dynamic Range (FW/RON)	11910.427

The nominal operating temperature is -30ºC.

Some other features are:

- Overscan: [0:46, 0:113].
- Windows: available in CARONTE´s interface.
- Binning: three binning possibilities are available: 1x1, 2x2, 4x4 .
- Quantum efficiency: see notes and QE curve figure below.



Quantum efficiency for gain 0 according to the wavelength of uniform light, with interpolation added between points.

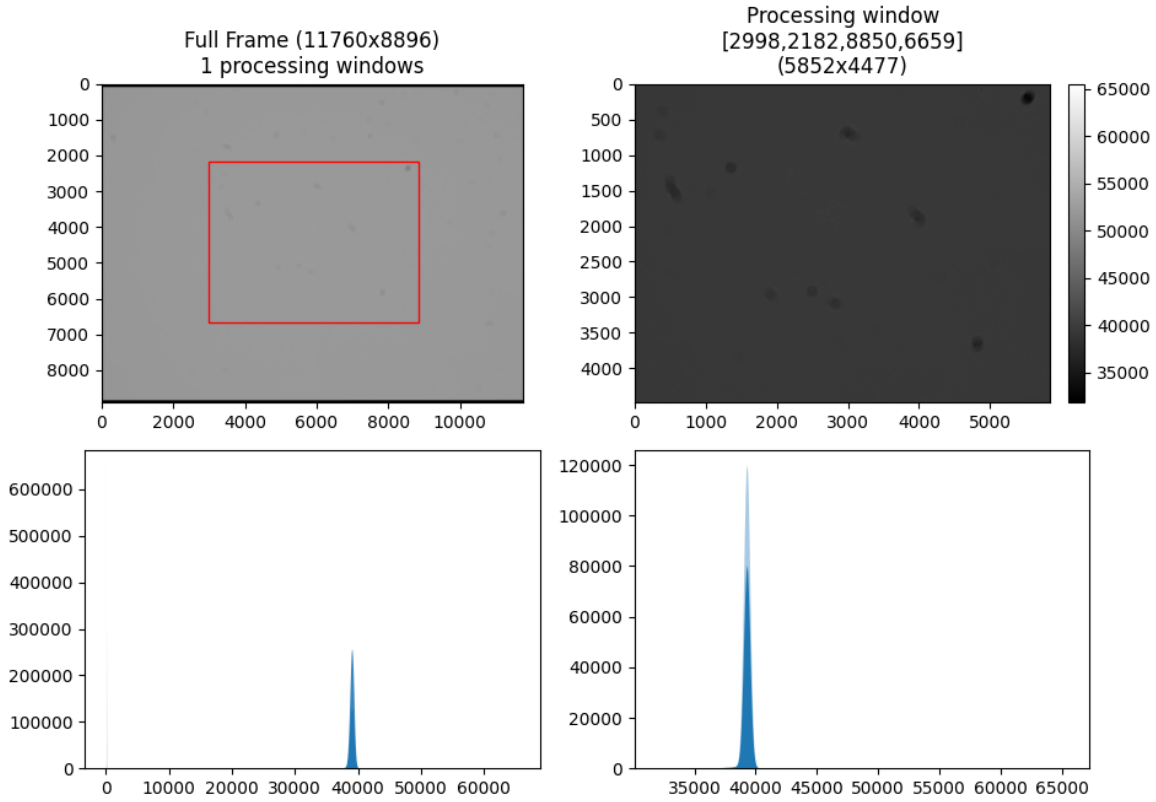
To obtain the quantum efficiency of the sensor, the Laboratorio de Imagen y Sensores de Astronomía (LISA) at IAC was used. For this purpose, the light from the source was filtered to make it nearly monochromatic. This was done using a software-controlled monochromator, where you select the desired wavelength. To ensure robust results, around 30,000 counts per pixel were targeted in each image. For the calculation of quantum efficiency (QE), the average of the pixel values in electrons (e−) had to be divided by the image exposure time (t) and the photon flux (flux).

$$QE = \frac{\overline{F_\lambda} \cdot gain}{t \cdot flux}$$

Fλ is the mean of the pixel counts from an image with uniform light at a certain wavelength λ. The photon flux was calculated using parameters established in the laboratory, such as the intensity measured by a picoammeter after the monochromator, the distance between the sensor and the light source, etc. Measurements are taken every 25 nm of wavelength, starting at 425 nm and ending at 975 nm.

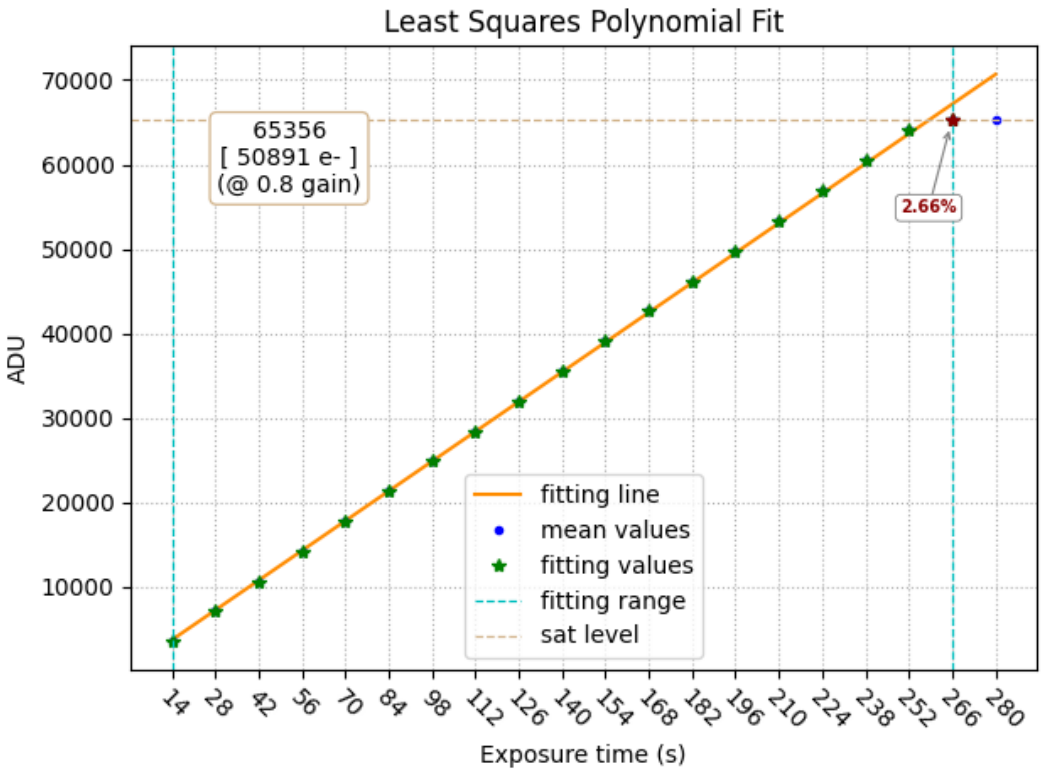
1.1 Linearity

The sensor linearity was evaluated by plotting the signal — adding the bias level — against the exposure time.

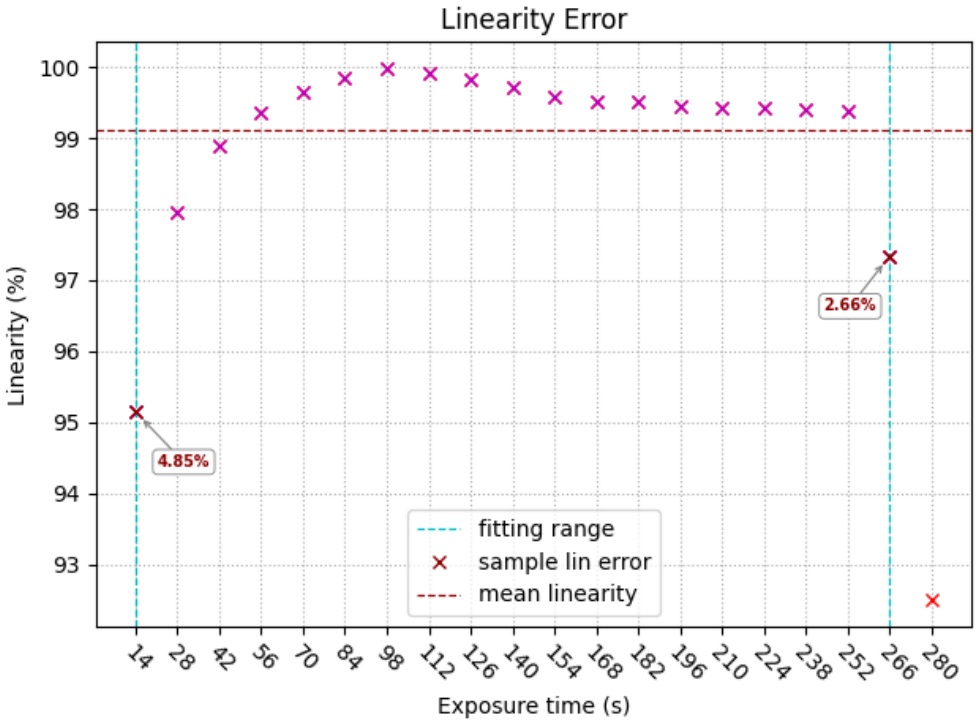


Left: Selection of the sensor area (red rectangle) where all the analyses will be performed.
Right: Zoom of the same area

Gain 0

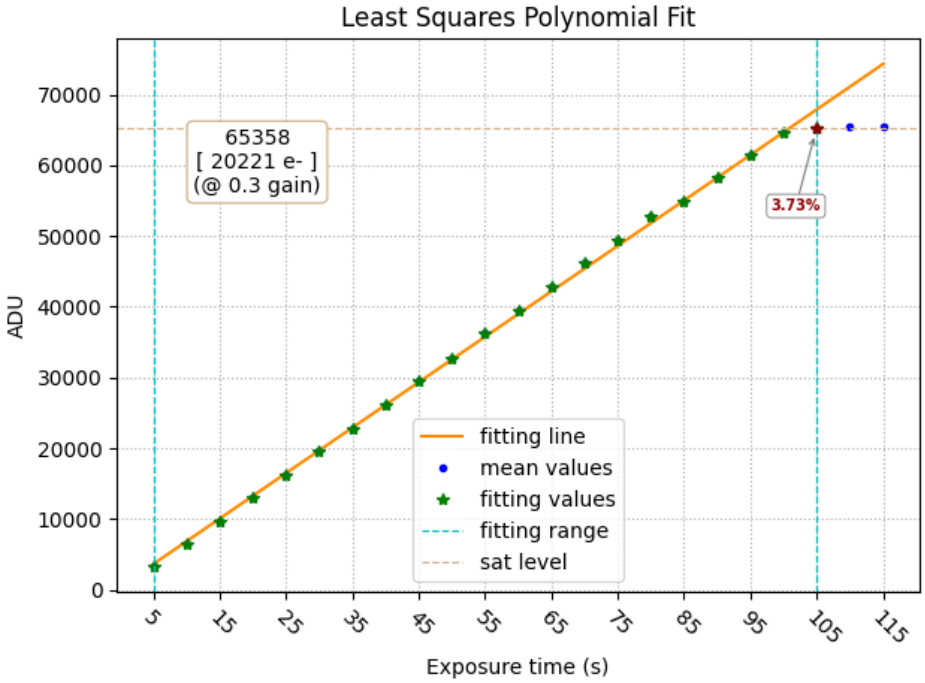


Mean of counts (ADUs) from pixels within the selection box plotted against exposure time, after subtracting the mean of the BIAS values. A linear fit using the least squares method is added.

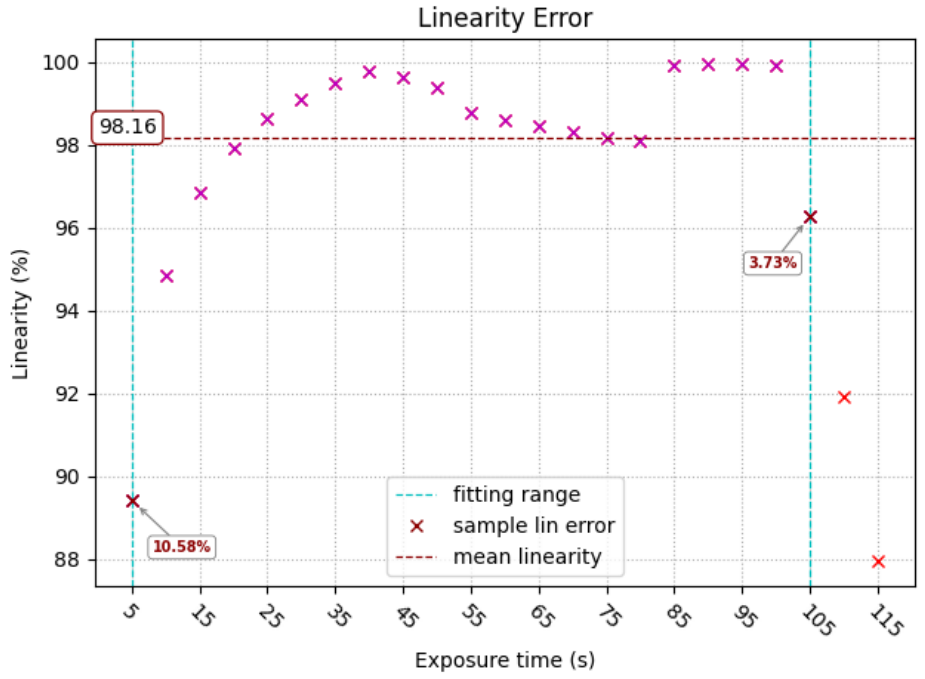


Percentage of linearity for each exposure time. The dashed line indicates a 99% limit of linearity error.

Gain 60



Mean of counts (ADUs) from pixels within the selection box plotted against exposure time, after subtracting the mean of the BIAS values. A linear fit using the least squares method is added.



Percentage of linearity for each exposure time. The dashed line indicates a 99% limit of linearity error.

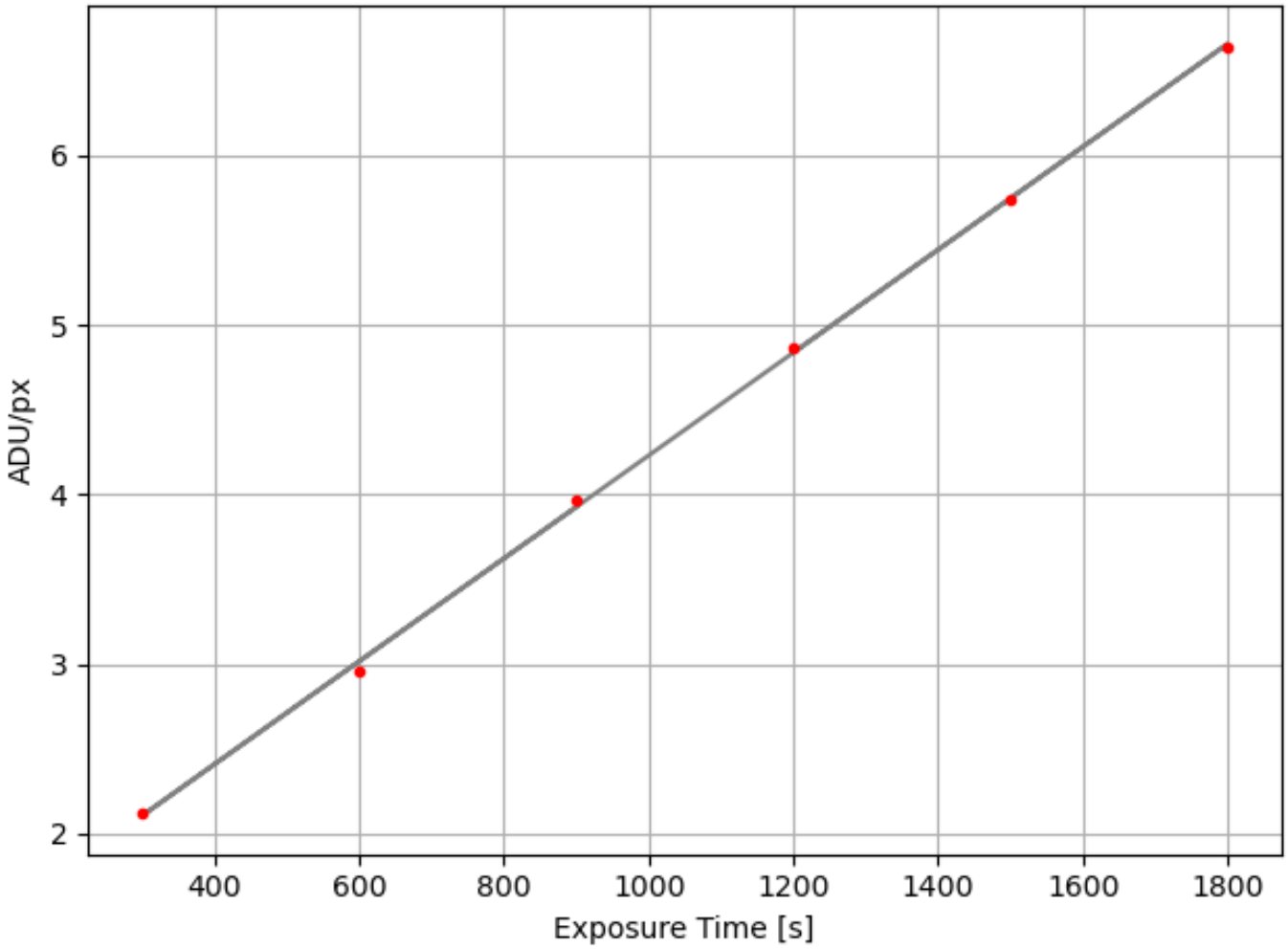
1.2 Darks

Dark current is the current generated in photosensitive devices in the absence of light. It is mainly due to thermal generation charge and is highly dependent on temperature and exposure time. Although the Darks tests shown below have the sCMOS cooled to -20ºC, it is possible to reach -30ºC with the cooler.

Median dark current (DC) for available gains:

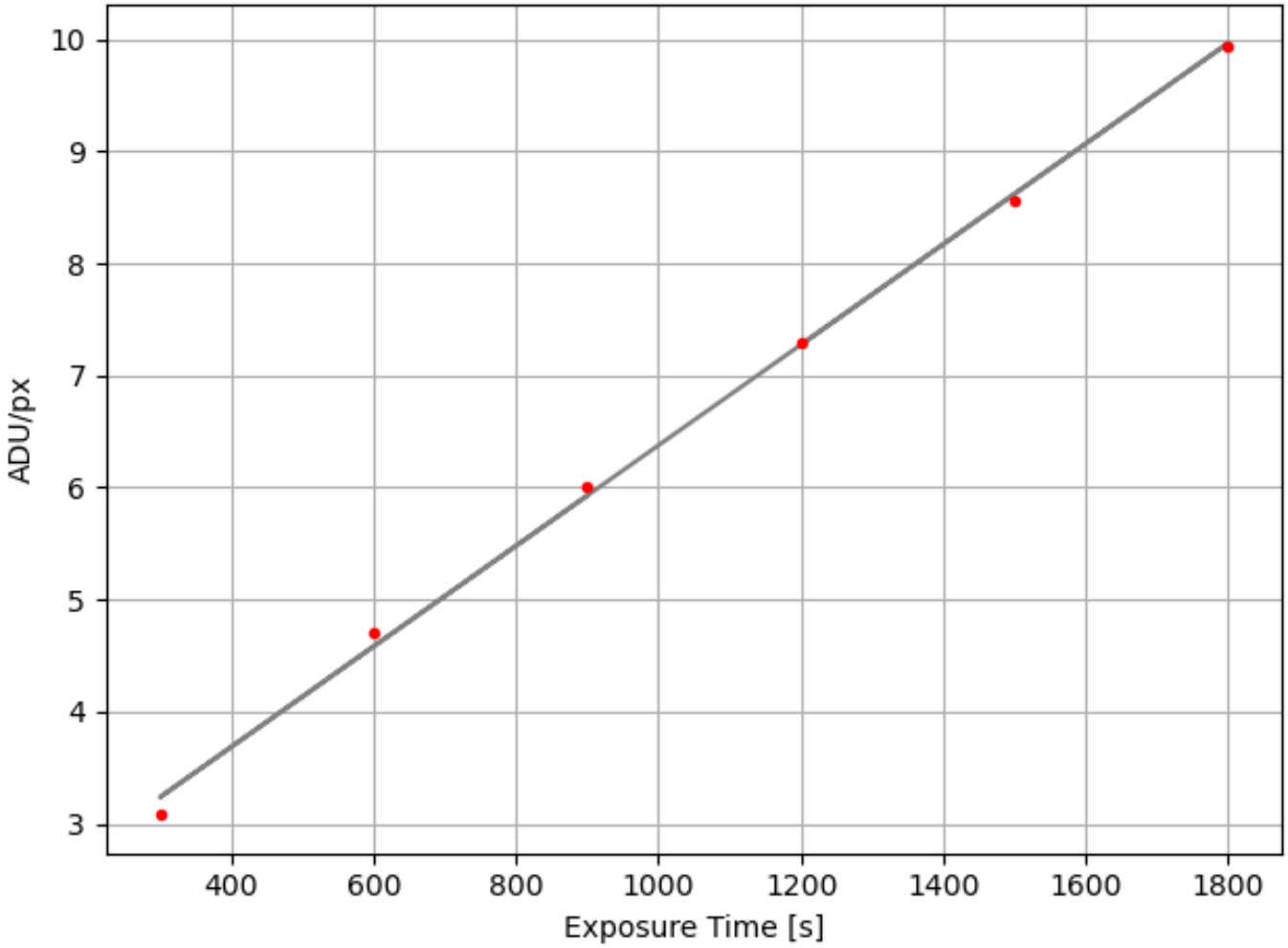
GAIN	DC(ADU/px/sec)	DC(e-/px/sec)
0	0.003	0.002
60	0.004	0.001

Gain 0



Mean of counts per pixel (after subtracting the BIAS) based on the exposure time of the capture.

Gain 60

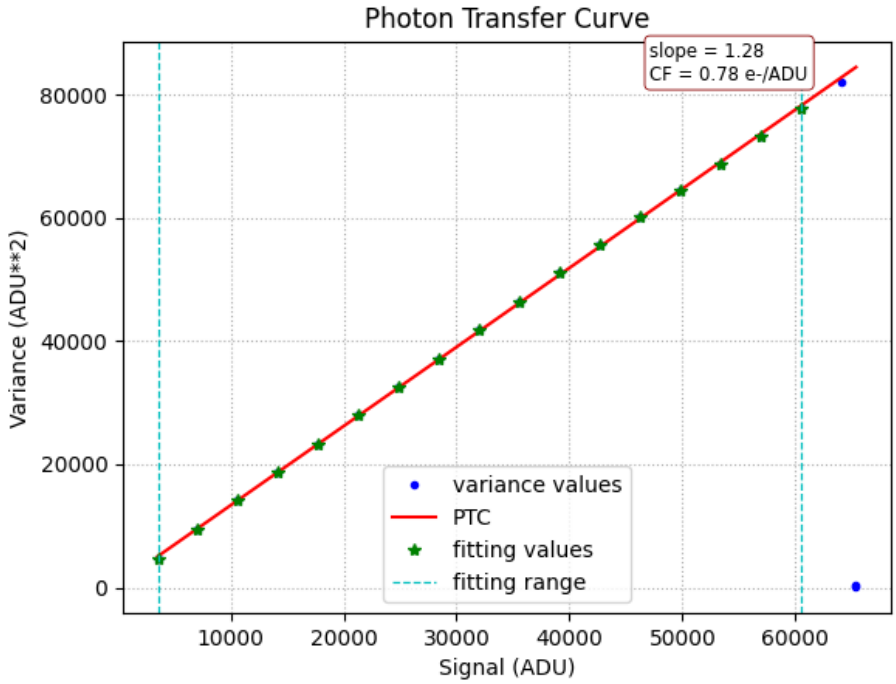


Mean of counts per pixel (after subtracting the BIAS) based on the exposure time of the capture.

1.3 The Photon Transfer Curve (PTC)

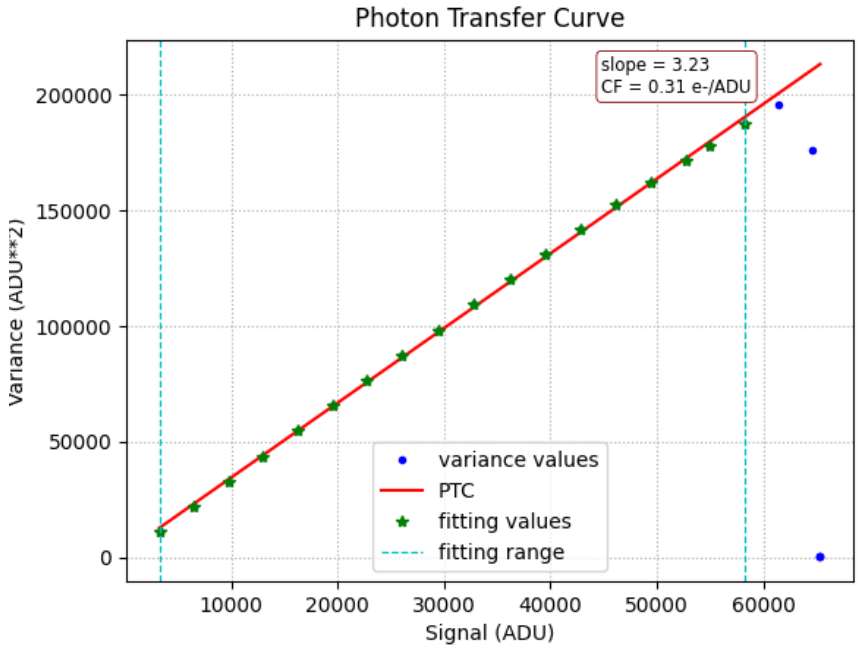
The Photon Transfer Curve (PTC) is used to characterize the response of the sensor to homogeneous illumination, obtaining main features such as the gain–conversion factor between electrons and digital counts (ADU), the full-well capacity (FWC) or the contribution of the different sources to the total noise.

Gain 0



Photon transfer curve with gain in electrons per ADU calculated. CF refers to the calculated gain, and slope refers to the slope of the fit.

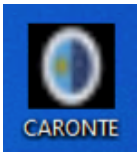
Gain 60

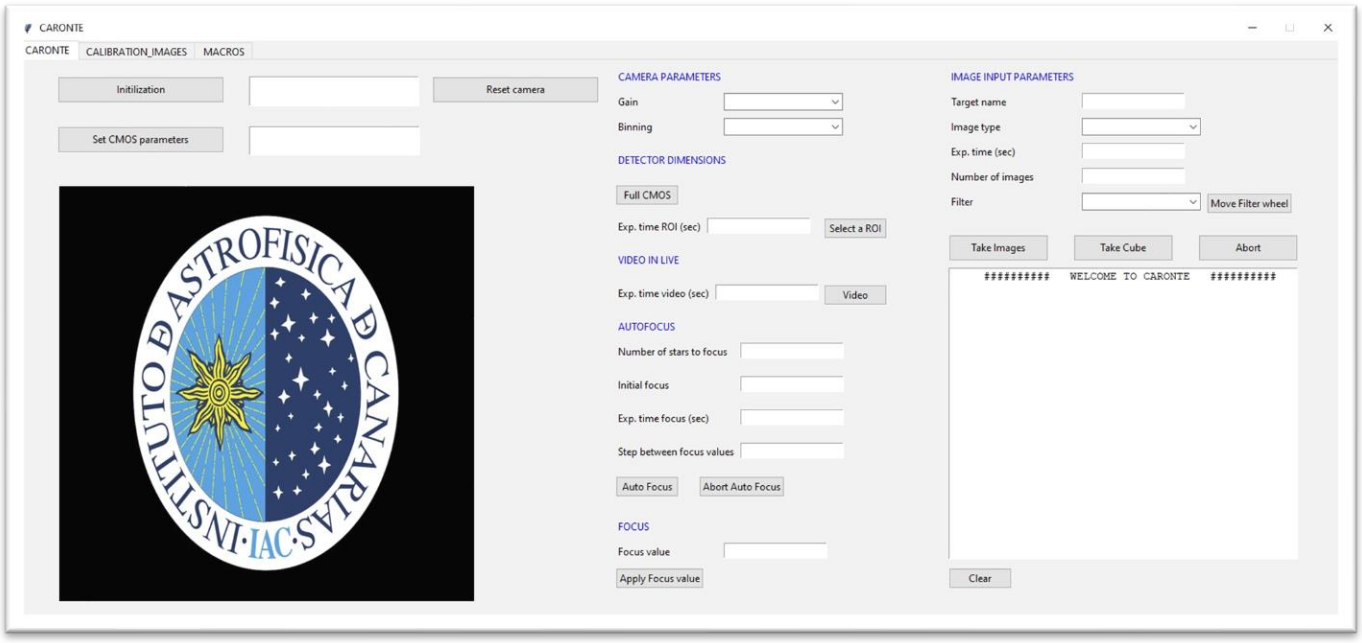


Photon transfer curve with gain in electrons per ADU calculated. CF refers to the calculated gain, and slope refers to the slope of the fit.

2. Graphical User Interface:

The CARONTE´s interface is the application to control the CMOS camera, the filter wheel and the telescope that allows interactive or advanced macros modes. It can be launched by double-clicking on the “CARONTE” icon located on the CARONTE PC, on the Windows welcome screen.





CARONTE´s interface general view

The different tabs of the CARONTE interface window are:

- **CARONTE**
- **TELESCOPE**
- **CALIBRATION IMAGES**
- **MACROS**

CARONTE

The different options available in the CARONTE´s tabs are:
2.1 Initialization and configuration of camera parameters
2.2 Real view
2.3 Focusing the telescope
2.4 Images acquisition

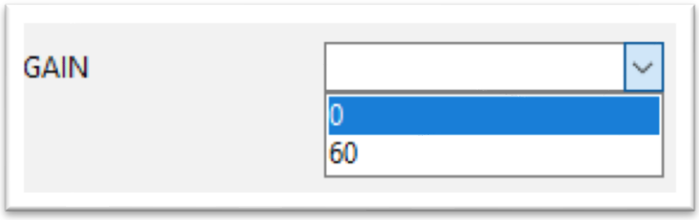
2.1 Initialization and configuration of camera parameters

The first tab in the CARONTE interface allows you to initialize the camera, configure CMOS parameters, focus the telescope, and the image acquisition.

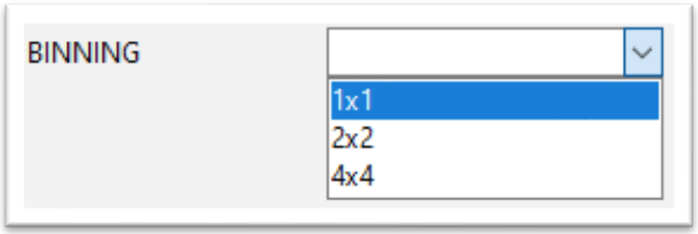
First of all, the camera must be initialized by clicking the "Initialization" button. If the camera initializes successfully, a green "camera initialized" message will appear, otherwise a red "camera not initialized" message will appear.

After camera initialization, the camera parameters gain, binning and detector dimensions must be chosen.

The gain allows two values, 0 or 60. The difference between them can be found in the instrument characterization section (**1.**).

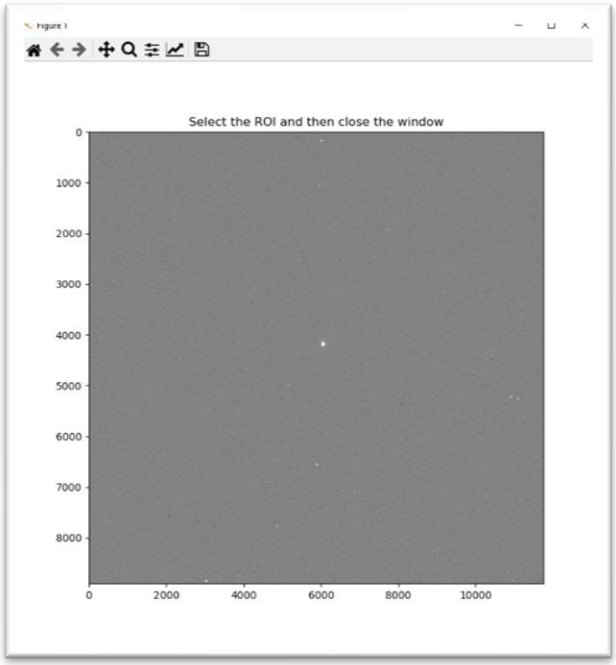


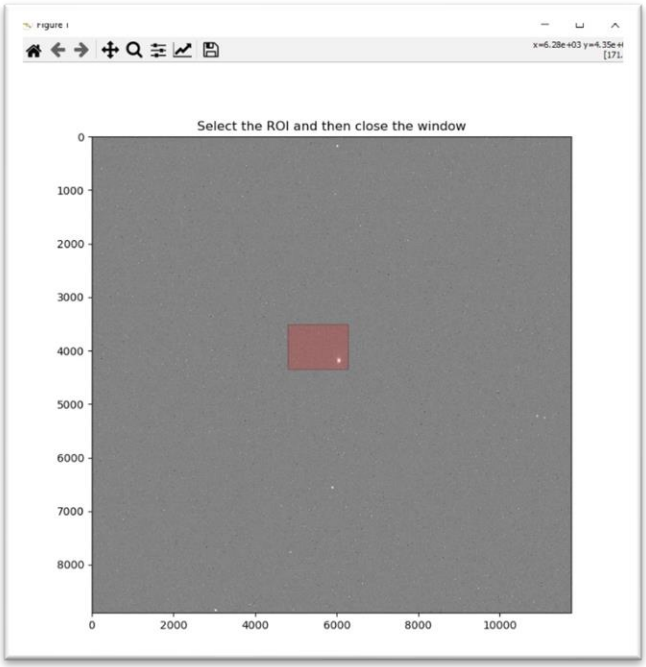
The binning options are 1x1, 2x2 and 4x4. The plate scale in each case is 0.0811, 0.1622 and 0.3244"/pixel. The field of view (FOV) is 15.9 x 12 arcmin^2.



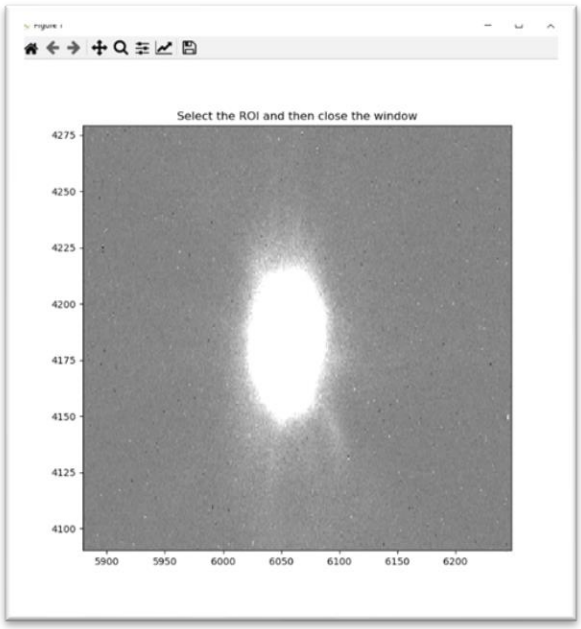
Detector dimension options are “Full CMOS” or “Select a ROI”. The first one will set up the full chip and therefore the full FOV that CARONTE offers. The second allows you to select a region of the FOV of the image, allowing the image to be smaller and to take up less space.

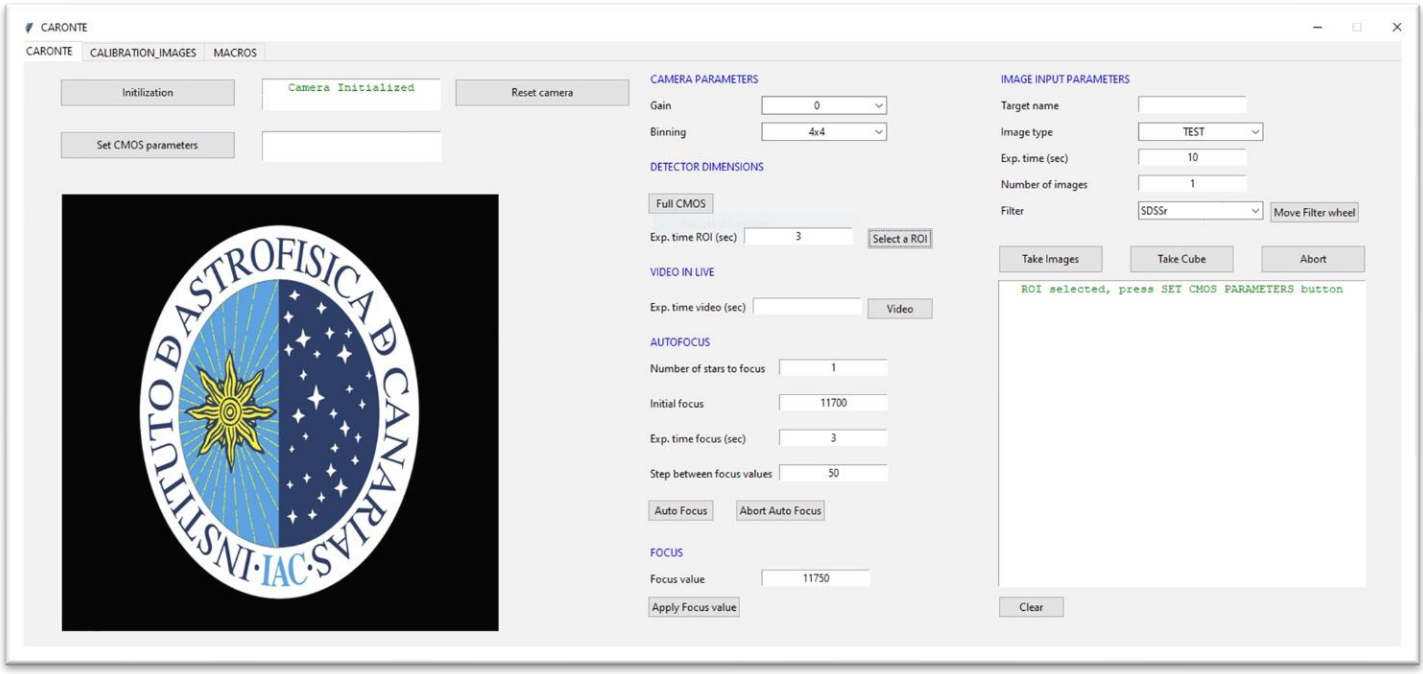
If the "Select a Roi" option is selected, the camera will take an image of the field with the exposure time (in seconds) set in the Exp.time ROI box. A plot of the field will then be displayed on the screen, prompting you to select the region. To do this, click on the upper left corner of the required area and drag the mouse until you reach the desired region of interest.



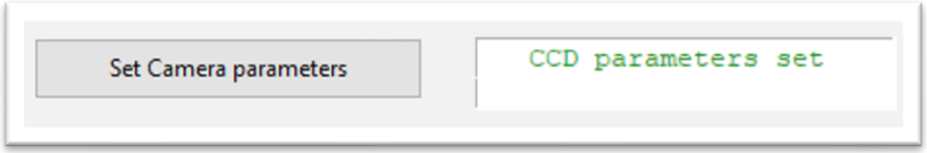


Once the region of interest has been selected, a zoomed image of the region will be displayed. If the region of interest needs to be modified, close the window and repeat the process.



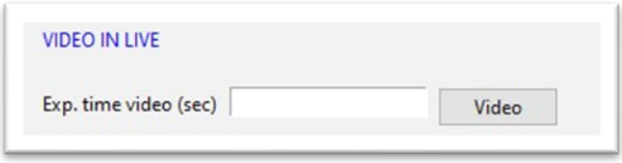


Once the CMOS parameters and the detector dimensions have been selected, this configuration must be performed. To do this, click the "set CMOS parameters" button. If the configuration has been carried out correctly, a green message "CMOS parameters set" will appear, otherwise a red message will appear with the specific error.



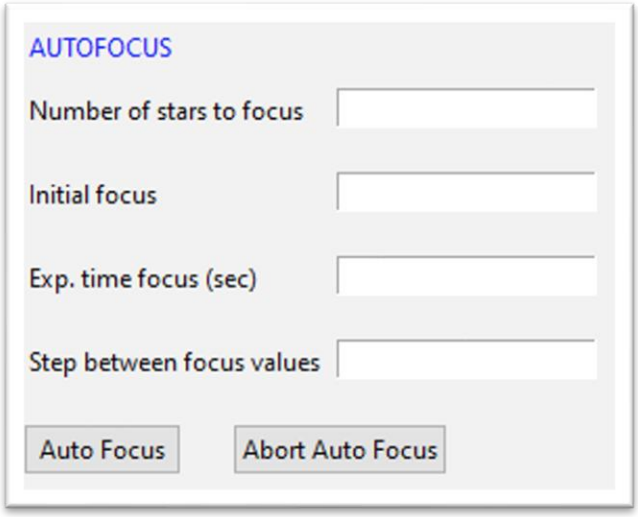
2.2 Real view

There is the possibility to obtain a real time video of the field, simply by entering the exposure time of the images in seconds and pressing the video button.



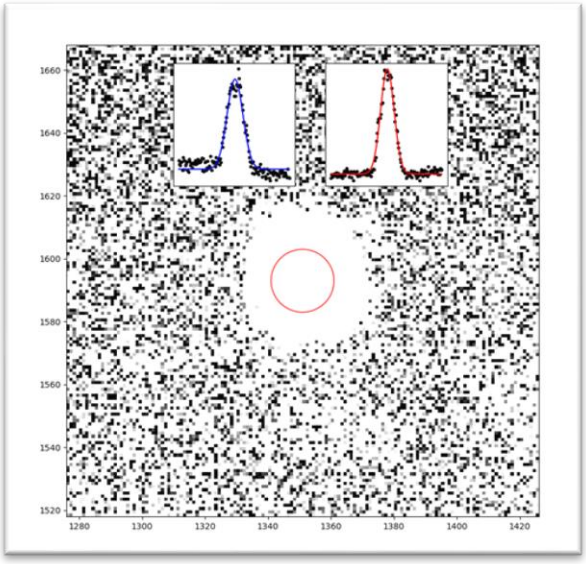
2.3 Focusing the telescope

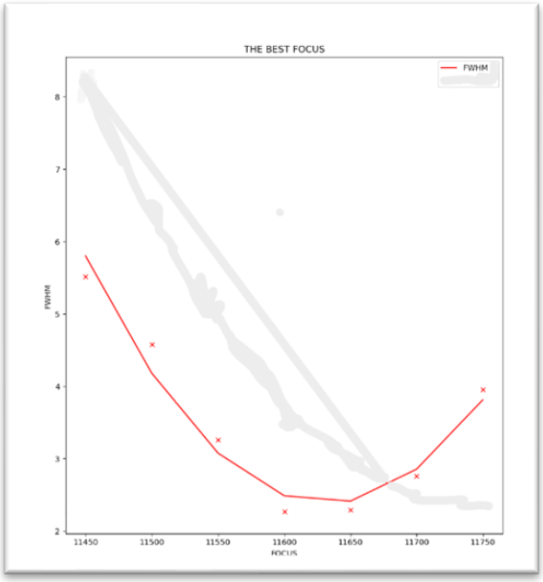
Before the image acquisition, it is necessary to focus the telescope. It is recommended to focus on the same field where the acquisition is going to be made. The focus process is automatic, the only thing that is entered in the "autofocus" panel is the number of stars to select in the field to focus, the initial focus, which must be consulted from previous nights (we recommend setting this initial focus slightly below the last used focus), the exposure time to focus and the step between focus and focus (recommended 50). Once these values have been entered, press the "Autofocus" button.



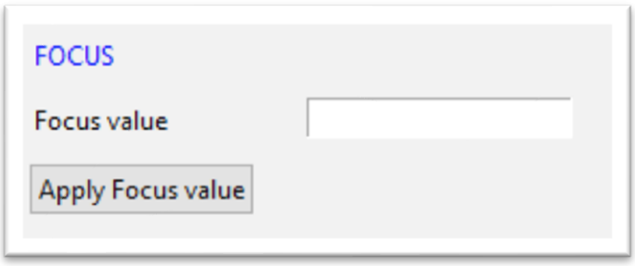
An image will automatically be acquired, with the settings previously established, to identify the field. Once the exposure is finished, the field will be displayed and you will be prompted to click on the star(s) in the field used to focus.

The automatic process will begin once the star(s) has/have been selected. It will begin fitting Gaussians to each of the stars, calculating their FWHM for 8 different focus positions centered on the entered initial focus. In addition, it will display on the screen the fit that is being made in each of the stars according to their focus (figure below left). At the end of the process it will plot a fit of the FWHM according to the focus (figure below right).





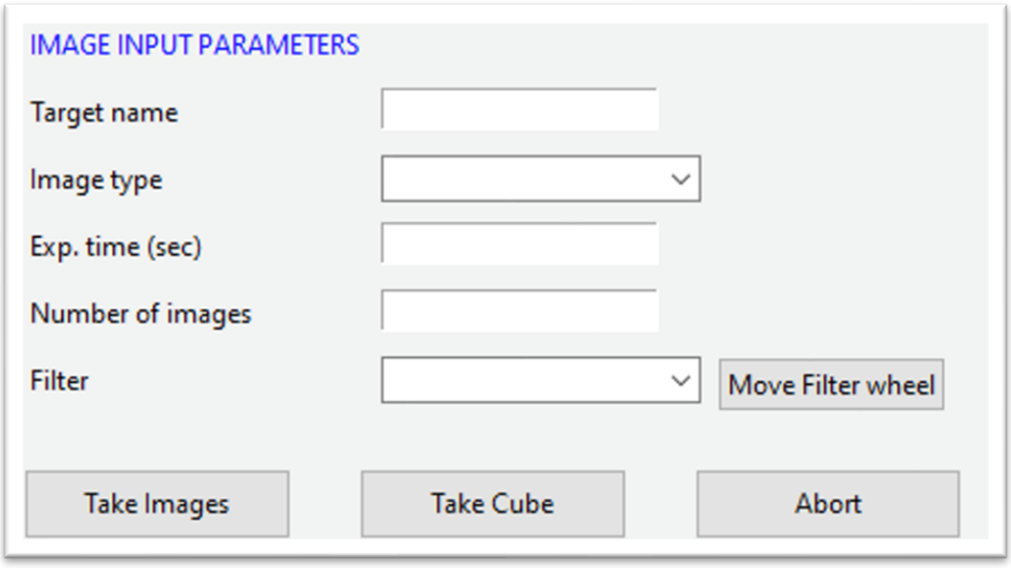
Finally, the best focus needs to be entered manually in the "Focus" panel, according to the plot shown on the screen after the fitting.



2.3 Images acquisition

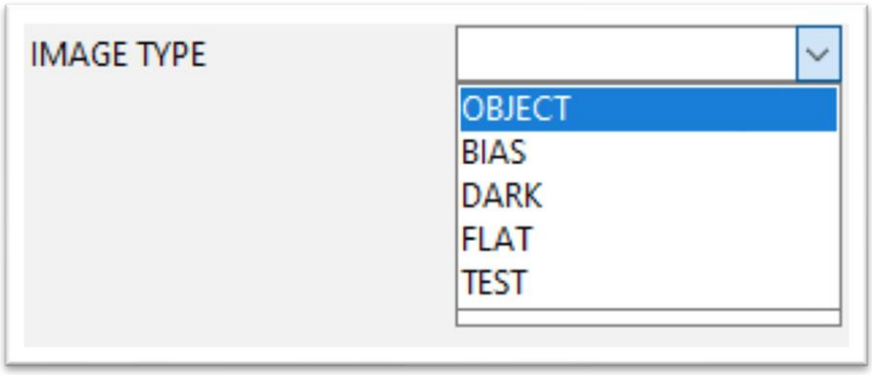
The images will automatically save to a date night folder on the desktop.

To acquire the images, it is necessary to enter the following parameters in the "image input parameters" panel:

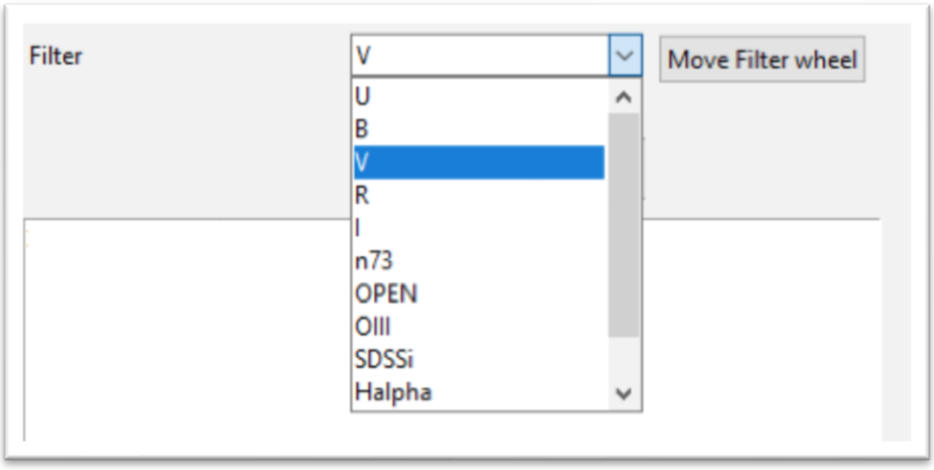


The "target name", which will be the prefix of the images when they are saved and will be used to locate them easily.

Specify the "image type", which is saved in the header and will be used to easily identify it for further reduction.



You must also enter the exposure time, in seconds, and the number of images required of the object. The desired filter must be selected and the "Move filter wheel" button pressed to position it. When the button is pressed, the text box will report that the filter wheel is moving and will also notify when it has moved into position.

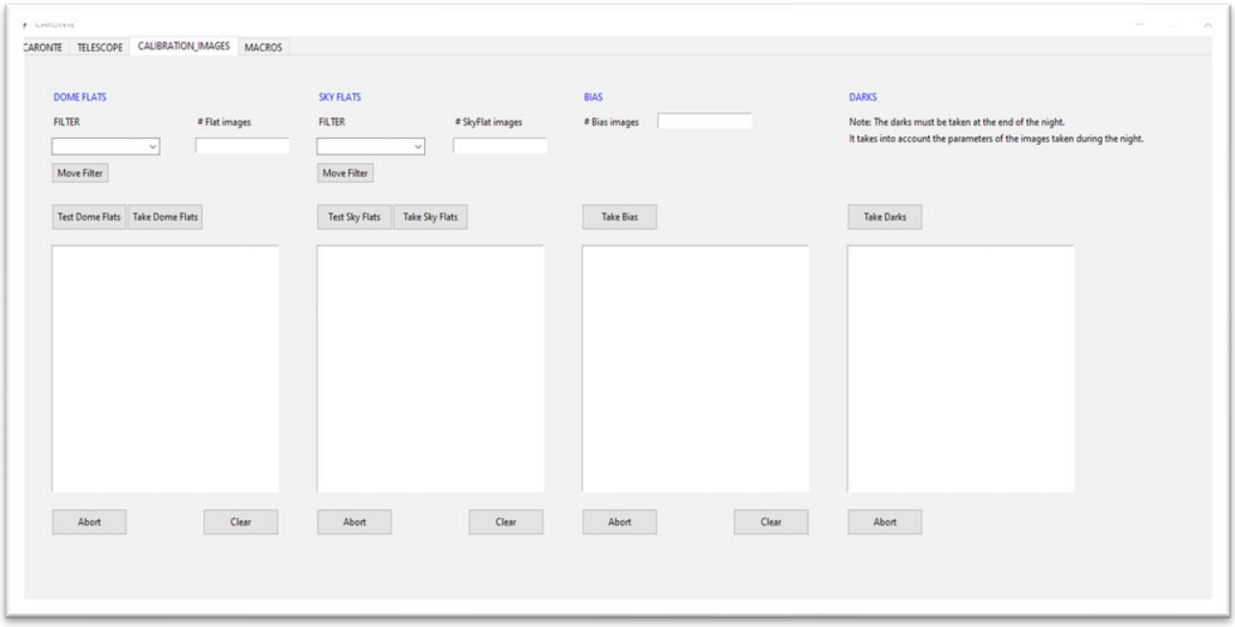


Once all the parameters have been entered, the image can be acquired by pressing the "Take images" button. Information about the number of images taken will be displayed in the text box. Taking cubes of images can also be done if a region of interest (ROI) has been selected by pressing the "Take cube" button. This option saves images in cubes of 500.

The acquisition, in both cases, can be canceled at any time by pressing the "Abort" button.

CALIBRATION IMAGES

The overview of the calibration images tab is as follows:



The different options available in the tab are:

2.4) Dome Flats

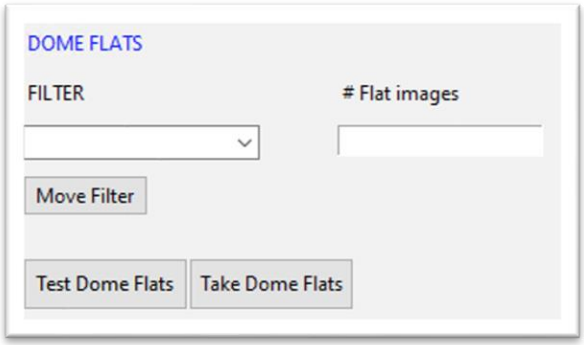
2.5) Sky Flats

2.6) Bias

2.7) Darks

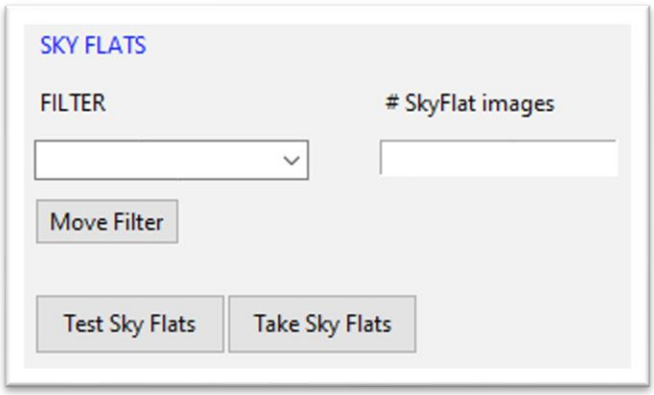
2.4) Dome Flats

The "dome flats" option allows you to use the dome lights with the telescope parked to the south and the dome at 360º, so that the telescope points to the white panel that will illuminate it with uniform light. Choose the desired filter from the drop-down menu, and move the filter wheel by pressing the "Move filter" button. Then pressing the "Test dome flats" button will take a test image with the settings set in the CARONTE tab and the text box will notify the time needed to take good flats. If the time is acceptable, fill in the desired number of dome flats and click the "Take dome flats" button. If the time is not correct, the intensity of the lights will be raised or lowered and the process will be repeated.



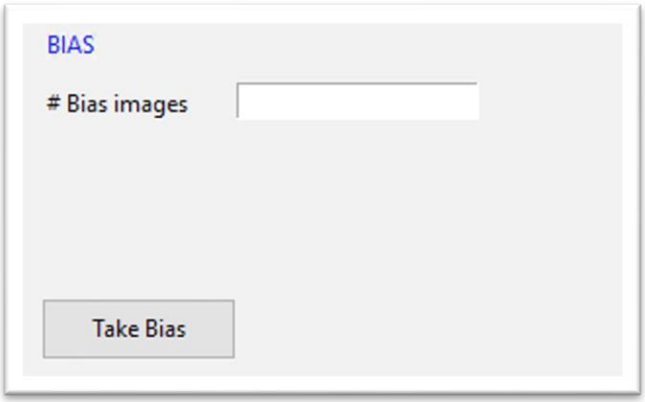
2.5) Sky Flats

The "sky flats" option allows you automatic acquisition of sky flats at sunset. The desired filter is selected and the filter wheel is moved by pressing the "Move filter" button. Once in position, click the "Test sky flats" button, it will take a test image with the settings set in the CARONTE tab and calculate the time needed to take good flats. If the time is correct, add the desired number of sky flats and click the "Take sky flats" button. It will automatically start taking images and between each image it will make an offset and recalculate the time needed for the next flats.



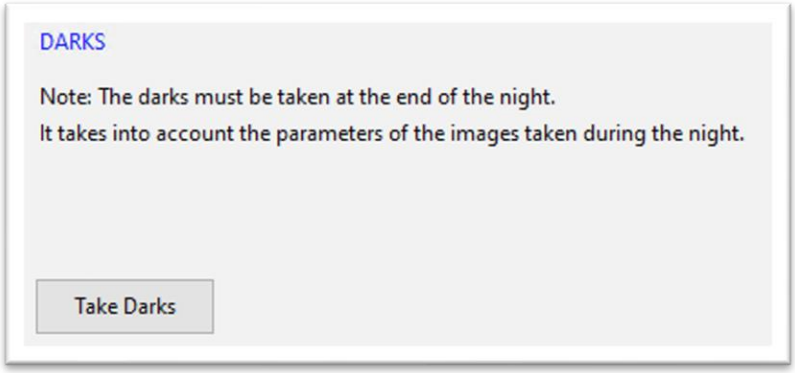
2.6) Bias

The "bias" option allows the automatic acquisition of bias, choosing the number of images to take and pressing the "Take Bias" button. It will automatically take the total number of images desired. Since the camera does not have a shutther, before the biases are acquired, the filter wheel will automatically move to the n73 filter position that does not allow light to enter the detector.



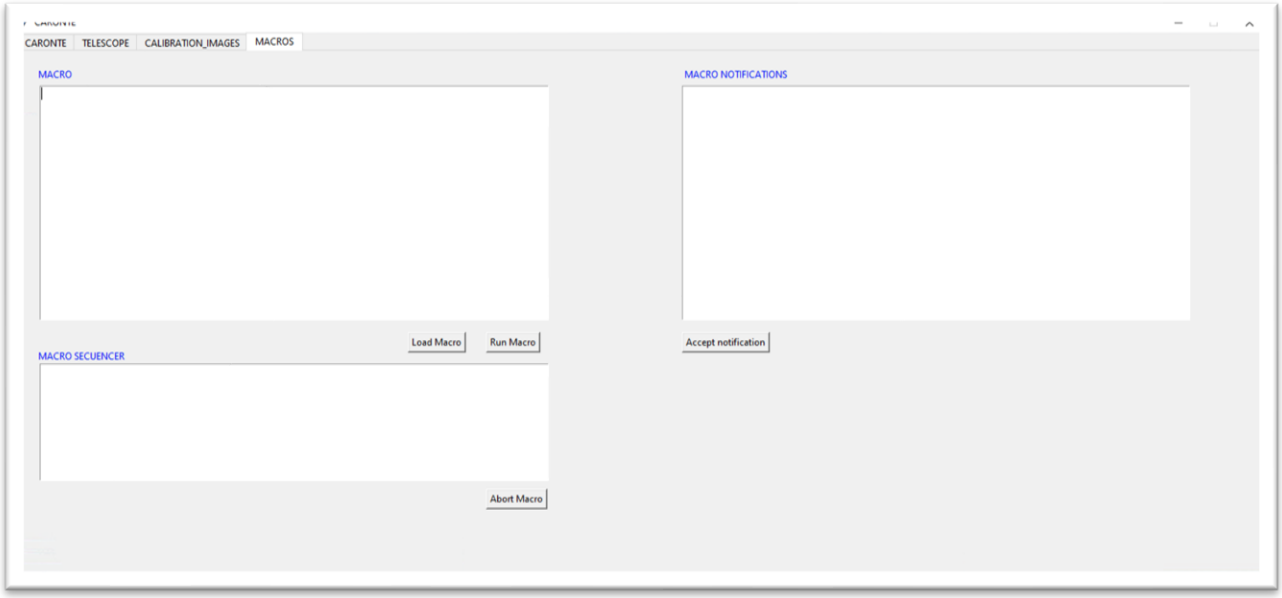
2.7) Darks

The "Darks" option allows the automatic taking of Darks. At the end of the night and once the observations are finished, press the "Take darks" button. It will automatically detect the different configurations that we have taken and take 3 images of darks with each of these configurations. Since the camera does not have a shutther, before darks are acquired, the filter wheel will automatically move to the n73 filter position that does not allow light to enter the detector.



MACROS

The execution of a macro simulates the behaviour of an operator that handle the interface. From the macro, you can automatically do the same as you would do manually from the interface.



Overview

Macros consist of directives. A directive is ALWAYS composed of the name, the "=" symbol and a value. For example, the most common directive, which states that a certain number of seconds must be exposed, is written: "EXPOSE = 3", where the number of seconds can be any floating point value. Directives are always written in uppercase. The directives can indicate an order, or also change the behavior of the macro executor or some device. On a line, there can be more than one directive, separated by commas. There are no directives that are incompatible with each other, but they should never be repeated on a line. Directives keep an order of precedence. For example: the first thing that will happen will be the filter change to SDSSg and then the exposure, although in our macro the exposure action is the first.

To load your macro, click on the "load macro" button, browse to the file on the system, and click the "accept" button. Remember that the syntax must follow the rules mentioned above. The macro will be displayed in the macro window. To run it, press the "Run macro" button. In the macro sequencer window, the line being executed will be displayed. In case any interaction command ("PROMPT") has been used in the macro, the message will appear in the macro's notification window. Until the "accept notification" button is pressed, the macro will not continue its course.

Command directives

The command directives indicate a direct action on the hardware of the instrument or telescope and are the following:

•**EXPOSE**: Shows a certain number of seconds. Accepts a floating-point value.

EXPOSE = 30
EXPOSE = 12.5

• **FILTER**: Change filter. Accepts the name of the filter.

FILTER = R
FILTER = OPEN

• **POINT**: Points to J2000 coordinates.

POINT=23 15 12.22 +17 23 34.44

• **PARK**: Brings the telescope to a parking position. Accepts a string of text with the full name of the position (ZENITH, NORTH, WEST, EAST, SOUTH).

PARK = ZENITH
PARK = WEST

Devices behaviour directives

Devices behaviour directives or the way in which the images are saved/captured.

•**TYPE**: Image type O = OBJECT, F = FLAT, B = BIAS, D = DARK, T = TEST

TYPE = O
TYPE = T

• **OBJECT**: Object name (it will be saved in the image header).

OBJECT = 'NGC 2121'

• **REPEAT**: Repeats a line a certain number of times. By default, it will only repeat once.

REPEAT = 3

• **RUNTO**: Synchronizes the execution of a line with a specific date and time.

RUNTO = '2017-03-03 22:03:31'

- **PROMPT**: Displays a message on the screen and waits for the user to press accept.

PROMPT = 'Please activate the autoguiding'.

#Macro example for CARONTE INTERFACE

Lines with # are comments

##MACRO EXAMPLE
##FIRST OBJECT-FIRST LINE
POINT=14:03:13.00 +54:20:57.0,EXPOSE=15,REPEAT=100,FILTER=B,TYPE=OBJECT,OBJECT=M101,
PROMPT=Look for guide star,RUNTO=2024-03-04 21:05,
##ANOTHER LINE
EXPOSE=15,REPEAT=100,FILTER=V,TYPE=OBJECT,OBJECT= M101,
##ANOTHER LINE
EXPOSE=15,REPEAT=100,FILTER=R,TYPE=OBJECT,OBJECT= M101,
SECOND OBJECT-ANOTHER LINE
POINT=12:56:48.88 +21:40:31.56,EXPOSE=15,REPEAT=120,FILTER=B,TYPE=OBJECT,PROMPT= Look for guide star,OBJECT=M64,RUNTO=2024-03-05 02:20,
##ANOTHER LINE
EXPOSE=15,REPEAT=120,FILTER=V,TYPE=OBJECT,OBJECT=M64,