Astronomical Event Observatory Network

User Guide to AEON programs on SOAR

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Introduction

First, congratulations of having your program approved and scheduled for being included in the queue we run at SOAR as part of the Astronomical Event Observatory Network (AEON).

Since the 2019B semester SOAR has been running a highly automated queue on select nights the first 4m-class facility available through AEON, offering a highly dynamical scheduling option ideally suited for Time Domain Astronomy, but also very useful for general programs that can benefit from having observing windows on many nights distributed along the semester. We encourage you to visit the SOAR AEON web pages for additional information and details on this new capability

The number of nights dedicated to AEON on SOAR each semester is based on demand. At the end of the TAC process, we receive a list of approved proposals, and we add up all the time from the programs requesting AEON mode; that determines how many nights we will schedule in AEON mode throught that semester. At the present time, all AEON programs have the same priority in our queue.
Currently, only the Goodman Hight Throughput Spectrograph (GHTS) is being offered in AEON mode at SOAR, both in spectroscopic and imaging modes. However, we are also working to add other instruments; we expect to include the TSpec near-IR spectrograph as an AEON capability as soon as the 2022B semester.

The configurations we offer on the GHTS instrument each semester depend on the requirements of the approved AEON programs. The most popular are the 400M1 and 400M2 setups, with the 1 arcsec slit (which samples well the median seeing of 0.7 arcsec at Cerro Pachón), with 2x2 binning. This setup provides low resolution spectroscopy (R~400, or a 3pix FWHM~15 A), over the 300-705nm and 500-905nm wavelength ranges respectively, allowing full optical spectral coverage of targets down to magnitudes ~20 in ~1h. Science cases that need data in the U-band, down to the atmospheric UV cutoff are ideal for the Goodman Blue Camera, with its superb throughput in the UV. All other programs that do not need such sensitivity in the UV, are best done with the Red camera, with its high overall throughput, extended red sensitivity and minimal fringing in the extreme red.

In the following pages we will guide you through the steps needed to get the most out of the valuable time you have been allocated on the SOAR AEON queue, and offer some tips and suggestions that we hope will make your experience with AEON on SOAR a satisfying one, and most importantly, provide your with what you really care about, useful data for your science goals.

Before the start of the semester

1. The SOAR AEON Support Scientist will send each user an email a few weeks before the start of the semester, with the general information of the AEON queue on SOAR, which includes this document and links to the SOAR-AEON web pages.

2. Also, before the start of the semester you will be contacted by our colleagues at Las Cumbres Observatory, who will provide you with the credentials to login to the Las Cumbres Observation Portal, so you can submit your observation requests, either via the web portal, or via the API specifically set for submitting AEON observations to SOAR, and download your raw data (including calibrations).

3. You should also receive credentials from us at SOAR that will enable you to access the Goodman Live Spectroscopic Data Reduction pipeline (GSP), a web-based service that provides browser-based access to both the raw and the 1-D, wavelength-calibrated fully reduced spectra (or reduced images), seconds after the

observation has been obtained. Beyond being another way of accessing and downloading your data, the GSP gives you fully reduced data in real time. You can also access all the raw data, including calibration files, through the [Las Cumbres Observatory Observation Portal (LCO-OP)] and the [NOIRLab Astro Data Archive.]

The AEON observation process at SOAR

The overall process of AEON observations on SOAR is shown at a glance in the diagram below.

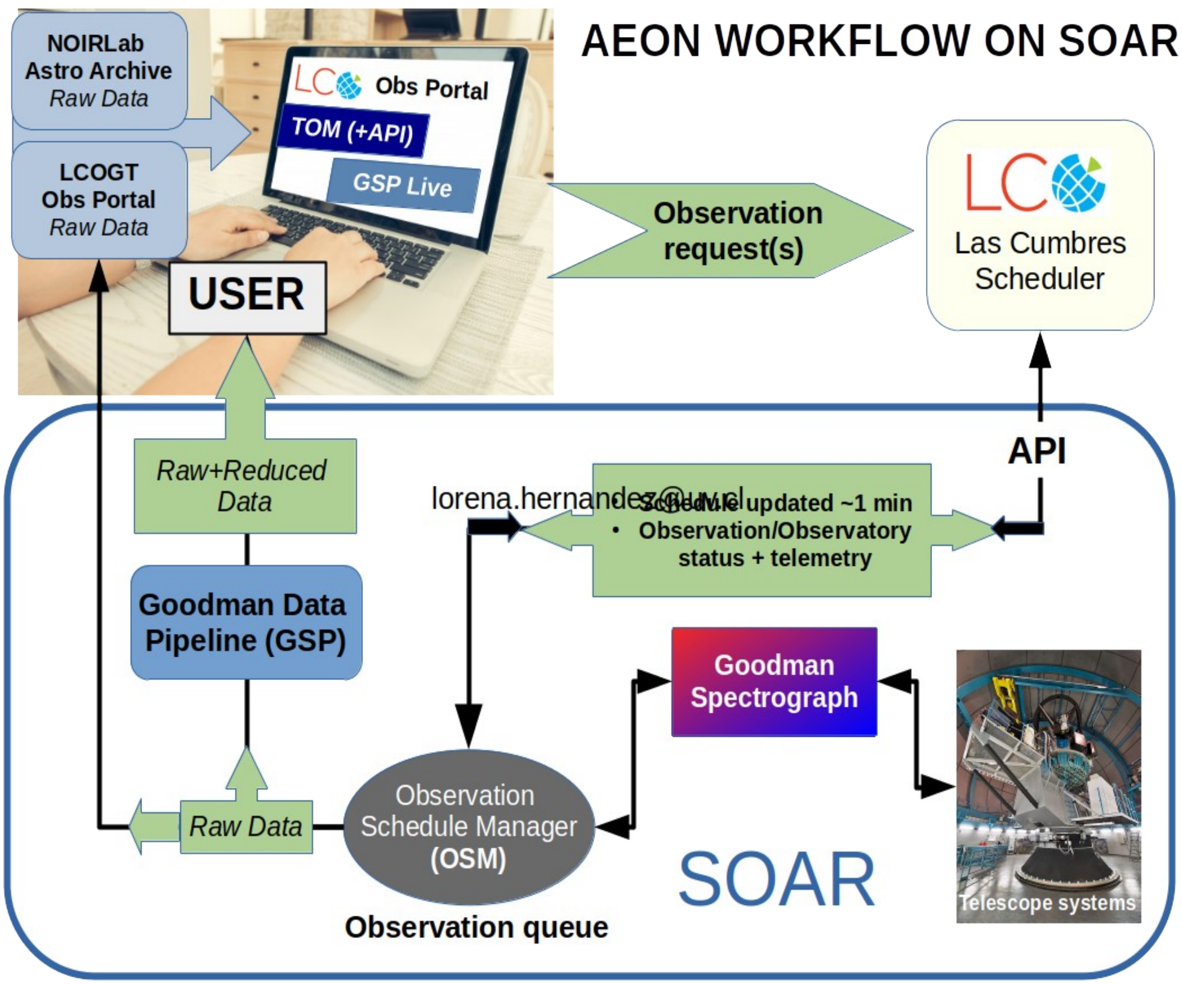

Figure 1: The AEON workflow on SOAR

The user prepares an observation request, most commonly using the [Observation Portal]()at Las Cumbres website, or alternatively submit a request using the SOAR API. Details can be found in the [Las Cumbres Documentation web page]() and in particular in the [Las Cumbres Getting Started Guide.]()

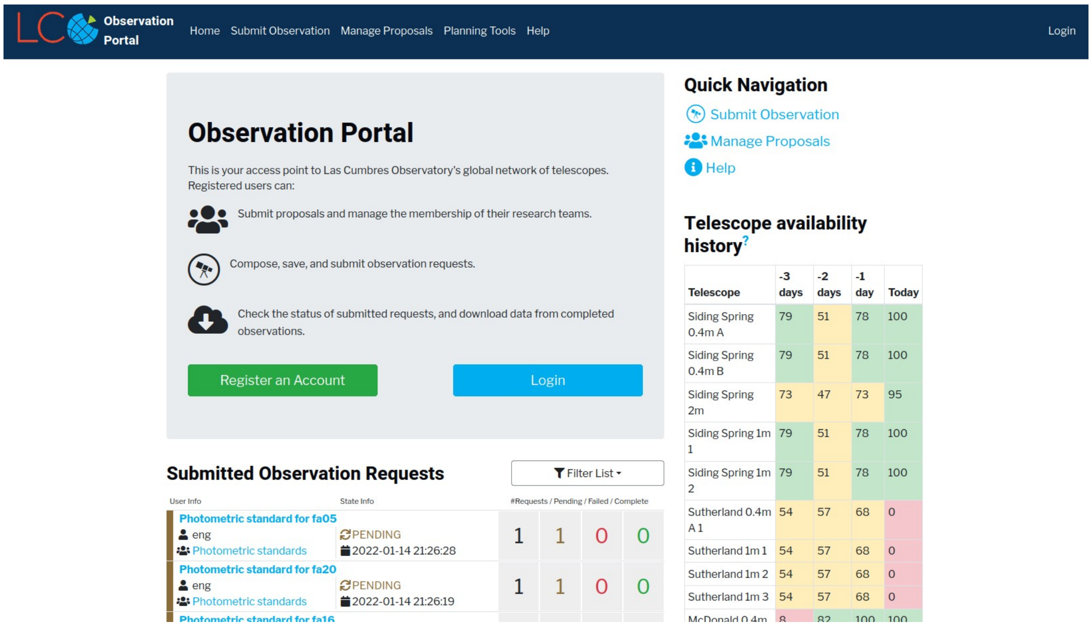

Figure 2: Las Cumbres Observation Portal login page

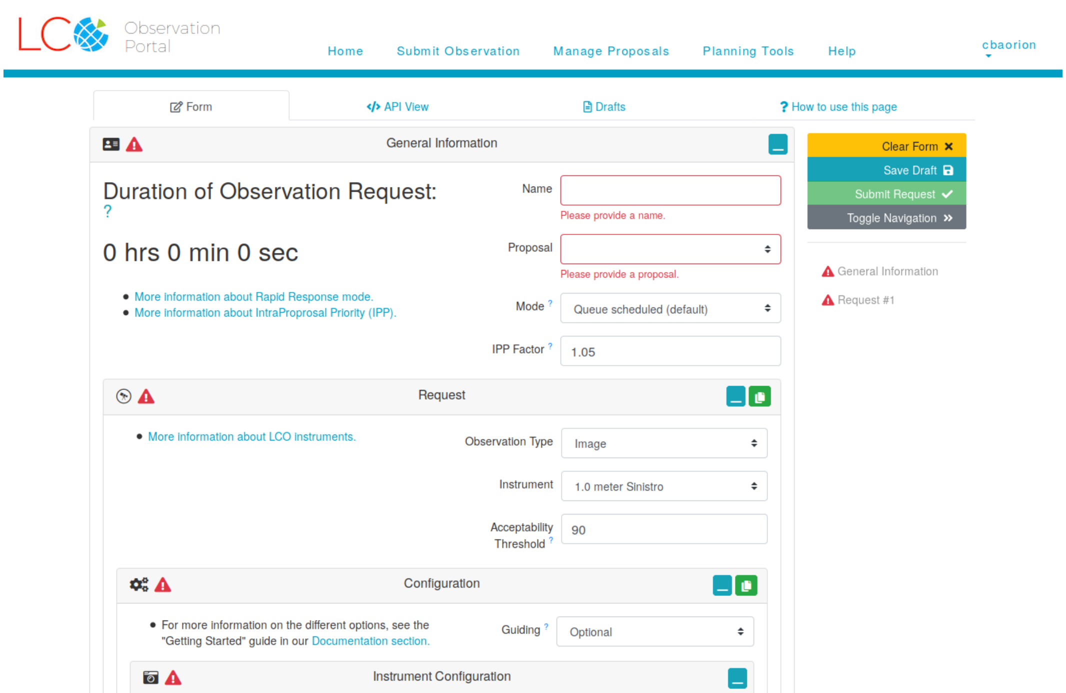

Figure 3: Las Cumbres Observation Portal Observation Request form

Las Cumbres Observation Portal (LCO-OP)

Here we will go through each of the fields found in the LCO-OP web form, which must be filled in order to submit an Observation Request (OR) to SOAR. *Firstly, an OR can be submitted at any time during the semester, even during an observing night. There is no limitation to this beyond the time your program has been allocated.*

Las Cumbres Observation Request Form

The LCO-OP OR web form is divided into the following main sections:

- General Information
- Request
  - Configuration
  - Instrument Configuration
  - Target
  - Constraints
  - Window

As we will see, there can be several Configurations within the same OR, each Configuration block containing equal or differing Instrument Configurations and/or Targets.

General Information.

Contains the overall information about the OR, including proposal ID, what mode is requested and the priority given to the observation.

I. **Name:** provide a name for your OR. Can be the same as your target name or whatever you like.

II. **Proposal:** select your proposal from the list.

III. **Mode:** Select from the menu. The default is "Queue scheduled", which will suit almost all programs. However, you can also chose "Time Critical" and "Rapid Response". For the meaning of these two modes please refer to the LCO Special Scheduling Modes web page.

IV. **IPP Factor (Intra-Proposal Priority):** if you want to give higher (or lower) priority to a given target among your sample, you can increase (or lower) the IPP factor, in the range 0.5 – 2.0. Note however that this will change how the Las Cumbres does the accounting against your total time allocation, for the time used up on that target. Most users don't need to change the default of 1.05, but if you want to, please read carefully the corresponding documentation.

Request.

This section contains all the details about the OR.

I. **Acceptability Threshold:** The percentage of the observation that must be completed to mark the request as complete and avert rescheduling. The percentage should be set to the lowest value for which the amount of data is acceptable to meet the science goal of the request. Default value is 90%.

II. **Mosaic:** Used only for imaging (“Image” selected in *Observation Type* below). Ignore, this parameter is not currently used with SOAR.

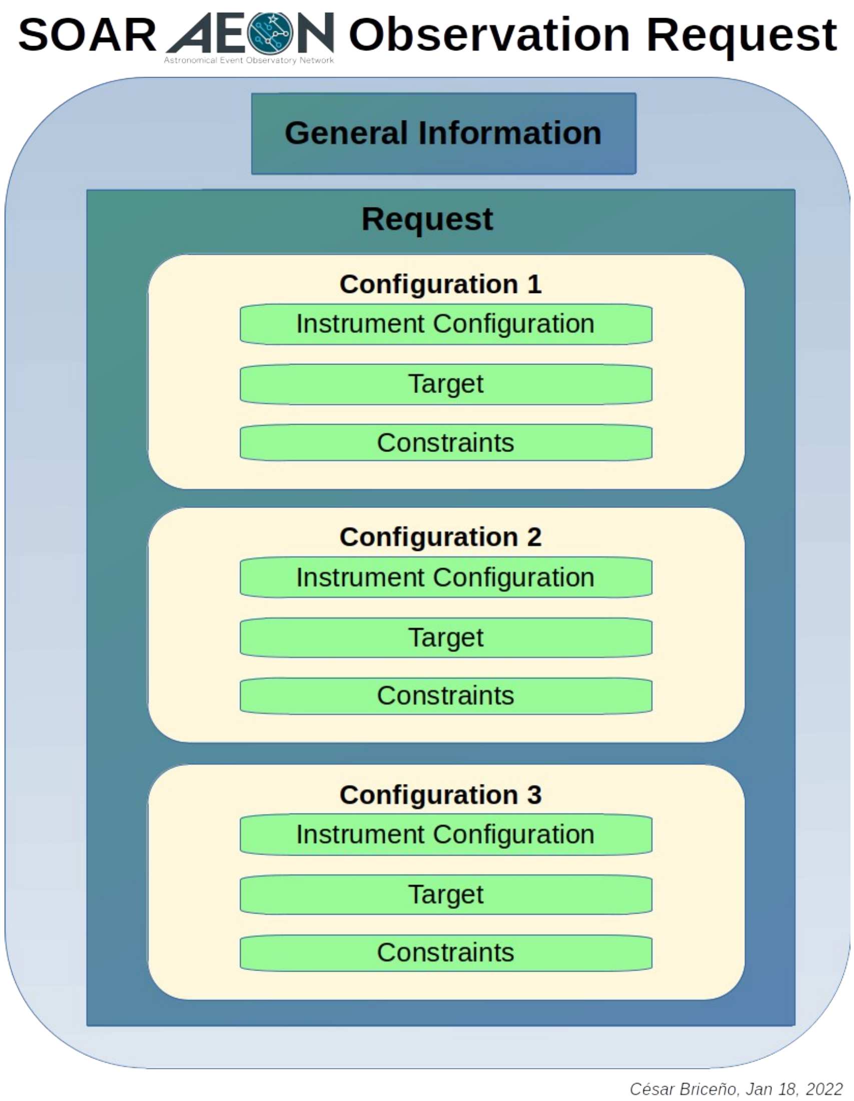

Figure 4: Schematic of the main elements of a Las Cumbres Observation Request

III. **Configuration.** The configuration section contains the specifics of the OR: type of observation(s) (imaging or spectra), position angle (called rotator angle), filters for imaging, gratings/slits for spectra, target details (object name, RA, DEC, type of target – sidereal or non-sidereal-, proper motion, epoch of coordinates, instrument configuration and constraints. You can have many configurations, for example, a series of 3 lampflats, followed by an arc, 3 exposures for the science target, an arc, and another set of 3 lampflats. Or alternatively, if you are imaging, you could have a several sets of SDSS-g, SDSS-r and SDSS-i frames, either of a fixed sidereal target, or a moving object (non-sidereal target).

- **i. Observation Type:** select either “Image” or “Spectrum from the drop down menu.
- **ii. Instrument:** Select either “Goodman Spectrograph Blue” or “Goodman Spectrograph Red” from the drop down menu.
- **iii. Guiding:** Ignore. Guiding is always managed at the SOAR end, by the SOAR Operator-Observer.
- **iv. Type:**
  - If “Image” was selected in “Observation Type” (7), then the only option here is “Exposure”.
  - If “Spectrum” was selected in (7), the drop down menu gives options “Arc”, “Lampflat” or “Spectrum”. With this option you are also presented with a blue button ”Create Calibration Frames” within the *Configuration* section. Clicking on it adds four calibration configuration frames in the “Instrument Configuration” section, one each for an ARC and a FLAT *before* your science spectrum, and one each for an ARC and a FLAT *after* your science spectrum. You can delete any of the calibration blocks to suit your needs (use the red trash bin button), e.g., if you only want a arc(s) and lampflat(s) before the science spectrum, or just one arc and no lampflats.

III.a Instrument Configuration

- **Exposure Count:** number of exposures
- **Exposure Time:** exposure time in seconds. ***Important note:*** exposure times for comparison lamps (*arc*) and quartz flats (*lampflats*) are fixed and hard-coded into the software that runs the AEON queue at SOAR, so for these types of exposures, the *Exposure Time* parameter is ignored.
- **Readout Mode:** select the spectroscopic mode from the pull-down menu. ***Important note:*** as of the end of the 2021B semester, the setup selected from this menu overrides any selection done in the Grating and Slit boxes. This will updated in the near future.
- **Grating:** grating from the pull-down menu. Goodman can hold at maximum, three gratings.
- **Slit:** The spectrograph slit
- **Rotator Mode:**
- **Rotator Angle:** Instrument position angle (PA), in decimal degrees, east of north.

III.b Target. Details of the target

- **Name:** object name. The LCO-OP form will look up the target name. If a match is found, it will automatically fill-in all the fields below.
- **Type:** object type – sidereal, or non-sidereal for targets like Solar System objects.
- **Right Ascension:** RA in decimal or sexagesimal formats
- **Declination:** DEC in decimal or sexagesimal formats
- **Proper Motion RA:** proper motion in RA (milliarcsec/yr)
- **Proper Motion DEC:** proper motion in DEC (milliarcsec/yr)
- **Epoch:** epoch of coordinates. Maximum is year 2100.
- **Parallax:** target parallax in milli-arcseconds (if known)

Note on non-sidereal targets: For non-sidereal targets, a set of orbital elements must be specified, so the Target parameters section changes. The “Scheme” parameter is used to identify the target as either a Minor Planet, a Major Planet, or a Comet. The required orbital elements are: “Epoch of Elements”, “Orbital Inclination”, “Longitude of Ascending Node”, “Argument of Perihelion”, “Eccentricity”, “Semimajor Axis”, “Mean anomaly”. However, the LCO-O supports lookup of the Minor Planet Center (MPC) and JPL Horizons databases, so just by typing the target “Name”, if it is featured in any of these databases, all the information for the orbital elements will be automatically filled in.

III.c Constraints. Minimum elevation and distance from Moon under which your observation can still be scheduled.

- **Maximum airmass:** Maximum acceptable airmass at which the observation can be scheduled. A plane-parallel atmosphere is assumed.
- **Minimum Lunar separation:** Minimum acceptable angular separation (degrees) between the target and the moon.

III.d Window. Time window within which your observation can be scheduled. The larger the time window, the more flexibility you give the scheduler software, within the Constraints, to fit your OR in the queue.

- **Start:** UT time when the observing window opens. *Defaults to current UT time.*
- **End:** UT time when the observing window closes. *Defaults to current UT+24h.*
- **Cadence:** if you set this parameter, it will replace your current observing window with a set of windows, one for each cycle of the cadence. The default is “None”, which results in a single observation executed within the specified time window.
  A cadence is defined by two parameters: **Period**, which is the time interval between individual observations, i.e. how often the observation should be rescheduled. **Jitter:** The dispersion (in decimal hours) around the period during which it’s acceptable to schedule the observation. The jitter must be long enough to contain one OR, including overheads.

API View

The OR form contains a tab **</>API View** at its top (Fig. 3). Clicking on it shows the text formatted as a JSON file, as it needs to be submitted via the API. The **</>API View** web page also provides a “Download as JSON” button that will download the JSON file.

In the following sample, the OR is for 3x300s spectra of the galaxy NGC 1566, preceded by a series of 5 lampflats, 1 arc, and followed by 1 arc.


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```

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        "meananom": null,
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    "guiding_config": {
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```

```
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                }
            ],
            "location": {
                "telescope_class": "4m0"
            }
        }
    ]
}
```


Important aspects of AEON queue observations on SOAR.

- **RED or BLUE camera.** Regardless of what you specified in your proposal, you can use either RED or BLUE camera, restricted only to which one is offered each night. This information is published in the AEON on SOAR semester calendar.
- **Imaging or Spectroscopy.** Even if your program is spectroscopy, you can always choose to do imaging and viceversa, of course limited to the gratings/filters offered each night, which depends on whether it is a RED or BLUE camera night. The configurations offered for each camera are published in the SOAR AEON Features web page
- **Slits and binning:** For spectroscopy, at present we only offer two slits, the 1 arcsec wide slit for most gratings/modes, and the 0.45 arcsec wide slit paired with one of the higher resolution gratings, e.g., the

930, 1200, 1800, or 2100 lines/mm gratings. These slits are well matched to the median 0.7 arcsec seeing at Pachon. All Goodman spectrograph slits are 3.5 arcmin long.

- **Position Angle.** All AEON observations are carried out with the Atmospheric Dispersion Corrector (ADC) deployed in the optical path. This enables the user to select any Position Angle they need for the slit orientation, not limited to the parallactic angle. The default PA=0 deg. For imaging, the ADC provides better images at low telescope elevations, by correcting atmospheric dispersion. The minimum elevation at which the ADC still provides 100% full correction is 30 deg.
- **SOAR elevations limits.** Because SOAR is an alt-azimutal mounted telescope, it has a blind spot close to zenith. Due to damage sustained in the elevation encoders during a 2019 earthquake, the maximum elevation is currently set at 79 degrees. The minimum elevation is 20 degrees. The Las Cumbres scheduler takes into account these elevation limits when scheduling observations, in addition to the constraints set in the OR.
- **Binning, Gain and Readout Noise:** We use a fixed readout modes, that result in 1.48 e/ADU gain and 3.89 e- readout noise for the RED camera, 1.4 e-/ADU gain and 4.74e- readout noise with the BLUE camera. We use 2x2 binning for low-res spectroscopy and all imaging; configurations with the 0.45 arcsec slit and higher resolution gratings, which use 1x2 binning (binning in the spatial direction).
- **Daytime calibrations:** these are obtained every AEON date, 21 bias frames, 15 dome flats in each configuration (except for higher resolution gratings with the 0.45 arcsec slit, which use quartz lamp flats). Users do not need to request daytime calibrations, and these are available to all users of the AEON queue.

- **Night time calibrations:**
  - **Spectrophtometric Standard:** every clear night we obtain spectra of a spectrophotometric standard from the list of Hamuy et al. , in each of the spectroscopic configurations used with the particular camera in use that night. These spectra are available as calibration files for all SOAR AEON users.
  - **Comparison and flat lamps:** through the LCO-OP the user can specify ARC lamps, or quartz flats, to go with their science target. These can be requested before and/or after the science frame(s). The user does not need to worry about exposure times, type of ARC, etc. These parameters are selected automatically by the control software at the SOAR end. Low resolution gratings use HgArNe comparison lamps, the higher resolution setups use HgArNe at visual to red wavelengths, and the CuHeAr lam for bluer setups.

- **Data Reduction:** SOAR provides a real time data reduction pipeline for all observations obtained with Goodman High Throughput Spectrograph (GHTS), both spectroscopy and imaging. Raw data are reduced as soon as the files are written to disk, so you can view (and download, see below) a 1-D, wavelength-calibrated[1] spectrum of your target seconds after the observation has finished. The [Goodman Live Data Pipeline] (GSP) is accessed through a browser (see Fig.5) , using credentials supplied to each SOAR-AEON user at the start of the semester, there is no software to download or install.

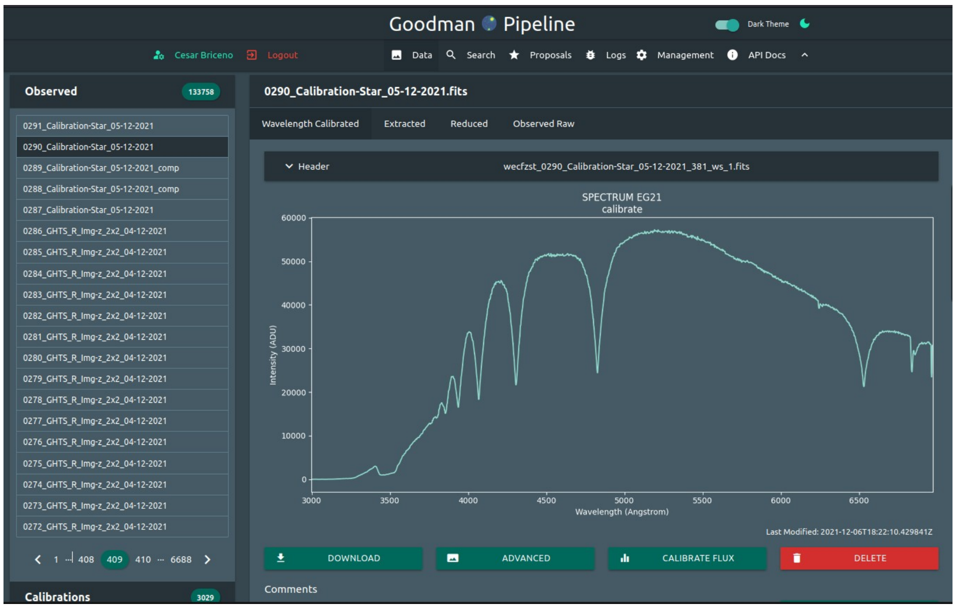

Figure 5: Reduced spectrum of a spectrophotometric standard star produced by the GSP

- **Data access and download.** There are several ways to access the data obtained through the AEON queue on SOAR. Use whichever option best suits your needs and preference.
  - **Las Cumbres Observation Portal.** See the [documentation] in their help page. Gernerally, you will login with your account credentials and then you monitor the progress of your ORs, and access/download all your data, including calibrations.
  - **Goodman Live Data Pipeline:** As we mentioned before, you can access your **reduced** data in real time, and download both the raw and reduced frames.
  - **NOIRLab Astro Data Archive:** All raw data is currently stored in the **[NOIRLab Astro Data Archive]**, which you can access via a web form or programmatically through its API.
- **Monitoring the progress of observations.** You can look up whether your observation has been executed, or failed, and even look at your reduced data, by connecting to the [LCO-OP] and the [GSP]. ***Observation requests can be submitted at any time during the semester,*** and in particular, if your observation failed, or you want to repeat the observation for any reason, you can submit a new OR at any time during the night, or for the next date.

1 The spectrum will be extracted automatically for most sources. Blended sources and spectra with very low SNR may not be extracted automatically by the software. The extracted spectrum will be calibrated in wavelength as long as suitable ARCs were obtained for the same configuration. The software will look for such calibrations in its database.

- **Can I modify, or request a modification to a submitted OR?** No. AEON on SOAR is a highly automated queue system, driven by the Las Cumbres scheduler software. At the SOAR end we have a software, the Observation Schedule Manager (Fig. 1), that communicates with the Las Cumbres scheduler, downloading an update schedule every ~1min, and parses as commands to our Telescope Control System and the Goodman instrument, the instruction to slew to target, set target name, exposure times, configuration and every other relevant parameter specified in the OR. Though we have a human operator at SOAR, he/she is in charge of starting/stopping the OSM (depending on weather/technical conditions), selecting a guide star for each target, and centering the target on-slit, in the case of spectroscopic observations.

  This means *the Operator/Observer at SOAR cannot intervene the queue as downloaded from Las Cumbres*, nor modify any parameter of a given observation. This is by design. If you realize you need to modify an observation request, you need to cancel it at the LCO-OP. Next time the scheduler updates, if the observation has not already started at SOAR, it should not feature in the new updated queue.

Where to get help

For assistance with composing observation requests, or for information on AEON-SOAR operations, users can contact LCO's Science Support team by emailing science-support@lco.global. For questions about the SOAR telescope, the Goodman spectrograph and the Goodman data reduction pipeline, please contact Cesár Briceño (cesar.briceno@noirlab.edu).

References and Useful Links

Observing with SOAR web page

Goodman High Throughput Spectrograph web page

Goodman Live Data Pipeline Documentation

AEON web page at SOAR

AEON web page at Las Cumbres Observatory

Getting Started on the LCO Global Telescope Network guide

Las Cumbres Observatory help page

NOIRLab Astro Data Archive

Arizona–NOIRLab Temporal Analysis and Response to Events System (ANTARES) broker

NOIRLab Astro Data Lab