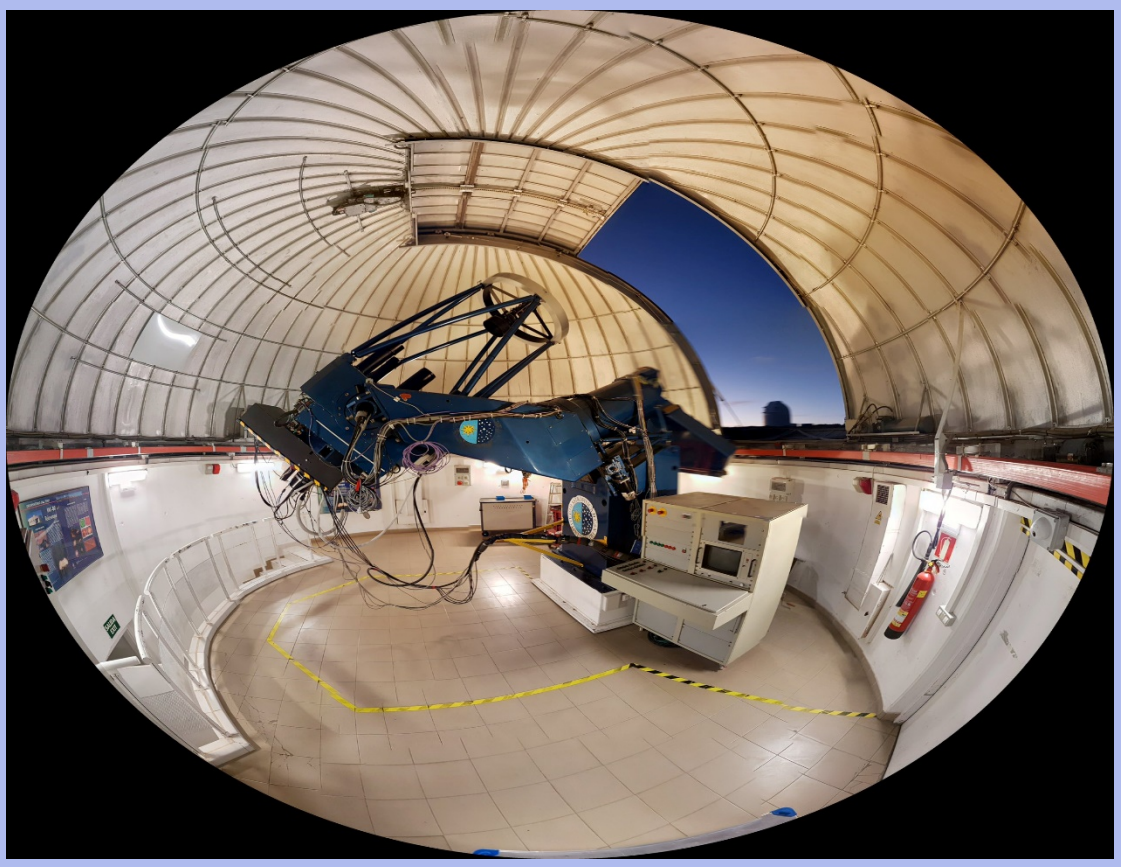

IAC80 @ OT

CAMELOT-2:

Detector characteristics and

CCD-Cap user guide

Telescope Operations Group

The aim of these series of user guides is to help the observer in some specific tasks concerning the telescopes and instruments available at the Observatorios de Canarias (OOCC). The information is supplied in a clear and simple manner, and it comes illustrated with screen captures in order to make the manual easy to use.

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

Ver. November 2021
Olga Zamora
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1. The detector

The detector is an E2V Technologies CCD231-84 back illuminated device (1100 SI Series Camera) with 4096 (H) x 4112 (V) pixels of 15 microns/pixel each, equivalent to 0.322" at IAC80. The FoV in the IAC80 telescope is ~ 21.98 x 22.06 arcmin^2 . However, the FoV free of vignetting is a rounded area of ~ 17 arcmin radius due to the installed filterwheel.

There are fifteen possible readout modes enabled, with four readout rates (100, 344, 709, and 855 Khz, all of them with Analog Attenuation = 0 and CCD Attenuation = 2), and 1, 2 or 4 outputs.

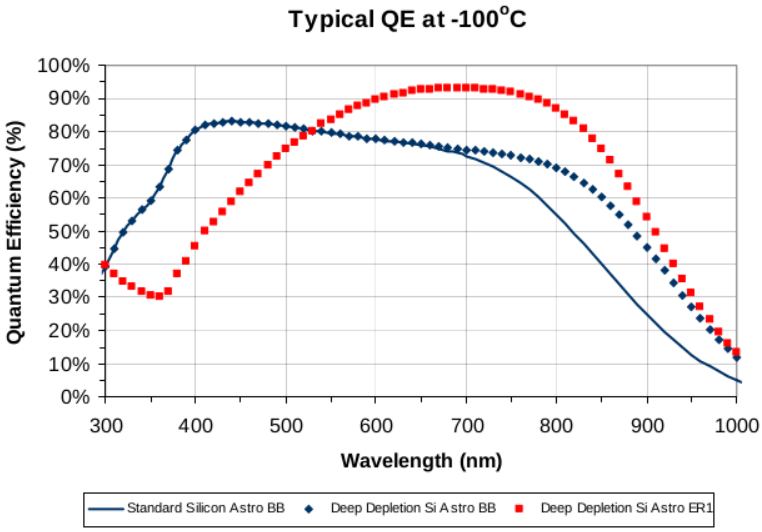
The main characteristics of the readout modes enabled (using 4 outputs) as given by the manufacturer are:

Mode (KHz)	Gain (e/ADU)	RNOISE (e)	RNOISE (ADU)	READOUT TIME (s)
100	0.78	2.41	3.09	43.26
344	3.78	5.22	1.38	13.5
709	7.63	11.42	1.50	7.2
855	16.54	20.67	1.25	6.5

The nominal operation temperature is -105 ºC and the cooling system (adapted to use NF-50 gas) takes ~3h to reach it in case of vacuum loss.

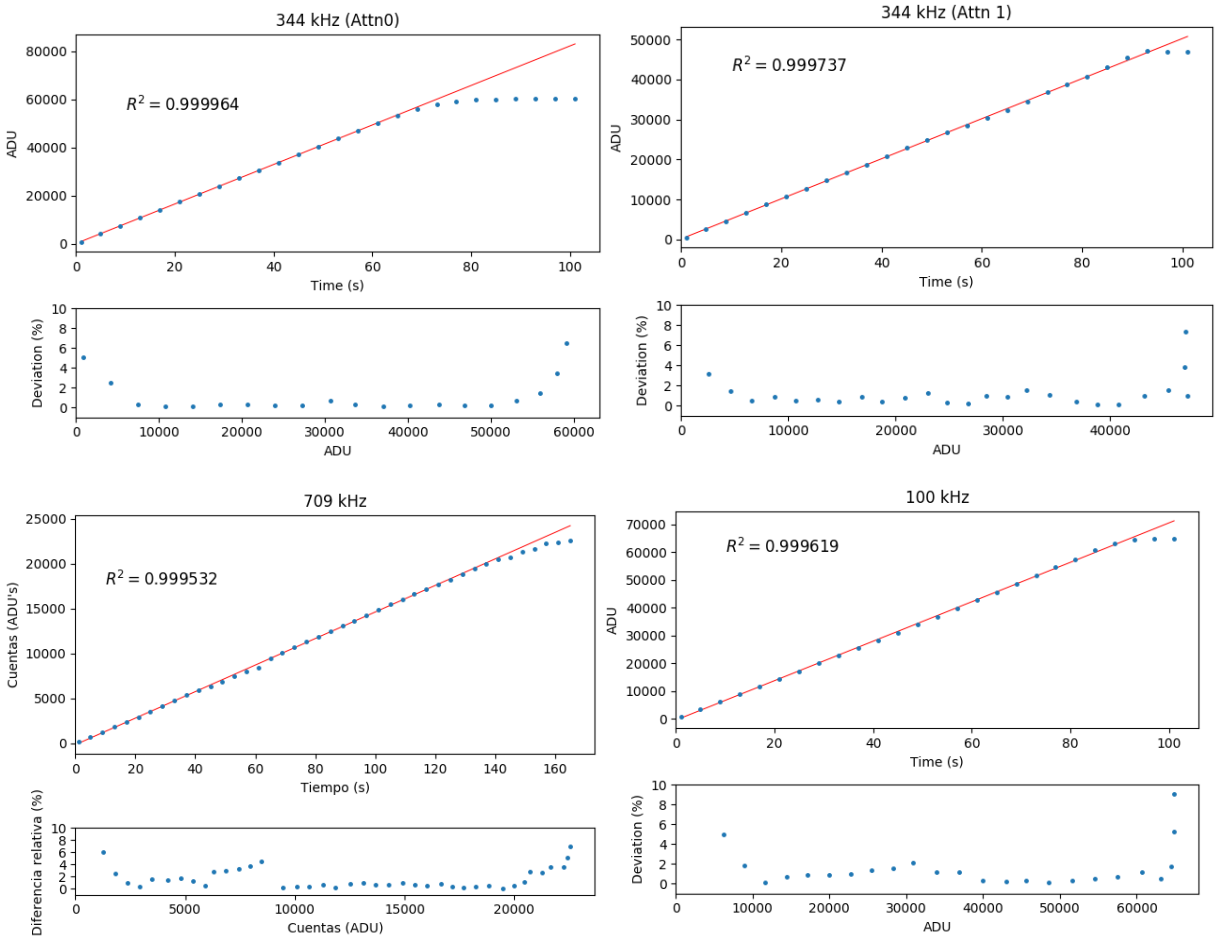
Some other features are:

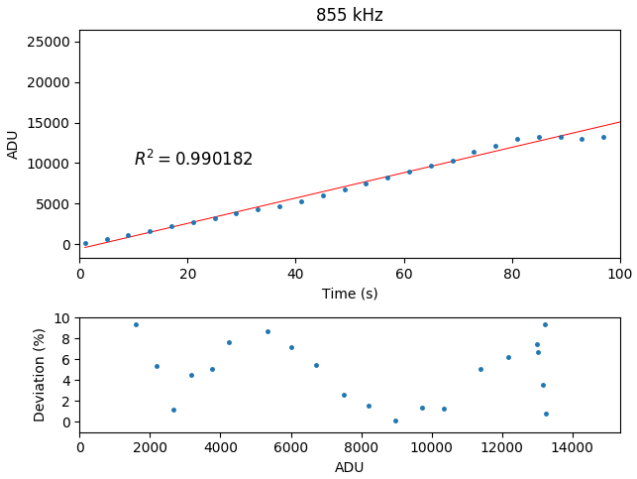
- Overscan: non available.
- Windows: non available in CCD-Cap.
- Binning: three possibilities of binning are available (see Sect. 2): 1x1, 2x2, and 3x3. Only 1x1 binning is actually operative.
- Quantum efficiency: it is given by the red curve provided by the manufacturer (see figure below and the CAMELOT2 webpage for our own measured QE curve).



1.1 Linearity

The linearity for the 5 readout modes with 4 outputs is shown below.





In all modes the deviation is below 2%, except for mode 4 that in some sections is upper 10%.

It is useful for the observers to know the appropriate level of counts (ADUs) for taking flat field calibrations depending on which readout mode is used. Using the arbitrary criteria of 70% of the dynamic range, the following values are obtained:

Mode (kHz)	DINAMIC RANGE (ADU)	FLATFIELD COUNTS (ADU)
100	60000	42000
344 (Attn 0)	56000	39000
344 (Attn 1)	40000	28000
709	22000	16000
855	12000	8000

1.2 Gain & RON

Is this section we show the values of gain an RON (readout noise) for the 5 possible readout modes (all of them using 4 outputs) as obtained from calibration images taken at the IAC80 telescope. We consider these values as compatible with the manufacture's values (given above) once non laboratory conditions are taken into account.

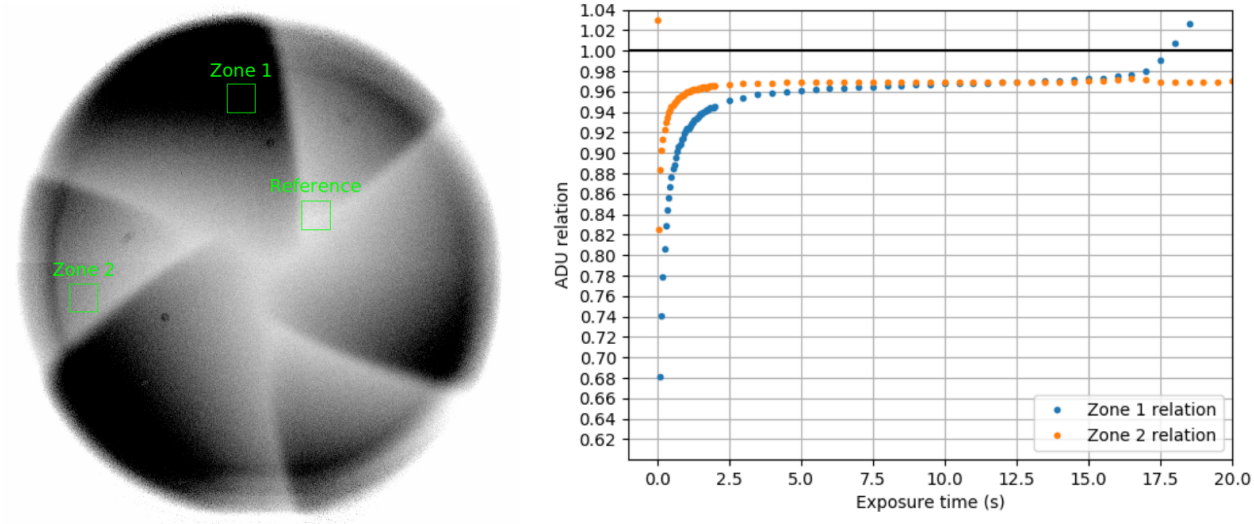
Mode (kHz)	Gain (e/ADU)	RNOISE (e)	RNOISE (ADU)	READOUT TIME (s)
100	0.79	5.31	8.04	43.26
344 (Attn 0)	4.23	6.01	1.64	13.5
344 (Attn 1)	8.54	11.62	1.42	13.5
709	8.98	12.11	1.49	7.2
855	18.97	23.82	1.27	6.5

A exposure time calculator can be found at :

http://research.iac.es/OOCC/iac-managed-telescopes/iac80/camelot/camelot-snr-calculator/

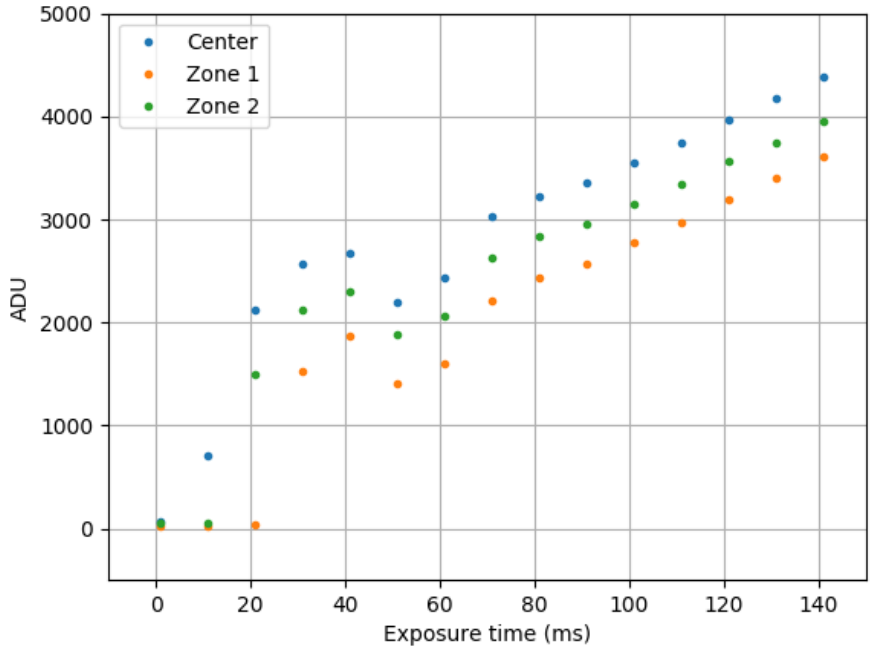
1.3 Shutter

The effects of the shutter are shown in this section. It is important to know that these tests were performed under strong dome lights and the shutter's effects do not represent a real problem in astronomical images.



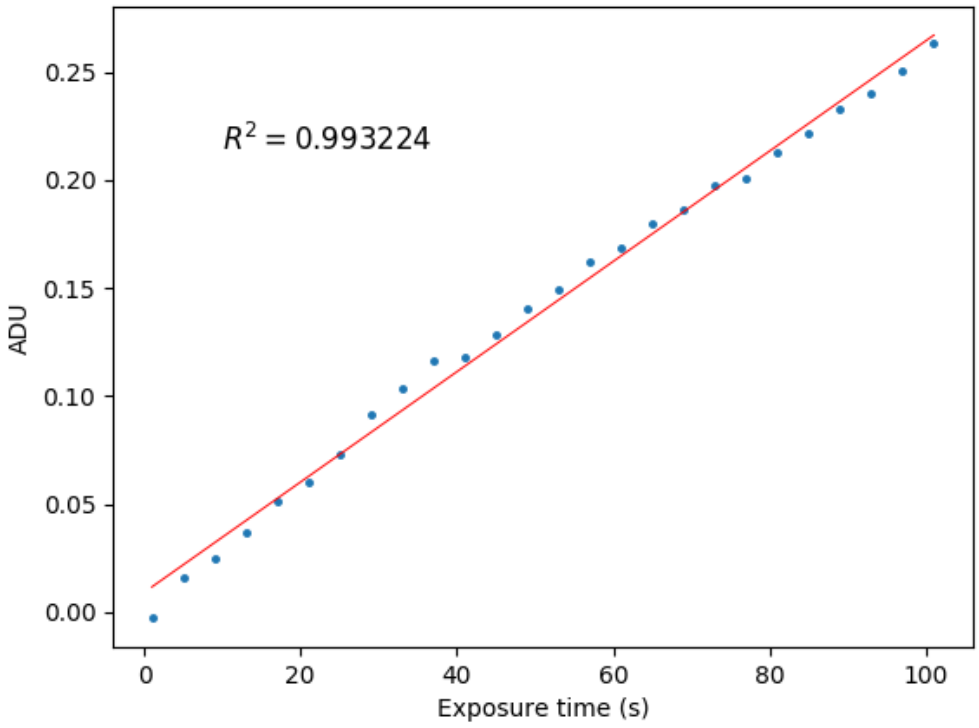
On the left panel it is shown an image of 0.051 seconds where the shutter is clearly visible. The ADU counts are measured in the three zones indicated in green. On the right panel are shown both the relation between zone 1 and the reference and the relation between the zone 2 and the reference.

In the following figure it is represented the counts of the three zones versus the exposure time. It becomes noticeable the strange behavior until, approximately, 70 milliseconds. This time coincide with the time given by the manufacturer.



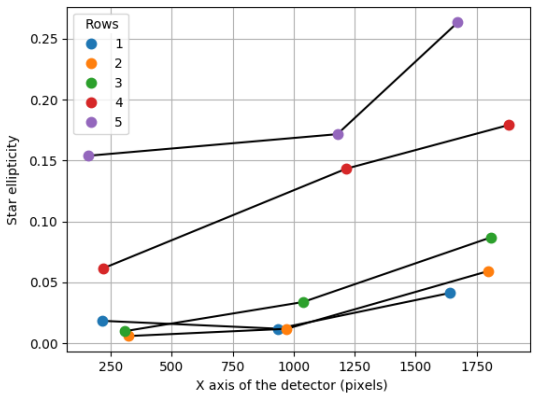
1.3 Darks

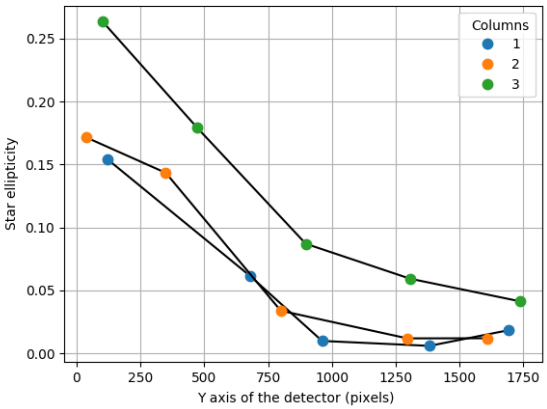
The typical working temperature of the detector is -105º and therefore the dark current should be almost negligible. However, this has been verified experimentally. The slope of the fit is 0.0255 ADU/s.



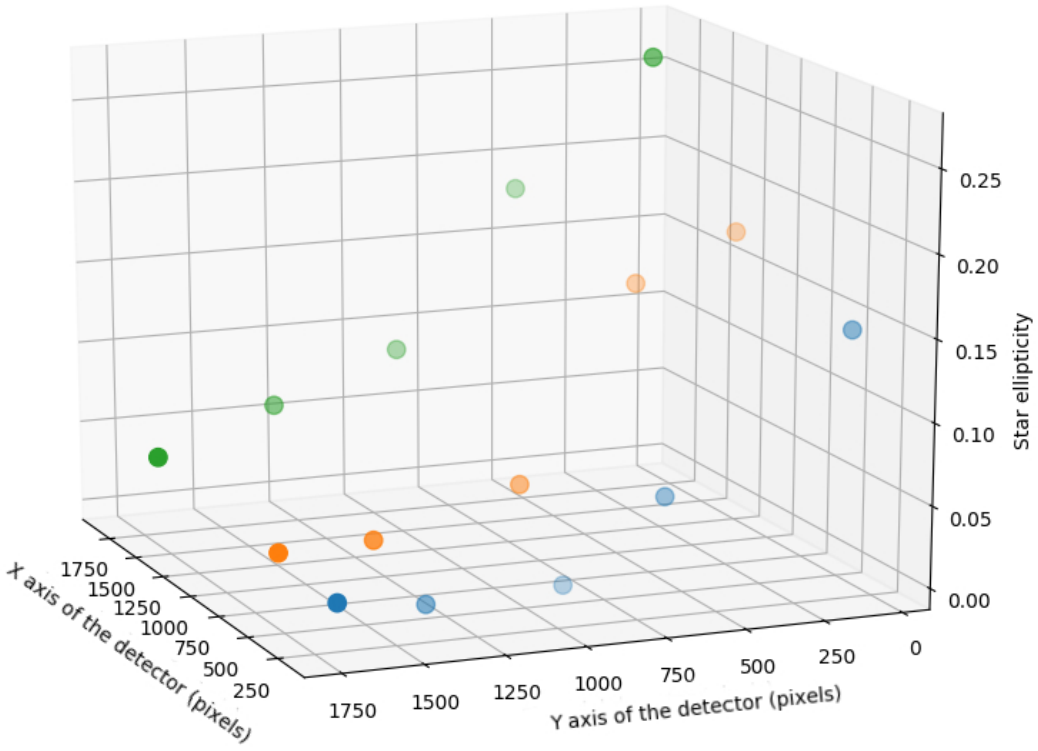
1.4 Point Source Function

The following figures show how the star's PSF change along the detector . On the right panel, the star's ellipticity grows as we go to the right side of the detector. On the left, this ellipticity grows as we go to the lower side of the detector.



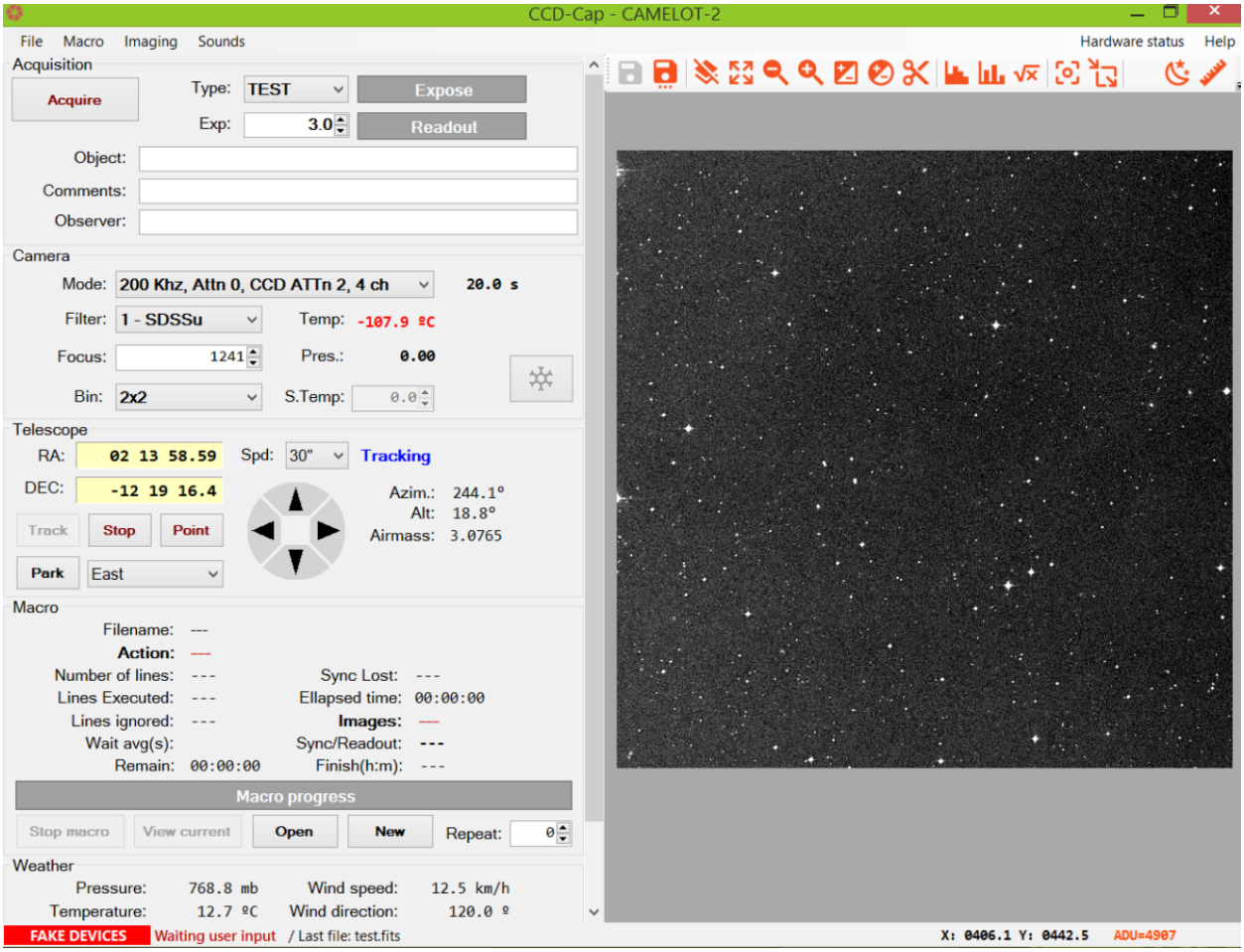


From a 3D sight, the deformation of the star's ellipticity is shown:


0.25
0.20
0.15
0.10
0.05
0.00
Star ellipticity
1750
1500
1250
1000
750
500
250
X axis of the detector (pixels)
1750
1500
1250
1000
750
500
250
0
Y axis of the detector (pixels)

2. Graphical User Interface CCD-Cap

CCD-Cap is the application for controlling the CCD, filter wheel and telescope that allows either interactive or advanced macros modes (see Sect. 4). It can be launched by double-clicking on the icon CCDCap.exe placed in CAMELOT2 PC, in the path: E:\CCDCAP or on the welcome screen in Windows. The present manual refers to the **CCD-Cap version 2.0.0.**



CCD-Cap control interface general view

The areas of CCD-Cap interface window are:

1. Upper-left menu

2. Upper-right menu

3. Advanced options panel

4. Acquisition panel

5. Camera panel

6. Telescope panel

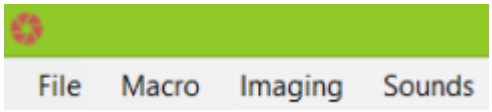
7. Macro panel

8. Weather panel

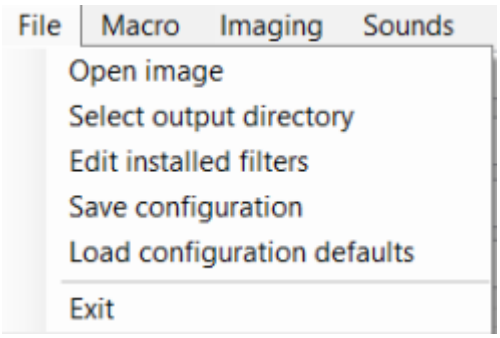
9. Informative panel

1. Upper-left menu:

In the upper-left part of the CCD-Cap window, there is a tab menu to perform several operations: **File**, **Macro**, **Imaging**, and **Sounds.**



The File menu options are the following:



Open image: loads a saved image from disk.

Select output directory: directory where the images will be saved.

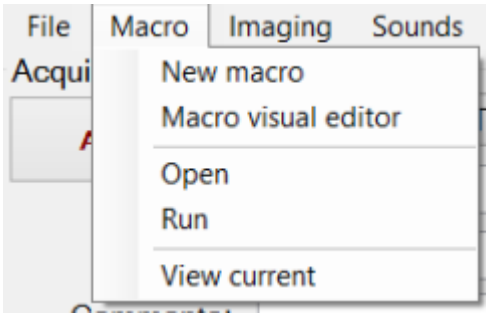
Edit installed filers: not implemented yet. They should be changed from CCDCAP.ini configuration file in the E:\CCDCAP directory.

Save configuration: not implemented yet.

Load configuration defaults: loads default configuration of CCD-Cap.

Exit: exit CCD-Cap.

Macro menu options are:



New macro: opens the Macro editor to compose advanced macros (see Sect. 4).

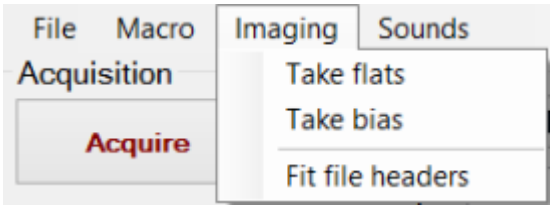
Macro visual editor: opens the abbreviated and interactive Macro editor (see Sect. 4).

Open: loads a previously saved macro.

Run: executes the loaded macro.

View current: shows the lines of the macro that are in execution.

Imaging menu options are:



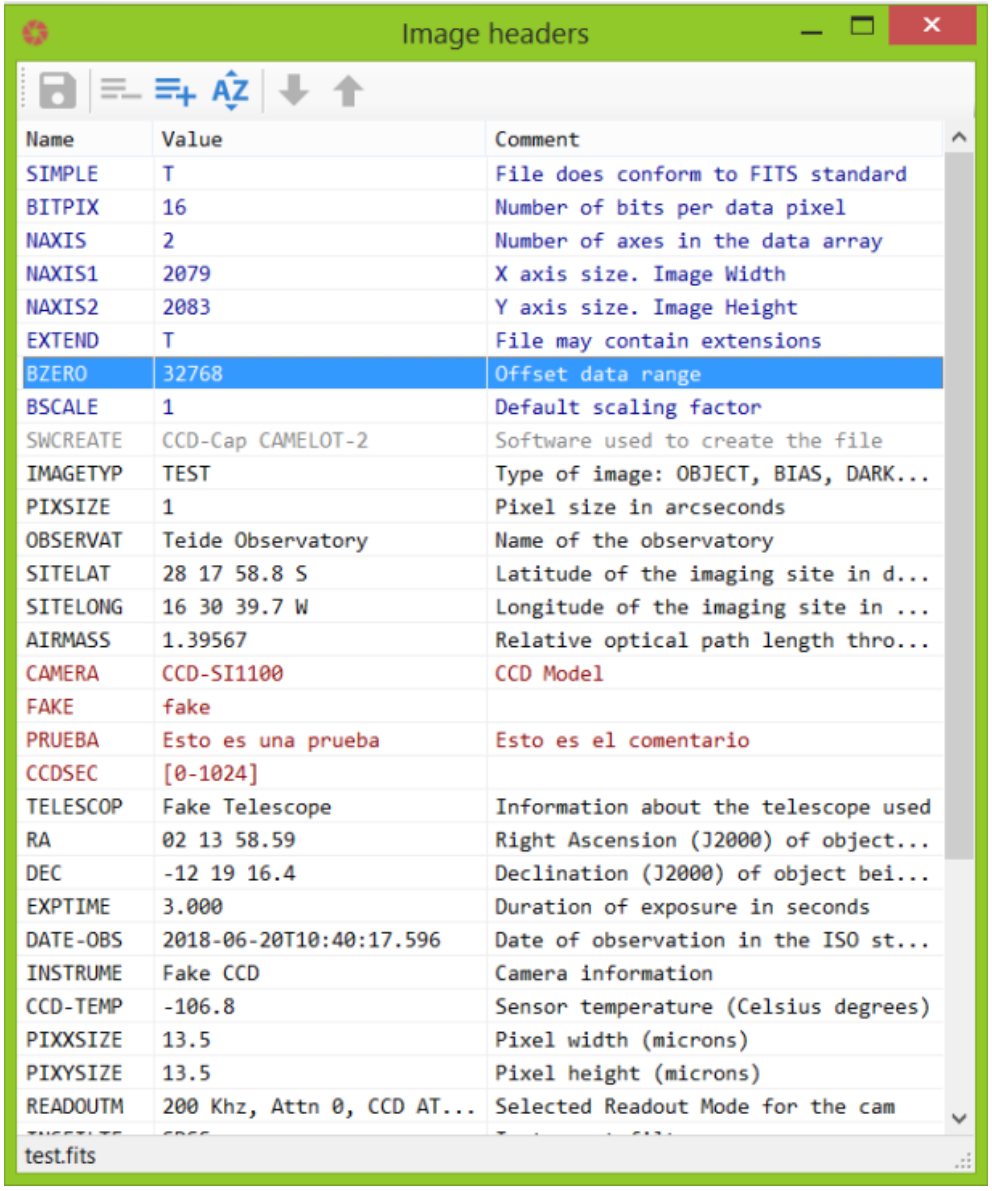
Take flats: specifies the number of flat field images to be taken.

Take bias: specifies the number of bias images to be taken.

Fit file headers: views/edits image headers interactively.

Sound menu: activates/deactivates the sound on different events:

When there is a new image, at the end of the pointing, at the end of the filter wheel movement, at the end of a macro, if the astrometry is OK, if there is an error on the astrometry.



Headers included in a sample image obtained by CCD-Cap

2. Upper-right menu:

In the upper-right corner of the CCD-Cap window, there are two menus:

Hardware status menu: displays/actives logs from the camera.

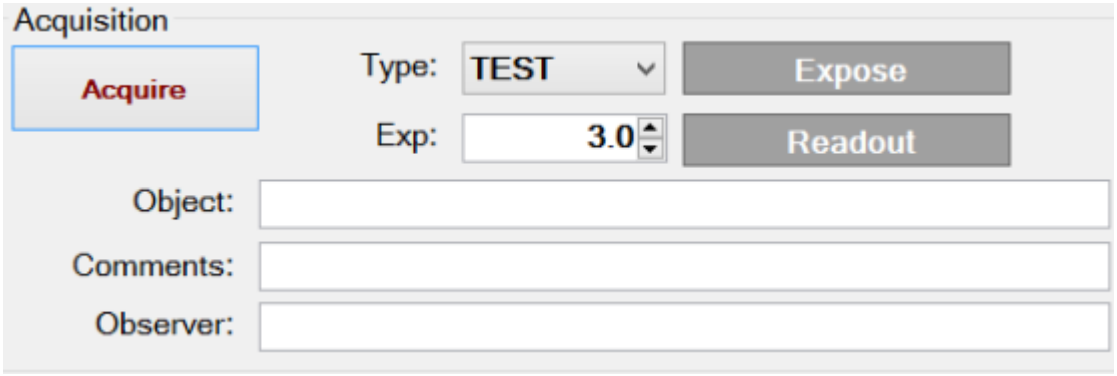
Help menu: shows several help options.

The advanced options panel is shown below.

3. Advanced options panel:

1. Save changes.
2. Save image as.
3. Clear layers.
4. Zoom to extension.
5. Zoom out.
6. Zoom in.
7. Automatic contrast.
8. Set contrast.
9. Crop image.
10. PSF.
11. Histogram.
12. Image stats.
13. Autofocus (see Sect. 3).
14. Telescope offset.
15. Show interesting objects.
16. Automatic astrometry.

4. Acquisition panel



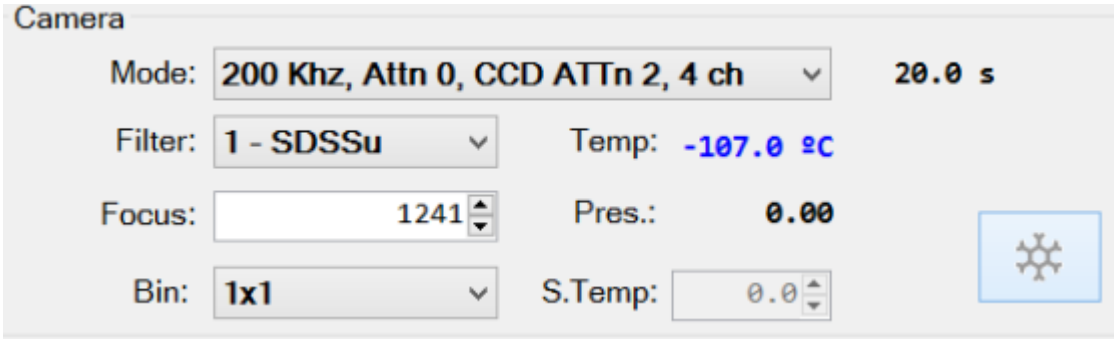
Specify the type of image (**Type**), exposure time (**Exp**, in seconds, with a minimum value of 0.01 s; note that the shutter will appear in the images with short exposure times as it takes 70ms to open, see Sect. 1.3**)**, objects name (**Object**), comments (**Comments)** and observer name (**Observer**). In the last three fields empty spaces can appear, but no tab are allowed.

Press **Acquire** button for taking an image.

Expose indicates the progress in the image acquisition process.

Readout indicates the progress in the readout process

5. Camera panel



Specify the readout mode (**Mode**), filter (**Filter**), telescope focus (**Focus**), and type of binning (**Bin**: 1x1 is the only operative).

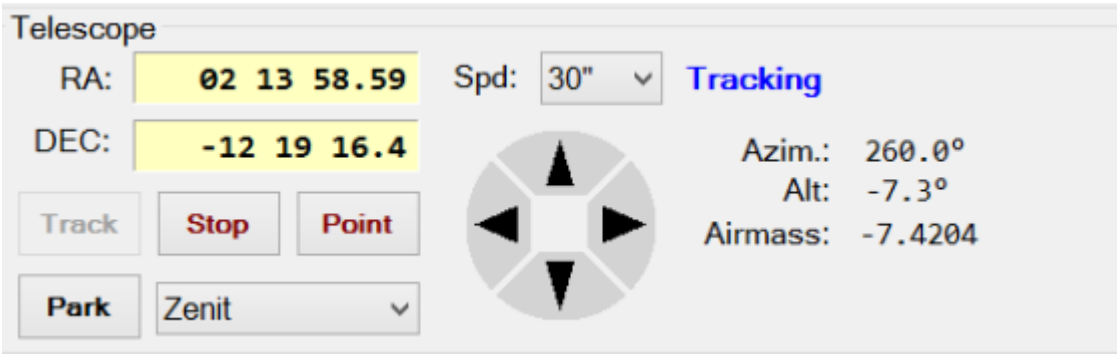
Readout time is indicated in the upper-right corner (in seconds).

Temp and **Pres** are the current temperature and pressure of the CCD. Nominal values are -105 and 0,0023.

By pressing on the icon  you can activate/deactivate the cooling system, **BUT THIS CAN ONLY BE DONE BY THE TELESCOPE OPERATOR**.

S. Temp sets the CCD working temperature to a given value, **BUT THIS CAN ONLY BE DONE BY THE TELESCOPE OPERATOR**.

6. Telescope panel



It shows the pointing coordinates Right Ascension (**RA**) and Declination (**DEC**).

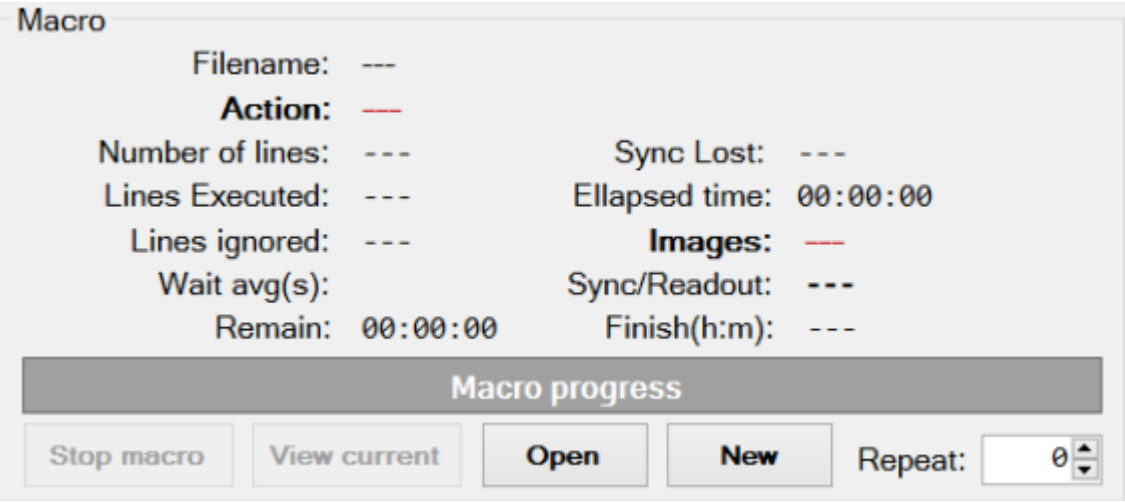
Press **Track**, **Stop** or **Point** to send an action to the telescope.

Park allows moving the telescope to different positions: zenith, west, and east.

Spd sets the magnitude of the telescope offset (in arcsecs) when clicking on the handpad to move into the different directions: north, south, east, west.

On the right-side, azimuth (**Azim**) and altitude (**Alt**) coordinates, and airmass are shown.

7. Macro panel



Macro panel shows information about the macro in execution. It is especially relevant for several programs, such as time domain astronomy or SST operations. See also Sect. 4.

The informative section is as follows:

Filename: name of the macro file in execution.

Action: status of the telescope/CCD.

Number of lines: total number of lines contained in the macro file.

Lines Executed: number of lines already executed in the macro file.

Lines ignored: number of lines ignored (or skipped) in the macro file.

Wait avg(s): waiting average (in seconds) to take the next image. In SST, this value should be as close to 0 as possible to avoid dead times.

Remain: time remaining to finish the macro in execution.

Sync Lost: Yes/No indicates that the pointing estimation is good or not.

Ellapsed time: time spent since the start of the macro execution.

Images: total number of images accumulated during macro execution.

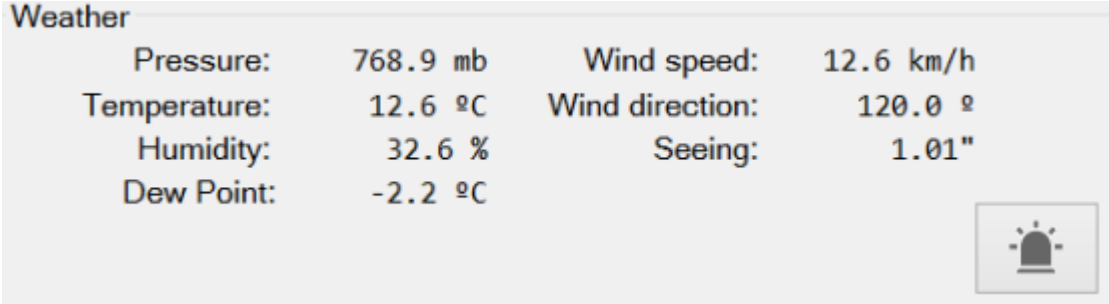
Sync/Readout: the telescope will point to the next coordinates in a macro while is reading the previous acquired image.

Finish: estimated end time for the macro.

Macro progress shows (in %) the status of the macro in execution.

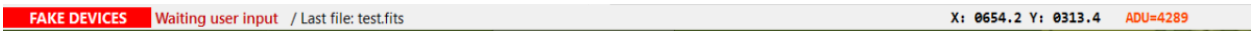
The bottoms in the lower part of the panel allow to perform several actions: **Stop** macro, **View current** macro, **Open** macro, **New** macro and **Repeat** macro (specifying how many times).

8. Weather panel



This panel shows the relevant meteorological information. If there is meteorological risk, the alarm icon  will be in red color; otherwise, it will be in green color. By clicking on this icon, the alarm can be activated/deactivated.

9. Informative panel



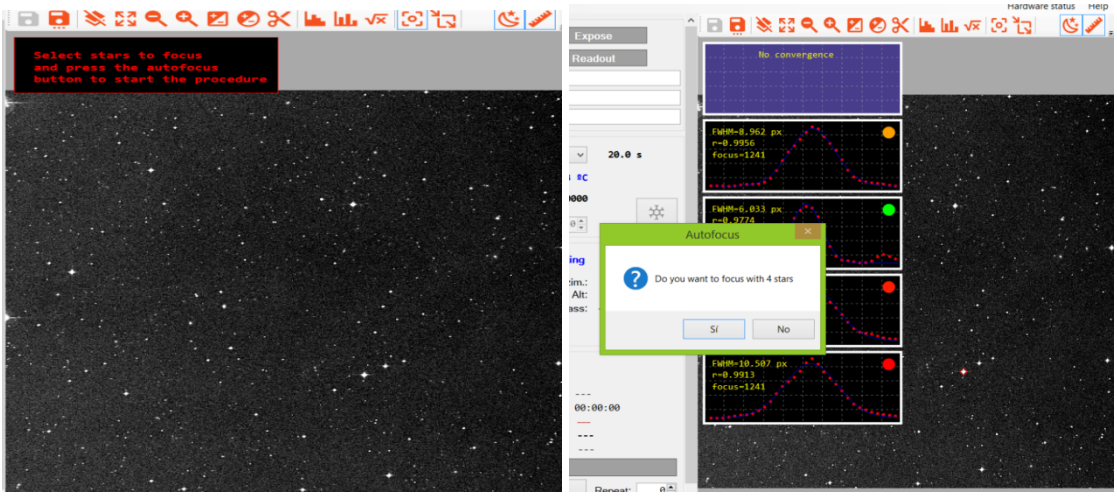
It shows complementary information as the device plugged in (FAKE in case it is a virtual CCD/Telescope), status, and the last file saved.

In the right border, the pixel coordinates (X, Y) and number of ADU corresponding to the current image are displayed.

3. Autofocus

Click on autofocus button in the advanced options panel 

Select stars to focus (e.g. 4 stars) and press autofocus button again to start the procedure

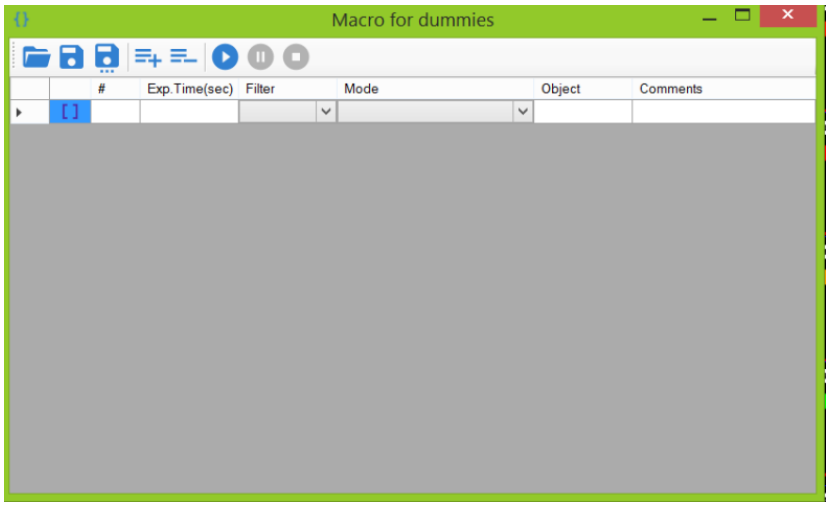


Full width half-maximum (FWHM, in pixels) will be displayed; the figures will be coded using a color scale: green for good focus value, orange for regular focus, and red for poor focus. The best focus value will also be displayed as that corresponding to the minimum of a para-bola. The number of images that will be taken to perform autofocus and the step variation in the focus value can be set in the CCDCAP.ini file.

4. Writing Macros

1. Macro visual Editor (macro for dummies)

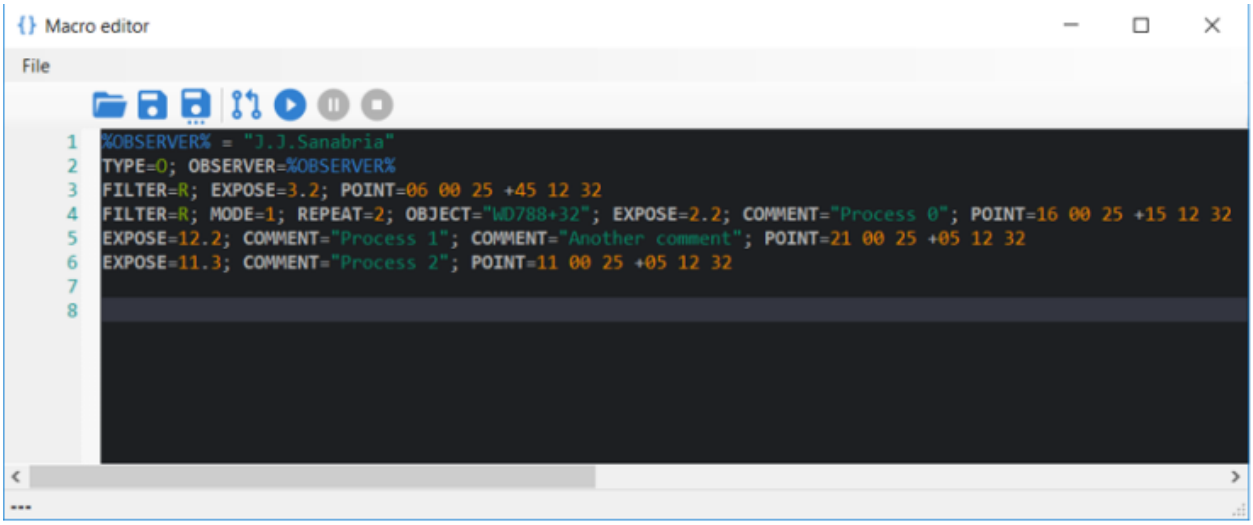
For quick macros, go to **"Macro-> Macro visual editor"**



Add as many lines as necessary to complete the macro. Macros can also be saved to be used later.

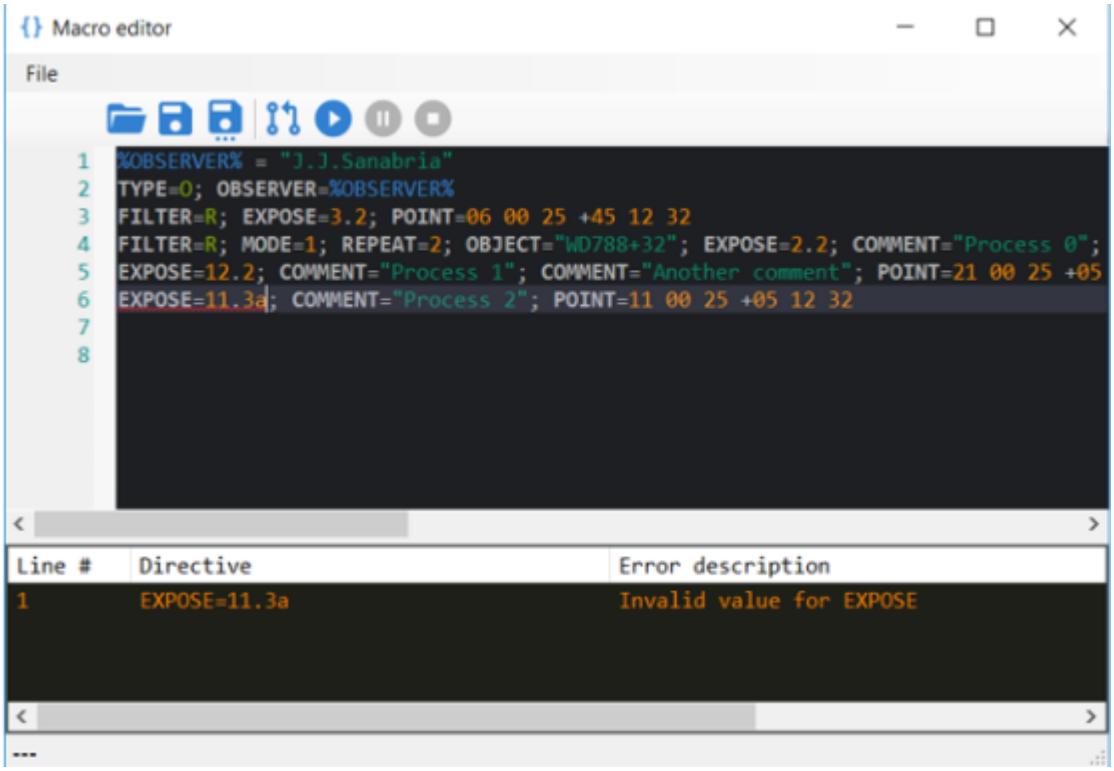
2. Advanced Macros

Advanced macros are perhaps the most powerful feature of CCD-Cap, we can access them from the menu "**Macro-> New**".



The macros can be edited/viewed with any text editor, but the CCD-Cap editor is recommended, because it will check in real time that the syntax is correct.

The execution of a macro simulates the behavior of an operator that was managing the interface. From the macro, you can automatically do the same thing that would be done manually from the interface. While executing the macros, you can see how all the elements of the interface are updated. However, certain directives may cause decisions or repetitions. Macros are not a programming language, and therefore do not contain loops or conditional statements.



When the macros are edited, they are interpreted in real time, showing compilation errors in the lower panel.

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.

The directives are always written in uppercase.

The directives can indicate an order, or also change the behavior of the executor of macros or of some device.

In a line, there can be more than one directive, separated by semicolons. There are no directives incompatible with each other, but in one line they should never be repeated.

```
FILTER=R; MODE=1; REPEAT=2; OBJECT="WD788+32"; EXPOSE=2.2; COMMENT="Proce
EXPOSE=12.2; COMMENT="Process 1"; COMMENT="Another comment"; POINT=21 00
EXPOSE=11.3; COMMENT="Process 2"; POINT=11 00 25 +05 12 32
```

The directives keep an order of precedence. For example, even if the following appears on one line:

```
EXPOSE=33; FILTER='SDSSg';
```

The first thing that will happen will be the change of filter to SDSSg and then the exposure.

Command directives

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

• **EXPOSE**: Displays a number of determined seconds. Accepts a floating-point value.
EXPOSE = 30
EXPOSE = 12.5

• **FILTER**: Change filter. Accepts the name of the filter or the numerical position of the filter. Index based on 1.
FILTER = R
FILTER = 3

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

• **OFFSET**: Performs an offset on the telescope indicated in arc seconds.
OFFSET = 30.30
OFFSET = 60.60

• **PARK**: Takes the telescope to a parking position. Accepts a single character or string of text with the full name of the position.
PARK = Z
PARK = W

Devices behavior directives

Behavior directives of the devices or the way in which the images are saved/captured.

• **TYPE**: Image type O = Object, F = Flat, B = Bias, D = Dark, T = Test

TYPE = OBJECT

TYPE = O

TYPE = T

• **MODE**: Capture mode of the camera. 1,2,3,4,... Index based on 1.

• **OBJECT**: Name of the object (it will be saved in the header of the image).

OBJECT = 'NGC 2121'

• **COMMENT**: Comment.

COMMENT = 'Observing with seeing of 31, possibility of unusable data'

• **OBSERVER**: Name of the observer (It will be saved in the header of the image).

OBSERVER = ''

• **HEADER**: Adds header. Name, value and comment separated by commas.

HEADER = 'SPD, 32MHz, CAPTURE SPEED'

All these directives are persistent and are maintained between successive exposures. There is no need to re-establish them. That is, if the line TYPE = F is executed, then flats will be taken in all subsequent exposures until another line containing TYPE is found. If set: OBSERVER = "J. Smith", the user's name will remain in all the images, without the need to re-execute this directive.

Macro behavior directives

Behavior directives affect the behavior of the macro's execution. They are the following:

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

REPEAT = 3

• **SLEEP**: Stops the execution of the macro for a number of seconds.

SLEEP = 2

• **SYNC**: Synchronizes the execution of a line with a specific date and time. That is, it will wait until that date and time and then the exposition will begin. Lines containing expired SYNC directives will be ignored, since the synchronization date was passed.
SYNC = '2017-03-03 22:03:31'

• **PROMPT:** Displays a message on the screen, activates a notification sound and waits for the user to press accept.
PROMPT = 'Please activate the autoguiding'.

• **RUNTO**: Executes the macro from the present line until the selected date and time.
RUNTO = '2017-03-03 22:03:31'

• **RPOINT**: Indicates the pointing mode of the telescope. Accepts the SYM and IND values that indicate respectively "while exposed", "after exposing".
RPOINT = SYM

• **HEADER**: Adds a header to the image.

• **LOG:** Enables or disables the logs system.

•**SYNC_TOLERANCE:** Synchronization tolerance in seconds. Allows an expired synchronization line to run as long as no more than the seconds indicated in this directive have passed.

• **SAVE_PATH**: Path where the images will be saved. Sometimes, when executing certain macros, we will be interested in saving the images in another route. If the route does not exist, an attempt will be made to create it. It does not affect the general CCD-Cap save path, and only changes the path for the current macro.

Persistent and non-persistent directives

Persistent directives are those that, once established, will prevail until the end of the macro. It is not necessary to rerun the directive unless you want to change it.

Persistent directives are:
FILTER TYPE MODE OBJECT COMMENT OBSERVER LOG SYNC_TOLERANCE SAVE_PATH

All other commands are non-persistent directives, that is, they must be given whenever we want to execute them.

```
#Macro example for CAMELOT INTERFACE
#-----------------------------------------------------------
# EXPOSE            => Expose for X seconds
# FILTER            => Set filter. Use number or name
# TYPE                    => Image type (T,D,B,O,F) (TEST,DARK,BIAS,OBJECT,FLAT)
(Default = O)
# MODE                    => Readout mode (0, 1, 2, 3.....)
# REPEAT            => Repeat this line X times
# OBJECT            => Object name to store in the file header
# COMMENTS                => Comments to store in the file header
# OBSERVER          => Observer to store in the file header
# SLEEP                   => Sleep for X seconds
# POINT                   => Move the telescope to RA DEC J2000
# SYNC                    => Synchronize with date-time
# SYNC_TOLERANCE=> Sync tolerance in seconds. default is 0
# RPOINT            => SIM (SIMULTANEOUS), IND (INDEPENDIENT default)
# PROMPT            => Prompt message and wait for user to accept
# RUNTO                   => Run this line until the specified UT date and time fmt (YYYY-MM-dd
HH:mm)
# HEADER            => Add a header to the FIT file HEADER='NAME,VALUE,COMMENT'
# LOG         => Enable/Disable logs LOG=ALL(for all) LOG=NONE(for none)
LOG=[TELESCOPE,CCD,FOCUSER,WEATHER,FILTERWHEEL]
# SAVE_PATH     => Change default save path i.e) SAVE_PATH="C:\IMAGENES\";
# OFFSET        => Move the telescope in RA & DEC a number of arcsecs
# PARK          => Park the telescope to a park position
#-----------------------------------------------------------
# Use %VAR1% To define varialbe
# %VAR1% = VALUE
#-----------------------------------------------------------
%OBSERVER% = "Olga Zamora"
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TYPE=O; OBSERVER=%OBSERVER%

FILTER=R; EXPOSE=3.2; POINT=06 00 25 +45 12 32

FILTER=R; MODE=1; REPEAT=2; OBJECT="WD788+32"; EXPOSE=2.2; COMMENT="Process 0"; POINT=16 00 25 +15 12 32

EXPOSE=12.2; COMMENT="Process 1"; COMMENT="Another comment"; POINT=21 00 25 +05 12 32

EXPOSE=11.3; COMMENT="Process 2"; POINT=11 00 25 +05 12 32

Summary of macro commands

Command	Action	Examples
EXPOSE	Expose a number of determined seconds. Accepts a floating-point value.	EXP EXPOSE = 30 EXPOSE = 12.5
FILTER	Change filter. Accepts the name of the filter or the numerical position of the filter. Index based on 1.	FILTER = R FILTER = 3
POINT	Points to coordinates J2000	
OFFSET	Performs an offset on the telescope indicated in arc seconds	OFFSET = 30.30 OFFSET = 60.60
PARK	Takes the telescope to a parking position. Accepts a single character or string of text with the full name of the position.	PARK = Z PARK = W
MODE	Capture mode of the camera. 1,2,3,4,... Index based on 1.	
TYPE	Image type O = Object, F = Flat, B = Bias, D = Dark, T =	TYPE = OBJECT TYPE = O

	Test	TYPE = T
COMMENT	Adds a comment	COMMENT = 'Observing with seeing of 31, possibility of unusable data'
OBSERVER	Name of the observed to be saved	OBSERVER = '' Olga”
HEADER	Adds header. Name, value and comment separated by commas.	HEADER = 'SPD, 32kHz, CAPTURE SPEED'
REPEAT	Repeats a line a certain number of times. By default, it will only be repeated once	REPEAT = 3
SLEEP	Stops the execution of the macro for a number of seconds	SLEEP = 2
SYNC	Synchronizes the execution of a line with a specific date and time. That is, it will wait until that date and time and then the exposition will begin. Lines containing expired SYNC directives will be ignored, since the synchronization date was passed.	SYNC = '2017-03-03 22:03:31'
PROMPT	Displays a message on the screen, activates a notification sound and waits for the user to press accept	PROMPT = 'Please activate the auto guiding'.
RUNTO	Executes the macro from the present line until the selected date and time.	RUNTO = '2017-03-03 22:03:31'
RPOINT:	Indicates the pointing mode of the telescope. Accepts the SYM and IND values that indicate respectively "while exposed", "after exposing".	RPOINT = SYM

HEADER	Adds a header to the image.	
SYNC_TOLERANCE	Synchronization tolerance in seconds. Allows an expired synchronization line to run as long as no more than the seconds indicated in this directive have passed.	
SAVE_PATH	Path where the images will be saved. Sometimes, when executing certain macros, we will be interested in saving the images in another route. If the route does not exist, an attempt will be made to create it. It does not affect the general CCD-Cap save path, and only changes the path for the current macro.	
LOG	Enables or disables the logs system	

Tips & Troubleshooting

-Paths:

DEV_CAMERA/CAMELOT/Debug

CCDCAP (OLGA)

-Headers added in CCDCap.ini file should be written in the form:

Name =Value

The empty space before "=" is relevant, otherwise the image could not be displayed with DS9