AEON @ the SOAR, Blanco and Gemini Telescopes

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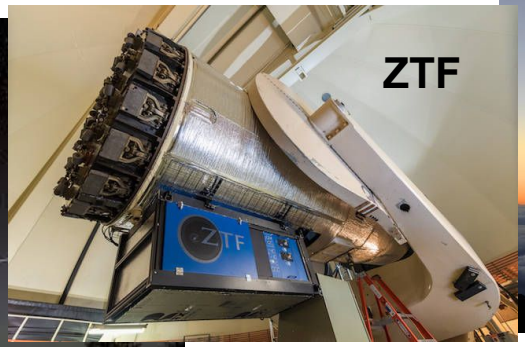
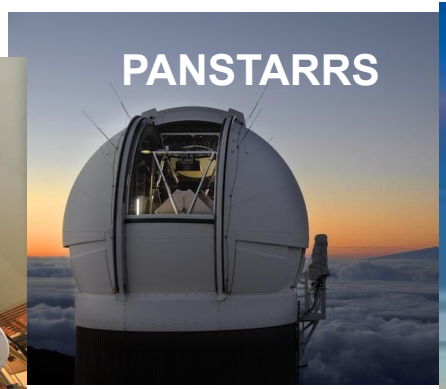
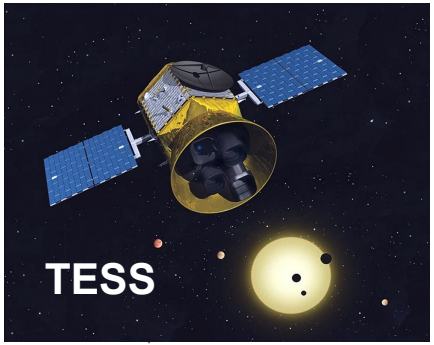
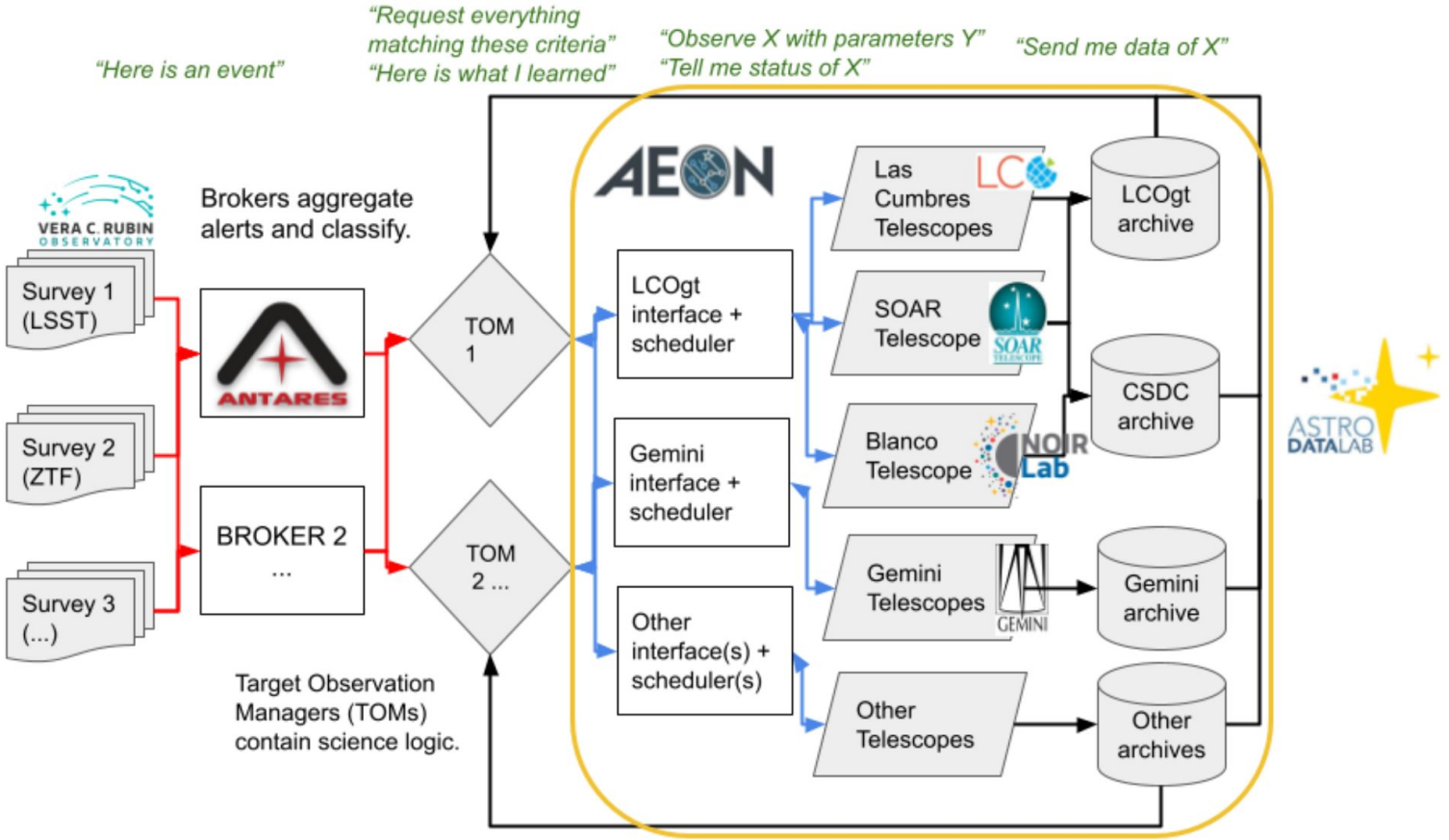
Discovery engines have propelled Time Domain and Multi-Messenger Astronomy







TIME DOMAIN ECOSYSTEM



The Astronomical Event Observatory Network

A collaboration (since 2018) between NOIRLab and Las Cumbres Observatory (LCOGT) to develop and promote a network of programmatically accessible, dynamically scheduled telescopes

- **Project Scientists**
  - Gemini: Bryan Miller, Monika Soraisam, Andrew Adamson
  - SOAR & MSO: César Briceño
  - Blanco: Guillermo Damke
  - Las Cumbres: Rachel Street
  - NOIRLab TAC: Dara Norman
- **SOAR AEON Support Scientists:** César Briceño, Mark Everett
- **Developers:** Diego Gomez, Hannah Crayton, Simon Torres, Omar Estay, Marco Bonati, Rolando Cantarutti (MSO/NOIRLab); Jon Nation, Nikolaus Volgenau, Mark Bowman (Las Cumbres)
- **Observatory Representatives:** Lisa Storrie-Lombardi (Las Cumbres), Jay Elias (SOAR), Andy Adamson (Gemini), S. Heathcote (MSO)

An AEON-compatible facility has:

- APIs for accepting observations requests and broadcasting status
- Queue observing mode, preferably dynamically/automatically scheduled
- Data archive for raw/reduced data with API access
    - Real-time data reduction if possible

NSF MSIP has funded US community Open Access time for AEON on SOAR and Las Cumbres

AEON SPECIFIC GOALS:

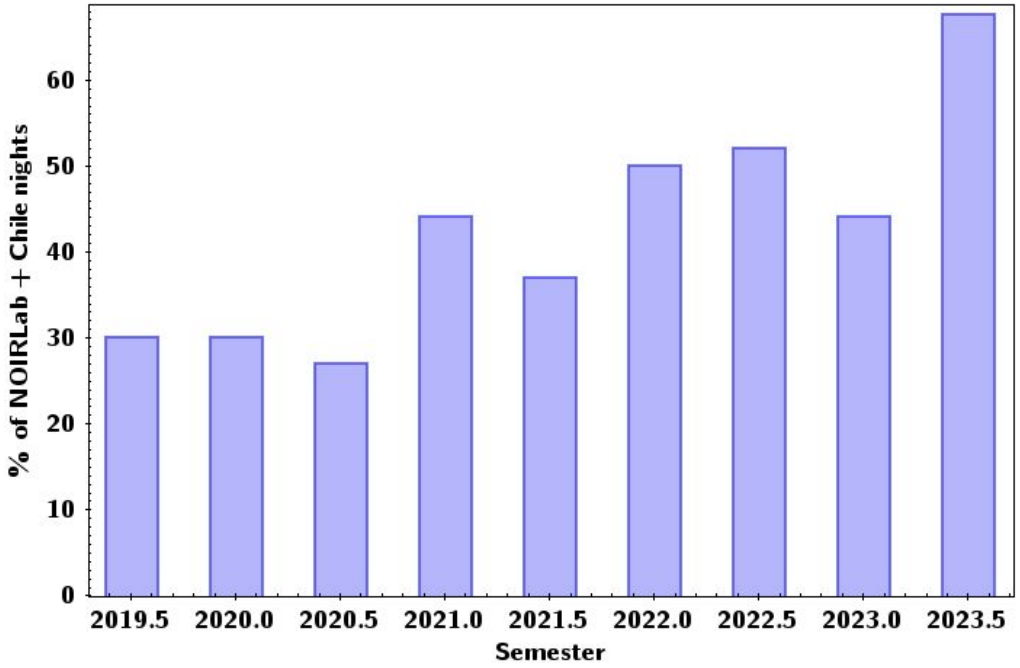
1. Develop interfaces (APIs):
    - connect a facility (SOAR, Gemini, Blanco) to network
    - submit observation request (SOAR, Gemini, Blanco)
2. Start with SOAR as pathfinder facility, running with LCOgt scheduler, execute queue on dedicated nights
3. Add the Blanco 4m with DECam & NEWFIRM, with LCOgt API/scheduler
4. Incorporate Gemini, implement APIs and an automated queue scheduler
5. Encourage data pipelining and archiving efforts
6. Investigate new TAC processes to encourage use of the network
7. Be ready to incorporate other facilities (Rubin in-kind, others)

AEON on SOAR: since 2019B

- **2023A:**
  - 15 programs: 11 Goodman, TSpec (80% NOIRLab, 20%Chile)
  - 37 nights: 45% of combined NOIRLab-Chile science time.
- **2023B:**
  - Programs: 15 regular, 10 ToO (19 Goodman, 6 TSpec)
  - 40.5 nights (additional nights expected to be added); **82% of NOIRLab time, 67.5% of combined NOIRLab+Chile**

- **Science:** *22 science papers w/SOAR AEON data*
  - SN follow up, AGN variability and characterization
  - Follow up of GW events, Kilonovae, GRBs
  - Solar System
  - Characterization of TESS TOIs, novae, nearby Brown Dwarfs
  - LSST Photometric Calibration (WDs)

Demand for the AEON queue mode on SOAR has increased steadily



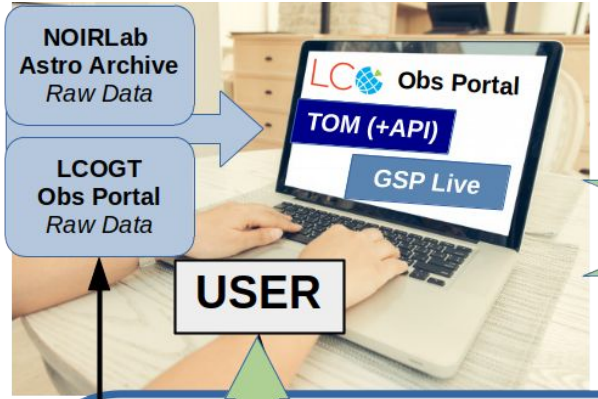
AEON on SOAR: Features

- **Instruments:**
  - **Goodman (optical)** - selected configurations, and **TSpec (near-IR)**
  - Long slit spectroscopy: Goodman - mostly R~850, TSPec R~3500 (fixed)
  - Imaging (optical 7 arcmin FOV) -> Goodman
  - Goodman with ADC always IN -> any PA allowed, better image quality at high airmass

- **Observing :**
  - **Dynamic queue (LCOGT robotic scheduler software),** parsed by custom SOAR software -> automated slews + instrum. Config.
  - Non-sidereal tracking
  - Automated selection of spectrophot standard (optical) - at start of night
  - Automated selection of telluric std (near-IR) for every science target
  - Manual guide star & target acquisition
  - System/observing run by Telescope Operators; Science Support: C. Briceño/M. Everett

- **Real time data reduction (GSP Live) for Goodman (optical) data**
- Automated book keeping -> Night Logs automatically generated, emailed to users at end of night.

AEON WORKFLOW ON SOAR



Observation request(s)

LC Las Cumbres Scheduler

API

- Schedule updated ~1 min
- Observation/Observatory status + telemetry

Raw+Reduced Data

Goodman Data Pipeline (GSP)

Goodman Spectrograph

TSpec Spectrograph

Raw Data

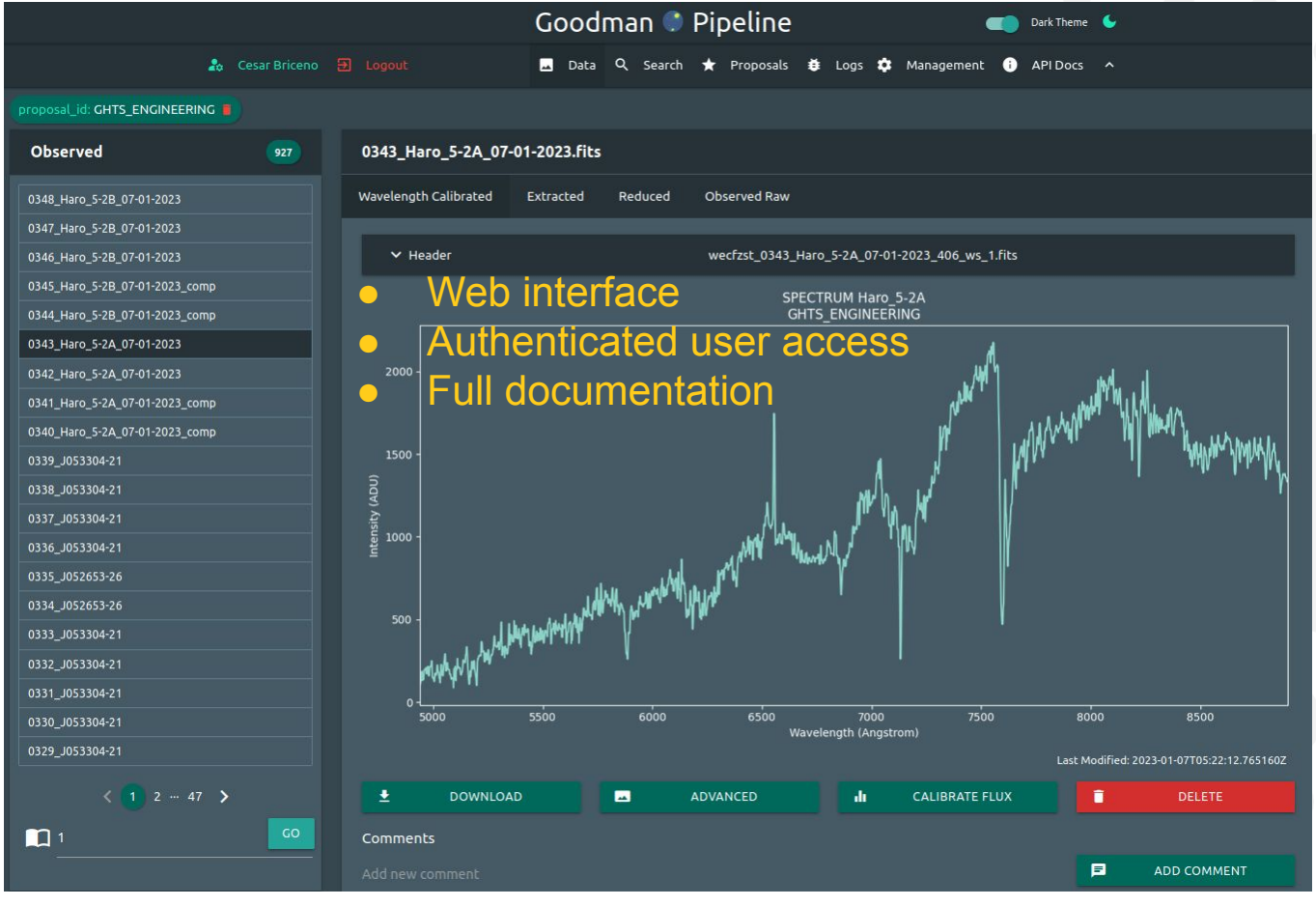
Observation Schedule Manager (OSM)

SOAR

Observation queue

Goodman Spectroscopic Pipeline: Realtime Data Reduction

GSP Live: data reduction in the web browser -> no software to download or install



- Torres-Robledo & Briceño 2019, ADASS XXVII
- Torres-Robledo et al. 2020, ADASS XXVII

AEON @ SOAR & BLANCO: 2023 - 2024

SOAR

- OSM architecture now more modular -> easier to add new telescopes/instruments
- **By end 2023: Add ISPI** (NSF funded) → **near-IR imaging capability** (control software = to TSPec = NEWFIRM)
- Possibly implement tiered observation conditions (by 2024A)

Blanco

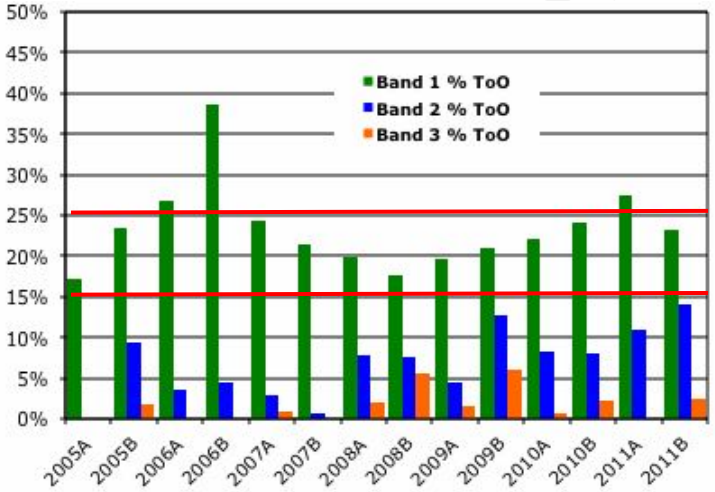
- **AEON implementation w/NEWFIRM ongoing** (control software = TSpec, TCS very similar to SOAR TCS) ⇨ **target 2024A**
- **Develop Blanco API for Las Cumbres Scheduler -> by end of 2023**
- **2024B: DECam.** GUI web-based => enables highly automated queue observ.
- **2024: Implement real-time difference imaging with DECam** - with CSDC

AEON @ GEMINI

Due to queue, Gemini has always done a substantial amount of TDA.

Target of Opportunity observations (ToOs) make up about 15-25% of the time observed in Band 1

- The process is rather manual and not as flexible or capable as it could be



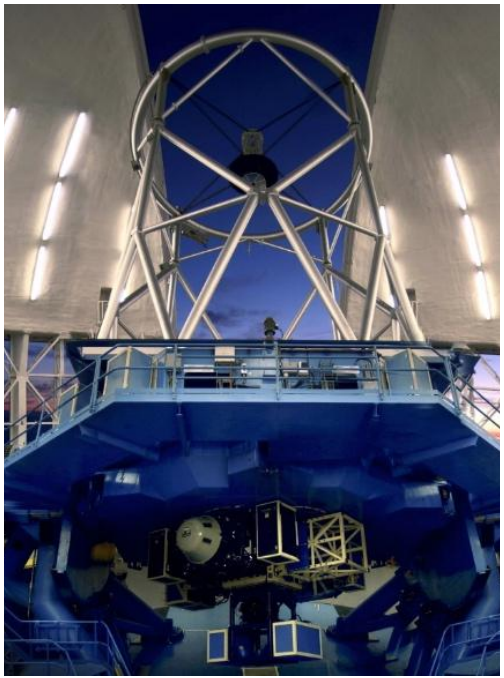
In the era of time-domain surveys (e.g. ZTF, Rubin/*LSST*) and MMA we must be prepared for a higher rate of ToOs.

Improvements are underway to improve ToO capabilities while continuing to enable the breadth of PI research pursued by the Gemini community.

Gemini Instrumentation for TDA and Follow-up

Most facility instruments can be used for ToOs. Workhorse optical/NIR instruments will be the most useful for follow-up. Mid 2020s facility instrumentation:

	Gemini North	Gemini South
Optical	GMOS-N	GMOS-S
	GNIRS	SCORPIO*
	IGRINS-2	GHOST
Near-IR	GPI-2	FLAMINGOS-2
		SCORPIO*
		GSAOI
AO	ALTAIR NGS & LGS	GeMS (MCAO) LGS (5)



Gemini currently works within AEON via a plugin for the TOM Toolkit and existing APIs

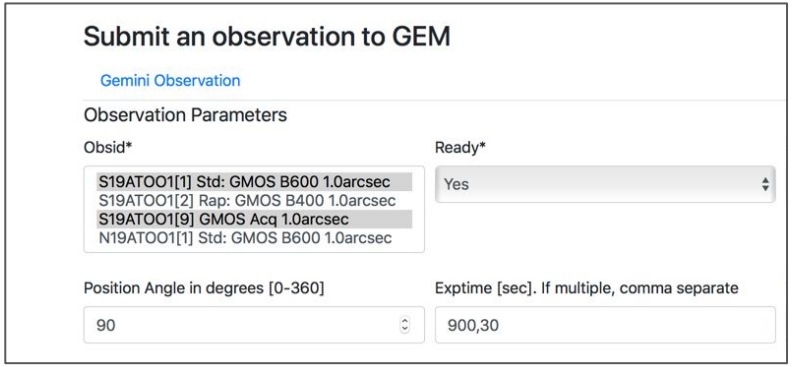
The plugin provides an interface for manual and automatic triggering of Gemini observations.

The ODB API allows programmatic submission of observation requests (ToOs) - but is limited

- https://github.com/bryanmiller/gsselect
- GSM21 ToO process workshop slides

The Gemini Observatory Archive APIs allow the downloading of raw data

- https://archive.gemini.edu/help/api.html
- https://astroquery.readthedocs.io/en/latest/gemini/gemini.html
- https://github.com/bryanmiller/pygoa_gemini




```
The details of the trigger are formatted as an URL string which can be
submitted to Gemini using any browser or URL tool such as wget.  The
following parameters are available.

prog        - program id
email       - email address for user key
password    - password for user key associated with email, site specific
obsnum      - id of the template observation to clone and update,
              must be 'On hold'
target      - name of the target
ra          - target RA (J2000), format 'HH:MM:SS.SS'
dec         - target Dec(J2000), format 'DD:MM:SS.SSS'
mags        - target magnitude information (optional)
note        - text to include in a "Finding Chart" note (optional)
```

Gemini will better support AEON via the Gemini Program Platform (GPP) and GEMMA projects

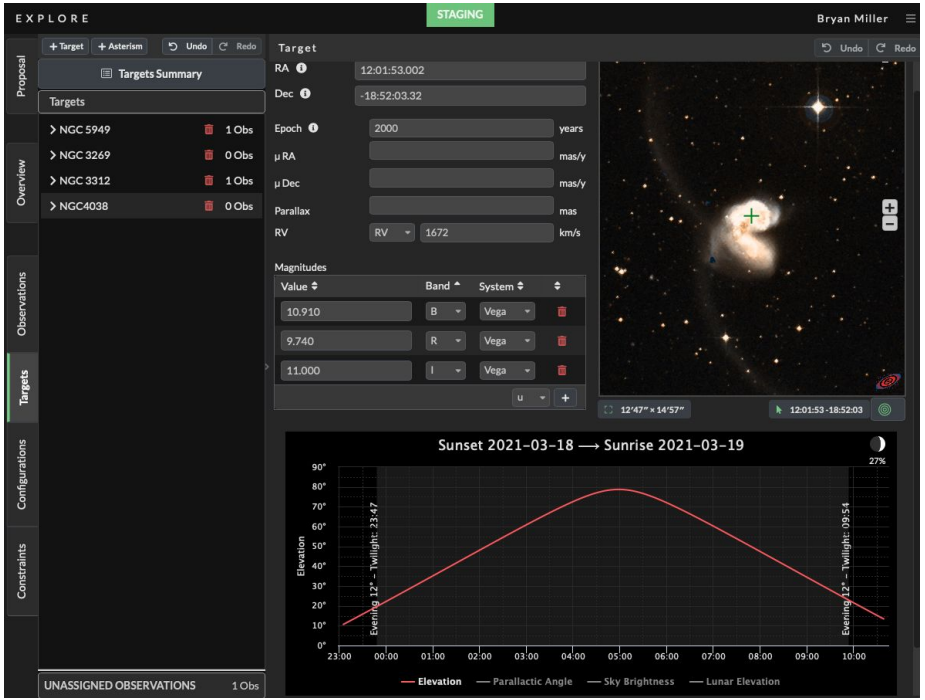
GPP - core of a new observing system

- Easier to use - replaces PIT, OT
- Web apps + APIs + database
- GN/GS observations in the same program
- Provides automation
- Constraints needed for the scheduler
- Makes code more maintainable

For more information:

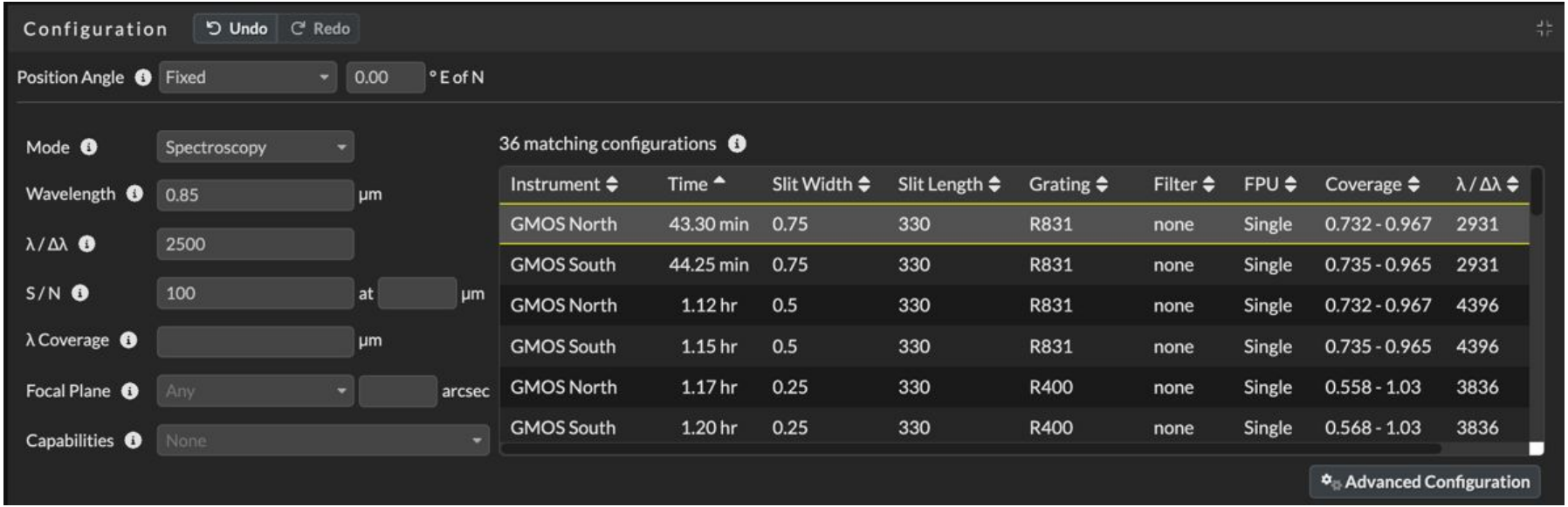
https://www.gemini.edu/observing/operations-development

https://noirlab.edu/public/products/mirro/mirror002/



GPP Explore web app

EXPLORE will allow users to find the capabilities that meet their science needs w/o digging through web pages



The ITC calculates the integration time needed to reach the desired S/N.

Selected an option => the observing steps, including calibrations, are generated automatically

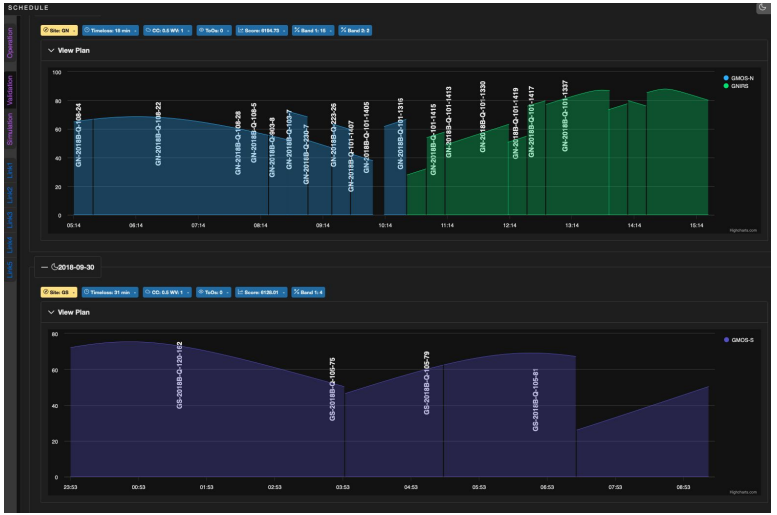
Gemini is implementing real-time scheduling and data reduction as part of the NSF-funded GEMMA (Gemini in the Era of Multi-Messenger Astronomy) project.

Scheduler - under construction

- Updates plans in real-time (weather, ToOs, etc)
- Schedule Gemini North and South together
- More capable APIs

Real-time data reduction

- DRAGONS, imaging and GMOS LS
- Quick look reduction for QA in use
- Real-time QL reduction of ToOs in 23B
- Working on archive and DRAGONS integrations in the TOM Toolkit



GreedyMax-generated plans in the Schedule app.

https://github.com/GeminiDRSoftware/DRAGONS

We expect to start the GPP early science use and testing phase (XT) in 2024.

XT1

- A special call for GMOS imaging/longslit (~May 2024)
- ~5% of telescope time (~100hr/tel) for a reasonable evaluation, scheduler testing

XT2

- Testing as new instruments/modes are implemented
- Convert existing programs, give PIs a time bonus as motivation

Transition to operations is currently expected to start in 2025.

Summary

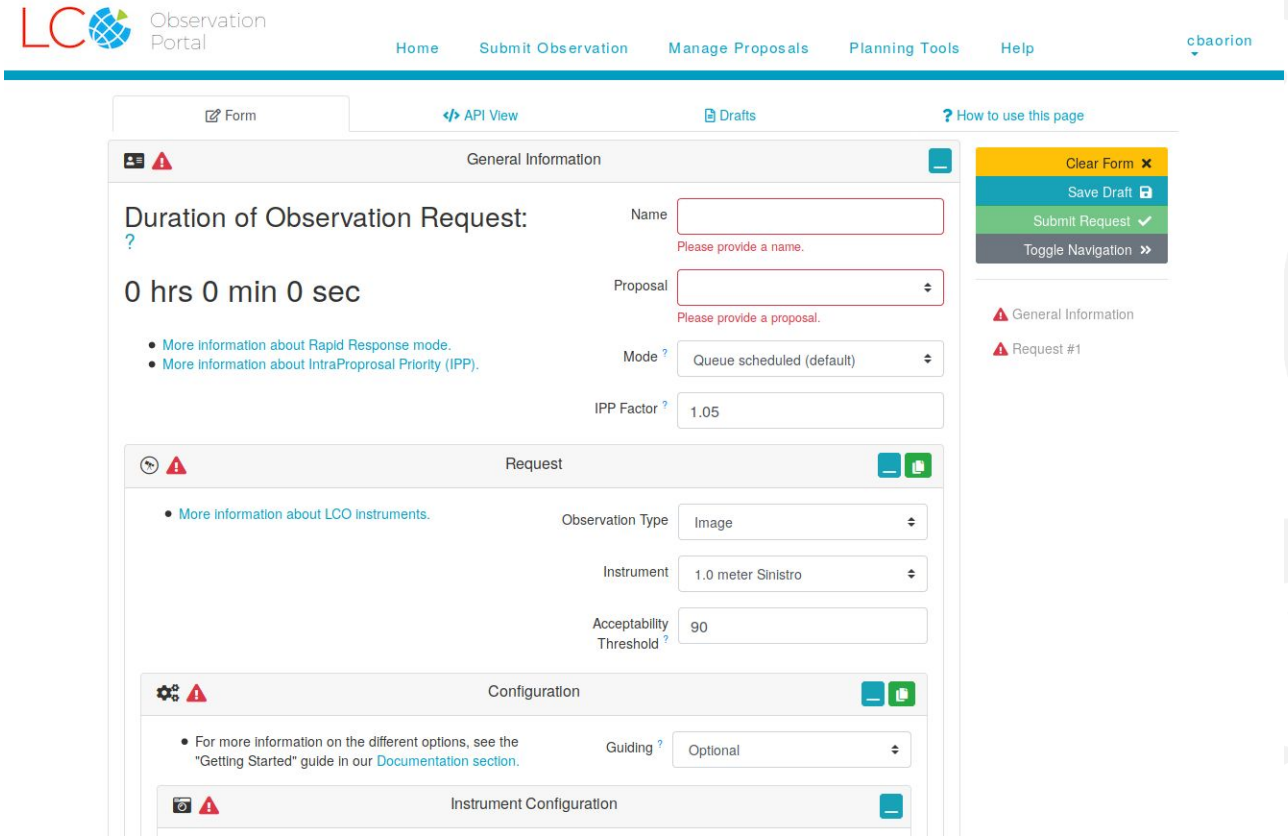
- AEON enables programmatic, automated observing requests & data retrieval
- AEON @ SOAR ~3.5yr: >~80% NOIRLab Open Access time (~24% total science time). TDA, MMA & wide range of science cases
- Users increasingly using GSP: real time quicklook & data reduction
- Work under way for implementing AEON @ Blanco
- TOM Toolkit interfaces for SOAR & Gemini
- Gemini is building an entirely new observing system - GPP & scheduler

⇨ improve automation, enhance ToO capabilities, real time data reduction

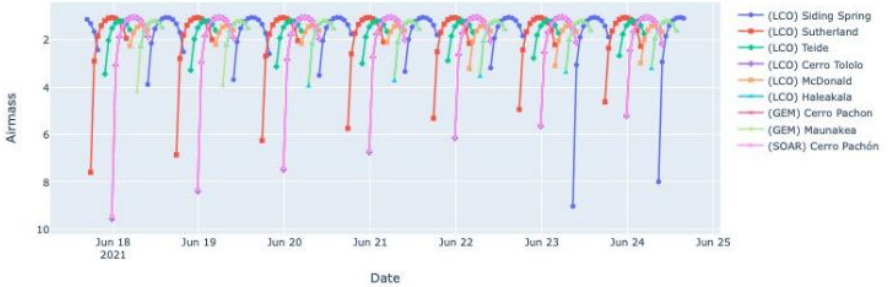
- AEON brings integrated system streamlined for complementary surveys (Blanco wide field optical/IR) & follow up (Blanco-SOAR-Gemini) to LSST

Additional slides

Observation Request on the LCOGT Observation Portal



SOAR AEON Observation Request using APIs & the Target Observation Manager (TOM) Toolkit



Names ANT2018c7igm

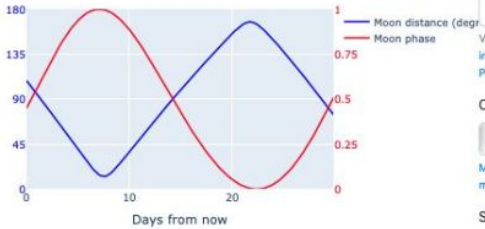
Target Type SIDEREAL

Right Ascension 280.6927
18:42:46.254

Declination -12.9041
-12:54:14.845

Tags

Lunar Distance



Imaging | Spectra

Name* SOAR blue spectroscopy

Slit* 1.0 arcsec slit

Proposal*

Instrument type* Goodman Spectrograph Blue

Intra Proposal Priority (IPP factor)* 1.05

Value between 0.5 to 2.0. More information about Intra Proprosal Priority (IPP). .

Exposure count* 3

Exposure time* 900

Try the online Exposure Time Calculator.

Observation mode* Normal

More information about Rapid Response mode.

Max airmass* 2.0

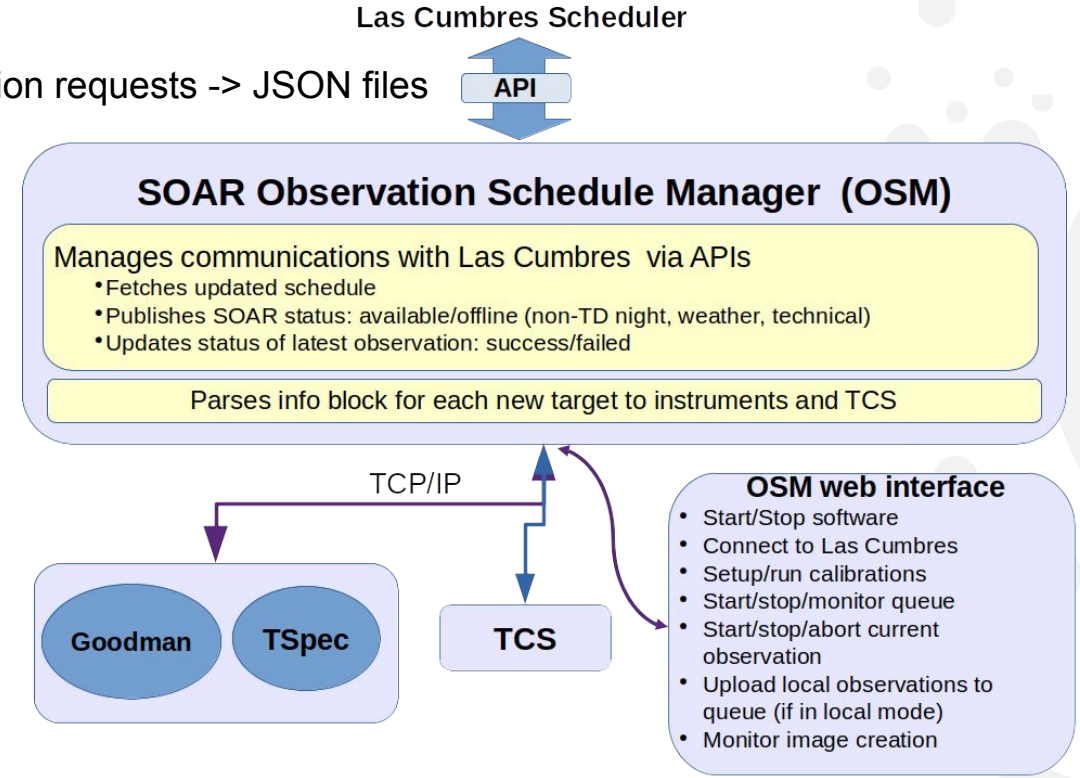
Advice on setting the airmass limit.

Start*

Rotator angle*

SOAR AEON software architecture

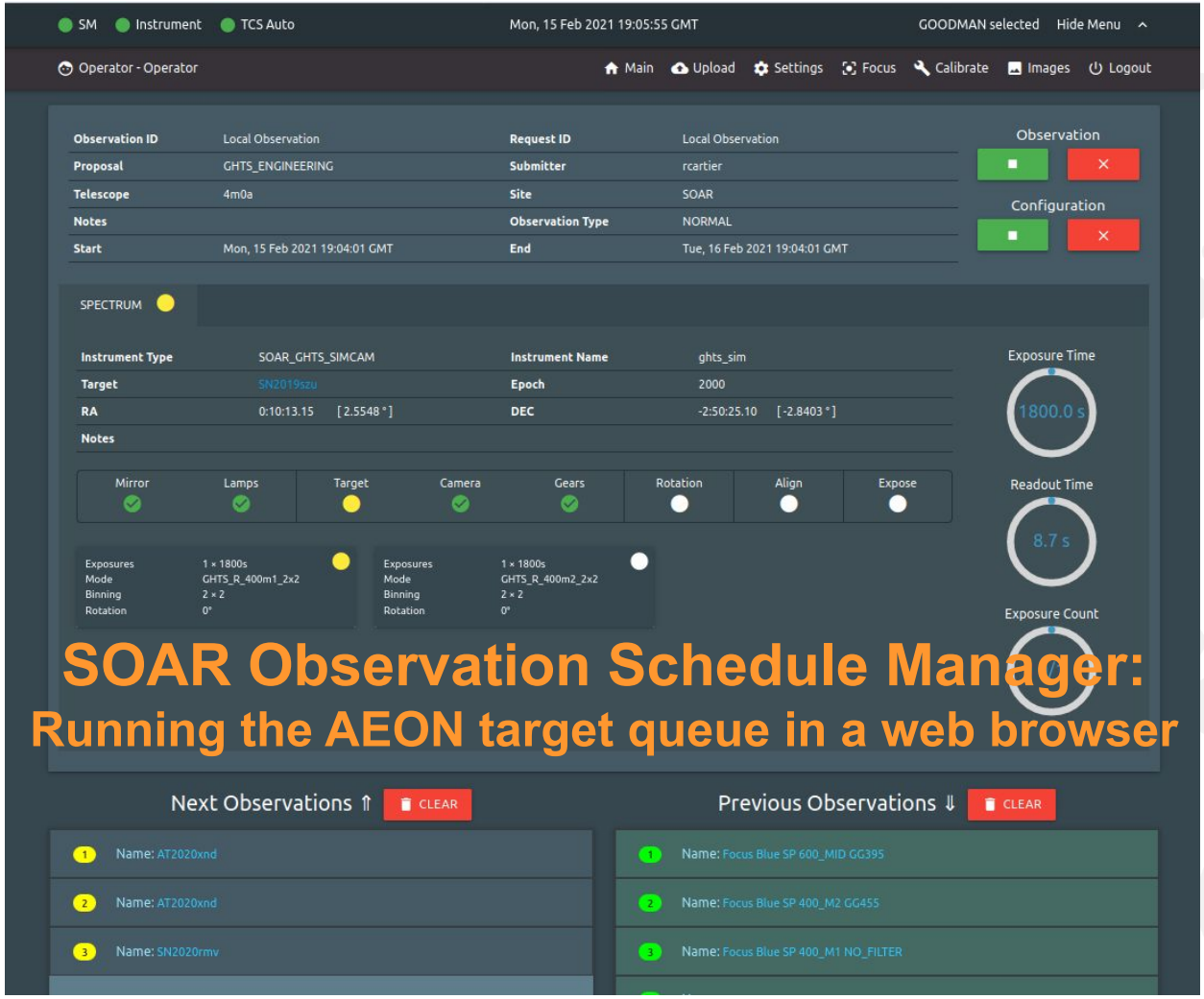
Incoming observation requests -> JSON files



Technologies:

- Python
- Docker containers
- React

Open Source



Gómez et al. 2020, SPIE