AEON on SOAR User Manual

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Table of Contents

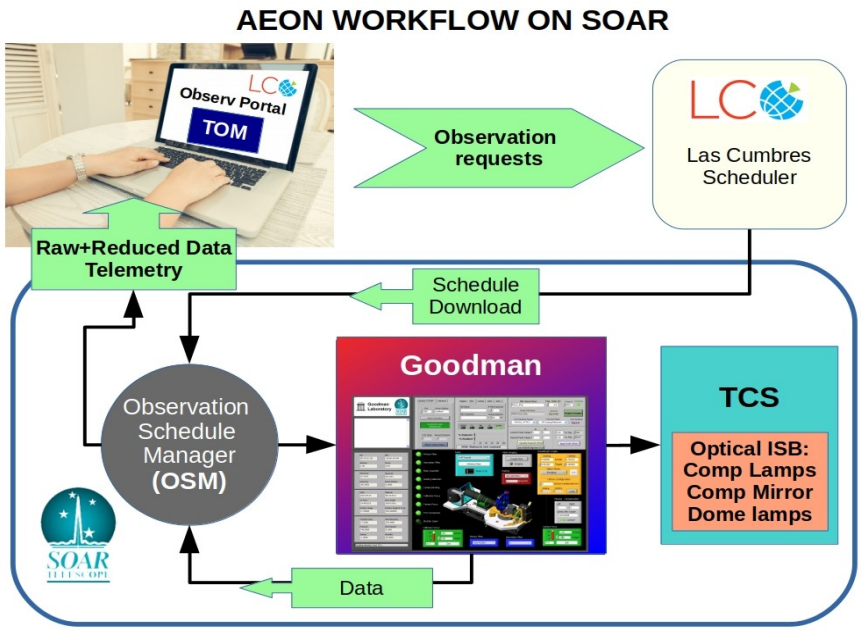
Introduction

The Astronomical Event Observatory Network (AEON) is a facility ecosystem for accessible and efficient follow up of astronomical transients and Time Domain science. At the heart of the network, NOIRLab, with its SOAR 4.1m and Gemini 8m (and soon the CTIO Blanco 4m), has joined forces with Las Cumbres Observatory to build such a network for the era of the Legacy Survey of Space and Time (LSST). SOAR is the pathfinder facility for incorporating the 4m and 8m class telescopes into AEON.

At the heart of the implementation of AEON on SOAR is the **Observation Schedule Manager (OSM)**, a Python-based software that handles all the communication between an external observation request scheduler, in this case the robotic scheduler of the Las Cumbres Observatory network and SOAR. Furthermore the OSM parses target observation requests received as JSON files, and translates them into the sequence of actions required to complete the observation, from moving the telescope and its subsystems (dome, Nasmyth rotator, active optics) to the target, to configuring the instrument, in this case the Goodman High Throughput Spectrograph (GHTS), and obtaining the necessary calibration frames to accompany the science data.

The AEON queue at SOAR was designed to be highly automated, so that it could be run by our Telescope Operators, with support from a SOAR staff scientist, without needing to hire additional staff. Therefore, the queue is generated automatically by the external scheduler, currently the Las Cumbres Observatory (LCOGT) robotic scheduler, based on the observation requests submitted to the Las Cumbres Observation portal by the users with approved SOAR AEON time.

In this document we describe how an AEON night is carried out at SOAR, and the use of the OSM.



Overview

For a SOAR AEON night, the queue operator tasks are the following.

Daytime: Observer Support

1. **Install SOAR AEON instrument setup.** ***The instrument setup for AEON is always the same one during the semester.*** As an example, in the case of Goodman, with both BLUE and RED cameras, the setup for 2021A is: 400, 600old and 930 gratings; g-SDSS, r-SDSS, i-SDSS and VR imaging filters. The *default* camera is the Goodman RED camera. The AEON nights and the corresponding detector are posted in the SOAR AEON web page.
2. **Create finding chart folder for the night:** Collect the finding charts submitted by users to soarops@ctio.noao.edu in a folder for the night and download the finder charts there. The folder name should follow the sintaxis: YYYY-MM-DD, example: 2021-02-26, with the date being the local start of the night. Observer Support will determine a permanent location for the nightly finding charts folders, and inform the other Telescope Operators.
3. **Run afternoon calibrations.** Starting at around 4pm, open mirror covers, point telescope to white spot, start OSM and GSP in two tabs of a Chrome browser in Goodman BLUE/RED VNC, open Goodman GUI in Goodman RED/BLUE VNC, and run afternoon calibrations with the OSM, which include a focus sequence for each setup, bias frames for each , and flats. Check that focus values, flat counts and bias std dev values are reasonable (see sample values in the Appendix).
4. **Connect to LCOGT and download a schedule.** At the end of the calibrations, turn off the dome lamps, stope the queue, and connect to LCOGT in the OSM. A schedule will be downloaded within minutes. Disconnect from LCOGT in the OSM.

Night Time: Observer Support & Telescope Operator

1. **Connect to Observers Zoom link for interacting with AEON Support Scientist.**
2. **Open VNCs for Goodman GUI, Goodman computer running Chrome with OSM, GACAM, soaric7 (for anaylsis with IRAF).**
3. **Do Spectrophotometric standard star observation.** Once dome is open, zero pointing has been done, and telescope AOS has been calibrated, start a Spectrophotometric Standard star observation in the OSM, making sure the appropriate modes for the current semester are selected. A std star observation in 4 spectroscopic modes (e.g., 400M1, 400M2, 600MDI and 930M2) will take approximately 20min.

4. **Connect to LCOGT in the OSM.**
5. **Acquire first science target from the queue, start observing. Next target, etc.**
6. **End of night.**
    - Disconnect from LCOGT in OSM.
    - Stop the OSM.
    - Exit and shutdown the Goodman GUI.
    - Run the End-of-Night Transfer app in the Goodman computer. Make sure in soaric7 that the */home3/observer/today/* directory contains no `.fits` files (Do not delete the `.txt` files in that folder).
    - Exit the Goodman Acquisition Camera (GACAM) application.
    - Turn off Goodman and GACAM electronics.
    - Send the standard End-of-Night report, with just the basic information for the night.
    - Send more detailed AEON Observation report to the AEON Support Scientist on the progress or details of the observations during the night. See examples in the Appendix.
    - Close telescope.

Afternoon Calibrations

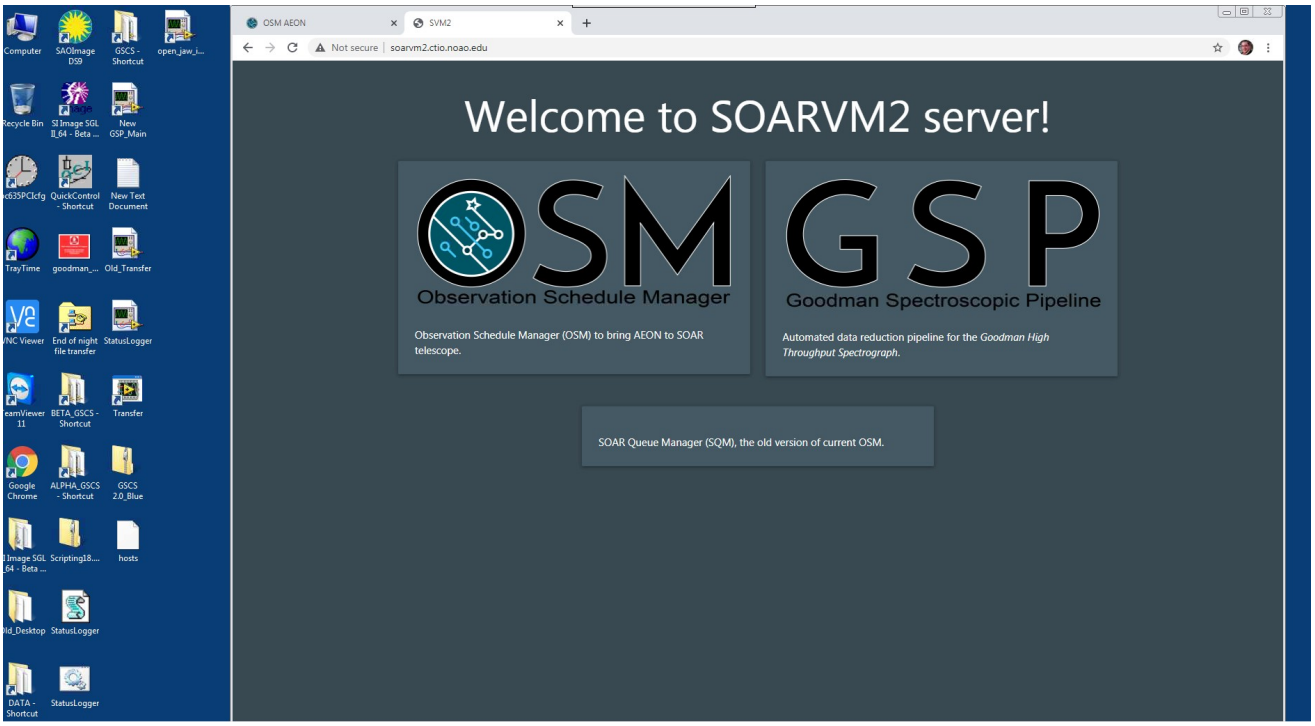
Starting at around 4pm, open mirror covers, point telescope to white spot. Make sure the *Goodman instrument is selected in the TCS.*

Start Goodman

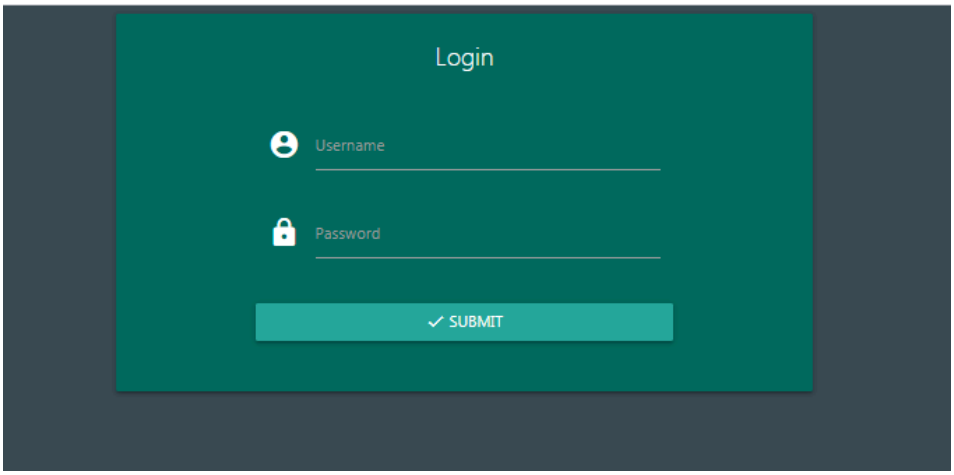
1. Turn ON Goodman electronics.
2. Open the VNC to the appropriate Goodman GUI (e.g., the default RED camera computer Sherman). Start the Goodman GUI. Login as user Soar. Home mechanisms. It is preferred (but now not indispensable) that the ISB rotator and instrument position angle both be set to 0 deg.
3. Connect to the Goodman VNC that will not be used as a detector. Example, if tonight is a RED camera night, then you will connect via VNC to the Goodman BLUE computer.

Start the OSM

1. Access the OSM main page by connecting to *soarvm2.ctio.noao.edu* in the Chrome browser.

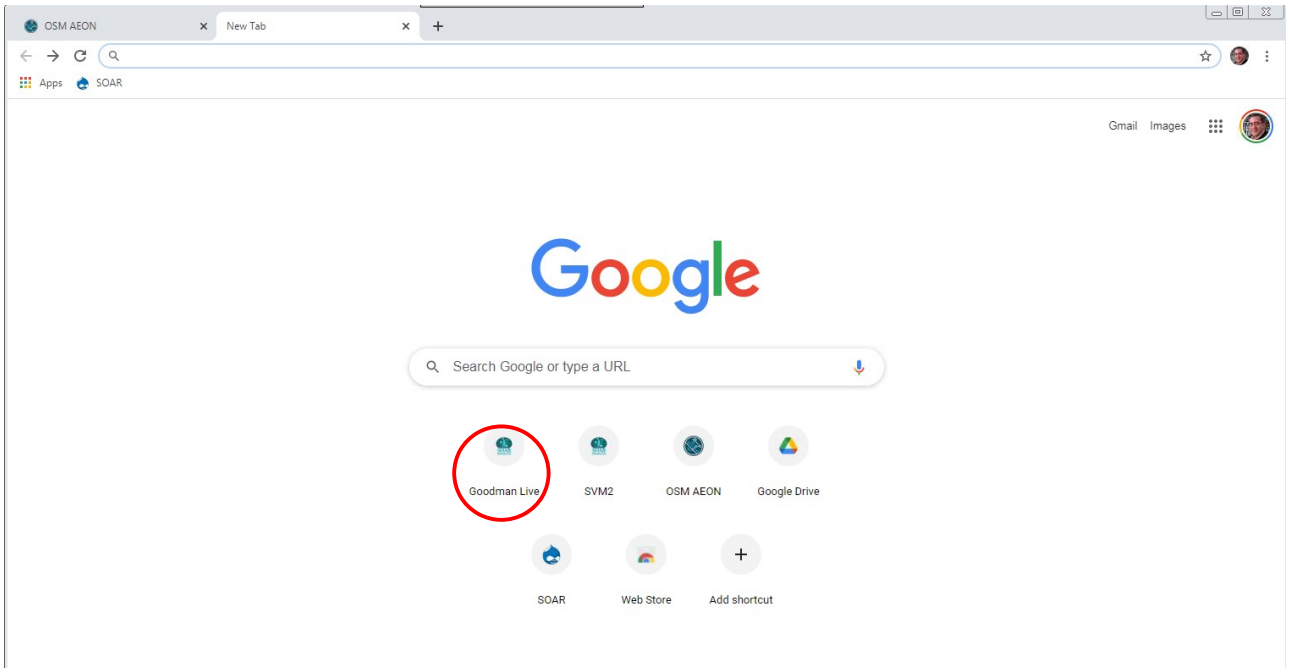


2. Click on the OSM box on the left, and provide your credentials in the login window.

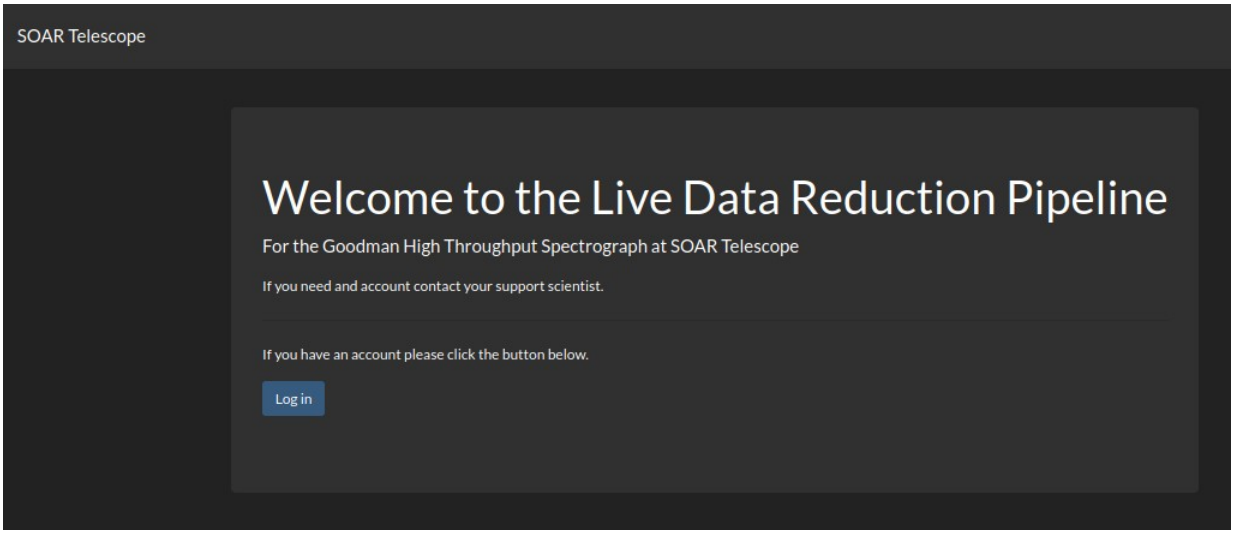


START THE GSP

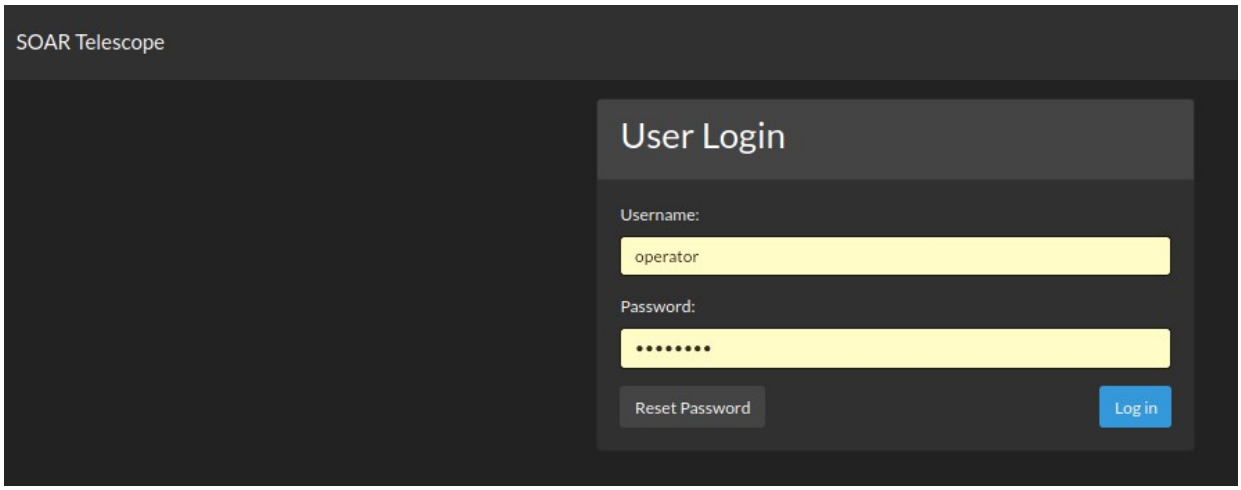
1. Open another tab in the browser and open the Goodman Spectroscopic Pipeline (GSP) live web page: *http://soarvm2.ctio.noao.edu/gsp/* or click on the bookmark icon circled in the figure.



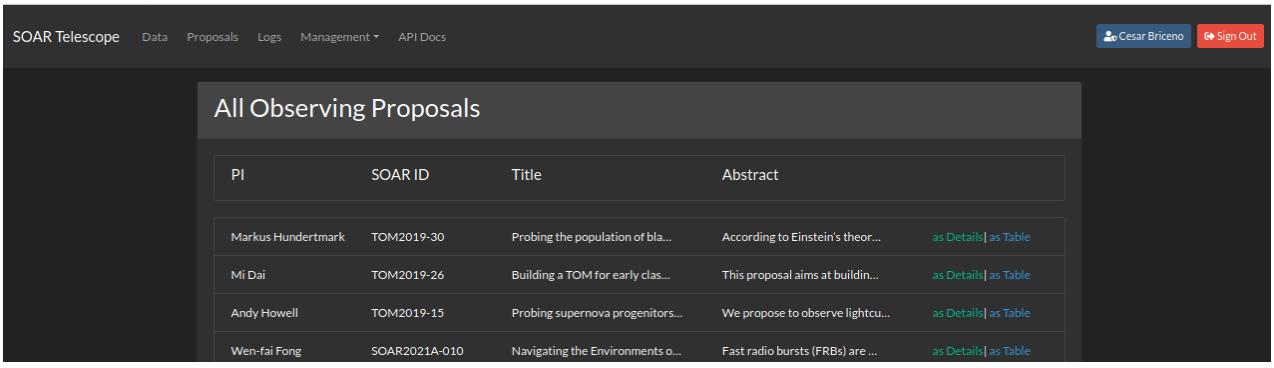
You will see the following login page. Click on the blue Login button.



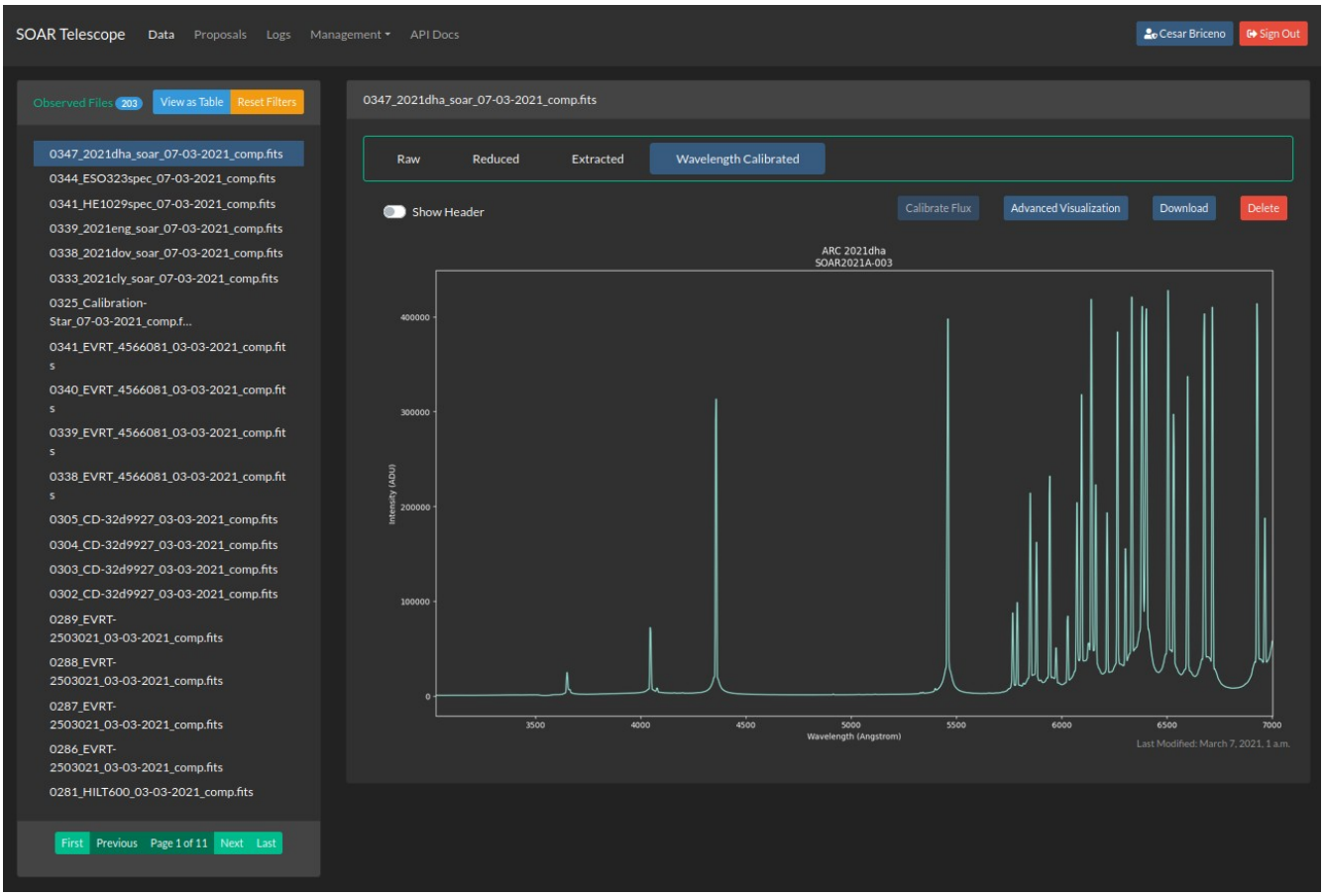
Login with the appropriate credentials (contact Simón Torres).



Once logged into the GSP, click on the *"Data"* option in the upper left menu.



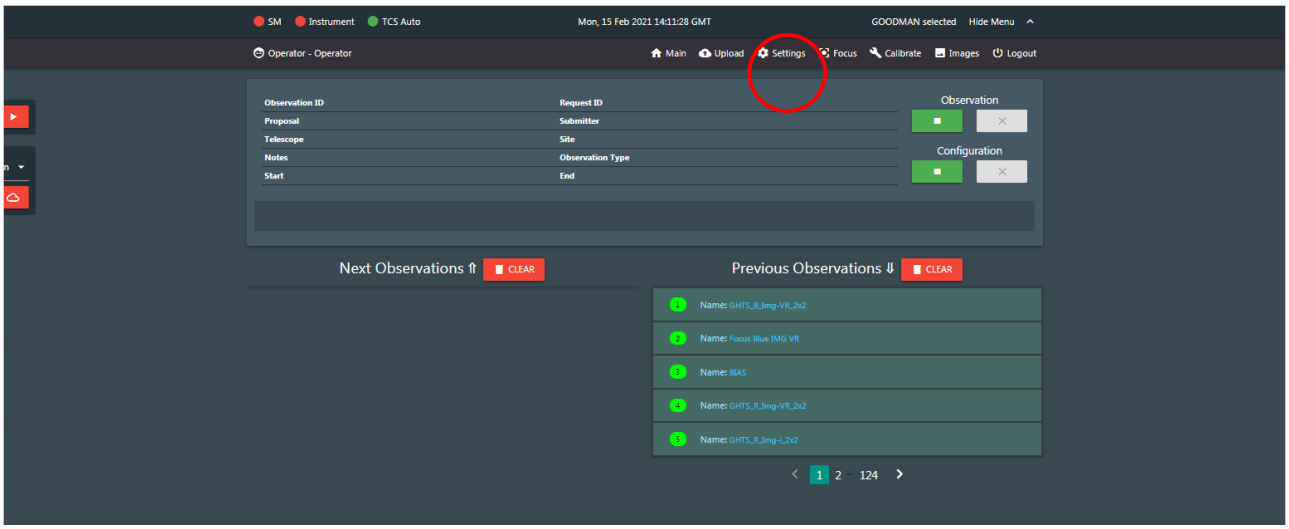
You will be in the GSP data window, which looks like this. This will be where you can look at the raw and reduced frames as they are saved to disk and processed, respectively.



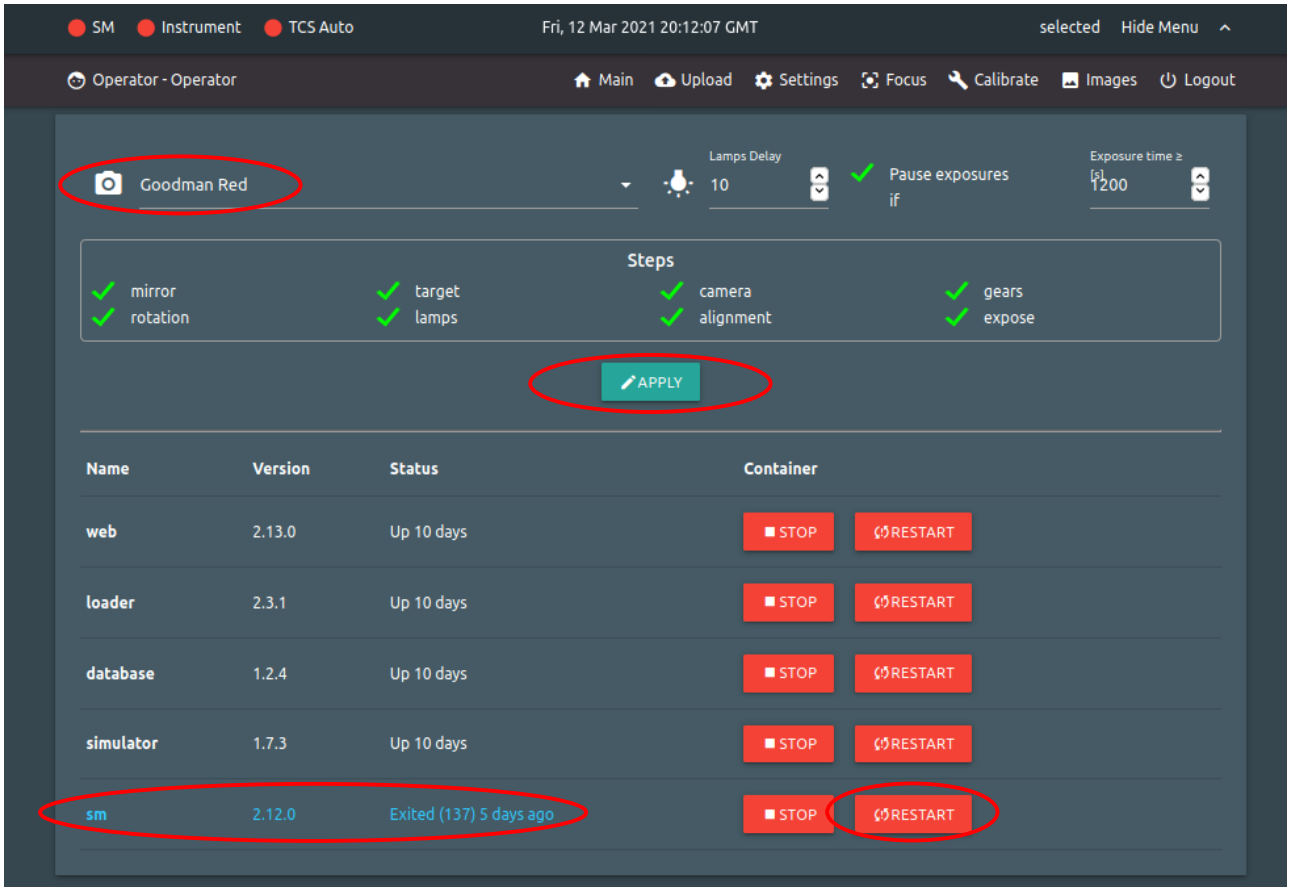
For more details on the use of the GSP, consult the GSP User Manual.

SETUP AND INITIALIZE THE OSM

1. Once you login to the OSM you will see the *Main* window (with the house icon).



2. Click on the ***Settings*** tab (wheel gear icon). You will be presented with the following window.



The ***Settings*** tab allows the user to:

- Select the Instrument (Goodman RED, Goodman BLUE or Goodman Simulator).
- START/STOP the OSM
- Select which mechanisms/processes to activate/deactivate (usually used only for engineering work and tests). **The default is that ALL boxes should have a green tickmark.**
- Select the pause or delay to allow lamps to warm up once they are turned on. The defaultis 10s. Do not change this value unless you have a very good reason to do so.
- Set wether to set a pause between sequences of long exposures. This feature will produce a alignment pop-up window at the end of exposures of the duration indicated in this parameter, or longer. This allows the user to check the on-slit alignment of the target before starting another long exposure. The default is 1200s (20min), but this value can be changed. The feature can be deactivated by clicking on the green tick mark so this option is not selected.

To start the OSM:

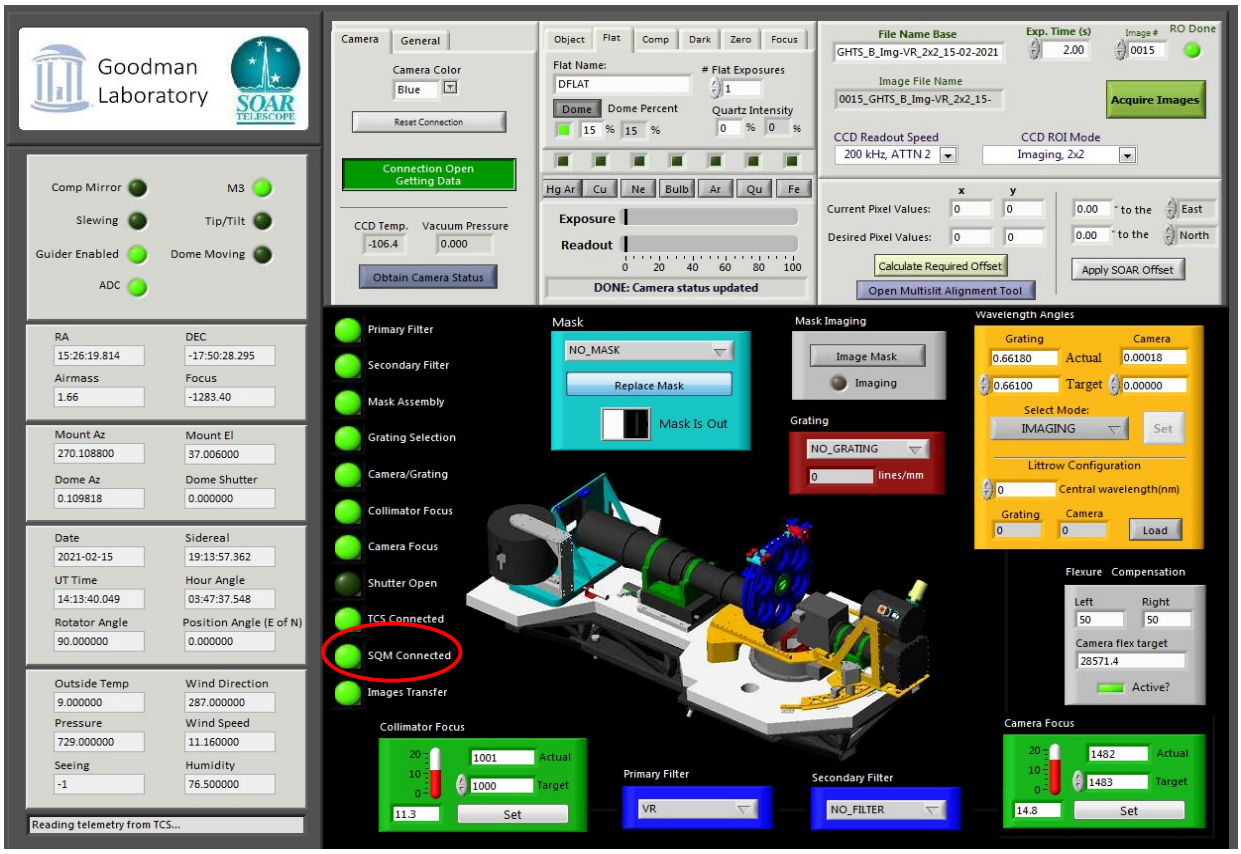
I. First, select the appropriate instrument, in the drop down menu in the upper left of the window.

II. Make sure **all** boxes in the *Steps* section have a green tickmark.

III. **Click the blue-green *Apply* button** in the upper middle part of the window (see image above). This is important because if you do not click this button, the selection of instrument in the menu or steps (green tickmarks) will not be applied.

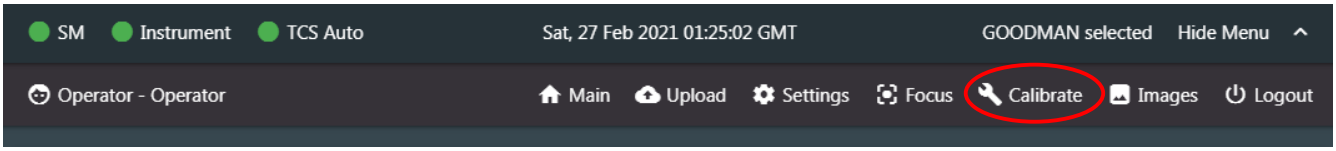
IV. Then Click on the red *RESTART* button corresponding to the "*sm*" (line with all characters in blue). This is the only system you need to restart. The others (*simulator, web, database and loader* are for debugging purposes only).

Once the OSM has been started, it will take several minutes to connect with the Goodman GUI. When the connection is established, all the LED lights in the upper left of the OSM widow will change from red to green. Also, in the Goodman GUI (see image below) the green "SQM" LED will turn on (bright green). If it does not, the OSM is not connected to the Goodman instrument (see screenshot below).

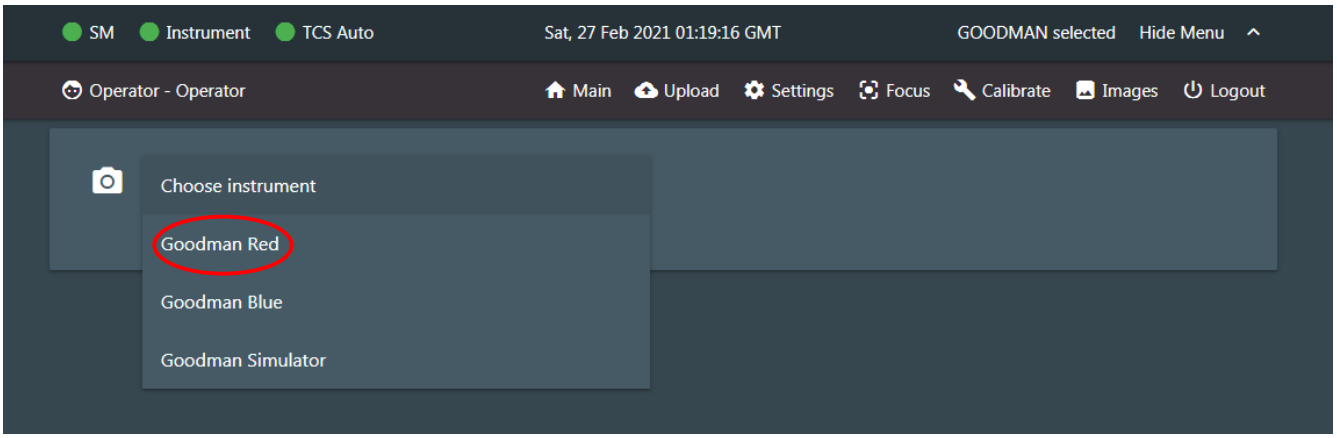


Setting up the daytime calibrations

1. **Start:** Click on the *Calibrate* tab:

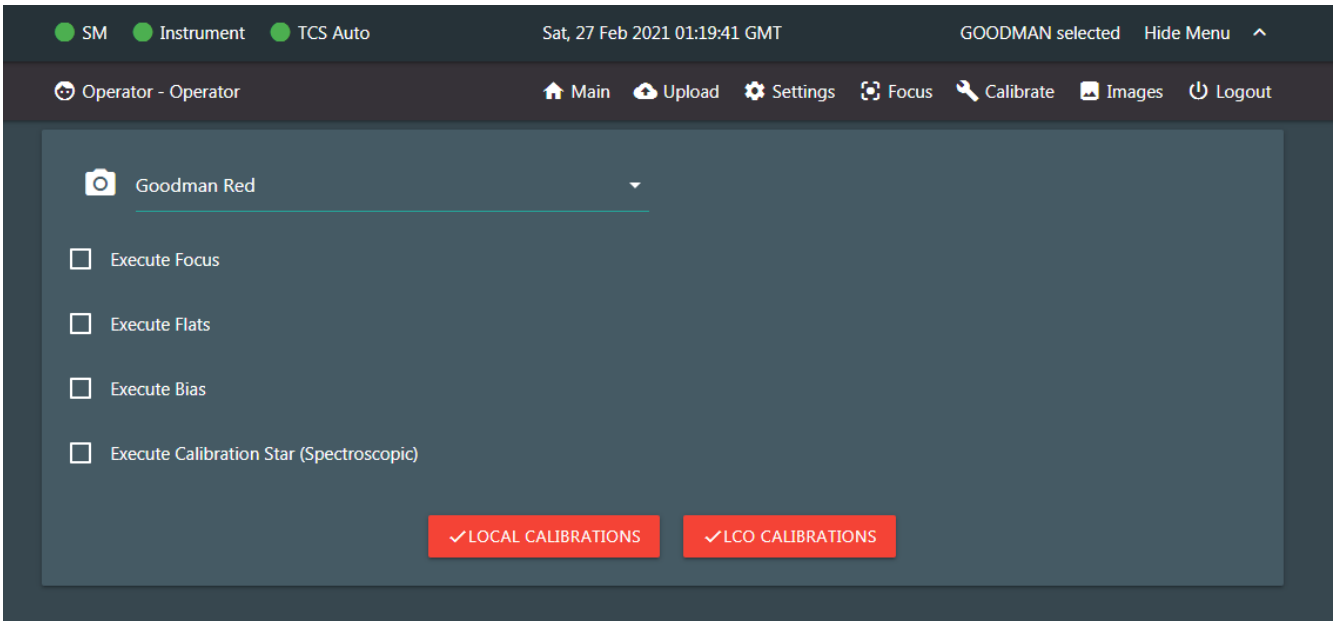


This will open the calibrations page, which allows the user to select which calibrations to carry out. These include: Focus, Dome Flats, Biases, and the spectrophotometric standard star. The afternoon calibrations include only focus, dome flats and biases.

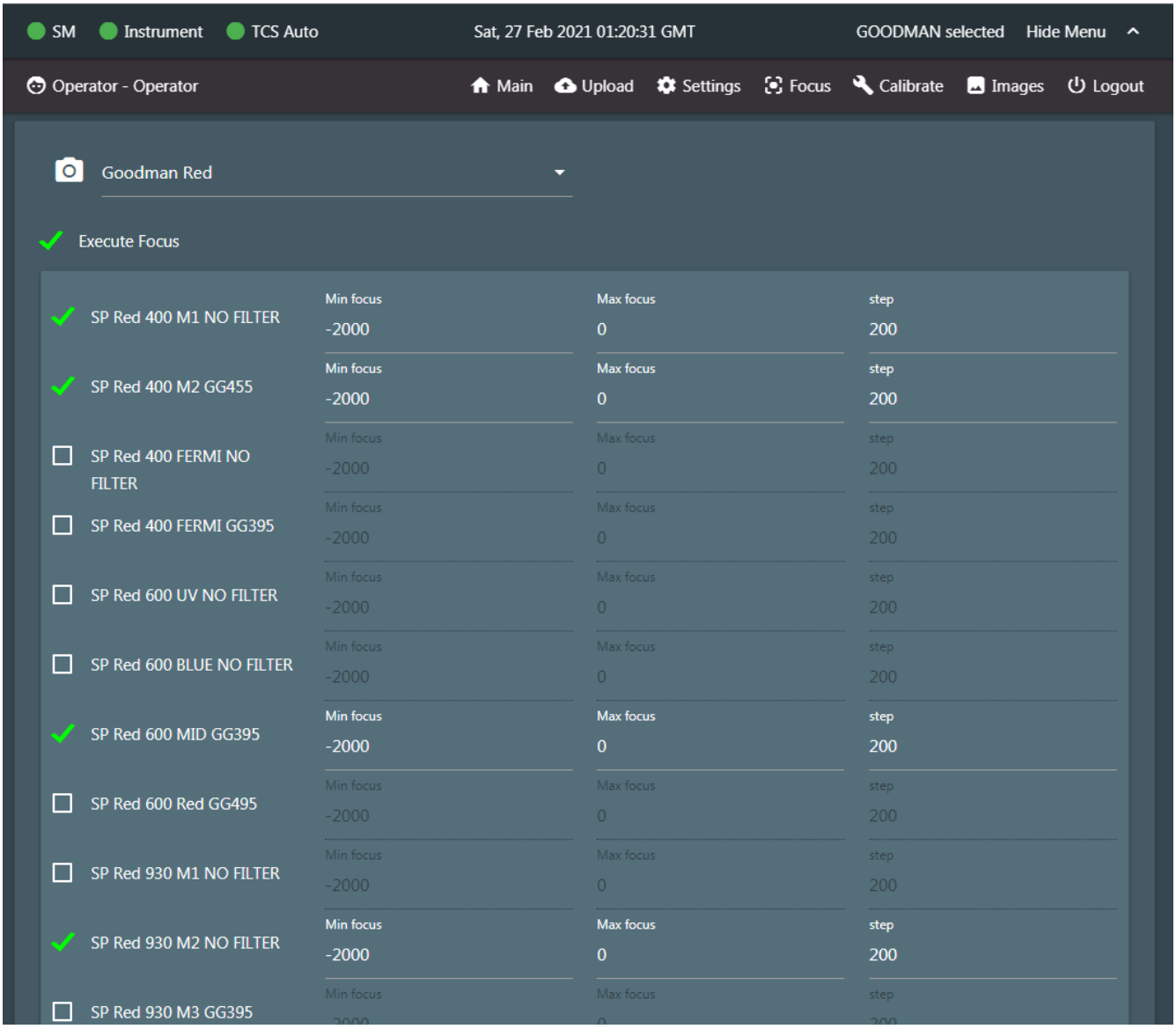


2. Click on the *Instrument* and select the appropriate instrument, e.g., *Goodman Red*.

3. This will open the calibration sections

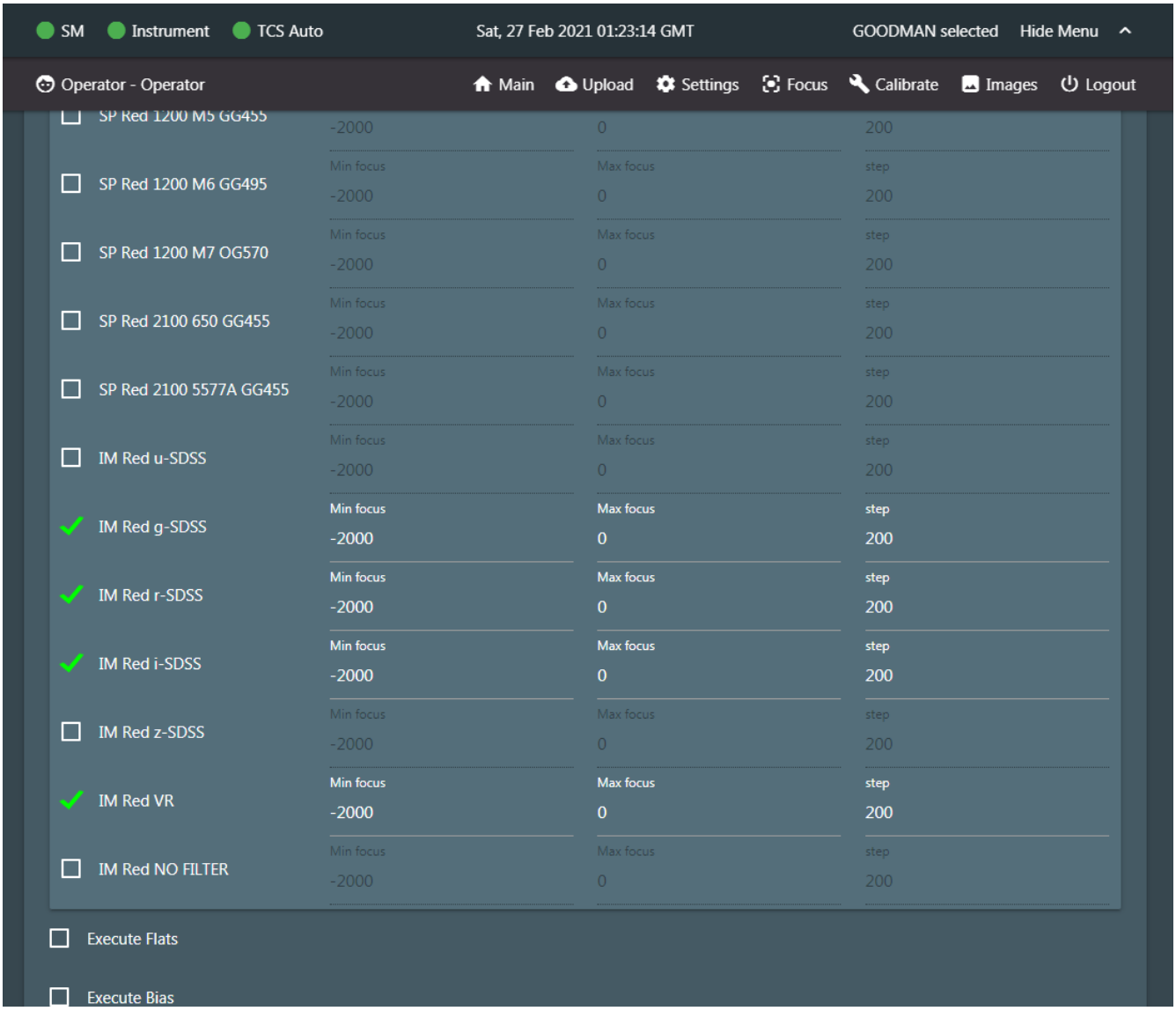


4. **Setup the Goodman internal focus sequences.** Select *Execute Focus*, and the focus page will be shown expanded, as shown below.



Make sure you select all the configurations or modes used for the current semester, for both spectroscopy and imaging. For example, in the 2021A semester we are using, for spectroscopy, the 400M1, 400M2, 600MID and 930M2 modes, which correspond to SP Red 400M1 NO FILTER, SP Red 400M2 GG455, SP Red 600 MID GG395, SP Red 930M2 NO FILTER, respectively.

For imaging, in 2021A we are using the SDSS-g, SDSS-r, SDSS-i and VR filters, which are shown as IM Red g-SDSS, IM Red r-SDSS, IM Red i-SDSS and IM Red VR respectively.

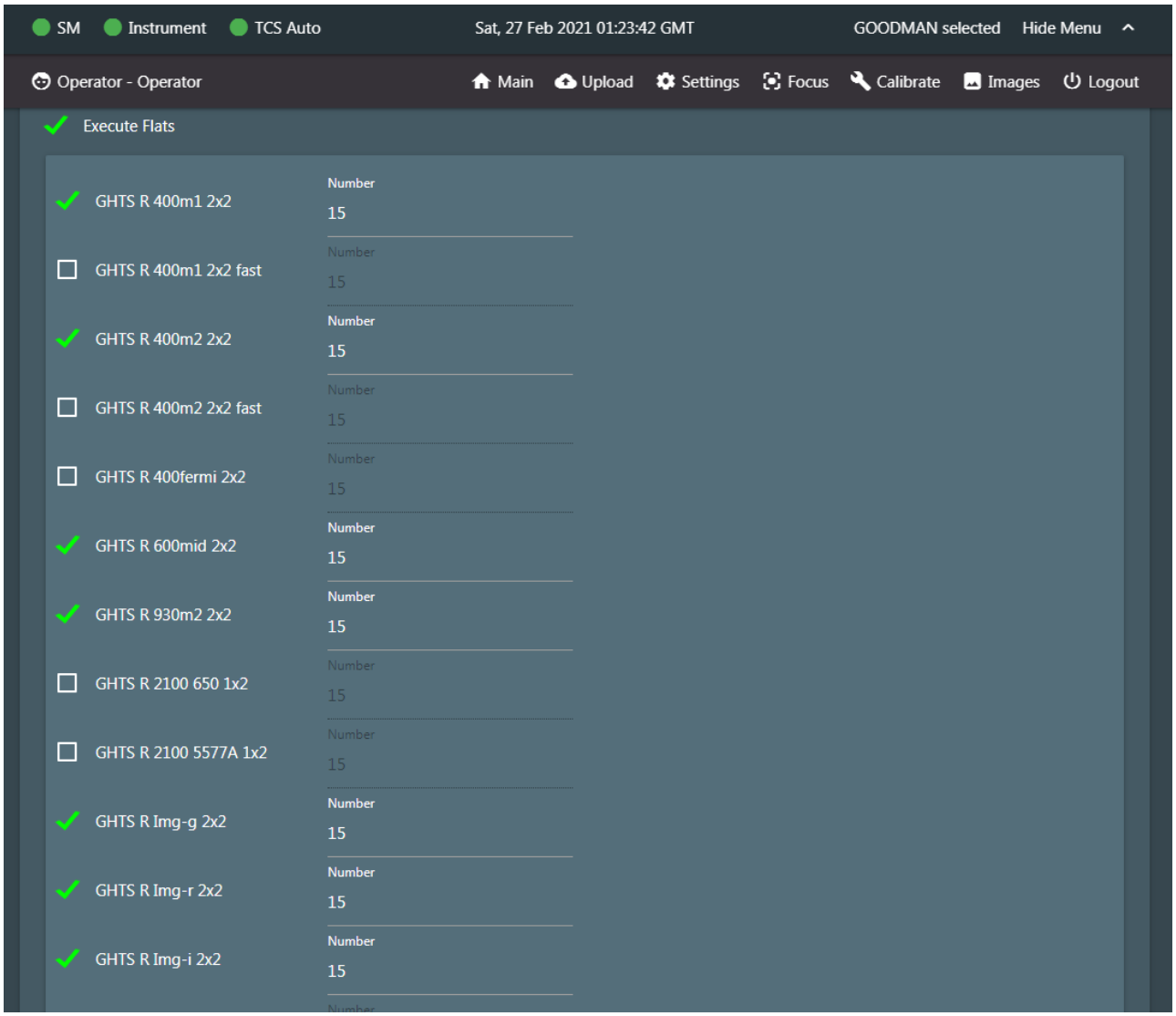


Note that for the RED camera, all focus sequences span the range of focus values from -2000 to 0, in steps of 200 units. These are appropriate values for the RED camera, which has negative focus values for essentially all setups. In the case of the BLUE camera, the range spans positive values, from 0 to 2000, also in steps of 200.

Though all these values can be modified by the user, it is unlikely regular users need to do so. So in normal operation, just select the focus modes needed. Nothing else should need to be changed.

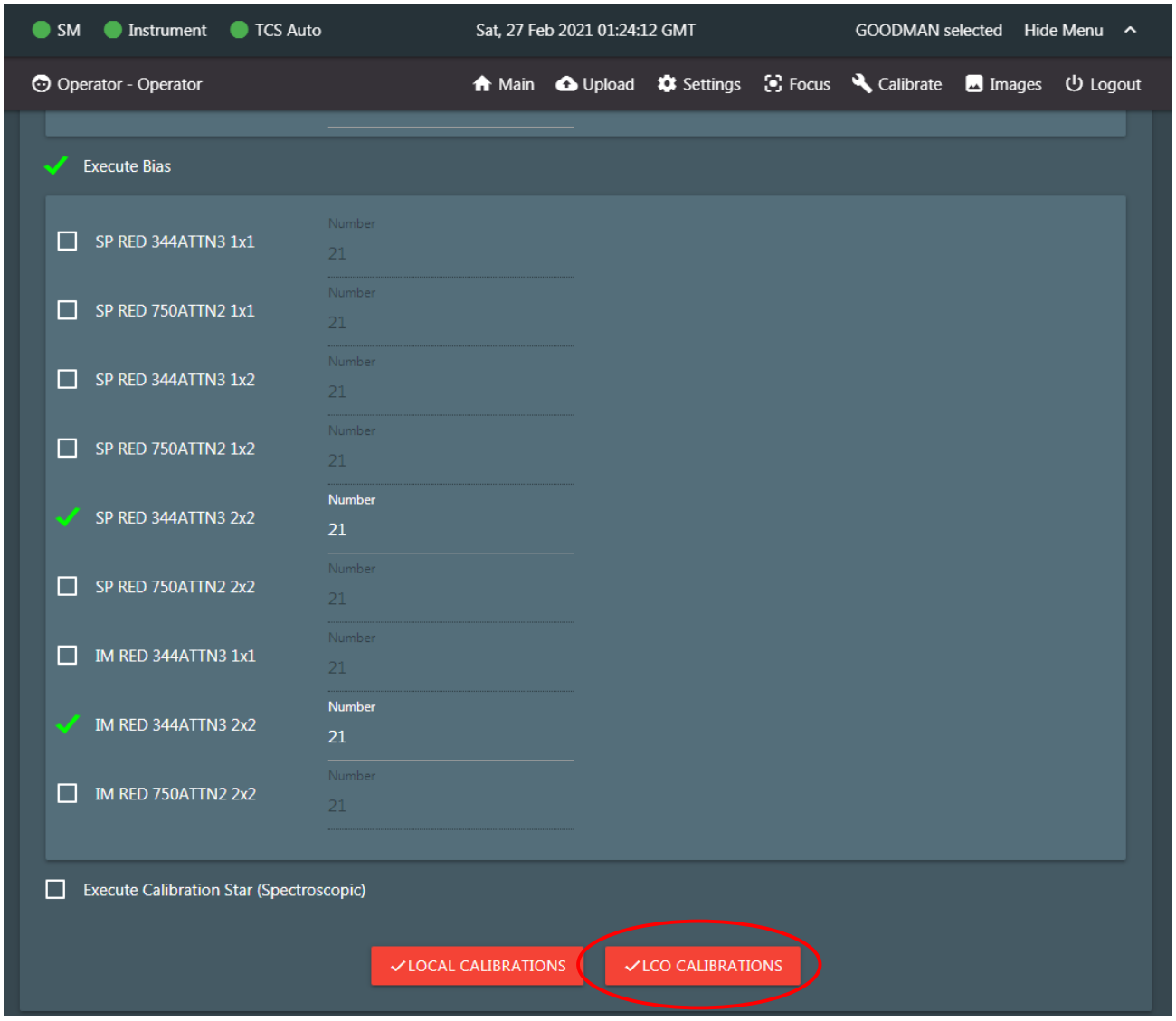
Once the focus sequences have been selected for each of the appropriate modes, we can proceed to setup the dome flats.

5. **Setup the Dome Flats.** Click on the *Execute Flats* box. Again, you will be presented with the expanded page for setting up dome flats. Click on each of the configurations used in the current semester, both for spectroscopy and imaging. As an example, for the 2021A semester we are using for spectroscopy, GHTS R 400m1 2x2, GHTS R 400m2 2x2, GHTS R 600mid 2x2, GHTS R 930m2 2x2, and for imaging, GHTS R Img-g 2x2, GHTS R Img-g 2x2, GHTS R Img-r 2x2, GHTS R Img-i 2x2, GHTS R Img-VR 2x2, which corresond to the SDSS g, r, I and the wide VR filters respectively. The letters GHTS stand for Goodman High Throughput Spectrograph, the "R" is for the RED camera (when using the BLUE camera, the same setups will start with "GHTS B". Then follows the spectroscopic setup or imaging filter, and finally, the "2x2" indicates the binning. We use 2x2 binning for all configurations offered in 2021A, though that may change in future semesters.



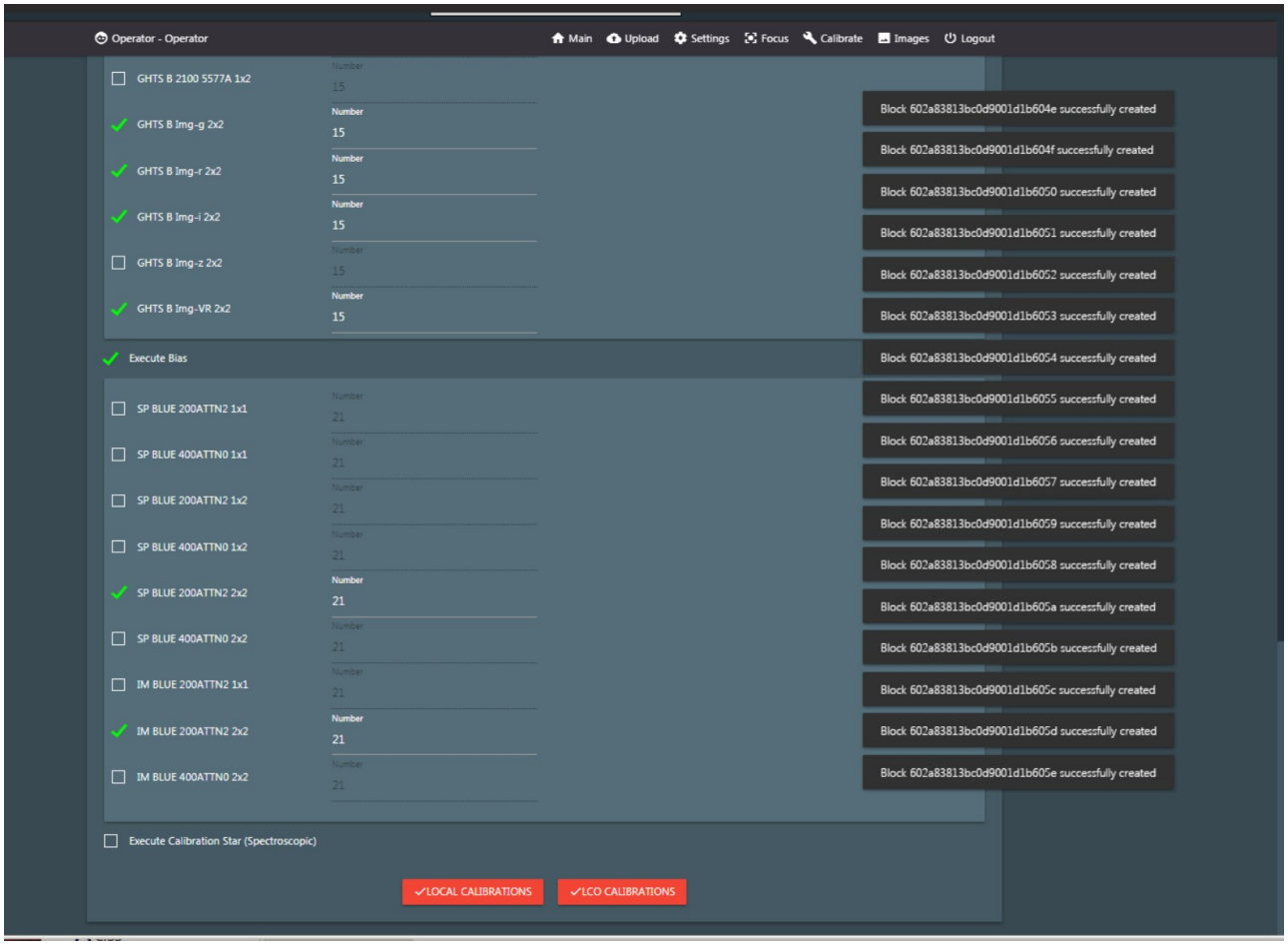
6. **Setup the BIAS frames.** Finally, click on the *Execute Bias* option, to expand the bias section. Select the appropriate bias modes, which for the 2021A semester, with the RED camera, are SP RED 344ATTN3 2x2 for spectroscopy and IM RED 344ATTN3 2x2 for imaging. The modes offered each semester are published in the SOAR AEON web page:

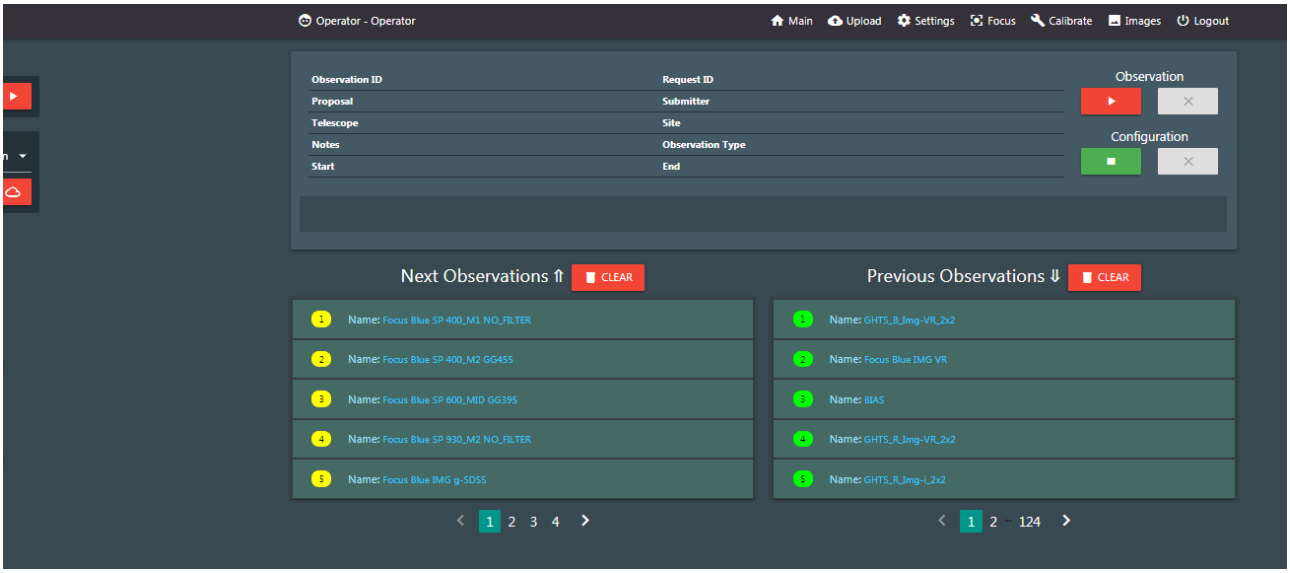
   http://www.ctio.noao.edu/soar/content/soar-aeon-home-page



7. **Upload Calibrations to the queue.** Finally, click on the red *LCO CALIBRATIONS* button, as shown above. This will upload all the selected calibration to the queue on the *Main* page, and then send the files to the LCOGT Observation Portal as the data is obtained. A long list of black box messages will briefly flash, and the calibrations will appear in the queue area (*Next Observations* in the *Main* page; see next two figures).

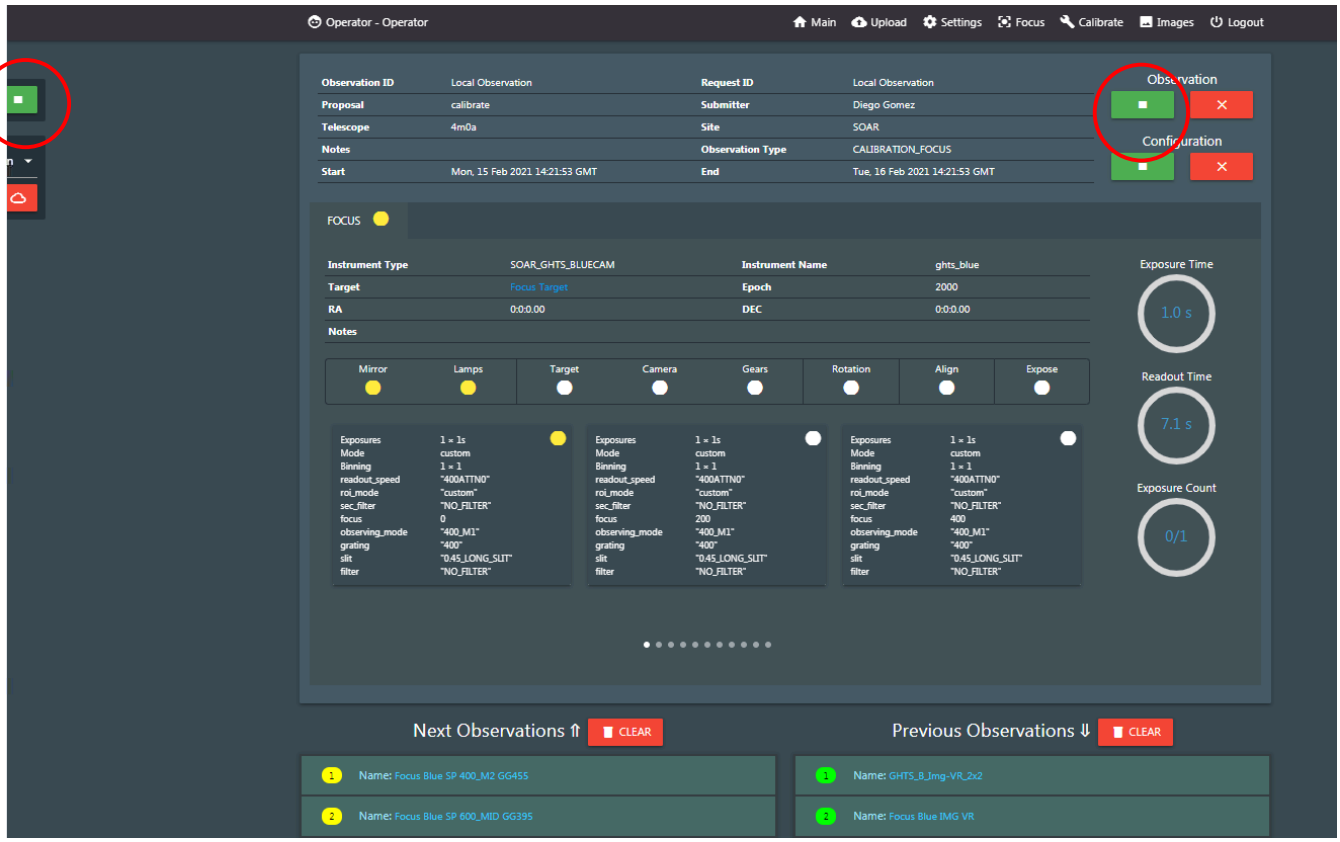
Note: If setting up calibrations for a classically scheduled, non-AEON night, click the red *LOCAL CALIBRATIONS* button. Calibrations will be uploaded to the queue, but no data will be sent to LCOGT.



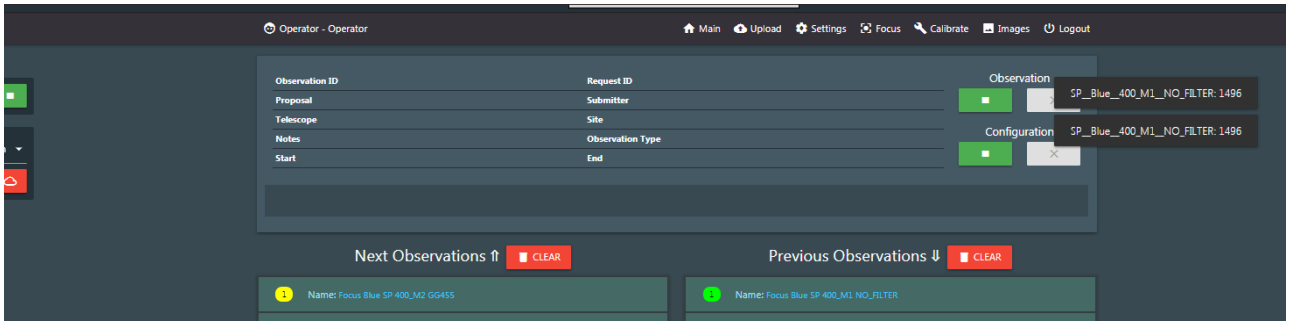


8. **Start of calibrations.** In the *Main* tab in the OSM, click on the hidden red *Start queue* button on the upper left, as shown below. The button will turn green and say “Stop queue”, and will hide again. The first “observation” in the queue, in this case a focus sequence, will be loaded from the *Next Observations* queue area to the main execution box as shown below.

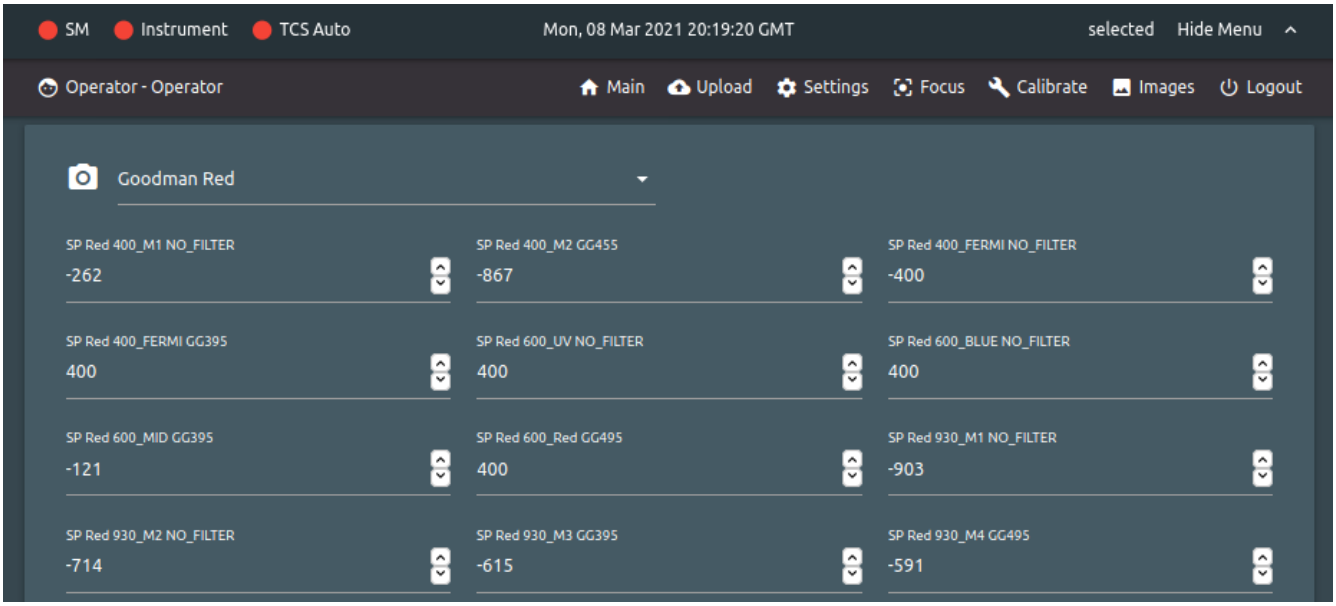
   Because this is the start of OSM operations, the initialization process will proceed with a moving progress circle indicating that the telescope Atmospheric Dispersion Corrector (ADC) is being initialized, and the optical ISB guide probe is being parked. When the initialization is done, click the upper right red play button (>) under *Observation*, it will turn green with the stop sign (solid square), as shown below. Calibrations will then proceed.



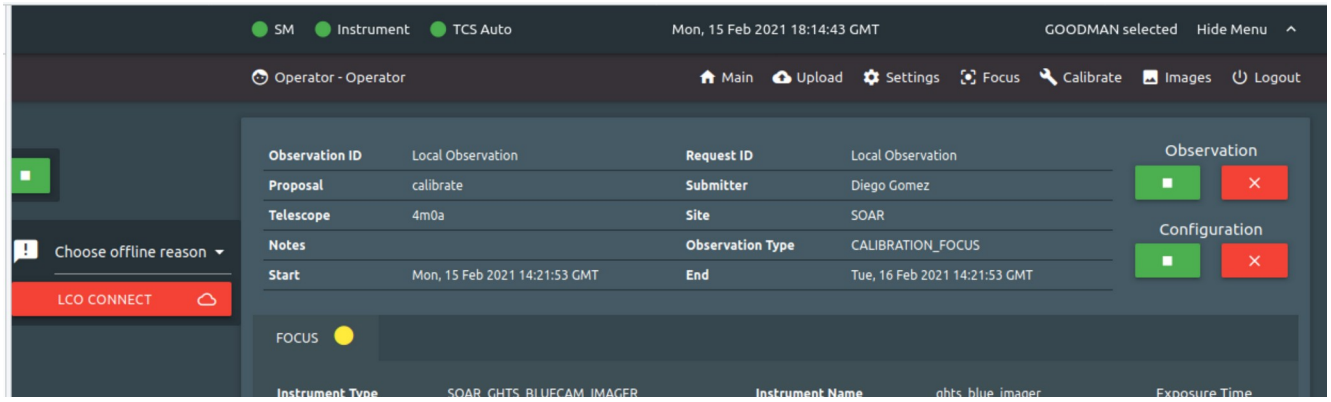
9. **Focus sequences:** each focus sequence is configured by the OSM as a series of individual exposures, each with a different Goodman camera focus value. Each one appears as a small square panel in the lower half of the execution area, and below those, the series of horizontal dots also indicate each focus step, and which one is being executed (dot in white, and LED of corresponding box panel in yellow). Once the focus sequence is completed, the OSM calculates the best focus value, displays it briefly in a message (see image below), and updates that value in the focus table for the camera, which is accessed in the Focus tab.

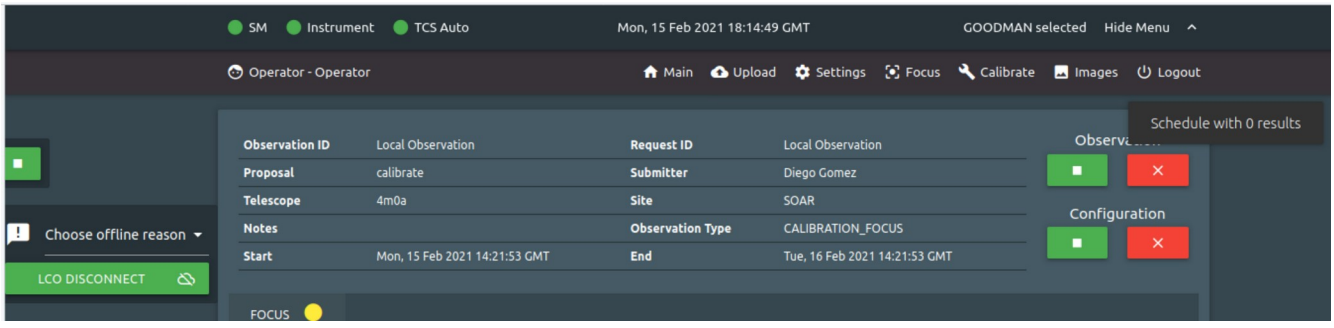


Write down the focus values as they appear, or consult the focus table values (note that the table will contain focus values for all settings, but only the focus sequences done up to now will have their values updated). The focus table for the Goodman RED camera looks as in the following image:



10. **BIAS:** usually biases are taken after the focus sequences have completed for all configurations.
11. **Dome flats:** these will proceed as setup initially. The OSM sets the ADC at 50% for dome flats, and will turn on the dome lamps and set the appropriate percentage and exposure times. The lamp intensities and exposure times are shown in the appendix, for both the BLUE and RED cameras.
12. **End of calibrations.** When finished:
    i. Turn OFF the dome lamps
    ii. Stop the queue, clicking on the hidden upper left button in the OSM *Main* tab (circled in red in the screenshot below). It will change to red.
    iii. Connect to Las Cumbres clicking on the CONNECT LCO hidden button on the upper left of the Main OSM tab, as shown in the screenshot below. The button will change to green, and the OSM will download a schedule of observations from Las Cumbres. Now click again to disconnect from Las Cumbres (button end state will be red). This initial schedule will work as a backup in case by some reason there is no Internet connection at the start of the night.



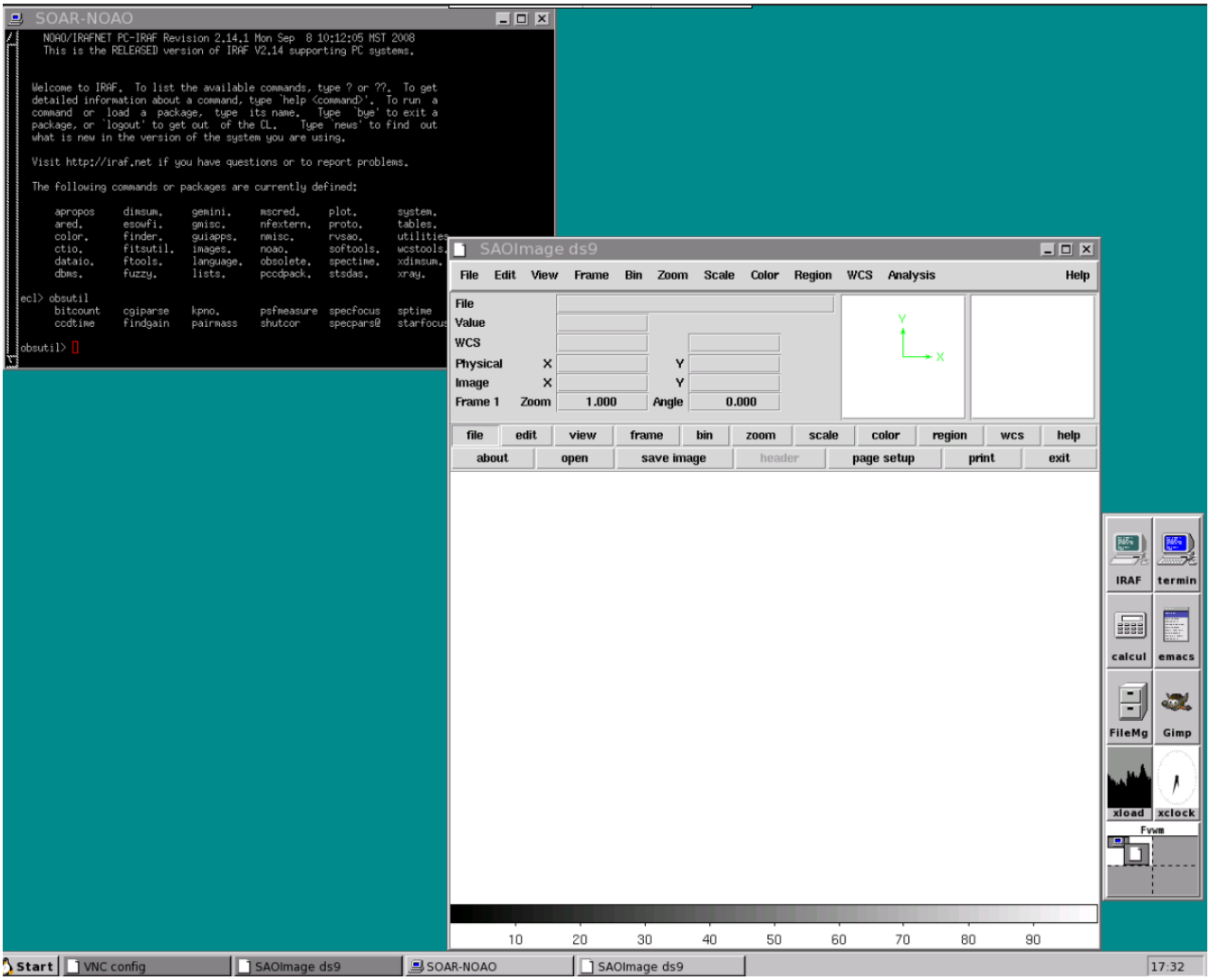


A full set of calibrations (focus sequences, biases, dome flats), as configured for the 2021A semester: 400M1, 400M2, 600MID, 930M2 spectroscopic modes, and imaging with the SDSS-g, r, i, and the VR wide filter, **takes approximately 1h 20min.**

Inspecting the Calibration data

It is important to look at the calibration data and verify that everything is nominal. This is best done using IRAF, running on soaric7.

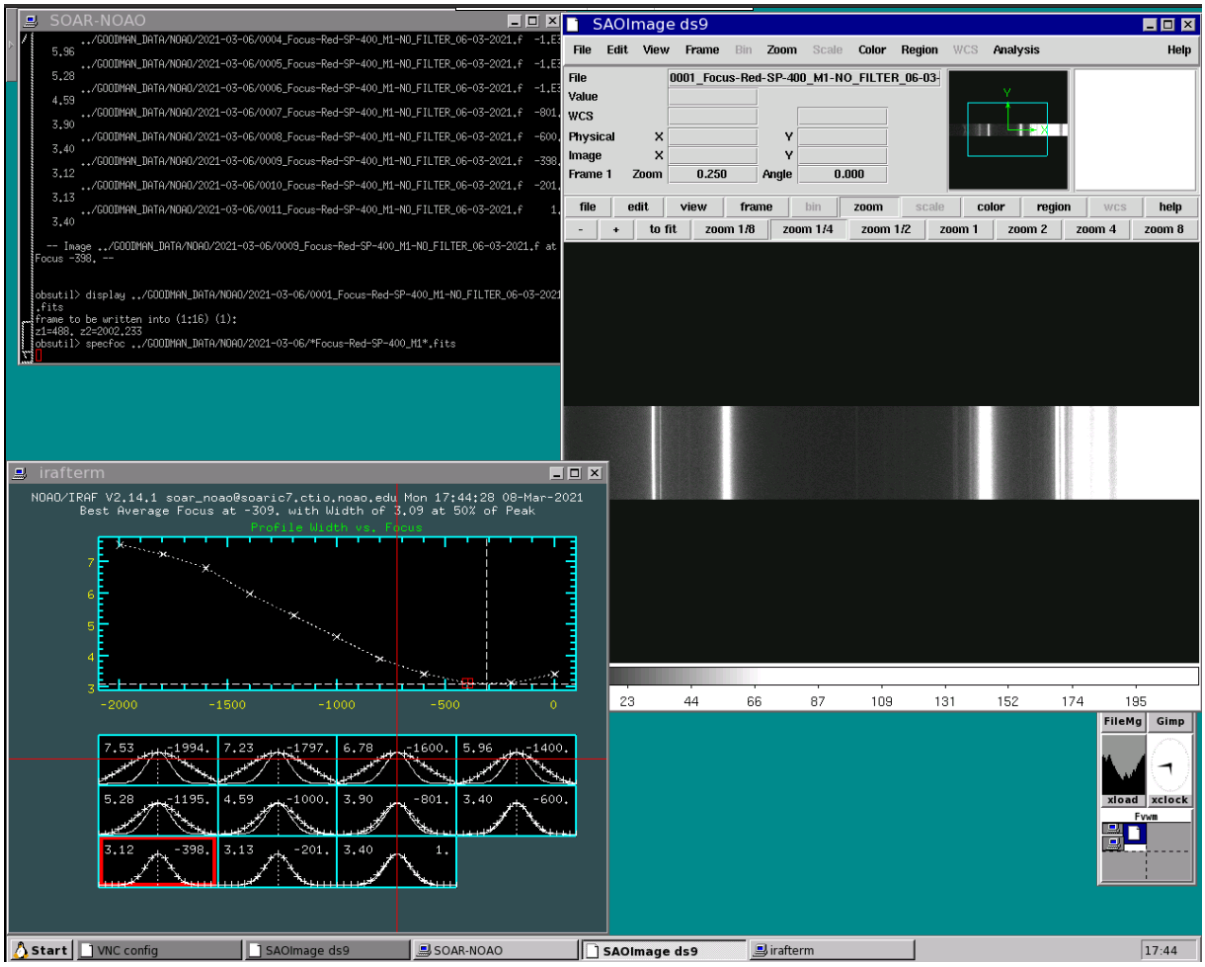
1. Open a VNC on soaric7, logging in as NOAO user (ask staff for the credentials).
2. If it is not running, click on the IRAF icon on the right hand panel of the soaric7 desktop. This will open the black IRAF terminal and a DS9 window, as shown below:



3. In the IRAF command line, type: `obstutil` This will load the *obsutil* package that contains the *specfoc* utility we will use to check the focus sequences.
4. Make sure you are in the /*home3*/observer/today folder: in the IRAF terminal type `pwd`. If not, then go to that folder, which is where all of today's data is located.
5. Type: `cd /home3/observer/today/`.
6. Now type `ls` to list the files (remember, only a few of the Linux native commands, like *"ls"* and *"pwd"* are implemented in IRAF. To run a Linux shell command from the IRAF terminal, precede the command with an "!" sign, e.g., `!ls -alh`)

Checking focus values

1. Typing `specfoc Focus-Red-SP-400_M1.fits` will calculate the focus for the 400M1 setup, which for this particular example is -309 with a FWHM=3.09 pixels; the IRAF graphical window will be shown, as in the image below. Take note of the focus obtained with IRAF. It should be within +/- 100 units of the value obtained with the OSM. If so, everything is ok.



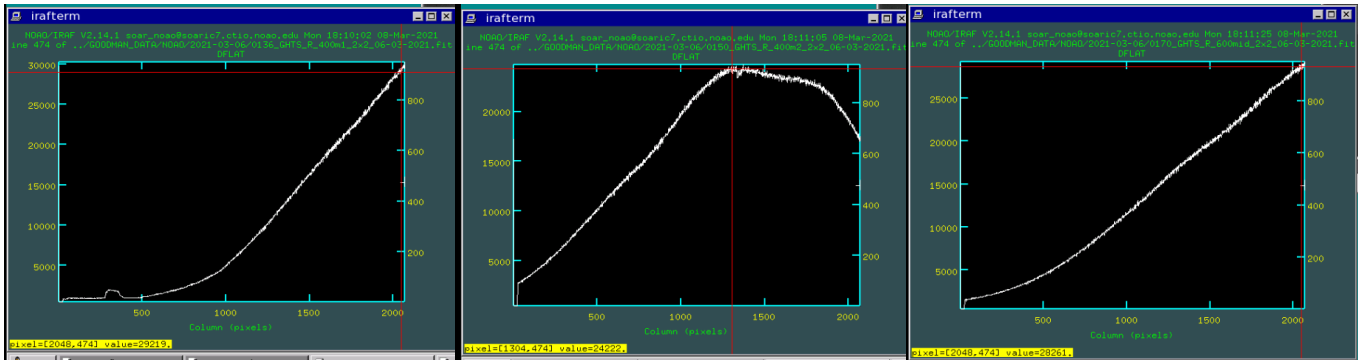
If you do not get the IRAF graphical window shown above, reset the parameters of specfoc:

Type `epar specfoc`. You will get the *specfoc* parameters output on the IRAF terminal. Make sure you edit it so that the highlighted parameters below have these values: *focus=CAM_FOC, dispaxi=2, slit1=30, and slit2=350*. Type *:wq* to save and exit. Run again specfoc; it should work now.

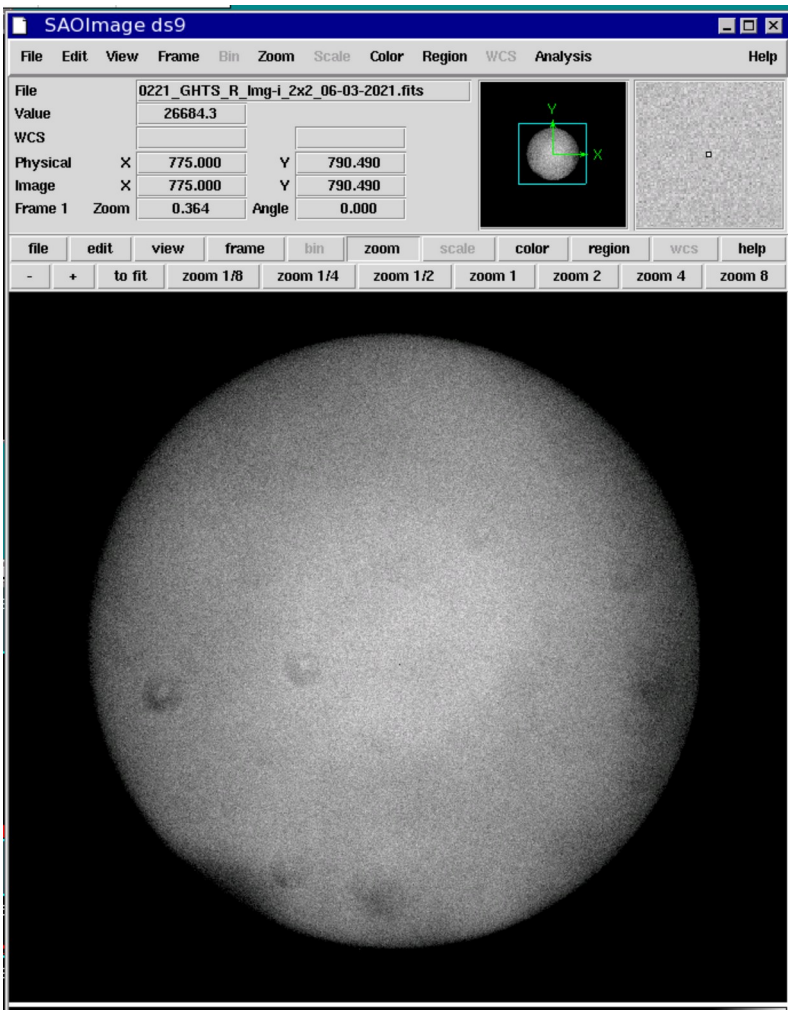
```
                                    I R A F
                         Image Reduction and Analysis Facility
PACKAGE = obsutil
  TASK = specfocus

images  = ../GOODMAN_DATA/NOAO/2021-03-06/*Focus-Red-SP-400_M2*.fits  List of images
(focus  =          CAM_FOC) Focus values
(corwidt=               20) Correlation width
(level  =              0.5) Percent or fraction of peak for width measurement
(shifts =              yes) Compute shifts across the dispersion?

(dispaxi=                2) Dispersion axis (long slit only)
(nspectr=                1) Number of spectral samples (long slit only)
(ndisp  =                1) Number of dispersion samples
(slit1  =               50) Lower slit edge
(slit2  =              350) Upper slit edge

(logfile=          logfile) Logfile
(mode   =               ql)
```

Checking Dome Flats

Dome flats are taken with lamp intensities and exposure times that produce maximum counts in a spectrum (average counts in an imaging flat), between 20000 and 30000 ADU. Inspect spectroscopic flats using *implot* in the IRAF terminal. Simply type `implot` and the name of the file in the IRAF terminal. This will show plots like the following examples for the (from left to right) 400M1, 400M2 and 600MID setups. In the appendix we show tables with the exposure times and lamp intensities used for dome flats in AEON, with both Goodman BLUE and RED cameras.



For inspecting imaging flats, you can either display one, as shown in the image on the right, which corresponds to an i-SDSS dome flat with roughly 26700 ADU.



Alternatively, simply run the IRAF statistics command in the IRAF terminal, and check that the overall counts from one frame to the other are consistent, and fall roughly in the range 20000-30000 ADU. For example, the following command will output the mean and median values for a 100x100 pixel area between coordinates 600 and 500 in both X and Y axes for all dome flats in the SDSS-i filter obtained during afternoon calibrations with the Goodman RED camera (hence the “R” in the GHTS file name), as shown in the sample output.

```
imstat *GHTS_R_Img-i*.fits[500:600,500:600]
```

# IMAGE	n	MEAN	MODE	STDDEV	MAX	MIN
0221_GHTS_R_Img-i_2x2_06-03-2021.fits		19678.	25222.	10539.	31143.	582.
0222_GHTS_R_Img-i_2x2_06-03-2021.fits		19481.	25233.	10431.	33289.	580.
0223_GHTS_R_Img-i_2x2_06-03-2021.fits		19716.	25434.	10560.	30667.	579.
0224_GHTS_R_Img-i_2x2_06-03-2021.fits		19502.	25180.	10442.	29226.	581.
0225_GHTS_R_Img-i_2x2_06-03-2021.fits		19710.	25361.	10557.	35189.	582.
0226_GHTS_R_Img-i_2x2_06-03-2021.fits		19320.	25449.	10342.	31717.	580.
0227_GHTS_R_Img-i_2x2_06-03-2021.fits		19202.	24671.	10278.	28059.	577.
0228_GHTS_R_Img-i_2x2_06-03-2021.fits		19491.	25088.	10436.	37954.	582.
0229_GHTS_R_Img-i_2x2_06-03-2021.fits		18982.	24731.	10156.	30245.	578.
0230_GHTS_R_Img-i_2x2_06-03-2021.fits		19368.	24938.	10368.	29188.	579.

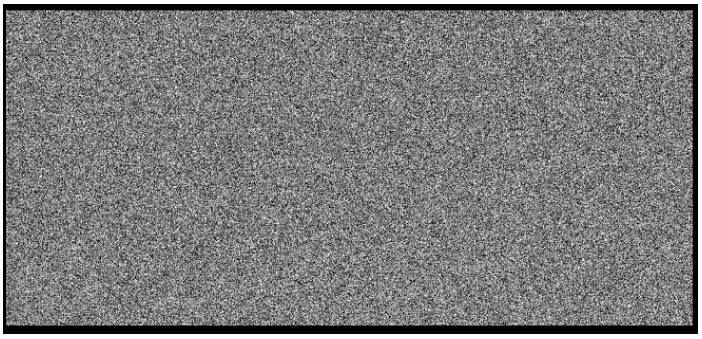
Checking BIAS frames.

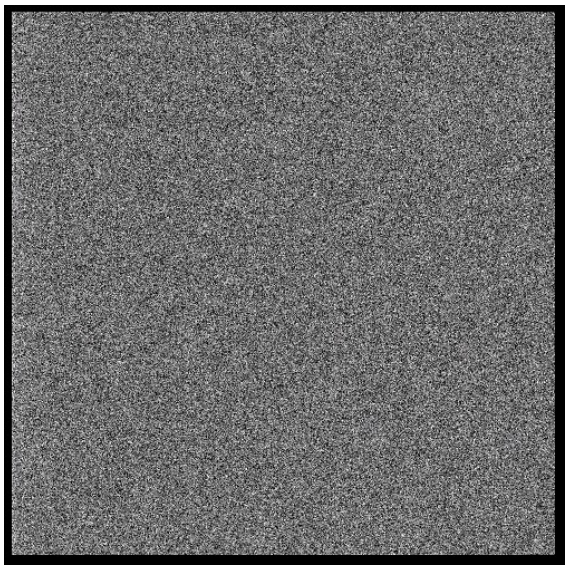
Finally, we must make sure that BIAS frames are coming out correctly. This is a basic diagnostic of the health of the detector. For the **Goodman RED camera**, a statistics of the bias frames should result in a standard deviation **STDDEV≃2.02 ADU**, for the standard readout mode used in AEON (344ATTN3). The following sample command in the IRAF terminal provides the required info for the Goodman RED camera (note this will output the statistics for **all** bias frames, both spectroscopic and imaging):

```
imstat *BIAS*.fits[500:600,500:600]
```

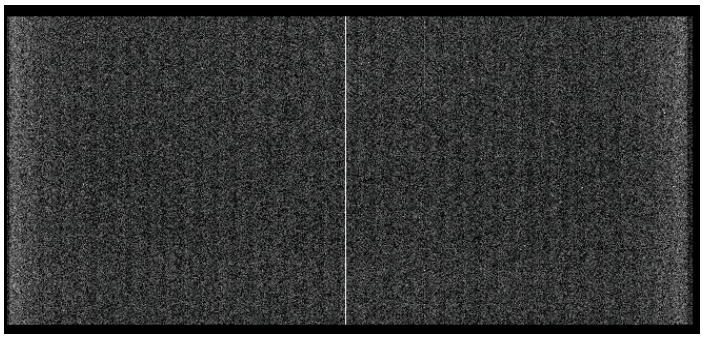
# IMAGE	MEAN	MODE	STDDEV	MAX	MIN
0089_BIAS_06-03-2021.fits	496.7	496.8	2.022	506.	487.
0090_BIAS_06-03-2021.fits	496.6	497.	2.02	506.	487.
0091_BIAS_06-03-2021.fits	496.6	497.	2.02	506.	487.
0092_BIAS_06-03-2021.fits	496.6	497.	2.015	506.	487.
0093_BIAS_06-03-2021.fits	496.6	497.	2.019	506.	487.
0094_BIAS_06-03-2021.fits	496.6	497.	2.019	506.	487.
0095_BIAS_06-03-2021.fits	496.6	497.	2.018	506.	487.
0096_BIAS_06-03-2021.fits	496.6	497.	2.016	506.	487.
0097_BIAS_06-03-2021.fits	496.6	497.	2.018	506.	487.
0098_BIAS_06-03-2021.fits	496.6	497.	2.017	506.	487.
0099_BIAS_06-03-2021.fits	496.5	497.	2.018	506.	487.
0100_BIAS_06-03-2021.fits	496.6	497.	2.017	506.	487.
0101_BIAS_06-03-2021.fits	496.6	497.	2.017	506.	487.

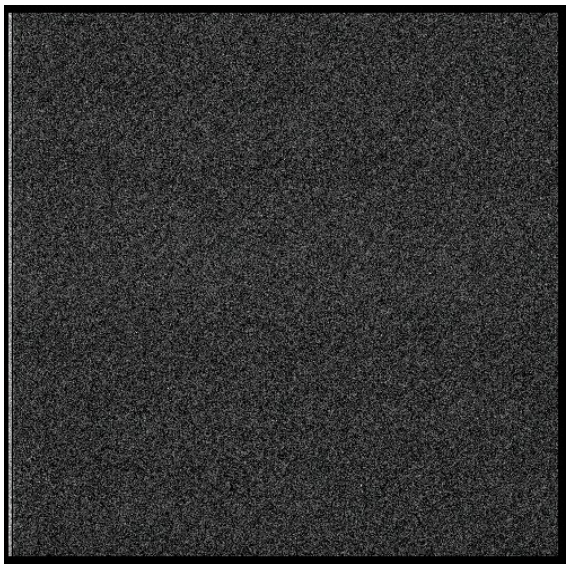
For the RED camera, a spectroscopic 2x2 bias should look like the image below left, and an imaging 2x2 bias like the one below right, neither showing any structure, just random noise:





For the **Goodman BLUE camera**, 2x2 biases (for the standard AEON readout mode 200ATTN0) have and overall **STDDEV≃3.78 ADU**, and when displayed show the following appearance, spectroscopic to the left and imaging to the right. Spectroscopic bias frames show low level structure in the form of vertical banding, and a bad column in the middle of the detector. The imaging bias shows diagonal banding and a bad column to the left edge of the detector.



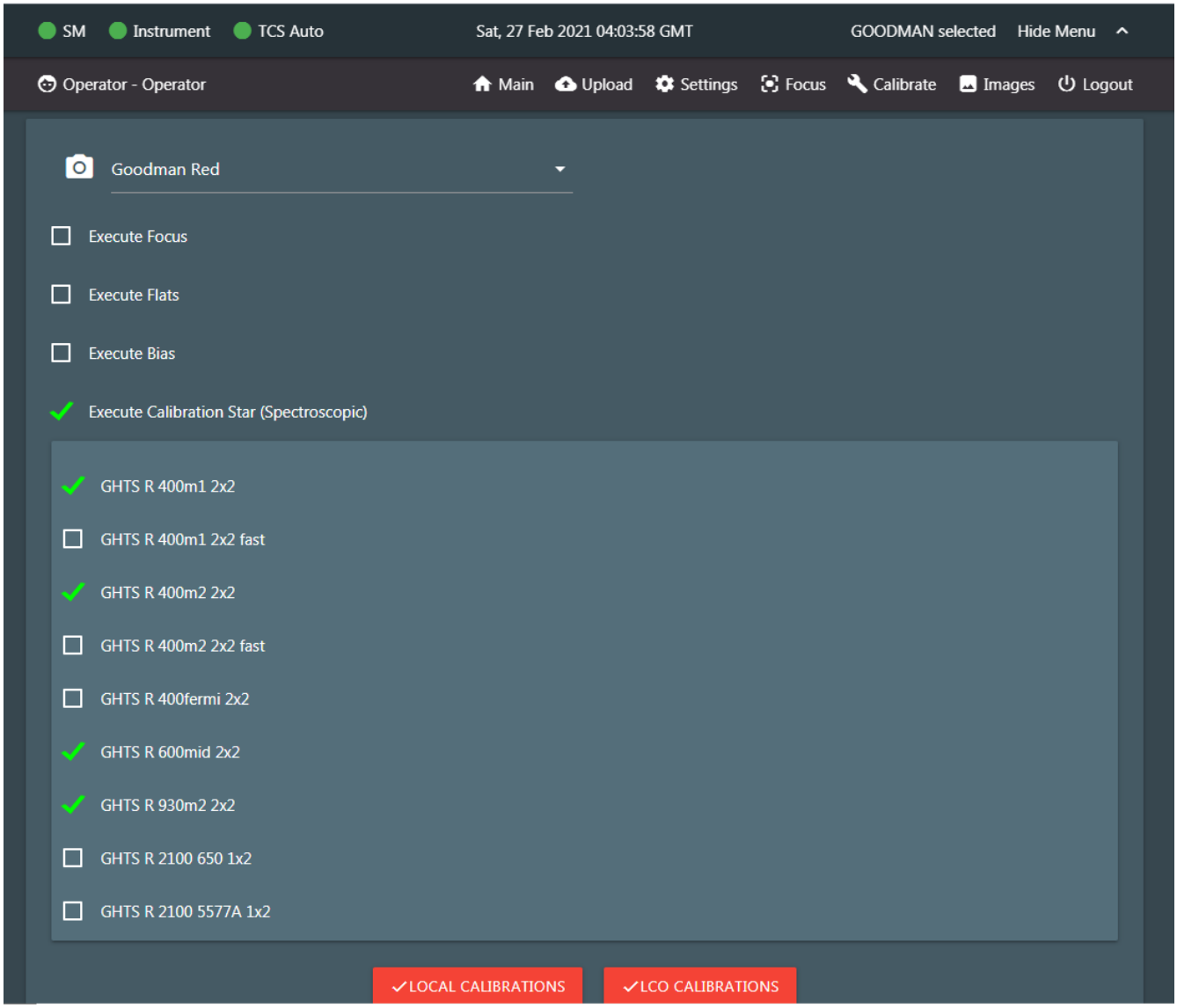


Night time observing with AEON

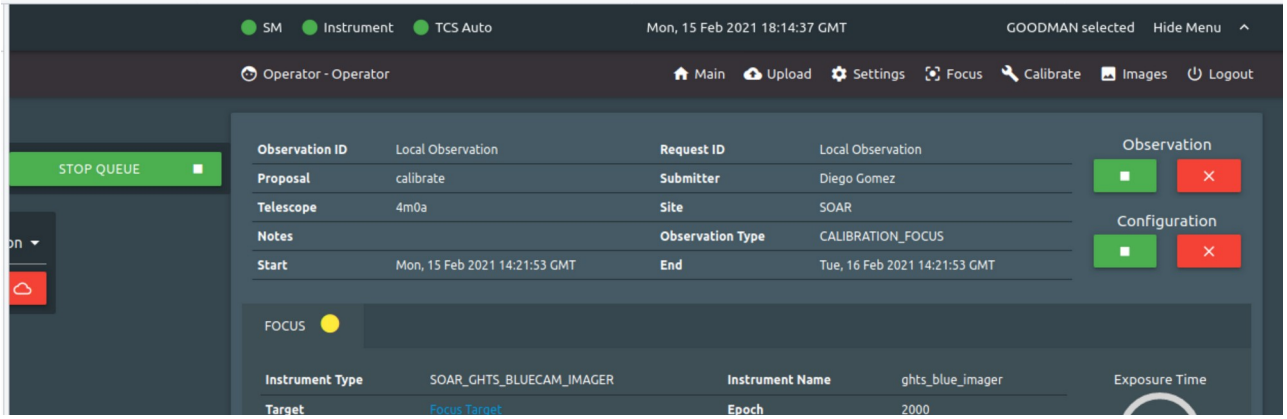
Spectrophotometric Standard Star Observation

At the start of the night, still during twilight if sky conditions allow, or whenever observations can start, and once the Observer Support/Telescope Operator has prepared the telescope (pointing zero point, AOS calibration), proceed with the observation of the spectrophotometric standard. This is a fairly automated process.

1. In the *Main* tab, **make sure BOTH hidden buttons are red** (i.e., we are both disconnected from Las Cumbres AND the queue is stopped).



2. Click the *Calibrate* tab, and then select *Execute Calibration Star (Spectroscopic)*. Select the appropriate modes in use for the semester. The modes shown in the image above are for 2021A with the Goodman RED camera.
3. Click the red *LCO CALIBRATIONS* button. Go back to the *Main* tab.
4. Click the hidden *START QUEUE* button. Regardless of what targets are in the queue, the observation of the standard star takes precedence and will be pushed into the execution area.

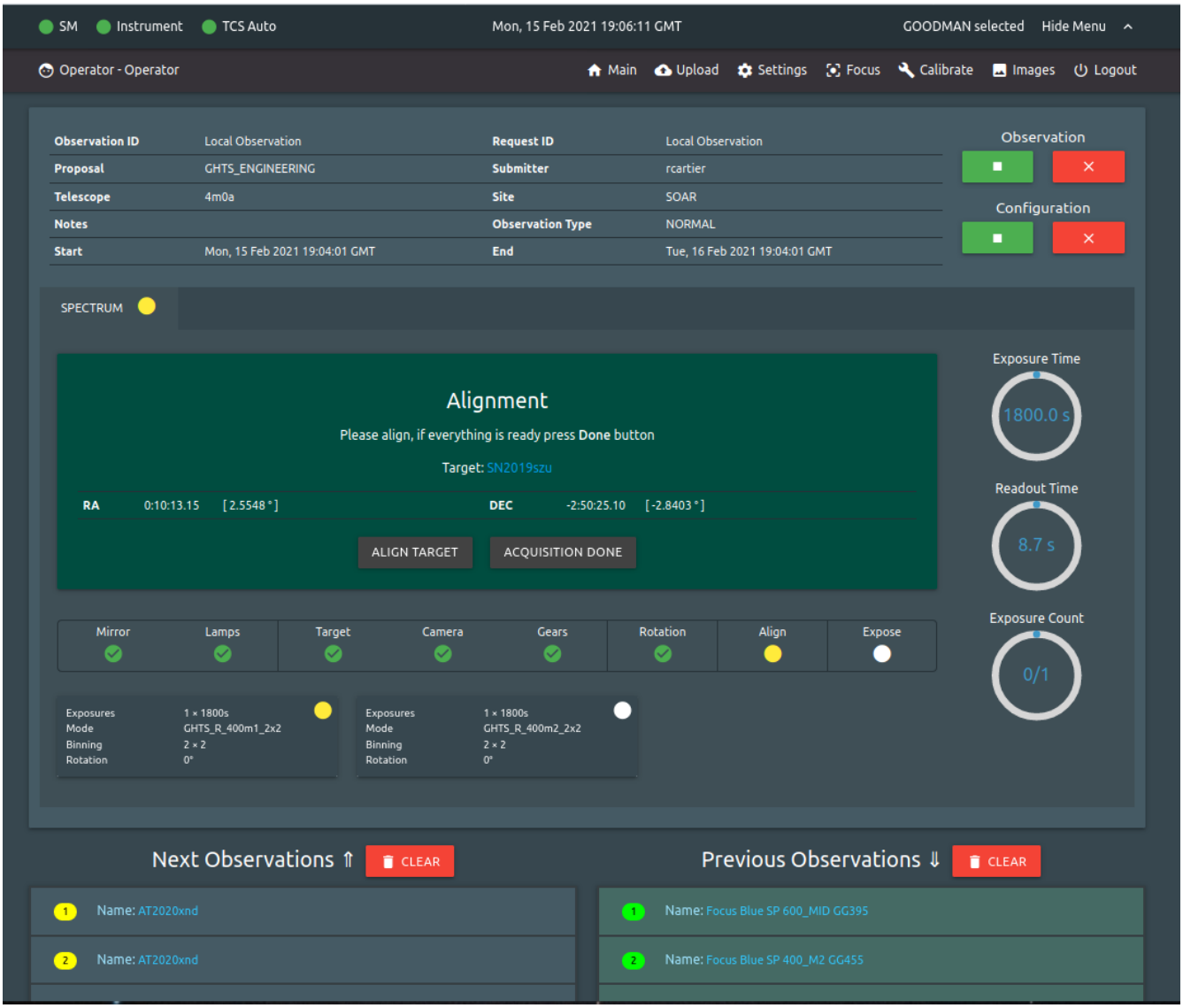


The automated spectrophotometric standard star observation routine in the OSM is designed to automatically pick the most suitable targets from among a list of standard stars (we use an abridged version, that eliminates northern targets and stars with data from models, of the [ESO list of Optical and UV spectrophotometric standards]). The OSM will select the star whose position on the sky is closest to the current telescope position. The OSM will then command the telescope to slew to that star, sets the correct exposure times for each of the spectroscopic modes, takes the appropriate comparison lamps once in position, and stops to prompt the user to do the on-slit target centering.

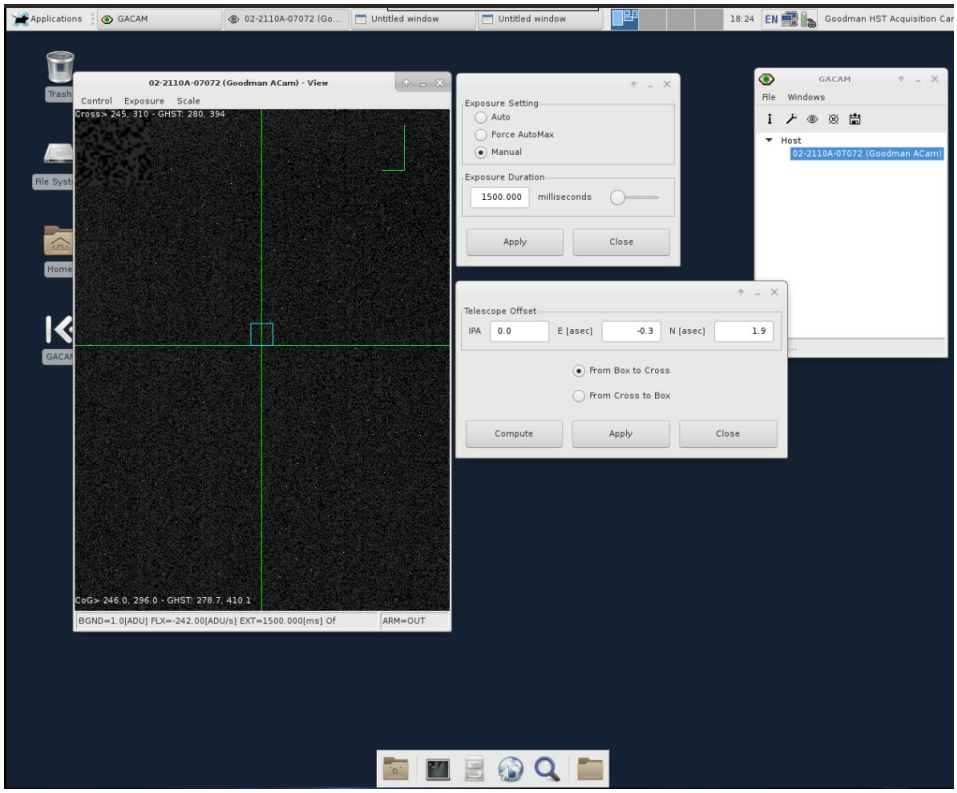
Note that because the std star is only selected once the observation enters in the execution area, the coordinates fields will show no values when expanding the info for the std star observation in the queue. The name of the star and its coordinates will appear once the observation enters the execution area.

Since these are relatively bright standard stars (brighter than V~13), exposure times for most, if not all setups will be under ~180s, which means guiding when taking the spectrphotometric standard star observations will rarely be necessary.

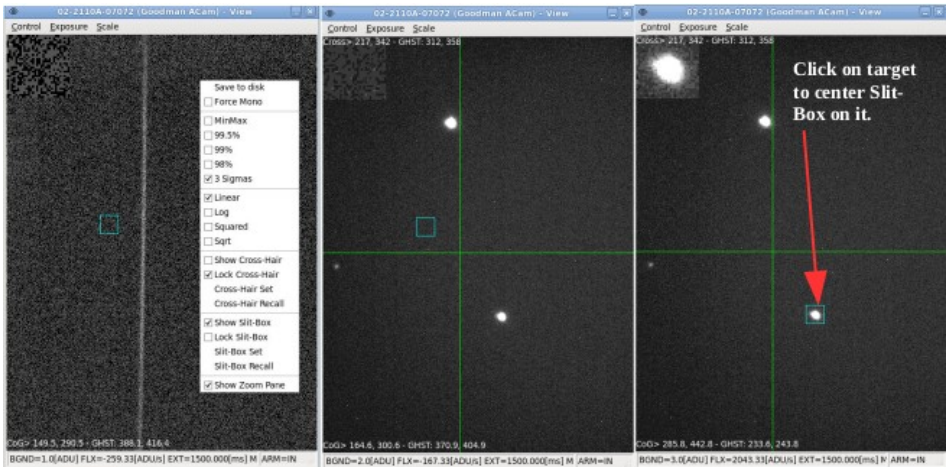
Also because of these being bright stars, **on-slit target acquisition is always done with the GACAM** (see example below).


SM
Instrument
TCS Auto
Mon, 15 Feb 2021 19:06:11 GMT
GOODMAN selected
Hide Menu
Operator - Operator
Main
Upload
Settings
Focus
Calibrate
Images
Logout
Observation ID
Local Observation
Request ID
Local Observation
Proposal
GHTS_ENGINEERING
Submitter
rcartier
Telescope
4m0a
Site
SOAR
Notes
Observation Type
NORMAL
Start
Mon, 15 Feb 2021 19:04:01 GMT
End
Tue, 16 Feb 2021 19:04:01 GMT
Observation
Configuration
SPECTRUM
Alignment
Please align, if everything is ready press Done button
Target: SN2019szu
RA
0:10:13.15
[2.5548 °]
DEC
-2:50:25.10
[-2.8403 °]
ALIGN TARGET
ACQUISITION DONE
Exposure Time
1800.0 s
Readout Time
8.7 s
Exposure Count
0/1
Mirror
Lamps
Target
Camera
Gears
Rotation
Align
Expose
Exposures
1 × 1800s
Mode
GHTS_R_400m1_2x2
Binning
2 × 2
Rotation
0°
Exposures
1 × 1800s
Mode
GHTS_R_400m2_2x2
Binning
2 × 2
Rotation
0°
Next Observations ⇑
CLEAR
Previous Observations ⇓
CLEAR
1
Name: AT2020xnd
2
Name: AT2020xnd
1
Name: Focus Blue SP 600_MID GG395
2
Name: Focus Blue SP 400_M2 GG455

Acquiring a target on the Goodman slit (example for a std star). Start the Goodman Acquisition Camera (GACAM) VNC window by double-clicking on the GACAM icon on the left of the GACAM computer desktop.

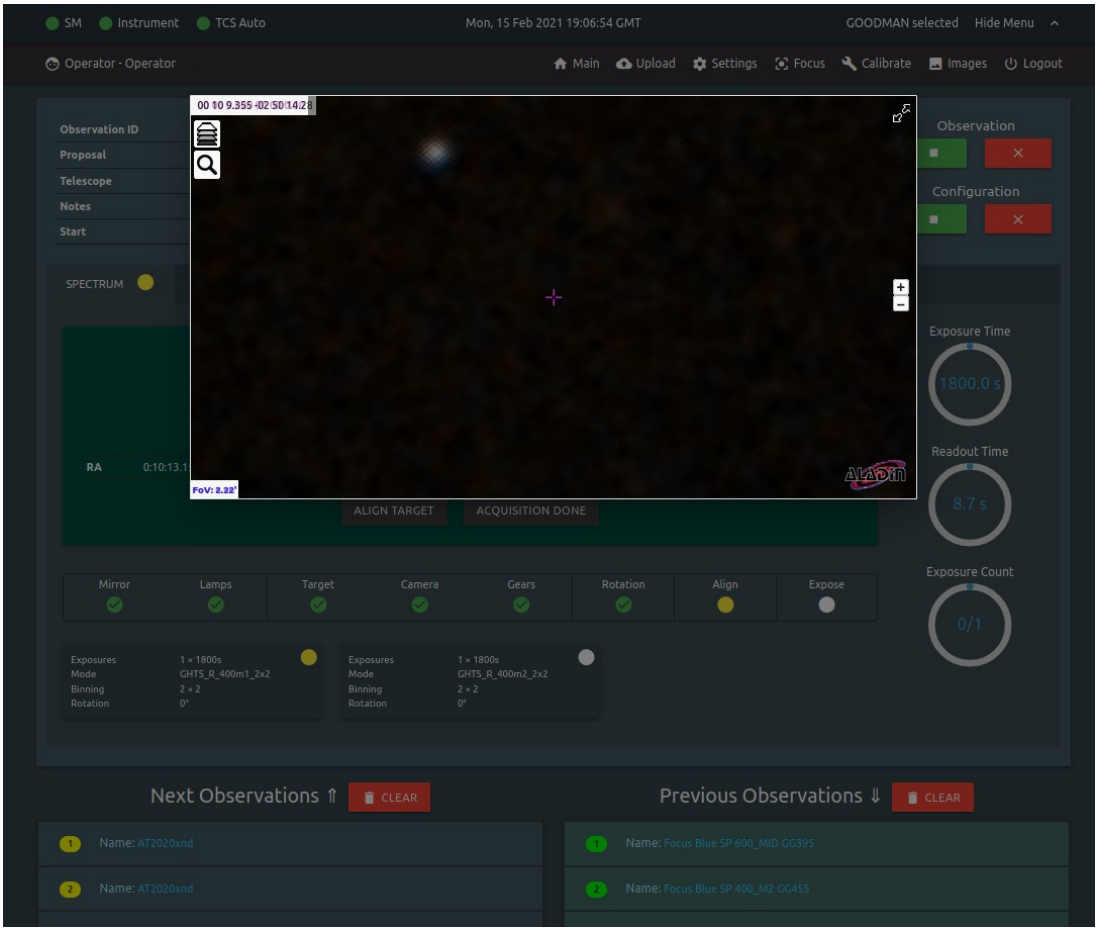


On the GACAM window click on the eye icon to open the main GACAM window and image display. Then open the *Telescope Offset* window by clicking on the *Control* menu, and the *Exposure Setting* window by clicking on the *Exposure* menu. Arrange these two windows conveniently around the main display window. For more details refer to the GACAM manual and cheat sheet in the SOAR Goodman web pages.



Acquire the star in the slit using GACAM, together with the Goodman GUI to put IN/OUT the slit mask, and continue the observation process in the OSM. **Remember to place the GACAM arm in the OUT position before** clicking *Acquisition Done*. Note that the OSM will stop and prompt to check star acquisition for each new spectroscopic mode during the std star observation. The operator can either quickly check with GACAM that the star is on the slit, and continue, or simply continue directly if confident the star has not moved out of the slit.

Also note that the OSM provides a default finding chart for all targets. This can be displayed by simply clicking on the target name in blue font in the green *Alignment* window. The following screenshot shows a typical finding chart. They are downloaded automatically from Aladdin, using the default DSS color sky map. Note that the default field of view is 9 arcmin, therefore, you should typically zoom-in (using the mouse scroll wheel or by clicking on the zoom in/out buttons on the right of the chart window), to the roughly 2 arcmin size of the GACAM field of view. To close the finding chart, just click anywhere outside of the finding chart window, or hit the ESC key.



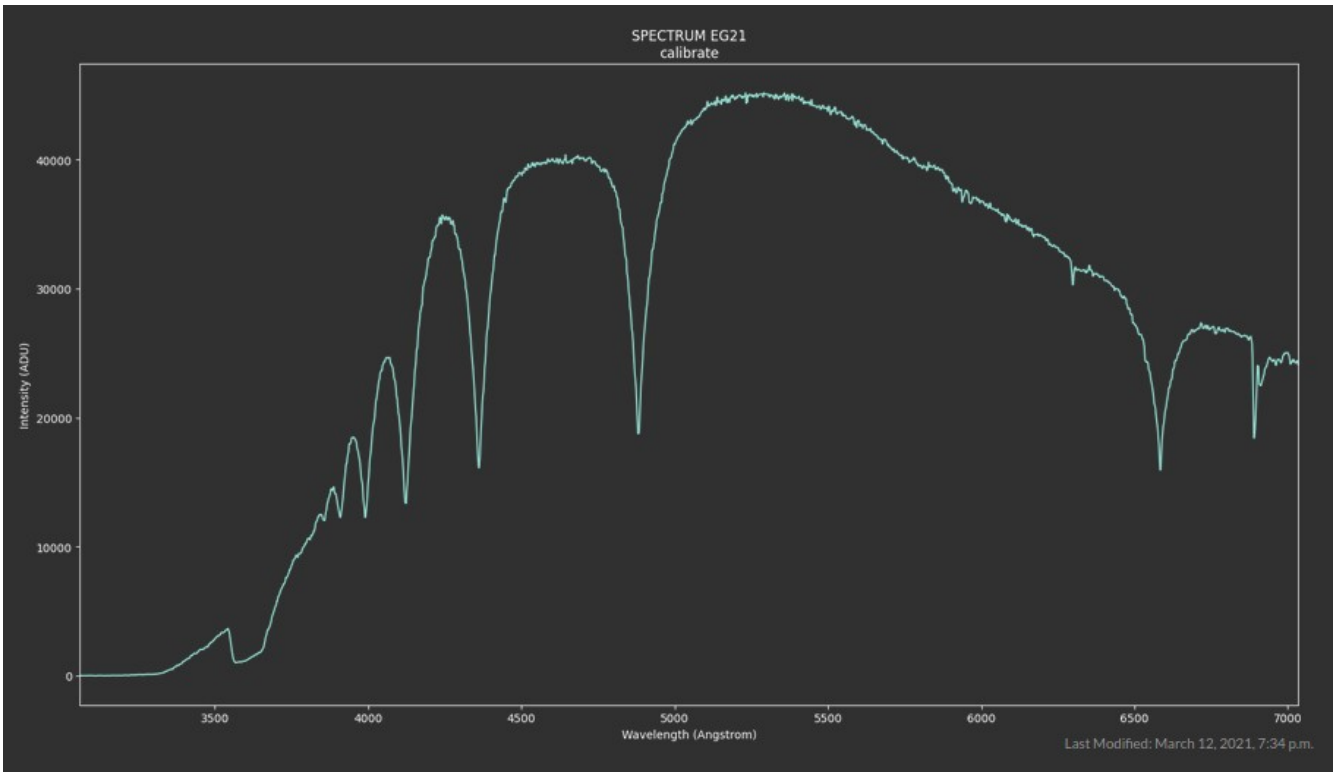
The OSM will show the pop-up alignment window after each setup is completed. This behavior allows the user to quickly check the star remains centered in the slit, by putting in the GACAM arm, and then out. This operation should take less than 10s. However, if you are confident the star remains centered, simply click the *"ACQUISITION DONE"* button, and the confirm the pop-up dialog.

Once the sequence of standard star observations has completed, we are ready to start observing the first science target.

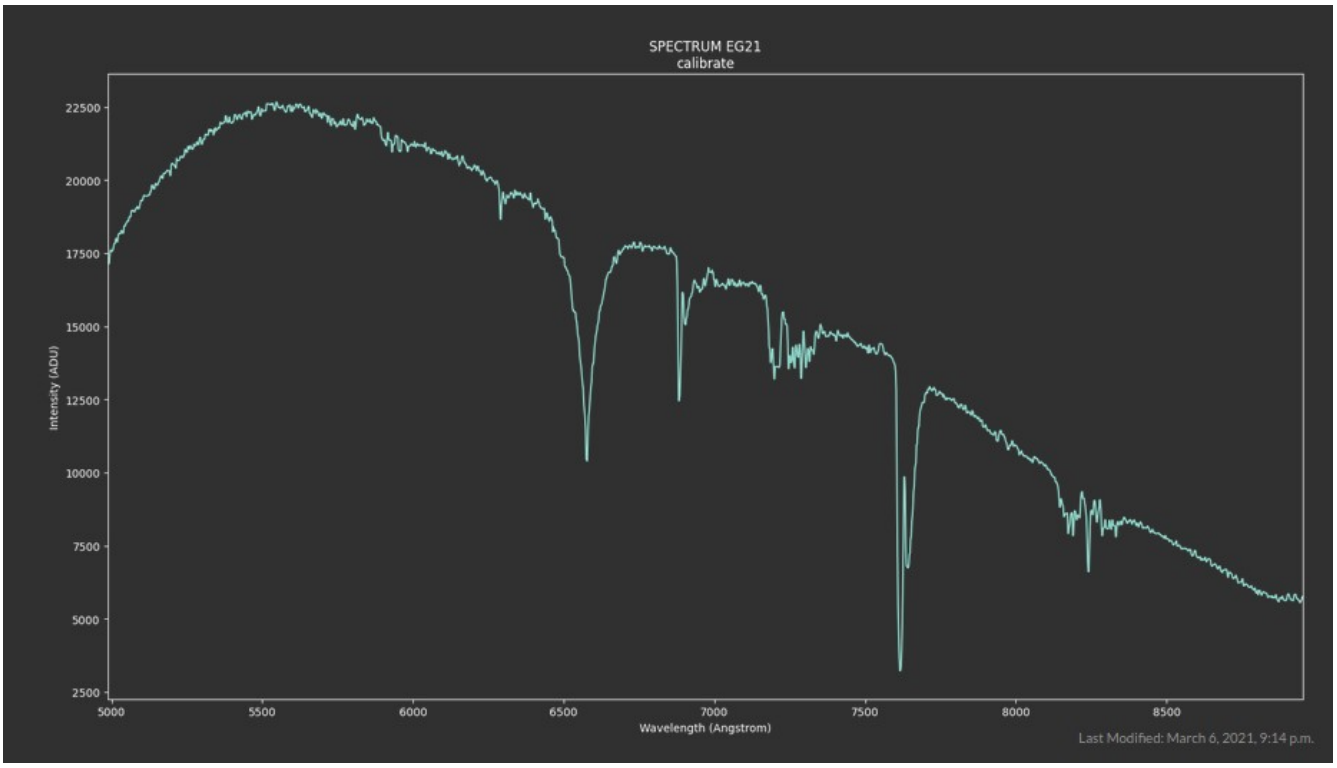
NOTE: The *"ALIGN TARGET"* button is for imaging acquisition of faint targets. It's use will be explained latter. This feature is not used for bright targets, certainly not for standard stars.

The next four figures show Goodman RED camera spectra of the spectrophotometric standard star EG21, a DA3 spectral type white dwarf, V=11.39, obtained with the AEON setups for 2021A, and automatically reduced with the GSP.

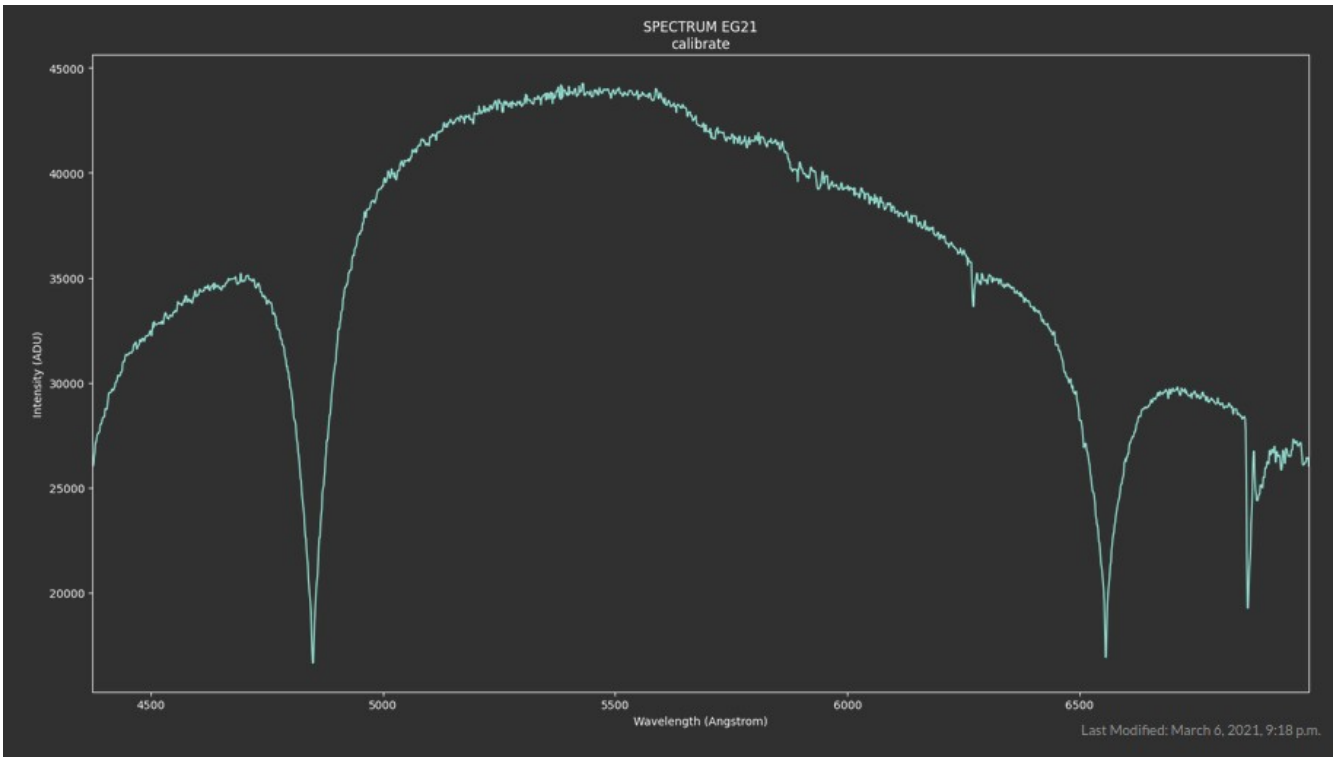
400M1



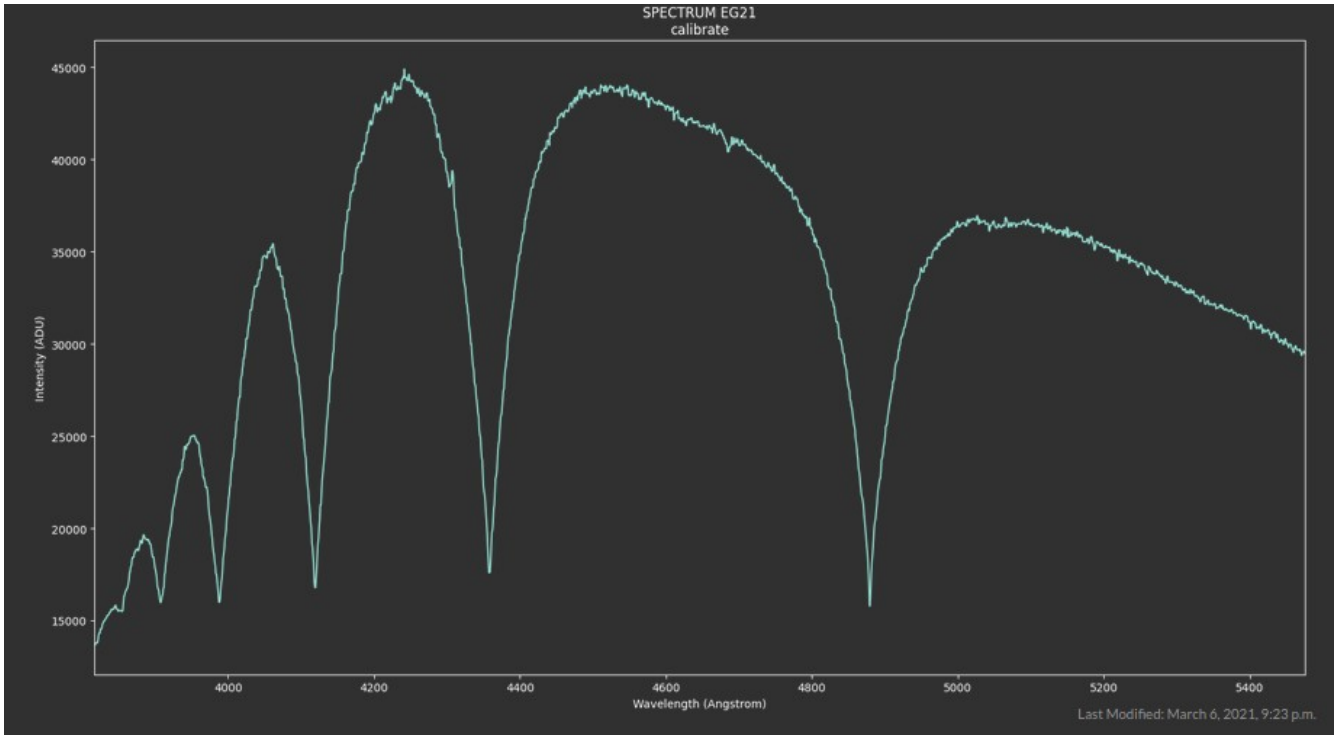
400M2+GG455 filter



600MID+GG395 filter



930M2


SPECTRUM EG21
calibrate
45000
40000
35000
30000
25000
20000
15000
Intensity (ADU)
4000
4200
4400
4600
4800
5000
5200
5400
Wavelength (Angstrom)
Last Modified: March 6, 2021, 9:23 p.m.

Observation of Science Targets

Observation of science targets with AEON on SOAR can be classified in two main categories: **spectroscopic and imaging.** The GHTS is capable of doing both. Moreover, AEON science targets may be of type SIDEREAL or NON-SIDEREAL, the later correspond to moving objects like comets and asteroids.

The main responsibilities of the Operator/Observer during science target observations are:

a) **Connect or disconnect from LCO,** depending on weather conditions or technical issues. If you realize you need to interrupt observations for any longer than a few minutes, because of weather or a technical problem, **first** select from the "Choose offline reason" menu in the hidden button: Weather or Technical, then click *LCO DISCONNECT*.

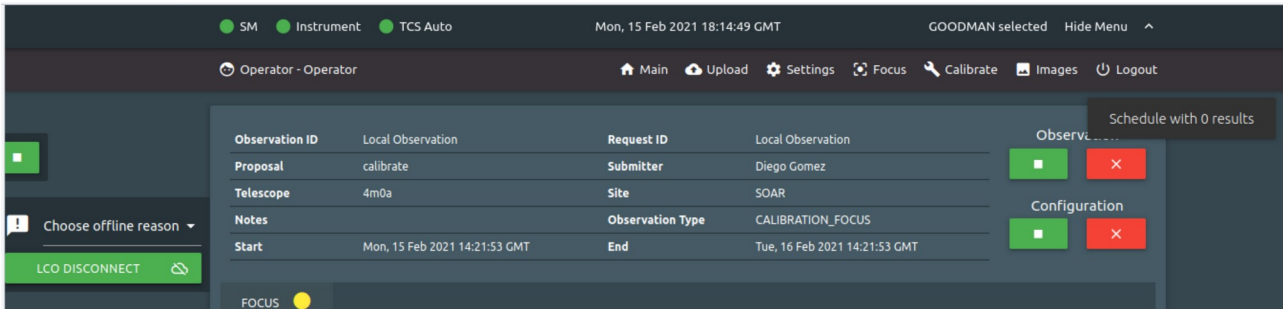
b) **Acquire a guide star,** if needed.

c) **Center the star on the slit**, if setting a spectroscopic observation. For this, GACAM is the main tool, but pre-imaging can also be used if the program or the difficulty of the target requires it. In some cases, combining both techniques may be used to advantage. The observer will also need access to the Goodman GUI to move the slit IN/OUT during the on-slit acquisition process.

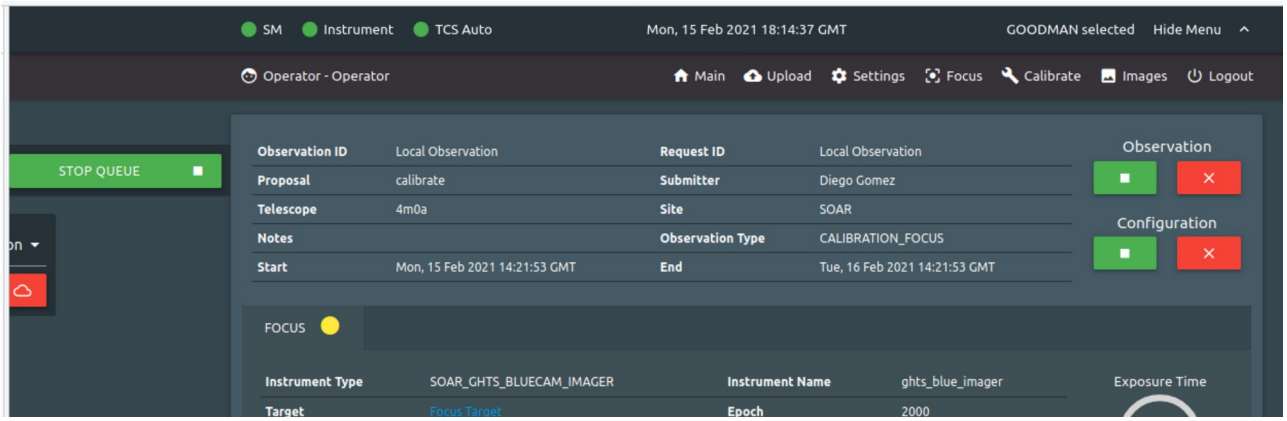
d) **Keep notes on individual targets as needed.** These notes are important when submitting the Observing Report at the end of the night.

To start science target observations:

1. Click on the red *CONNECT LCO* hidden button, in the *Main* upper left OSM window, to connect to Las Cumbres and download the latest updated schedule. The button will turn green as shown here.



2. Click on the *START QUEUE* hidden button on the upper left of the *Main* OSM tab, in order to start the queue. The button will change to green as shown here.



3. Make sure you click on the upper right red button, to start running the first observation in the execution area. The button will turn green.

   Now the first observation will start the execution area, as long as the time in the upper part of the OSM coincides with the *Start Time* of the observation.

Imaging of sidereal targets.

This is usually a rather simple observation compared to spectroscopy. Though users may supply finding charts, the SOAR pointing is usually good enough (less than 10 arcsec RMS all-sky) that no target acquisition is required. After the slew process has completed (the OSM requires that the telescope slew is finished, rotator and instrument position angle have reached their values, the dome has finished moving, and the AOS is ready), the operator may look for a guide star, assuming the exposure length or specific program instructions require it.

Imaging exposures of less than ~180s should rarely require guiding, but make sure that the program PI's instructions do not require guiding even for short exposures.

Imaging of Solar System objects.

Imaging of Solar System objects with SOAR, or moving targets in general, which in AEON are identified as **non-sidereal** targets, is different from imaging of **sidereal** targets, in that:

a) RA and DEC coordinates are not shown in the OSM until the target is pushed to the execution area.

b) In addition to the target RA and DEC coordinates, RA and DEC rates (in arcsec/hr) are passed to the SOAR TCS when the target goes into the OSM execution area, so that the telescope will track at the specified, non-sidereal rate in both axes.

The OSM uses as its primary source of RA, DEC and rates, the ephemeris for the target published in the NASA JPL Horizons web page (https://ssd.jpl.nasa.gov/horizons.cgi#top) using their API. If no data

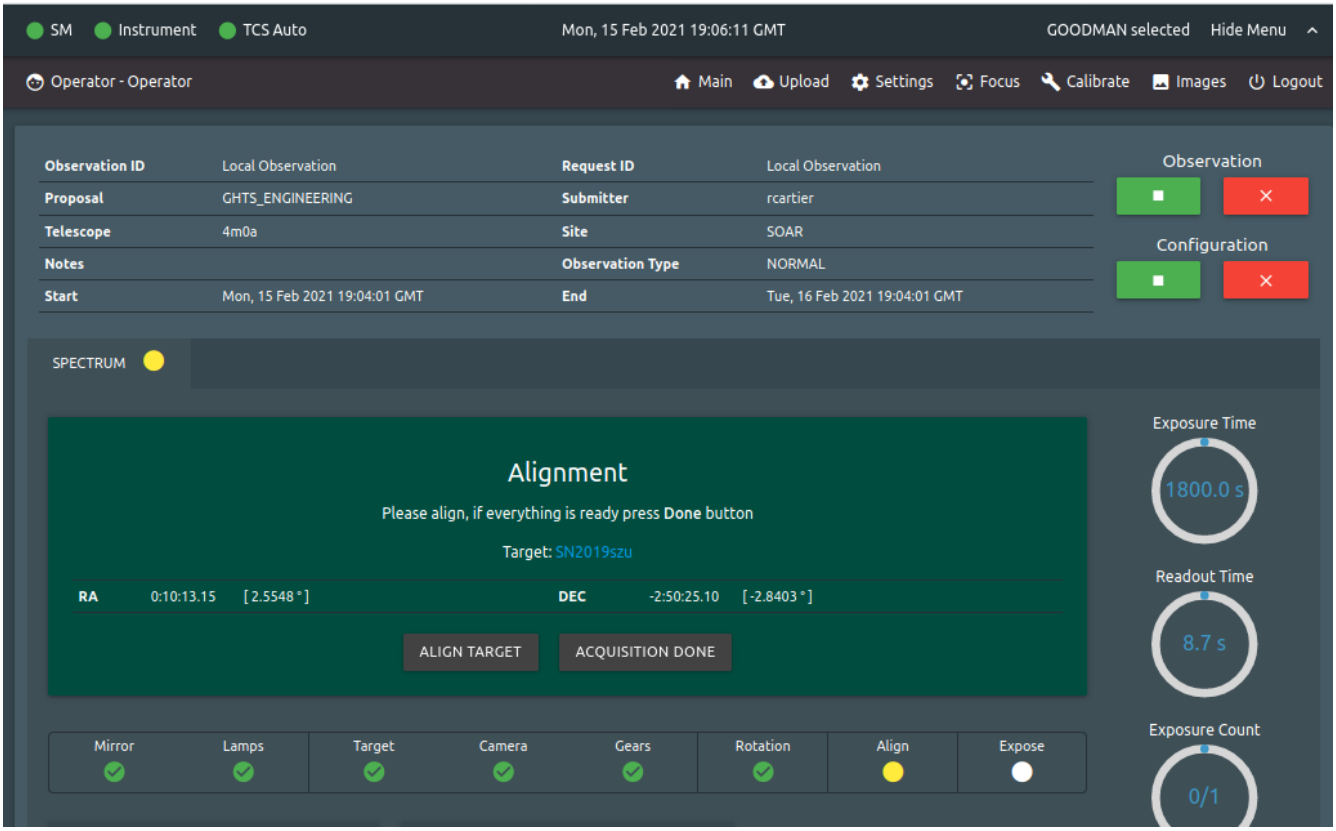
are found in the JPL Horizons page, the OSM will calculate its own ephemeris using the orbital elements provided by the user for the target.

Though the usual acquisition pop-up will appear once the OSM is ready, the user will just click on *"ACQUISITION DONE"* to proceed with the observation. Note that **no guiding is done when observing non-sidereal targets, regardless of whether it is imaging or spectroscopy.**

Spectroscopy

In order to successfully carry out spectroscopic observations, the Observer needs to concentrate on only two key factors, first, identify the correct target, for which good finding charts are important, second, center correctly the target on the slit. Every other step of the observation is controlled automatically by the OSM.

1. Once on the OSM is on-target, which means that all mechanisms movement have completed: telescope, dome, Nasmyth rotator, instrument position angle, ADC adjustment, internal spectrograph mechanisms (grating, camera stage, filter wheels, slit changer), an acquisition window will pop-up prompting the user to start the acquisition process, with two buttons: *"ALIGN TARGET"* and *"ACQUISITION DONE"*, as shown in the following image.

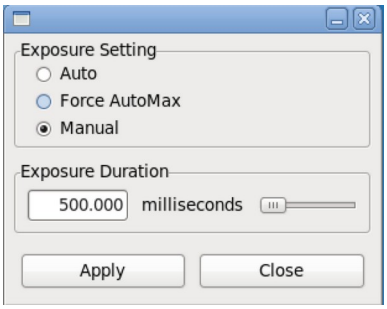


2. At this point the Operator should **look for a guide star** and start guiding (if guiding is required).
3. Once guiding, **proceed to acquiring the science target on-slit**, either using GACAM as described in the case of the spectrophotometric standard star, or using Goodman imaging.

As was shown for the observation of the spectrophotometric standard star, the user can either use the finding chart provided by the program PI (if any), or click on the name of the target in the alignment box (in blue font), to get a pop-up default finding color DSS finding chart using Aladin.

GACAM Acquisition

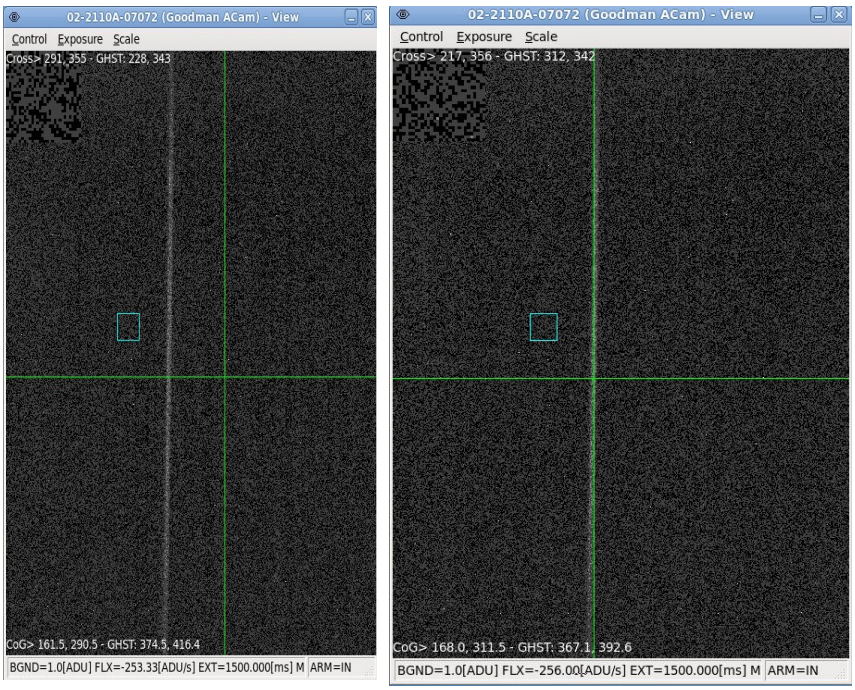
The detailed use of GACAM will not be repeated here, other than to say that for science targets you will likely have to increase the default exposure time. Remember that the exposure times in the GACAM *Exposure* window are given in milliseconds (ms), with the default being 500ms or 0.5s. Therefore, if you want to increase the exposure time to 10s, you will need to edit the number to read 10000.



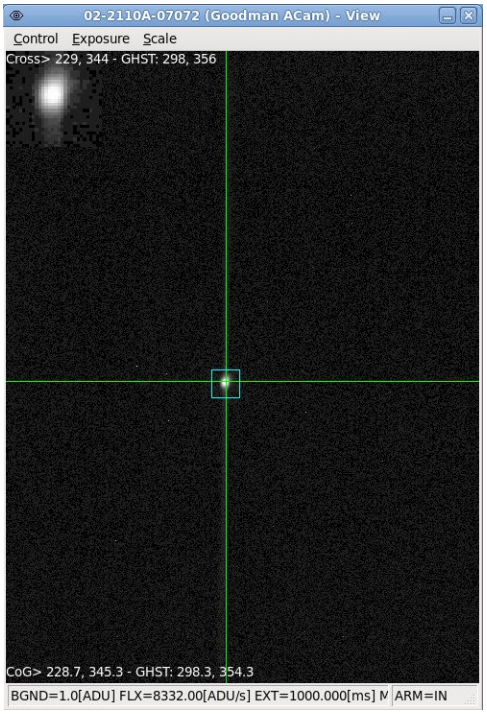
How faint the source can be to still be able to use GACAM depends on various factors. In general, GACAM will be able to reach V~19 point sources with exposure times of 15-20s, under dark skies. You need to bear in mind that with longer exposure times you need to wait that much for the image to refresh. A longer exposure time also allows the slit to be seen more easily, especially in dark nights.

Also, take the opportunity to examine the image quality when you are acquiring with GACAM. Telescope defocus will be readily apparent in GACAM, and a quick adjustment of focus can be made, if needed, during this acquisition time.

When acquiring with GACAM, always check first the slit position with the green cross. It is advisable, specially if it is the first target or the telescope changed position significantly respect to the previous target, to put IN/OUT the slit mask twice (in the Goodman GUI), when setting the reference position of the green cross, as it is known that the mask may not return to the exact position after large telescope slews.



Once the slit position has been set with the green cross reference (and it is locked), take OUT the slit mask in the Goodman GUI, to see the target field. Click on the science target and the cyan box will be placed on the target. Then proceed to click on the *Compute* and *Apply* buttons in the GACAM *Offsets* window, to move the telescope so the target is on the center of the green cross. More than one iteration may be needed to get the center correct.



Note that in GACAM you can apply manual offsets to fine tune the centering of the target in the slit. For example, an offset of 0.5 in the “E” box, and of 0. in the “N” box, will offset the telescope 0.5 arcsec East. If you want the offset to be West, type a negative value, e.g., -0.5 in the “E” box will apply a 0.5 arcsec offset to the West. Similarly, an -1.0 value in the “N” box will apply a 1 arcsec offset to the South.

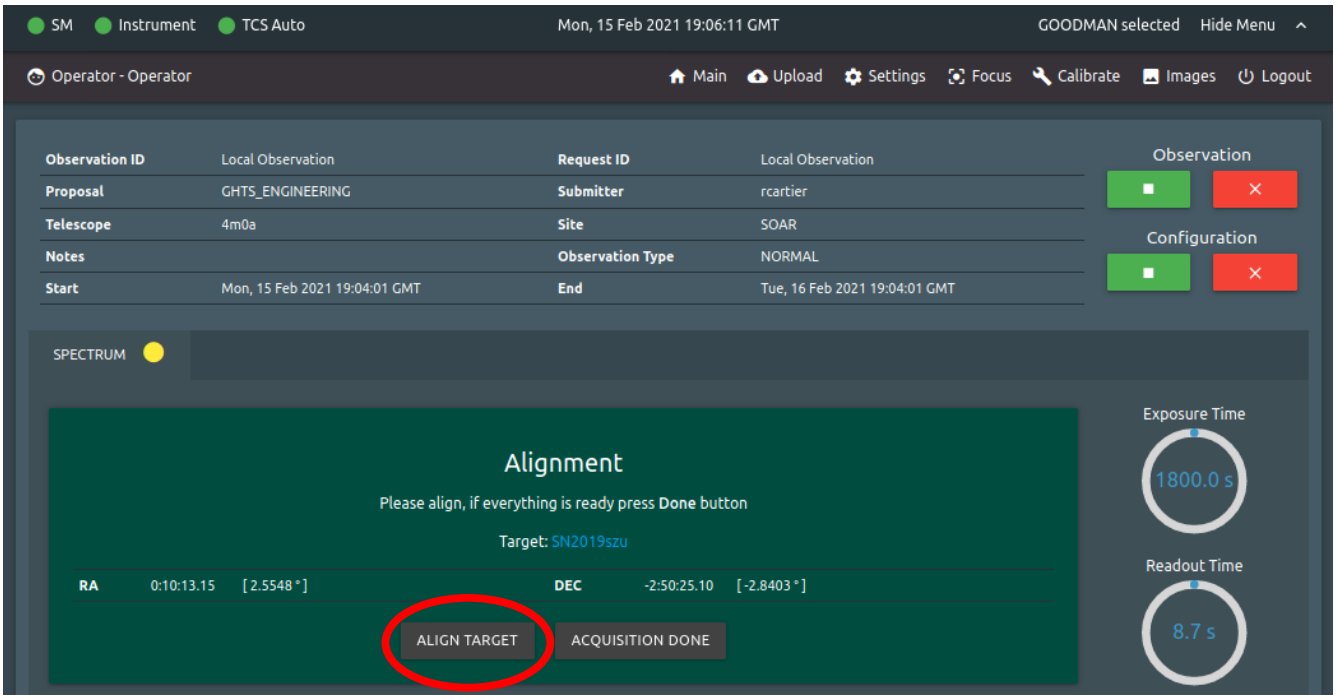
The Operator also has other tools they may use for fine centering with offsets, any of which will work. Examples are applying the offsets from the Offsets panel of the Goodman GUI, or applying the offsets from the TCS applications available to the Telescope Operator.

Imaging Acquisition

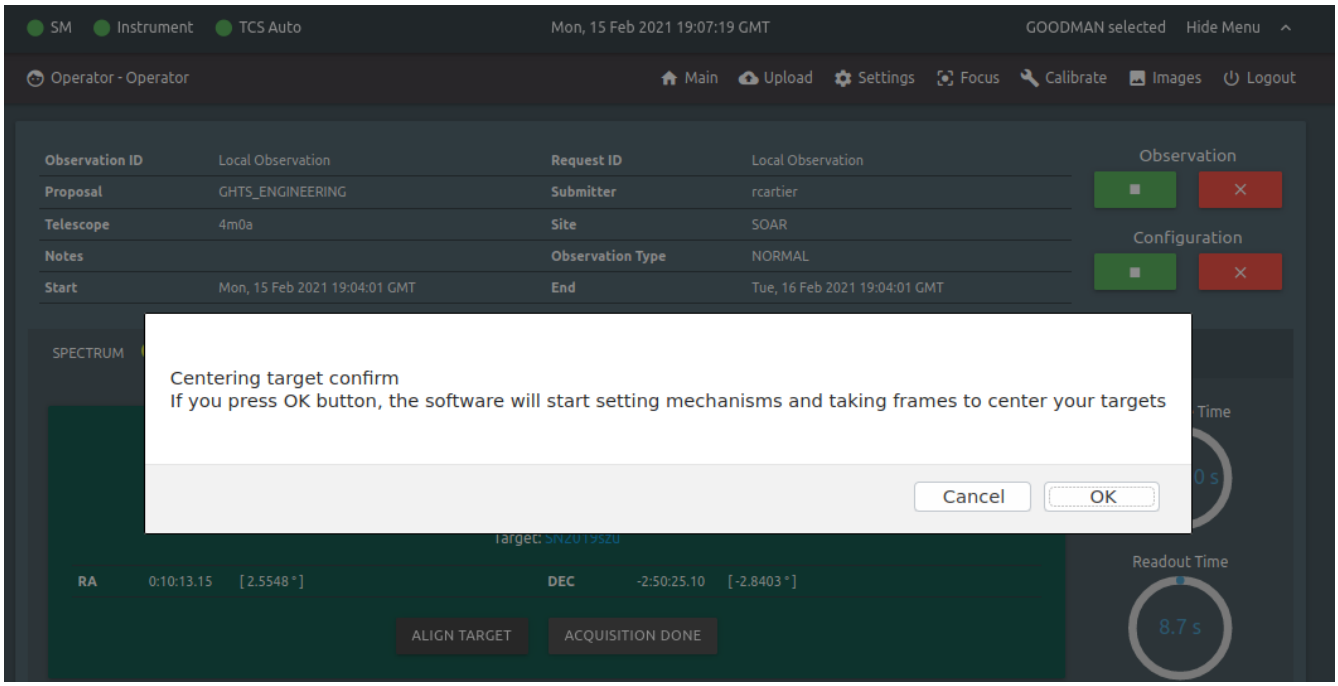
Imaging acquisition is the process of setting Goodman in imaging mode, taking an image of the field, and image of the slit, allowing the user to compute X and Y coordinates for the science target in the field image, and for the slit in the slit image, type those coordinates in the Goodman GUI offsets panel, compute and apply those offsets in that tool, and take a third image, with the slit mask in the IN position, to check that the target is centered in the slit.

Imaging acquisition is used for very faint targets, or complicated target, such as a faint SN blended with its host galaxy.

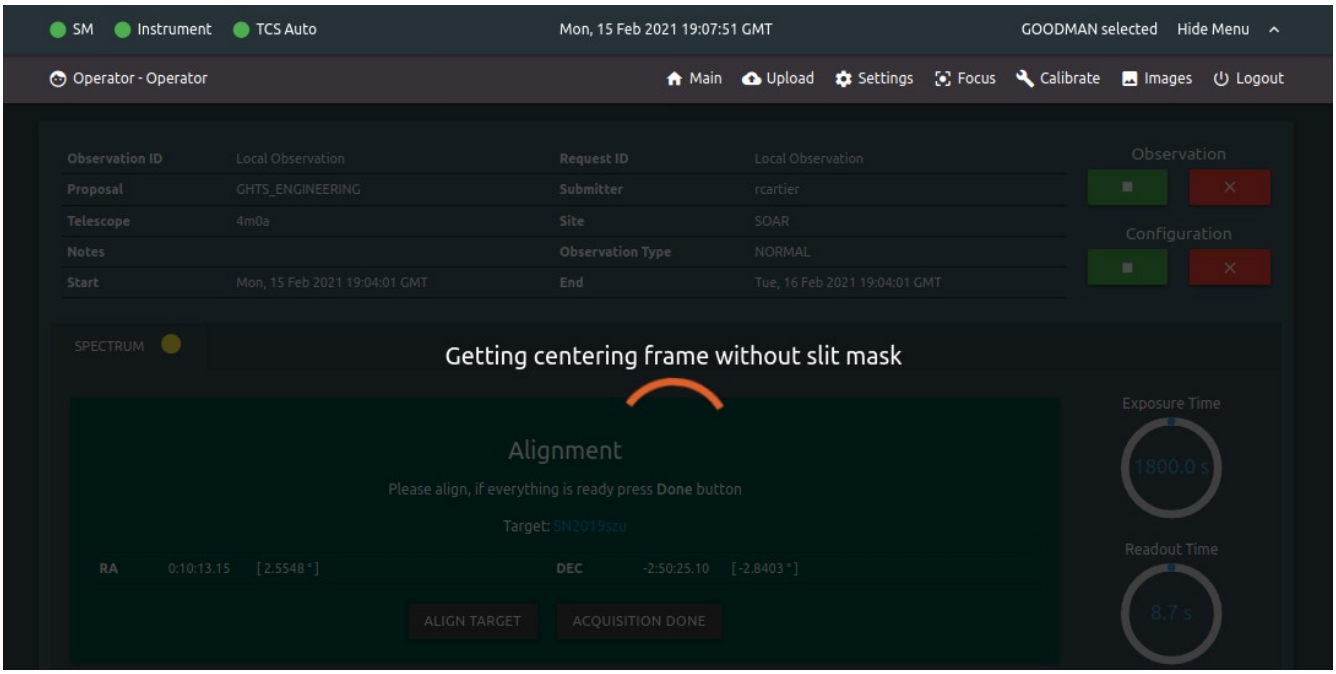
The imaging acquisition process in the OSM is triggered by clicking on the *"ALIGN TARGET"* button in the green alignment pop-up window.

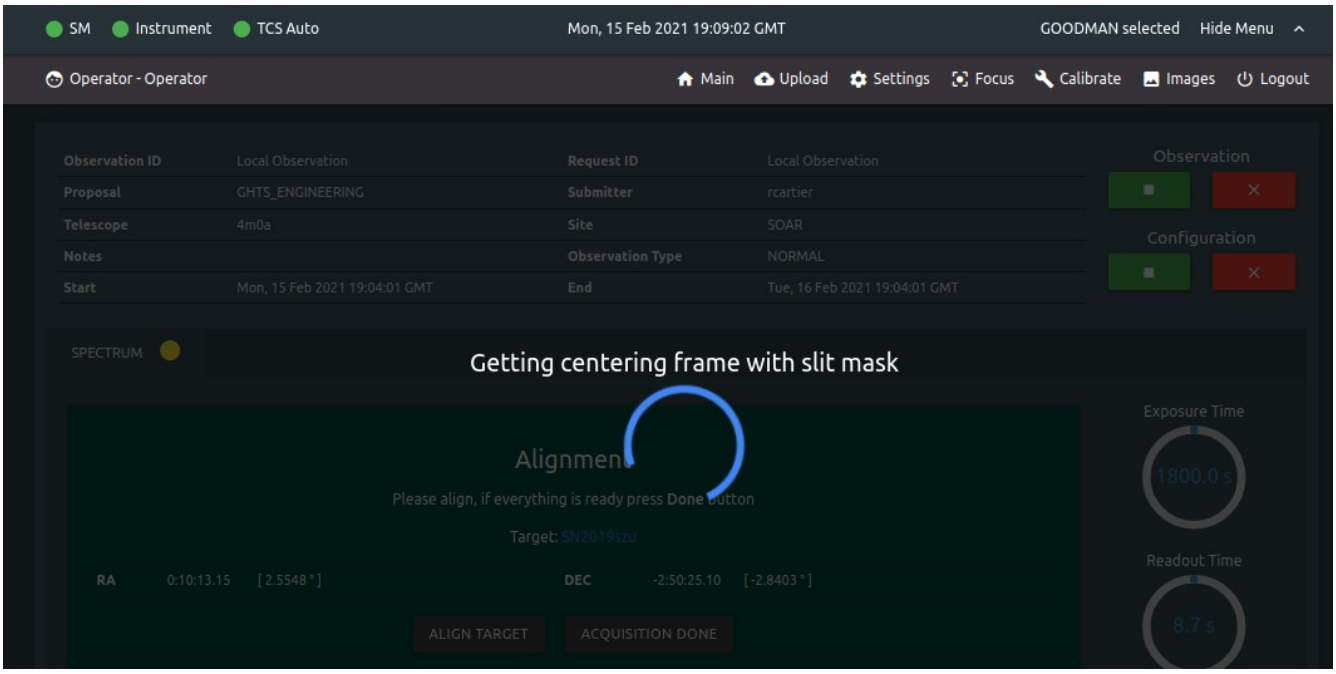


A confirmation dialogue window will pop up. Click OK to continue.

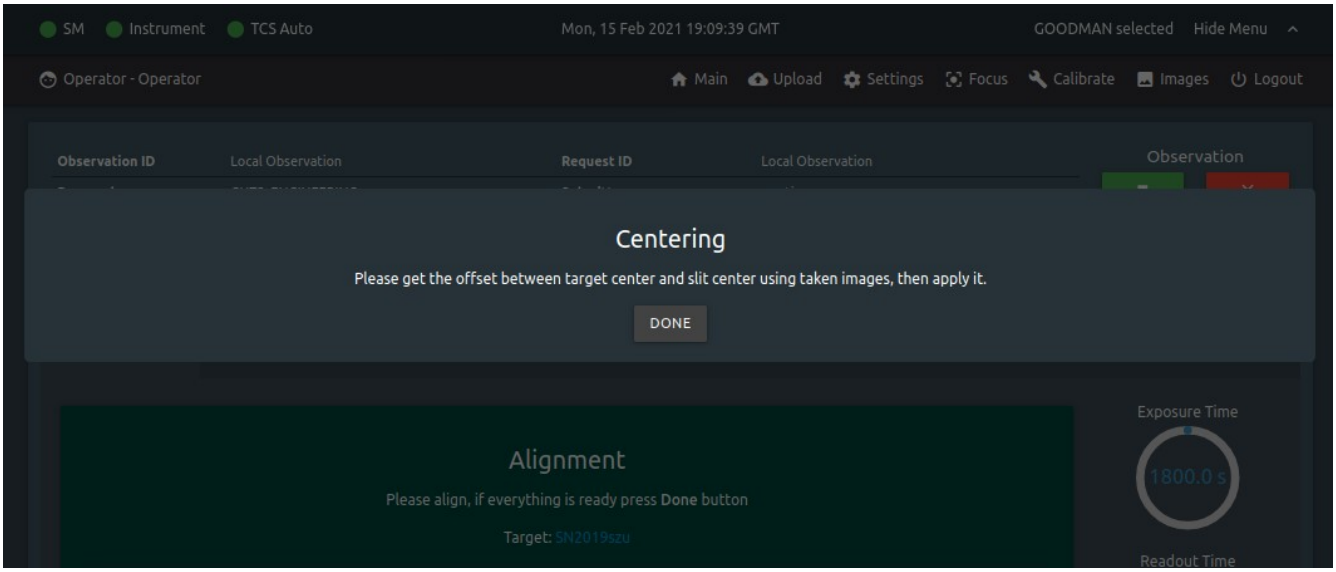


The process will start and the OSM will display the following progress messages. Exposures are 30s.





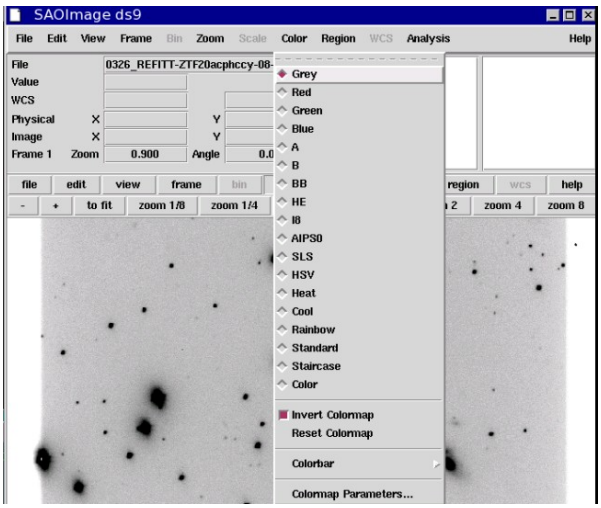
Once both exposures have been obtained, you will be presented with the following screen:

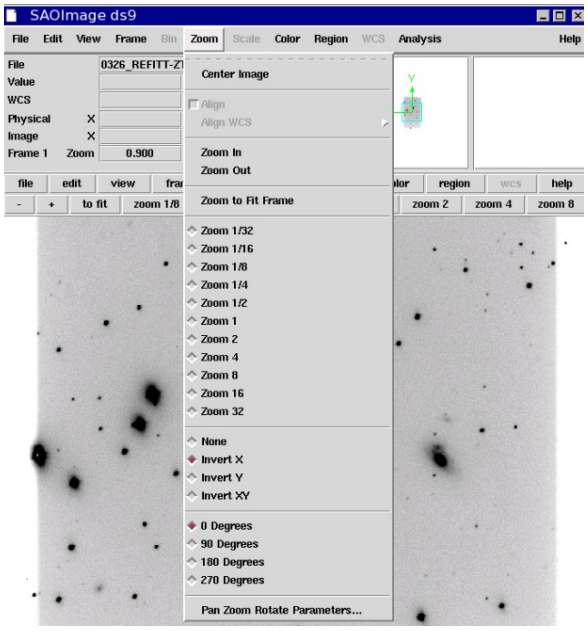


Analysis of the Acquisition images.

You do not need to wait until both exposures are finished to start your analysis, in fact, it is recommended you are ready in the IRAF environment in soaric7, to display the first image as it is done. But first set up the DS9 display tool in IRAF:

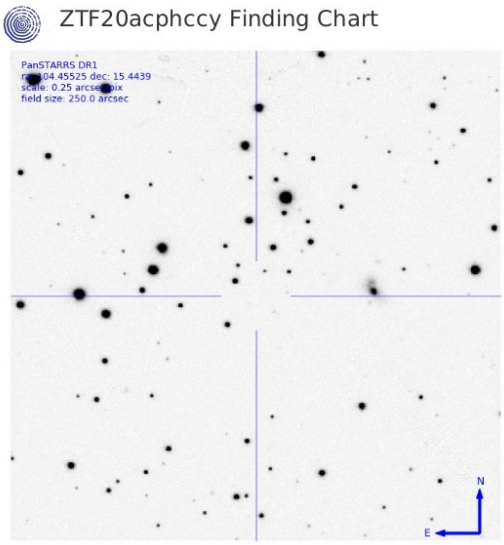
- Select the Inverse Grey scale map in the Color menu, as shown below left.
- Set the correct display orientation in the Zoom menu, as shown below right. This setting will mean that E will be to the left of the image and N up (for an instrument PA=0 deg).



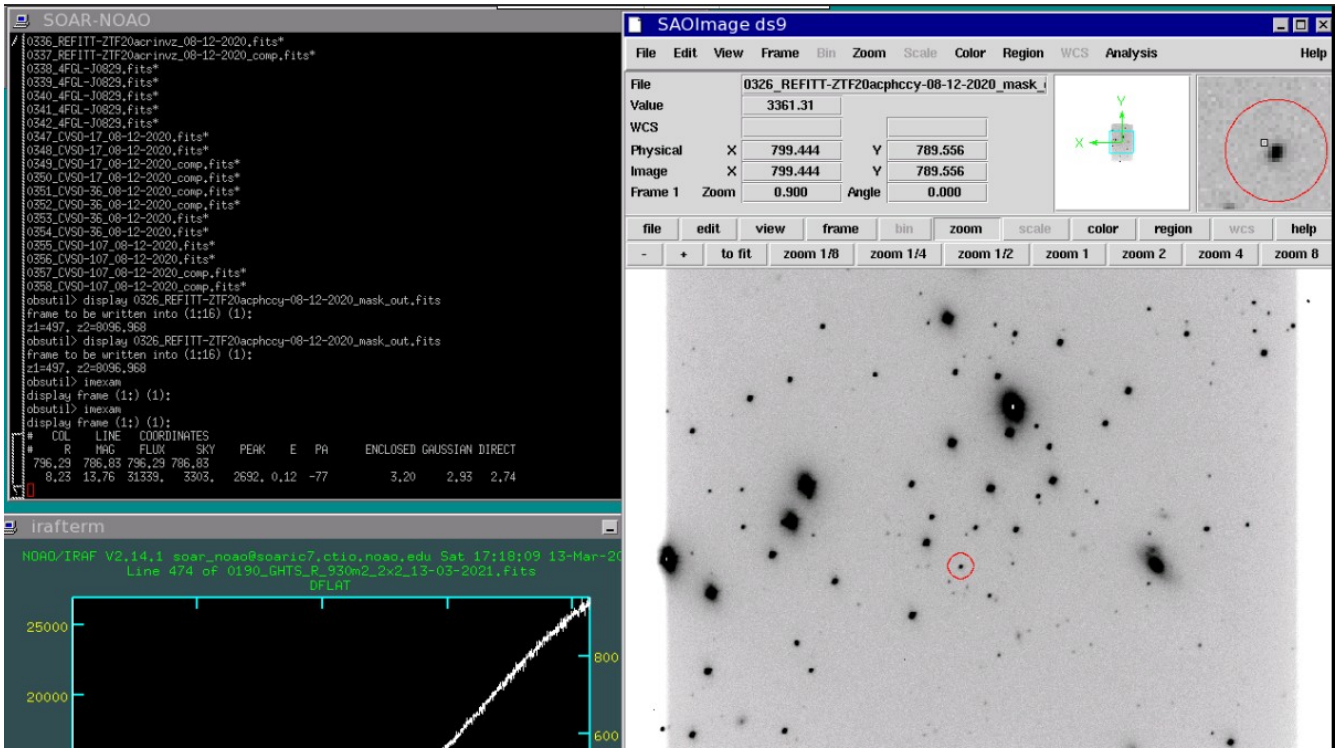


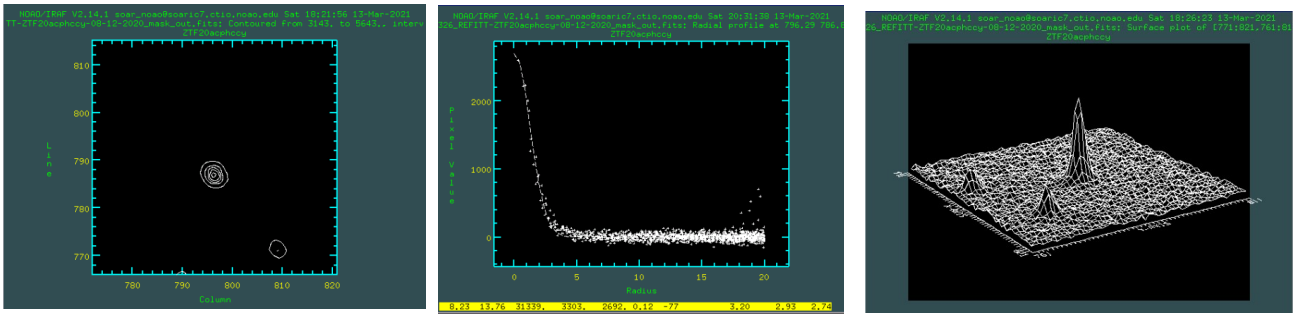
1. Display the image of the field (extension "*mask_out.fits*") typing the `display` command in the IRAF terminal, followed by the name of the image. Remember that you can take advantage of the autocomplete feature in IRAF, by starting to type the image name….e.g., *"0326_"* followed by the TAB key. Adjust the contrast in the DS9 display by dragging the mouse over the image holding down the right mouse button.

2. Identify the target. In the example shown below, the target is the faint point source inside the red circle in the image shown in DS9 below. The finding chart sent by the program PI is shown here on the right.



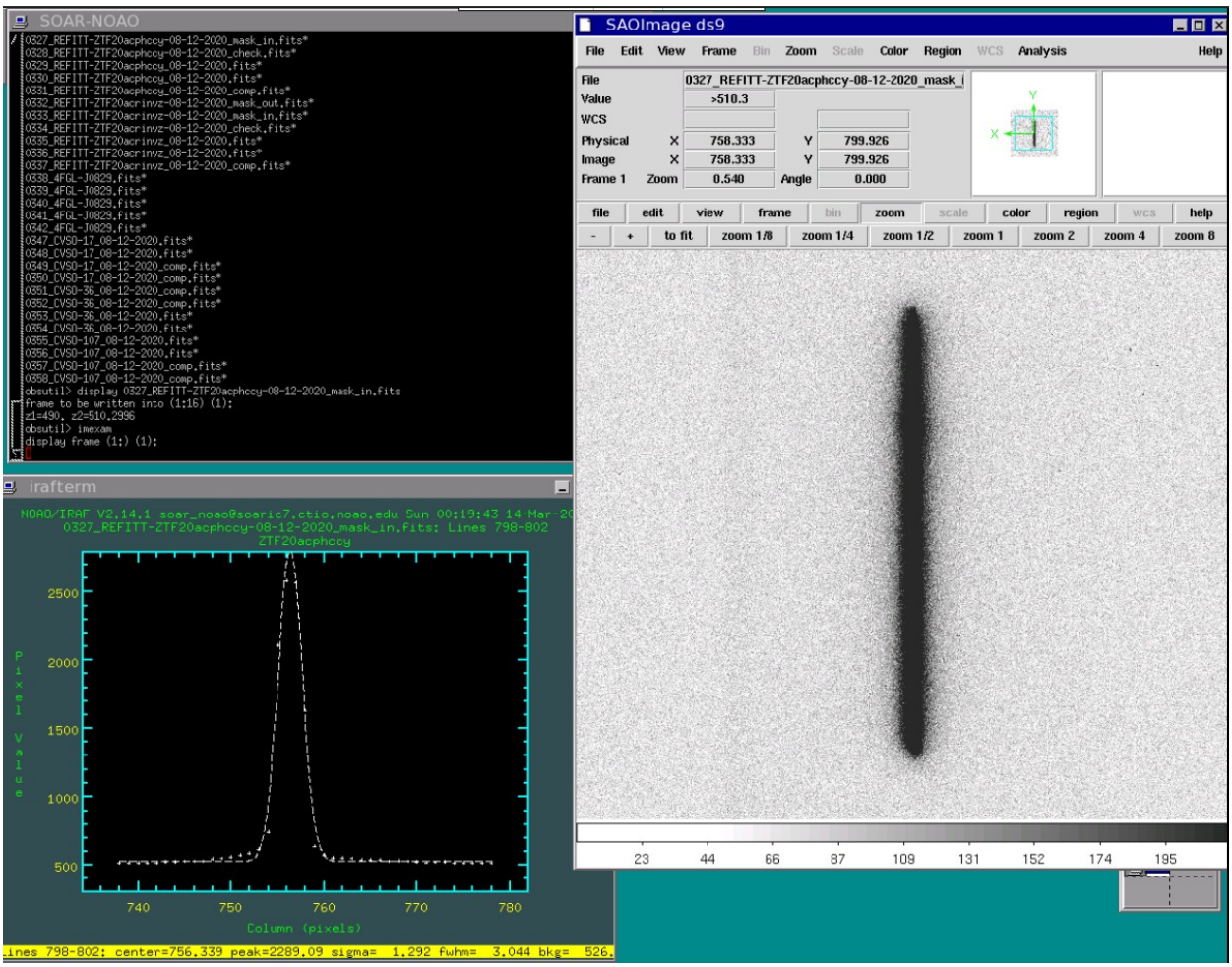
3. Type `imexam` in the IRAF command terminal, to enter the interactive image examination mode. The cursor on the DS9 window will now appear as a blinking small circle. Center the cursor on the target, and hit the "a" key in the keyboard. The X and Y coordinates of the object, and additional information, will be displayed in the IRAF terminal. In the example, the target coordinates are X=796.29, Y=786.83, counts are PEAK=2692 ADU, and DIRECT=2.74 pixels (=Full Width at Half Maximum – FWHM of the target profile, which for the standard 2x2 binning used in AEON observations, is equivalent to 0.15 arcsec/pixel x 2 x 2.74 =0.82 arcsec). This last number is a direct mesaure of the image quality, and should be similar to the site seeing.





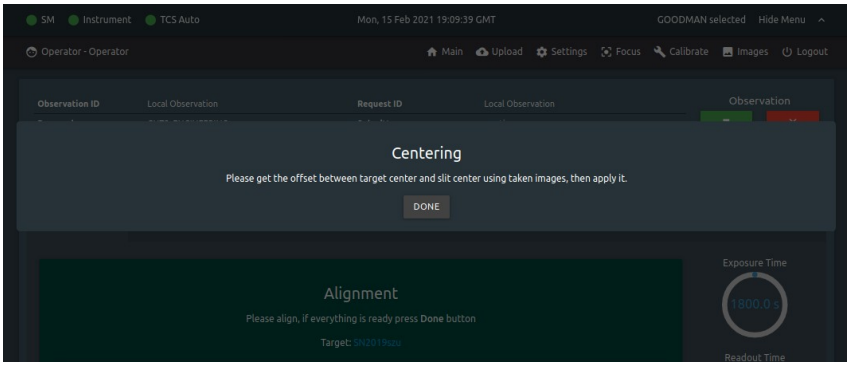
Other functions in interactive mode are: “e”, for an iso-contour plot (below, left), useful to determine how round the images are; “r”, for a radial plot of the target (below, center), displaying coordinates and other info in the plotting window; and “s”, to produce a 3-D plot (below, right), useful to see if the object is saturated. To quite the interactive mode, type “q” when the cursor is on the DS9 window.

4. Display the image of the slit, and use `imexam` to measure X for the slit center. As shown below, place the cursor vertically roughly in the center of the slit (Y $\simeq$ 800), and center it horizontally in the slit, then type “j” to plot the cut along the X coordinate. In this example, X=756.34



5. Type the coordinates of the target in the X and Y boxes for *Current Pixel Values* in the Goodman GUI offset panel. Type the X center of the slit, and 800, in the *"Desired Pixel Values"* X and Y boxes, respectively. Then click the *"Calculate Required Offset"* button. The offsets in arcsec will appear in the two boxes on the right hand part of the panel. Finally, click the "*Apply SOAR Offset"* button. Make sure the guide star returns to its position.

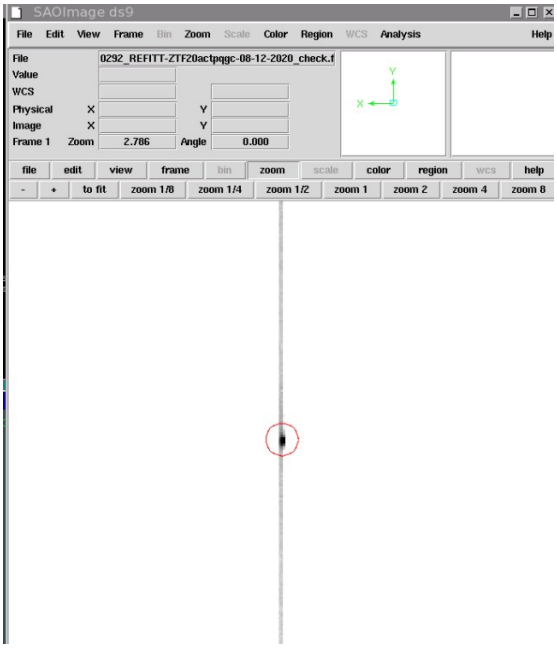
6. Click "*DONE"* in the Centering dialog. The OSM will obtain a third image, with the slit IN. Once finished, display this image (extension *check.fits*). In order to be able to see the target in the slit, you have to adjust the range of display values. The following command in the IRAF terminal will provide a suitable display range for most targets. Adjust the maximum value *z2* to lower/higher counts if needed.




```
display 9292_REFITT-ZTF20actpqgc-08-12-2020_check.fits zs- zr- z1=0. Z2=10000.
```

Adjust the display in the DS9 display with your mouse (right click dragging).

Here is an example of the third, check image showing the target in the slit (circled in red). Some targets will be much harder to see than this one.



7. Complete image acquisition by clicking on the "*Alignment Confirm"* dialog.

   NOTE: After finishing imaging acquisition, and **before** you click *"ACQUISITION DONE"*, you can always go to GACAM and check that the target is centered. For example, in this image it is evident the target is not well centered. That final, small adjustment, is usually more easily done, and much faster, with GACAM, rather than repeating the entire imaging process.

8. Complete acquisition by clicking on the *"AQUISITION DONE"* button. The first target exposure will start.

APPENDICES

Typical Goodman Focus Values (Cam T=15 °C; ambient)

MODE	RED CAMERA FOCUS	BLUE CAMERA FOCUS
400M1	-580	1350
400M2+GG455	-1120	790
600MID+GG395	-365	1450
930M2	-990	950
g-SDSS	-730	1180
r-SDSS	-750	1130
i-SDSS	-925	1000
VR	-740	1140

NOTE: the depth of focus of the GHTS is ~100 focus units. This means that in practice, the focus for the SDSS g, r filters, and the VR filter, are the same. The OSM keeps a database of all focus values. Focus is obtained in 1x1 binning, using the 0.45 arcsec wide slit.

Typical Goodman BIAS std dev values

CAMERA	READOUT MODE	Readout Noise (e-)	Gain (e_/ADU)	AVERAGE VALUE (ADU)	STD DEV (ADU)
RED	344ATTN3	3.89	1.48	496.6	2.02
BLUE	200ATTN0	4.74	1.4	482.3	3.65

NOTE: 2x2 binning

AEON Goodman RED camera exposure times and counts for Dome/Quartz FLATS and ARCs

Mode	ARC Lamp	ARC Texp (s)	QUARTZ LAMP (%)	QUART LAMP Texp (s)	ADU(1)	DOME LAMP (%)	DOME LAMP Texp (s)	ADU
GHTS_R_400M1_2x2	HgNeAr	0.5	70	7		100	7	28700 (3)
GHTS_R_400M2_2x2	HgNeAr	0.5	70	5		100	5	23800 (3)
GHTS_R_600MID_2x2	HgNeAr	0.5	70	5		100	12	28600 (3)
GHTS_R_930M2_2x2	CuHeAr	120	100	3.5	30500	100	60	26700 (3)
GHTS_R_Img-g_2x2	---	---	---	---	---	30	2.5	21000 (4)
GHTS_R_Img-r_2x2	---	---	---	---	---	15	1.5	24300 (4)
GHTS_R_img-i_2x2	---	---	---	---	---	10	1	25900 (4)
GHTS_R_img-VR_2x2	---	---	---	---	---	10	3	25600 (4)

NOTES:

(1) Readout mode: 344ATTN3. Binning: 2x2. Readout times: spectroscopy=8.7s, imaging=10s
(2) All spectroscopy flats done with 1 arcsec wide slit
(3) Maximum counts at the red end of the spectrum
(4) Average counts on a 100x100 pixel box

AEON Goodman BLUE camera exposure times and counts for Dome/Quartz FLATS and ARCs

Mode	ARC Lamp	ARC Texp (s)	QUARTZ LAMP (%)	QUARTZ LAMP Texp (s)	ADU(1)	DOME LAMP (%)	DOME LAMP Texp (s)	ADU
GHTS_B_400M1_2x2	HgNeAr	0.3	70	2.5	30900	100	7	29600 (3)
GHTS_B_400M2_2x2	HgNeAr	0.3	70	2	31800	100	7	30000 (3)
GHTS_B_600MID_2x2	HgNeAr	0.3	70	4	28700	100	12	29500 (3)
GHTS_B_930M2_2x2	CuHeAr	90	100	3	29000	100	45	23600 (3)
GHTS_B_Img-g_2x2	---	---	---	---	---	40	1.5	32000 (4)
GHTS_B_Img-r_2x2	---	---	---	---	---	15	1.5	24600 (4)
GHTS_B_Img-i_2x2	---	---	---	---	---	10	1	22600 (4)
GHTS_B_Img-VR_2x2	---	---	---	---	---	15	1	25100 (4)

NOTES:

(1) Readout mode: 200ATTN0. Binning: 2x2. Readout times: spectroscopy=12.8s, imaging=15s
(2) All spectroscopy flats done with 1 arcsec wide slit
(3) Maximum counts at the red end of the spectrum
(4) Average counts on a 100x100 pixel box

OSM interface *Main* page

Sample AEON Night Observing Report

TBD