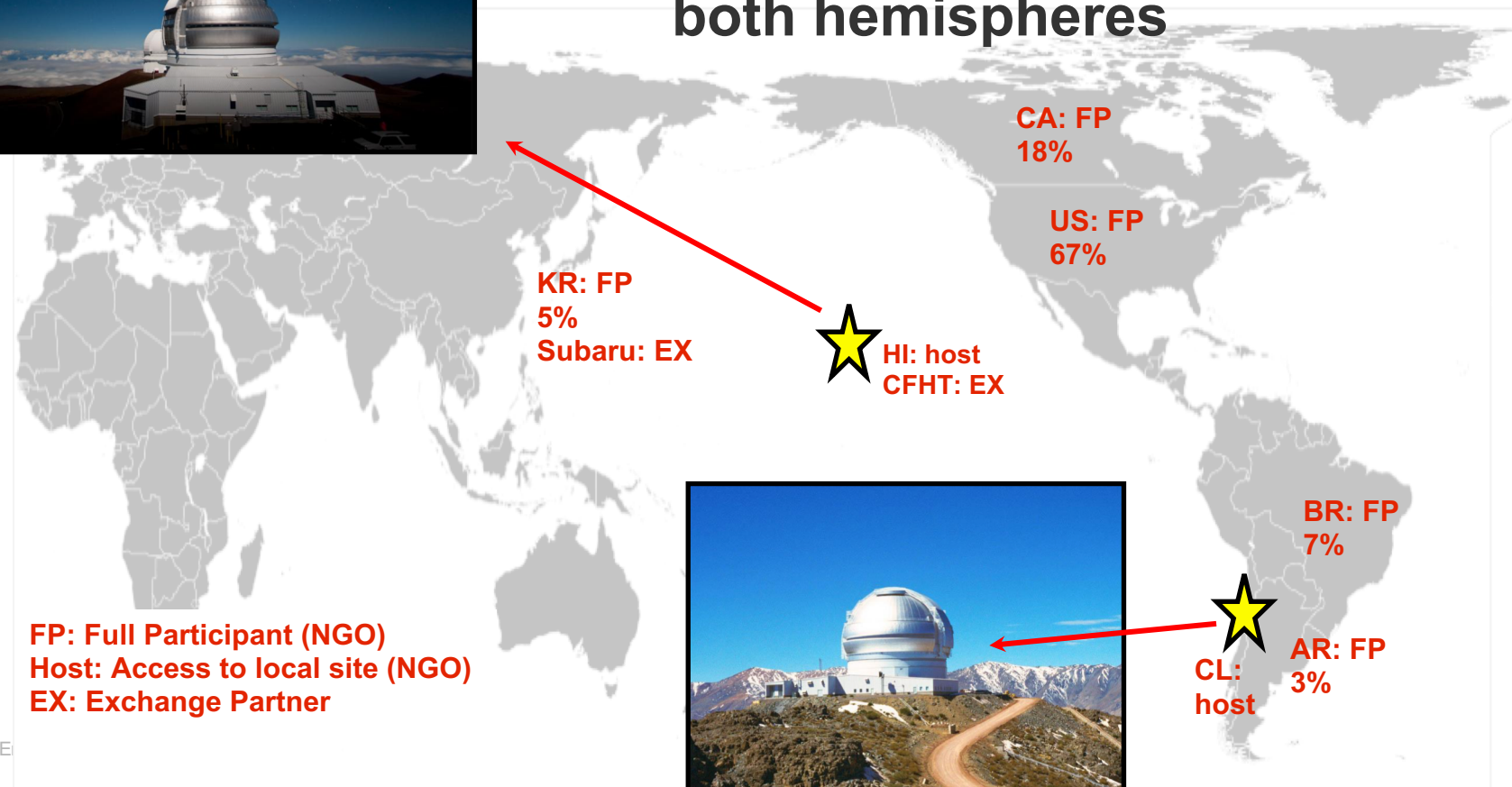
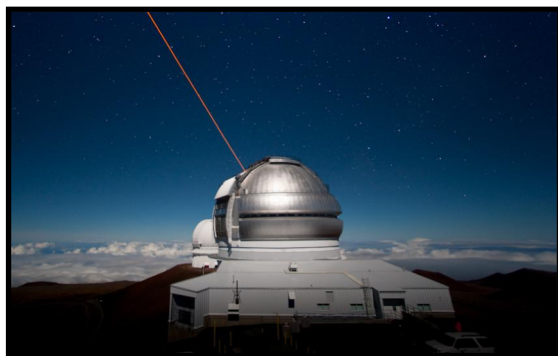


# Gemini Operations for Multi-Messenger Astronomy

Bryan Miller

Andy Adamson, John Blakeslee, Andy Stephens, Arturo Núñez,  
and the AEON team

# Gemini: twin 8-meter telescopes with coverage of both hemispheres



# We support four facility instruments + AO at each site. Up to three + AO at a time in queue.

## Gemini North

Optical

GMOS-N

GNIRS

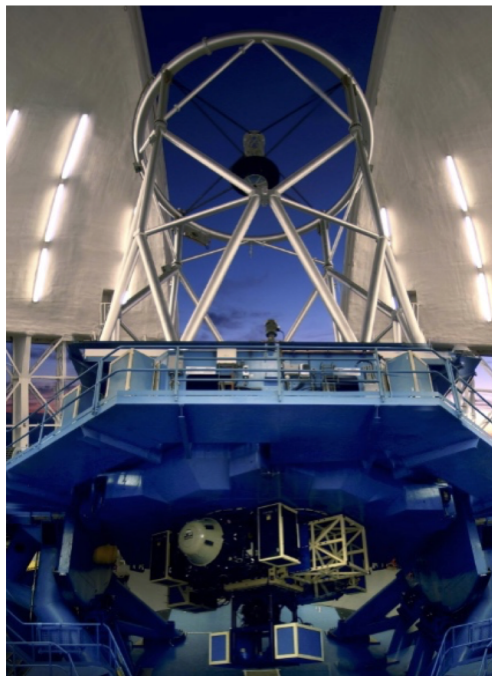
Near-IR

NIFS

NIRI

AO

ALTAIR  
NGS & LGS



## Gemini South

GMOS-S

FLAMINGOS-2

GPI (ExtAO)

GSAOI

GeMS (MCAO)  
LGS (5)

Visitor instruments

# ***Maximizing the science return from LSST/LIGO/IceCube/etc is a high priority for the US NSF***

Recommendations of the 2015 “Elmegreen” report:

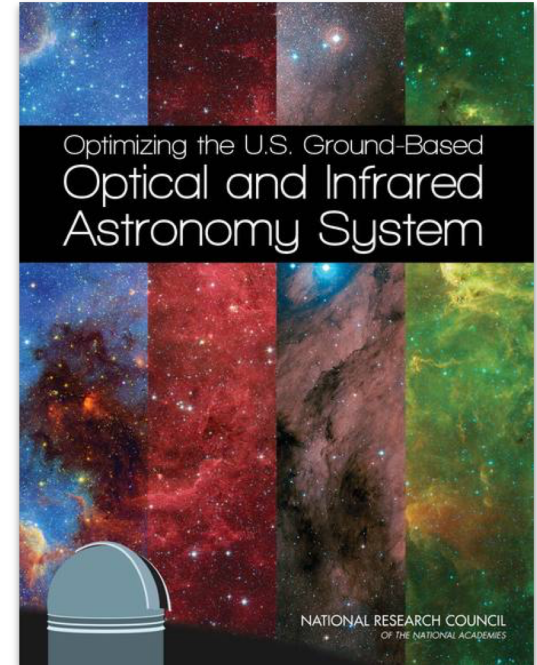
- Recommendation 4b: high throughput, broad wavelength spectrograph

➡ SCORPIO (0.4-2.4  $\mu\text{m}$ ,  $R \sim 4K$ , imaging spectrograph)

- Recommendation 4d: coordination among NSF facilities, especially in Chile, to optimize LSST follow-up studies

➡ AEON: NOAO/SOAR/Las Cumbres/Gemini

collaboration to create a system for performing dynamic queue-scheduled observations and automating follow-up





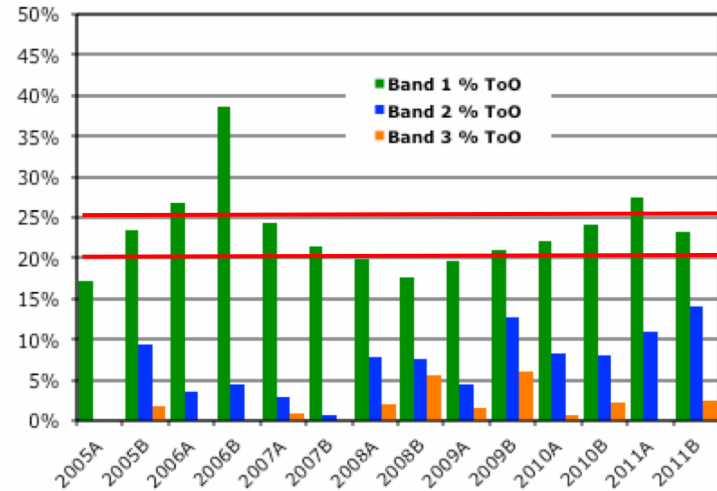
# Updates are needed to handle the expected increases in ToOs from LSST and MMA.

At Gemini, ToOs make up about 20-25% of the time in Band 1

- Max rates are 1-2/night
- Many more will overwhelm the manual scheduling process and observers

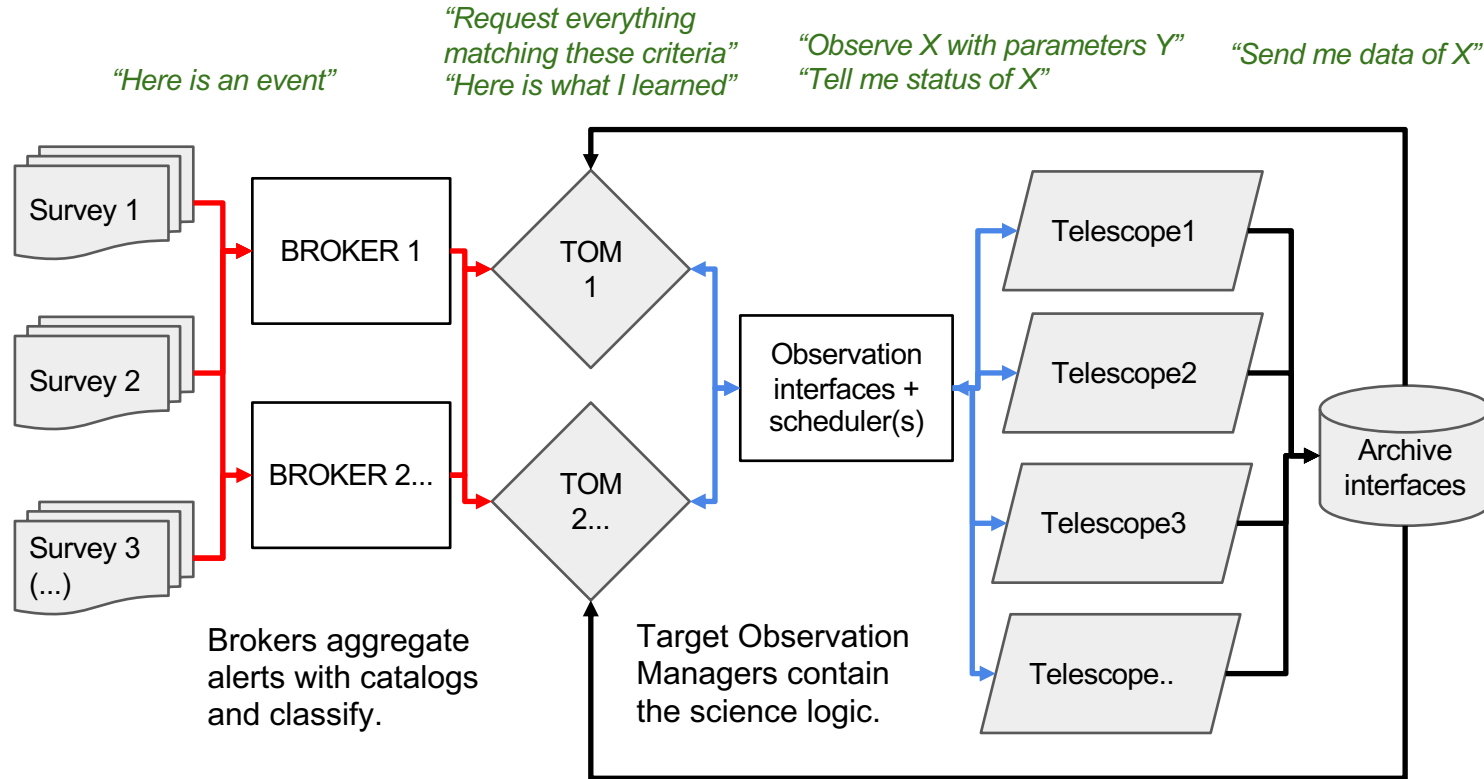


At CTIO/SOAR, ToOs interrupt visitor nights. More will be disruptive.



Coordinating with other facilities, e.g. VLA/Chandra, is manual and error prone.

# The proposed solution is a follow-up system that dynamically turns alerts into requested data.



# Several brokers are under development and are processing alerts

NOAO's ANTARES (<https://antares.noao.edu>)

- Alpha release
- Filtering ZTF alerts



Chile's ALeRCE (<http://alerce.science>)

- Under development



UK's Lasair (<https://lasair.roe.ac.uk>)

- See yesterday's talk by Lightfoot



# Target/Observation Managers match targets with telescopes, coordinate observations, and manage data.

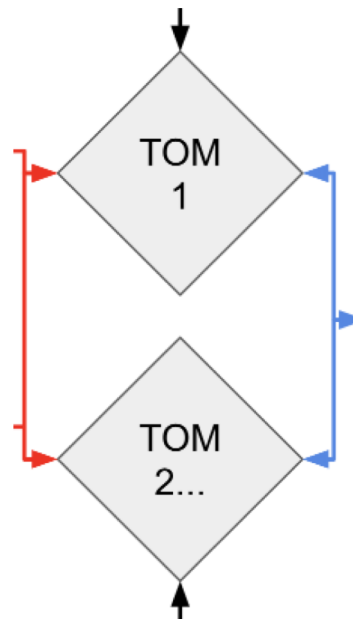
TOMs make up the main science layer:

- Collect and prioritize targets from alert streams (e.g. brokers)
- Are aware of available resources
- Request observations
- Collect and display data
- Manage data access for members
- Share information between interested parties

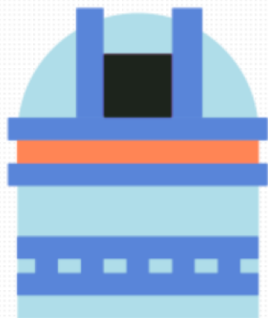
In use by SNe, exoplanet, NEO, AGN, and microlensing teams.

*"Request everything matching these criteria"*

*"Here is what I learned"*



# Las Cumbres Observatory is developing a “toolkit” to make these easier to create.



## TOM Toolkit

The TOM Toolkit is a framework for building software for the next generation of astronomy.

### Navigation

- » [Home](#)
- » [About](#)
- » [Documentation](#)
- » [Github](#)

## Target and Observation Manager

<https://tomtoolkit.github.io>

The TOM Toolkit project was started in early 2018 with the goal of simplifying the development of next generation software for the rapidly evolving field of astronomy. Read more [about TOMs](#) and the motivation for them.

Are you looking to run a TOM of your own? The [documentation](#) is a good place to get started. The source code for the project is also available on Github.

- [JPL Scout Support](#) » 17 Jan 2019
- [\[Video\] Triggering Target of Opportunity Observations with Gemini Observatory.](#) » 11 Jan 2019
- [TOM Toolkit at the AAS](#) » 19 Dec 2018
- [MARS Alert Broker Support](#) » 23 Aug 2018
- [TOM Toolkit Development Started](#) » 22 May 2018

<https://github.com/TOMToolkit> - Powered by Jekyll.

This project is managed by Las Cumbres Observatory, with generous financial support from the Zegar Family Foundation and the Heising-Simons Foundation.



Python + Django. Easy installation and configuration  
Under active development - looking for feedback

# You can define broker queries,

Create a new query using [MARS](#) [Lasair](#) [Scout](#) [MyBroker](#) [AutoBroker](#)

Name	Broker	Created	Run	Delete
<a href="#">Deltamag &gt; 1, R/B &gt; 0.75, r</a>	MARS	2018-12-28 02:12:12	<a href="#">Run</a>	<a href="#">Delete</a>
<a href="#">Name Query</a>	MyBroker	2018-12-28 14:12:00	<a href="#">Run</a>	<a href="#">Delete</a>
<a href="#">Score &gt; 50</a>	AutoBroker	2018-12-28 18:12:28	<a href="#">Run</a>	<a href="#">Delete</a>

Broker

Name contains

[Filter](#) [Reset](#)



... manage  
targets and  
check visibilities,

TOM Toolkit

Home

Targets

Alerts

Observations

Data

Users

User 1

Logout

# NGC4792

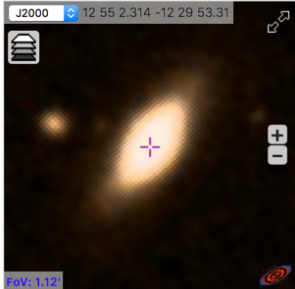
Update Target

Delete Target

Identifier	NGC4792
Name	NGC4792
Name 2	
Name 3	
Target Type	SIDEREAL
Right Ascension	193.765
	12:55:3.685
Declination	-12.497
	-12:29:49.474
Epoch Of Elements	None
Proper Motion (Ra)	None
Proper Motion (Declination)	None
Galactic Longitude	None
Galactic Latitude	None
Distance	52.240
Distance Error	None

## Survey View

J2000 12 55 2.314 -12 29 53.31



Fov: 1.12

Observe

Observations

Data

## Observe

LCO

GEM

## Plan

Start Time

2019-03-05 00:00:00

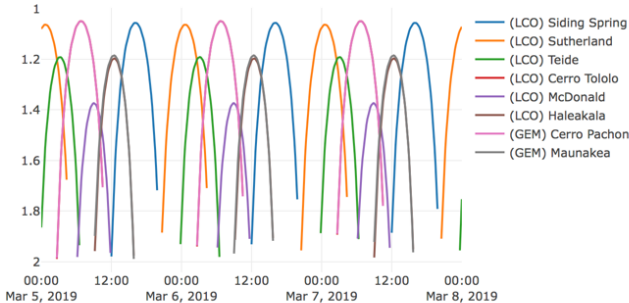
End Time

2019-03-08 00:00:00

Maximum Airmass

2.0

Plan



Color	Observatory
Blue	(LCO) Siding Spring
Orange	(LCO) Sutherland
Green	(LCO) Teide
Red	(LCO) Cerro Tololo
Purple	(LCO) McDonald
Brown	(LCO) Haleakala
Pink	(GEM) Cerro Pachon
Grey	(GEM) Maunakea

... and submit observations.

This is being used now for LIGO follow-up on Gemini.

See the video at [https://youtu.be/PC\\_5kmSdZBU](https://youtu.be/PC_5kmSdZBU)

TOM Toolkit

HomeTargetsAlertsObservationsDataUsers

User 1Logout

Submit an observation to GEM

Obsid\*

S19AT001[1] Std: GMOS B600 1.0arcsec  
S19AT001[2] Rap: GMOS B400 1.0arcsec  
S19AT001[9] GMOS Acq 1.0arcsec  
N19AT001[1] Std: GMOS B600 1.0arcsec

Ready\*

Yes

Group

NGC4792 standard ToO

Position Angle

330

PA Mode

Flip180

UT Date Time (for Parallactic PA Mode)

Target brightness

19.5

Brightness band

r

Brightness system

AB

Airmass/Hour Angle Constraint

Airmass

Min Airmass/HA

1.0

Max Airmass/HA

2.0

Note

UT Timing Window Start [Date Time]

Timing Window Duration [hr]

Guide Star Name

Guide Star RA

Guide Star Dec

Guide Star Brightness

Guide Star Brightness Band

UC

Guide Star Brightness System

Vega

Instrument

GMOS

Guide Probe

OIWFS

IFU Mode

None

Image Quality

Any

Cloud Cover

Any

Sky Brightness

Any

Exptime [sec]. If multiple, comma separate

ISS Port

Side

Search for guide star if none entered?

Yes

Overwrite previous guide star query?

No

Submit

# Our experience with GW170817 follow-up led to a new policy for competitive ToOs

## Policies for Competitive ToOs

[Gemini Observatory](#) > [Sciops](#) > [Observing With Gemini](#)

Effective November 20, 2017, the policies described below will regulate the activation of queue programs, the priorities for their execution as well as the data access rights for the acquired data. *multiple teams activate ToOs on the same target and on the same or subsequent nights.*

### Approval of ToO Triggers and DD Time

1. To be activated, Queue ToOs must be scientifically aligned with the nature of the observations requested. This is a general rule that applies to all ToO programs.
2. DD proposals will not be accepted if they effectively duplicate, in their observations, a Queue ToO that has been activated to observe the same target. DD proposals that are accepted in addition to a Queue ToO will be subject to the Prioritization and Data Sharing Policies discussed below.

### Prioritization for ToO Triggers and DD Time

1. In case of multiple Queue ToO triggers on the same target and night, the Gemini Observatory reserves the right to prioritize the observations so that the science is maximized. If no coordination is possible, the Gemini Observatory reserves the right to prioritize the observations to the following criteria: 1) how well the scientific justification of the proposal aligns with the Gemini science goals; 2) the ITAC ranking of the proposals, if available; 3) the temporal order in which the triggers were received, subject to the constraints, such as whether the Gemini observations are coordinated with data from Chandra, HST, other ground facilities).
2. As a rule, all DD programs will be given lower priority than Queue ToO programs. A DD program awarded to extend a Queue ToO program that has used all of its allocation during the campaign will have higher priority than other DD programs.

### Policies on Data Access Rights for ToO and DD Programs

Pre-approved queue programs get priority over Director's Discretionary (DD) programs.

If multiple ToO requests for the same target...

- Will work with PIs if possible
- Rules for prioritization defined (e.g. first ToO wins...)
- If multiple requests for the same configuration, then data may be shared.

<http://www.gemini.edu/node/12731>

# NOAO/SOAR/Las Cumbres/Gemini are working to dynamically schedule requests from TOMs on SOAR, Gemini, Blanco, others...

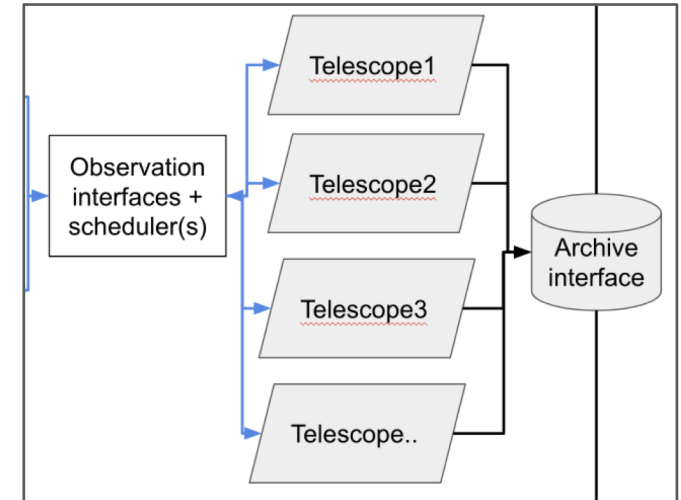


Rachel Street (LCOGT, PS)  
Bryan Miller (Gemini, PS)  
Stephen Ridgway (NOAO, PS)  
Cesar Briceño (NOAO/SOAR)  
Andy Adamson (Gemini)  
John Blakeslee (Gemini)  
Bob Blum (LSST)  
Adam Bolton (NOAO)  
Todd Boroson (LCOGT)  
Jay Elias (SOAR)  
Steve Heathcote (NOAO)  
Catherine Merrill (NOAO)  
Joanna Thomas-Osip (Gemini)



# Astronomical Event Observatory Network (AEON):

1. Develop interfaces (APIs)
2. Incorporate SOAR into the LCOGT network, execute observations on dedicated nights
3. Coordinate data pipelining and archiving efforts
4. Incorporate Gemini, develop automated queue scheduler
5. Be ready to incorporate other facilities (Blanco, etc)



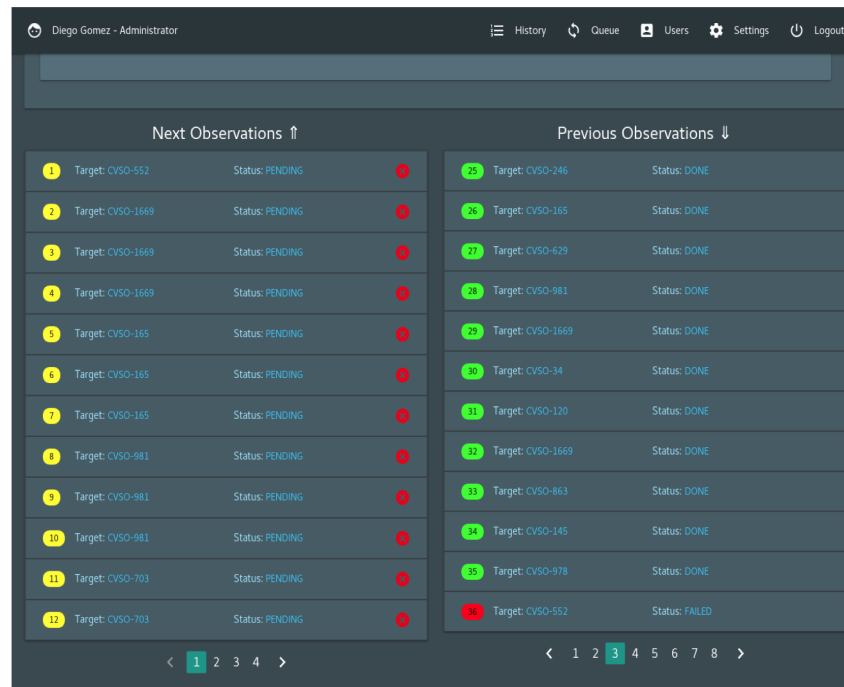
<https://lco.global/aeon/>

# AEON Status

1. Updates to the LCOGT APIs for scheduling/telemetry defined
2. SOAR Goodman scripting capabilities implemented
3. Tested live connections between scheduler@LCOGT and SOAR, executed observations (March 2019)

We are planning for shared-risk science use/testing in 2019B.

Expecting to offer the mode in 2020A



The screenshot shows the SOAR Queue Manager interface. At the top, there's a header with the user 'Diego Gomez - Administrator' and navigation links for History, Queue, Users, Settings, and Logout. Below the header, there are two main sections: 'Next Observations' and 'Previous Observations'. Each section contains a table of observation entries. The 'Next Observations' table has 12 rows, all with 'Status: PENDING' and a red status icon. The 'Previous Observations' table has 12 rows, all with 'Status: DONE' and a green status icon, except for the last row which has 'Status: FAILED' and a red status icon. At the bottom of each table, there are pagination controls with arrows and page numbers.

Next Observations ↑			Previous Observations ↓		
1	Target: CVSO-552	Status: PENDING	25	Target: CVSO-246	Status: DONE
2	Target: CVSO-1669	Status: PENDING	26	Target: CVSO-165	Status: DONE
3	Target: CVSO-1669	Status: PENDING	27	Target: CVSO-629	Status: DONE
4	Target: CVSO-1669	Status: PENDING	28	Target: CVSO-981	Status: DONE
5	Target: CVSO-165	Status: PENDING	29	Target: CVSO-1669	Status: DONE
6	Target: CVSO-165	Status: PENDING	30	Target: CVSO-34	Status: DONE
7	Target: CVSO-165	Status: PENDING	31	Target: CVSO-120	Status: DONE
8	Target: CVSO-981	Status: PENDING	32	Target: CVSO-1669	Status: DONE
9	Target: CVSO-981	Status: PENDING	33	Target: CVSO-863	Status: DONE
10	Target: CVSO-981	Status: PENDING	34	Target: CVSO-145	Status: DONE
11	Target: CVSO-703	Status: PENDING	35	Target: CVSO-978	Status: DONE
12	Target: CVSO-703	Status: PENDING	36	Target: CVSO-552	Status: FAILED

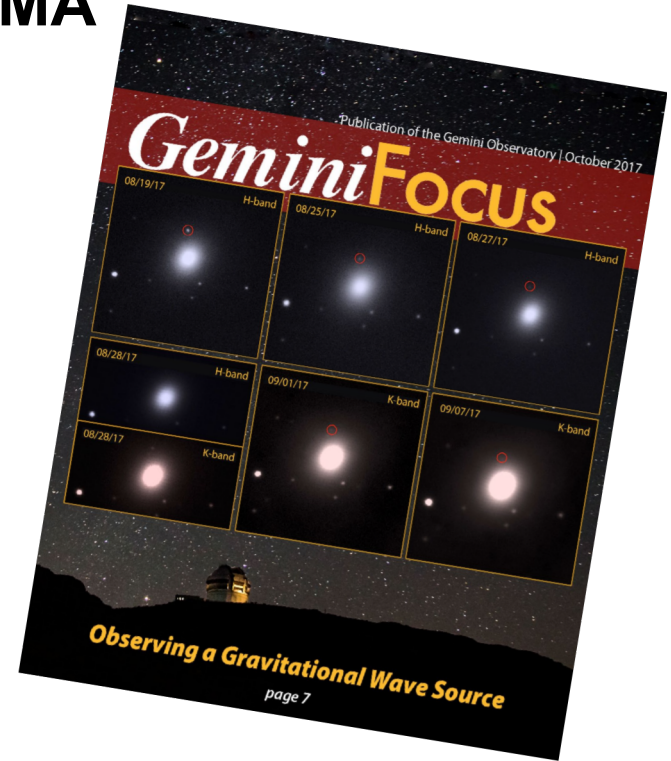
SOAR Queue Manager



# Gemini will support AEON as part of the ongoing OCS Upgrades Program and GEMMA

## OCS Upgrades Goals:

- Rethink the purpose and UI from first principles
- Make Phase 2 preparation much easier
- Include new features that are not possible in the current code
- Make it API accessible
- Make the code maintainable and scalable

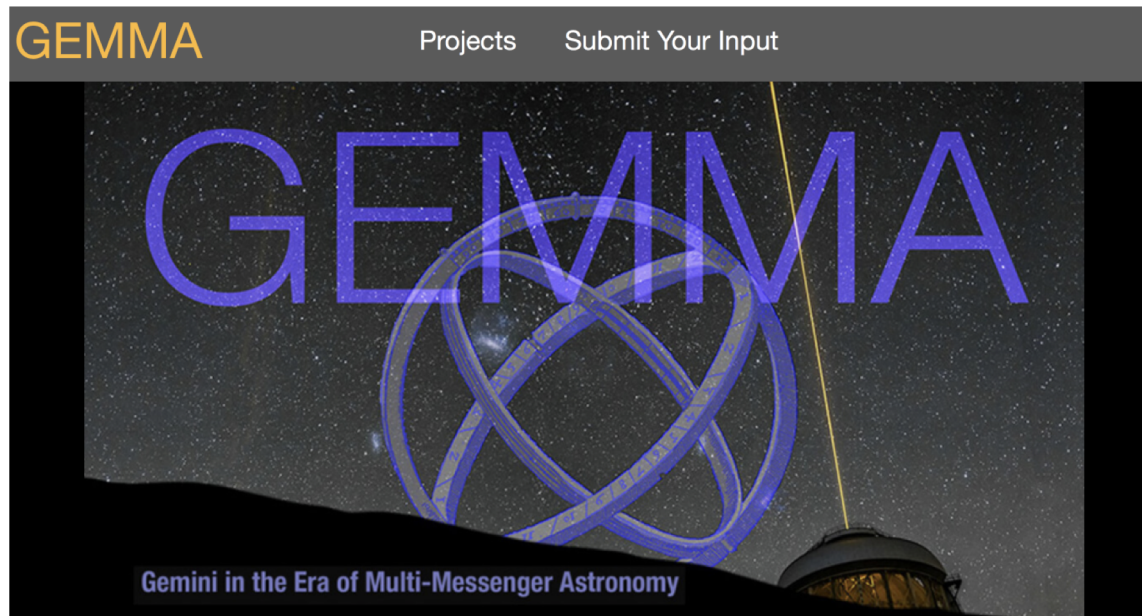


See Oct 2017 Gemini Focus, pg. 20

# Gemini will implement automatic scheduling and necessary APIs as part of the GEMMA (Gemini in the Era of Multi-Messenger Astronomy) project.

\$26M supplemental funding award from the NSF

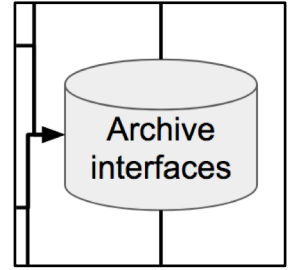
- MMA outreach program
- New MCAO system for Gemini North
- Adaptive queue scheduler
- Real-time data reduction capability



<https://www.gemini.edu/gemma/>

# We close the loop by serving data via the Gemini Observatory Archive and providing tools for science quality reduction.

- Automated processing is now a requirement
- Gemini IRAF to python transition
  - Python imaging package release in 2019
  - Spectroscopy reduction in python **in collaboration with SOAR**
- New Gemini instruments come with reduction tools that work in our pipeline environment (DRAGONS).



# Summary

Gemini is re-imagining the observing system to be a productive member of a TDA/MMA follow-up network that will consist of:

- Brokers (alert filters)
- TOMs (target/resource matching)
- Dynamic scheduling and execution
- New instrumentation (SCORPIO)
- Data reduction pipelines



We are interested in discussing common issues and observation coordination ideas.