New Infrastructure and Processes for Time-Domain Follow-up

Bryan Miller

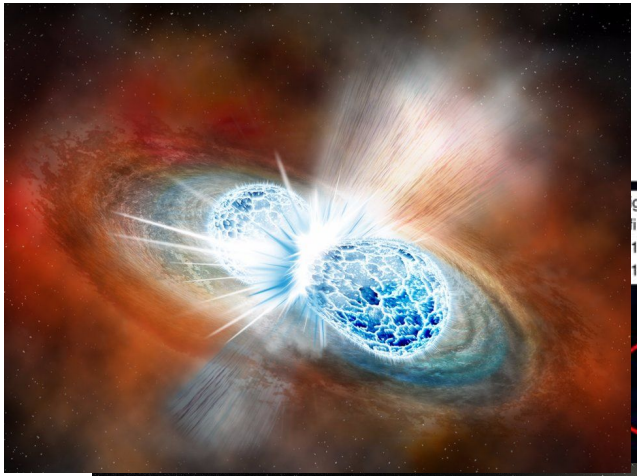
Gemini Observatory

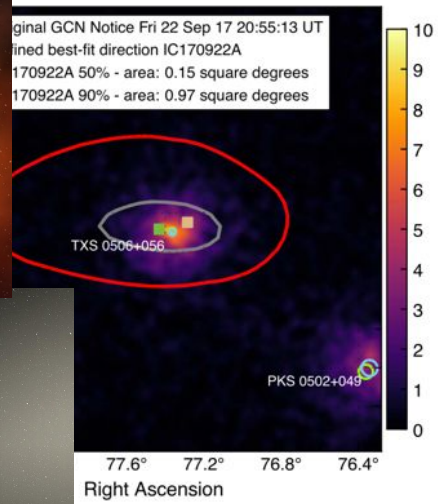
In 2017 it was clear that we were in a new era of Time Domain (TDA) and Multi-messenger Astrophysics (MMA)

In short succession

- GW170817
- IceCube-170922A
- `Oumuamua

Observed with multiple facilities, wavelengths, or “messengers” and on short timescales



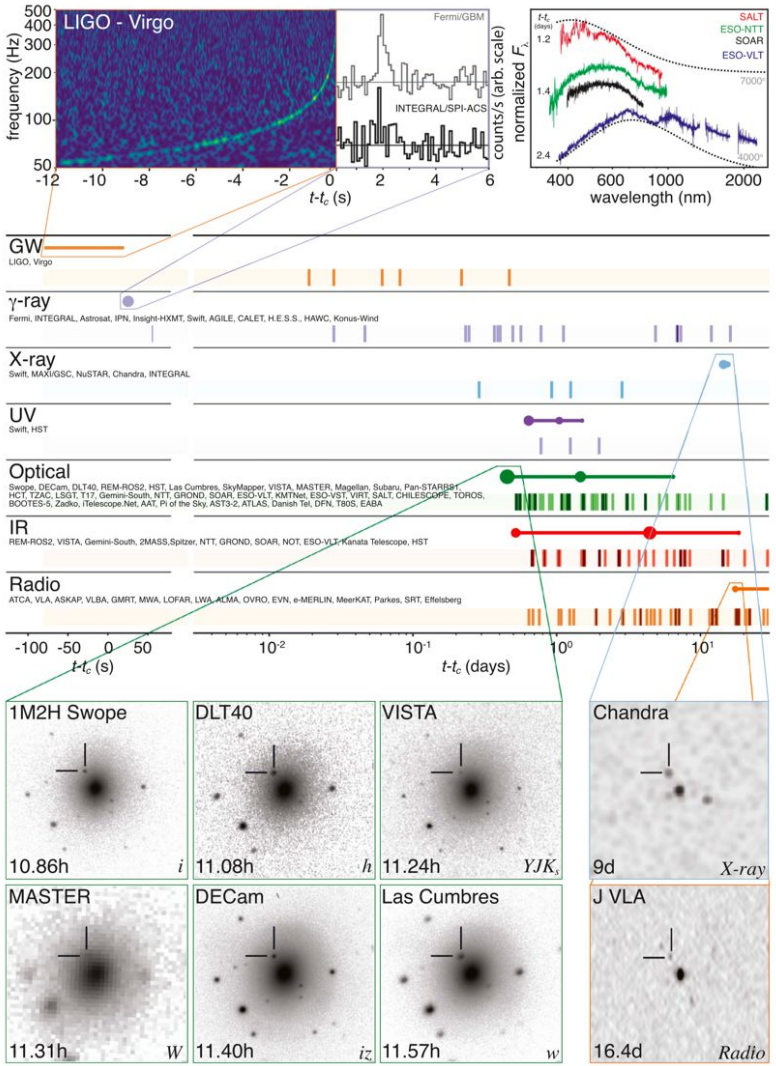


GW170817

Merger of two, ~1 M_{sun} neutron stars

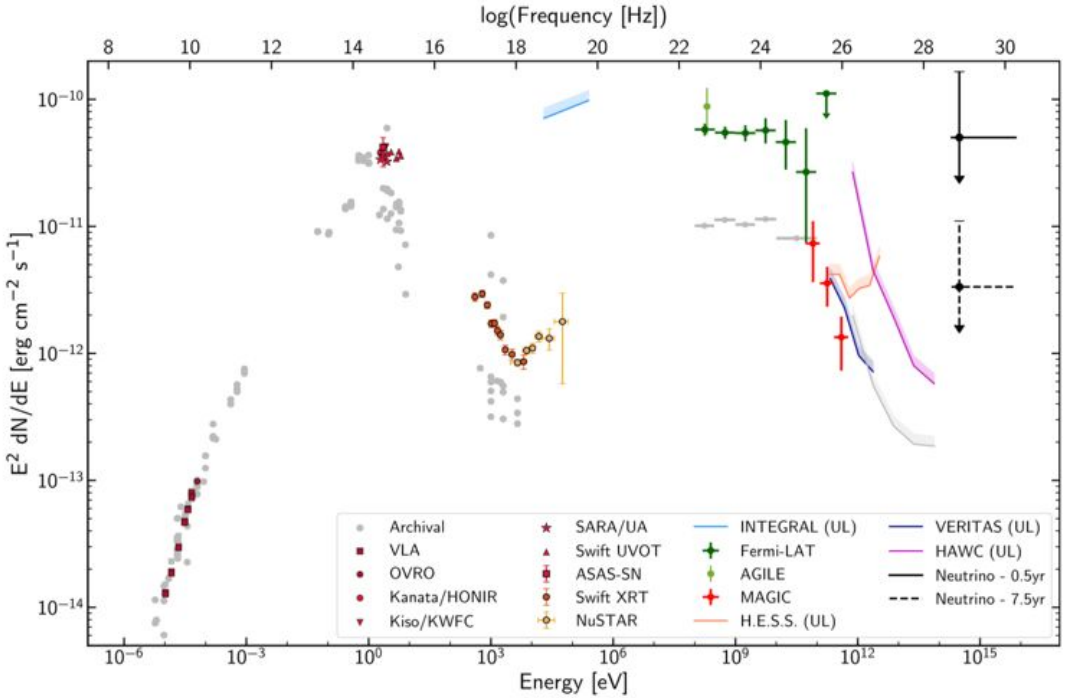
The resulting “kilonovae” was observed at all EM frequencies within a day.

Coordinating all the requests was chaotic, stressful.



Abbott et al. (2017)

IceCube-170922A and TXS 0506+056



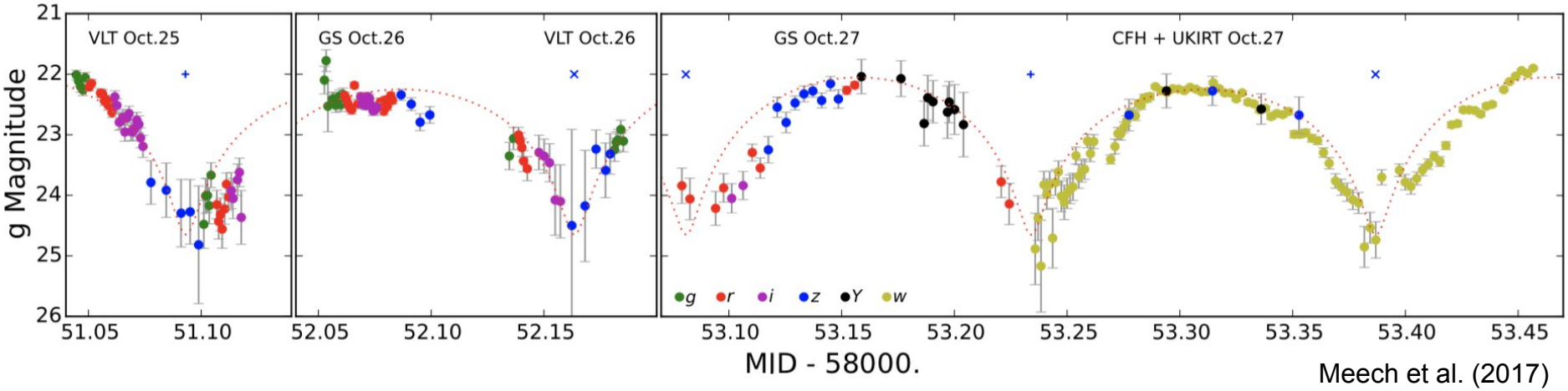
IceCube Collaboration (2018)

IceCube detects the muon from a 290 TeV neutrino.

EM follow-up showed it to be from a flaring blazar TXS 0506+056

`Oumuamua

Pan-STARR1 detected a fast-moving object on a hyperbolic orbit



Meech et al. (2017)

Follow-up by many facilities showed it to be an elongated body originating outside the solar system

These events are rare, but ongoing/future surveys should make detecting things like them more common

Zwicky Transient Facility (ZTF)

- Palomar 48in Schmidt with 6.6 degree FoV
- 3 night cadence
- Alerts from the public surveys

Large Synoptic Survey Telescope (LSST)

- 6.5 meter equivalent telescope with 3.5 degree FoV under construction
- ~3 night cadence
- 10 year survey to start in 2023

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

Recommendations of the 2015 “Elmegreen” report:

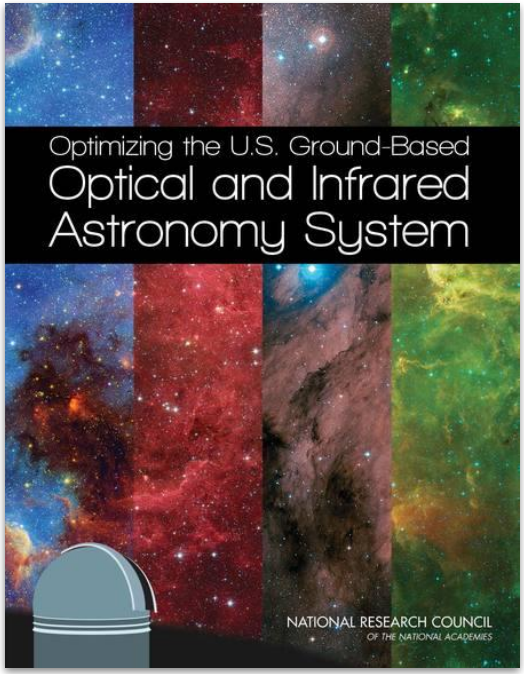
- Recommendation 3: Event broker development
- Recommendation 4b: high throughput, broad wavelength spectrograph

→ SCORPIO (0.4-2.4 um, R~4K, imaging spectrograph)

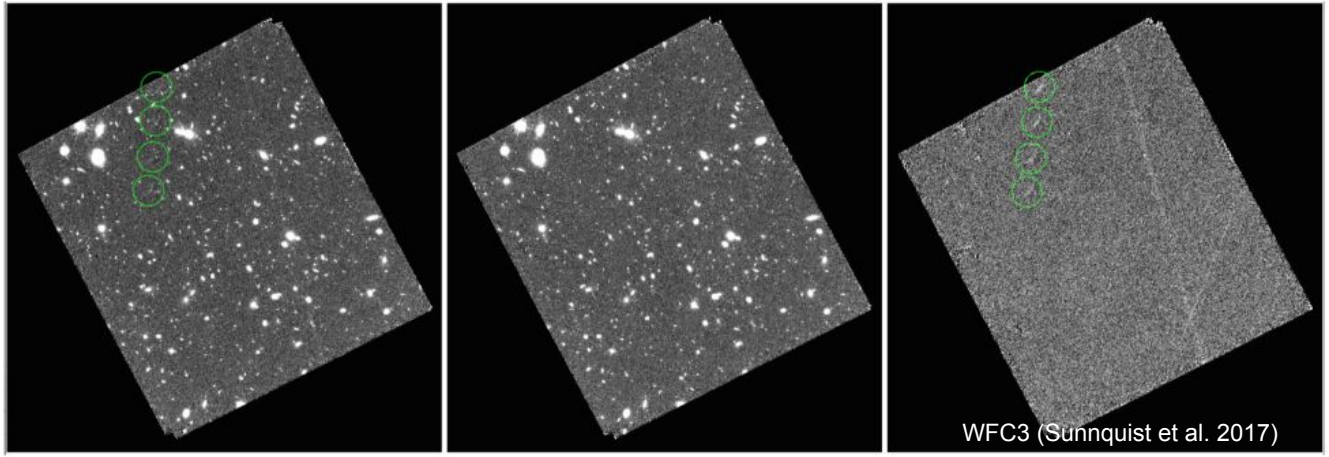
- Recommendation 4d: coordination among NSF facilities, especially in Chile, to optimize LSST follow-up studies

→ AEON: NOAO/SOAR/Las Cumbres/Gemini

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



Why all the fuss? LSST will generate ~10^7 transient alerts (~1500 new solar system objects) per night!

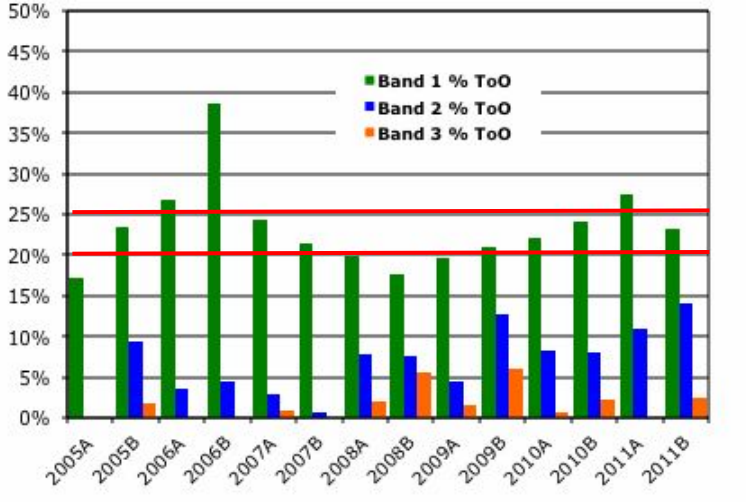


- 2 x 15 sec exposures/visit ⇒ ~10^4 alerts within 60 sec
- We must prepare for *Order(10-100)* triggers/night/tel plus regular queue

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

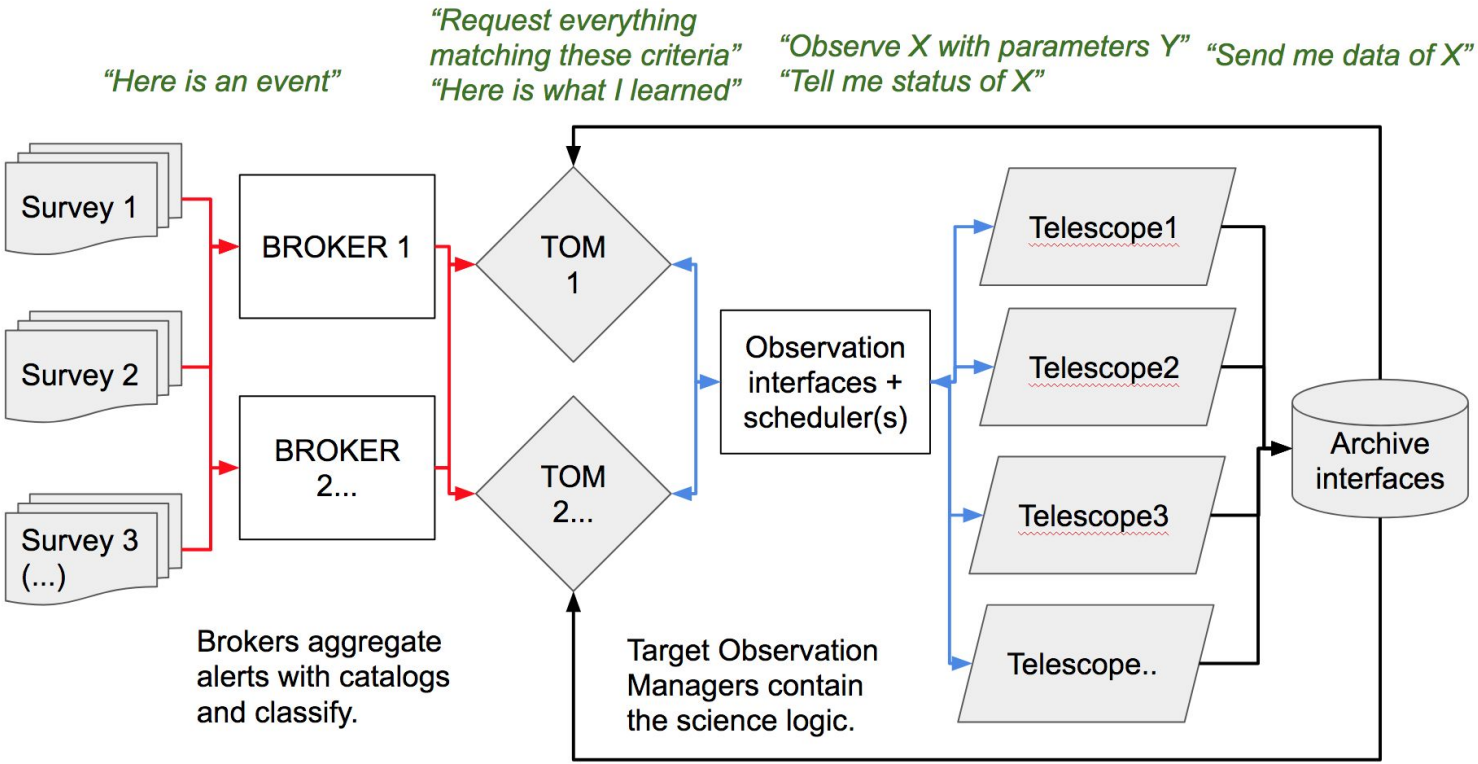
- Max rates are 1-2/night
- Many more will overwhelm the manual scheduling process and observers



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.



Time domain infrastructure workshop
(https://www.noao.edu/meetings/lsst-tds/)

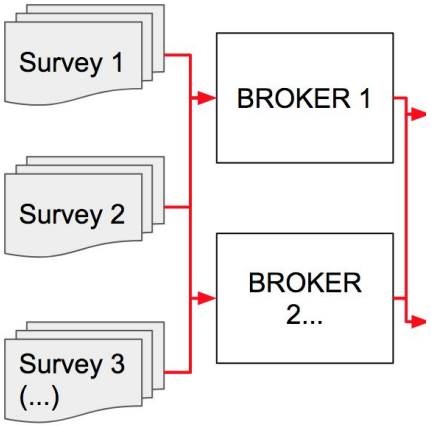
Brokers aggregate and classify alerts

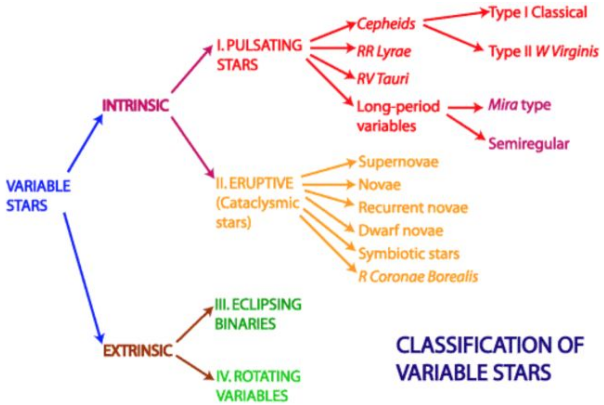
Cross-matches with available catalogs

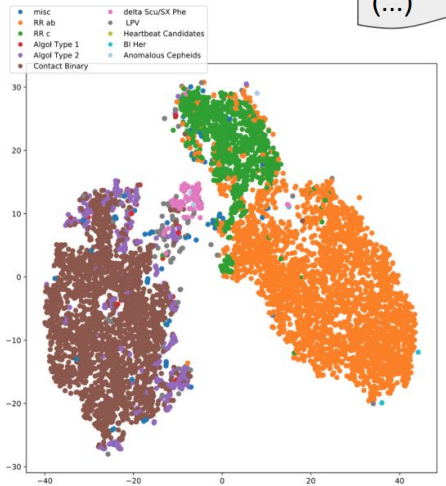
Characterizes based on properties like color, light curve, variability, etc.

Estimates rarity

Applies filters to select a particular kind of object







Light curve basis vector decomposition

https://www.noao.edu/ANTARES/

Several brokers are under development and are now processing alerts

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

- Alpha release
- Filtering ZTF alerts

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

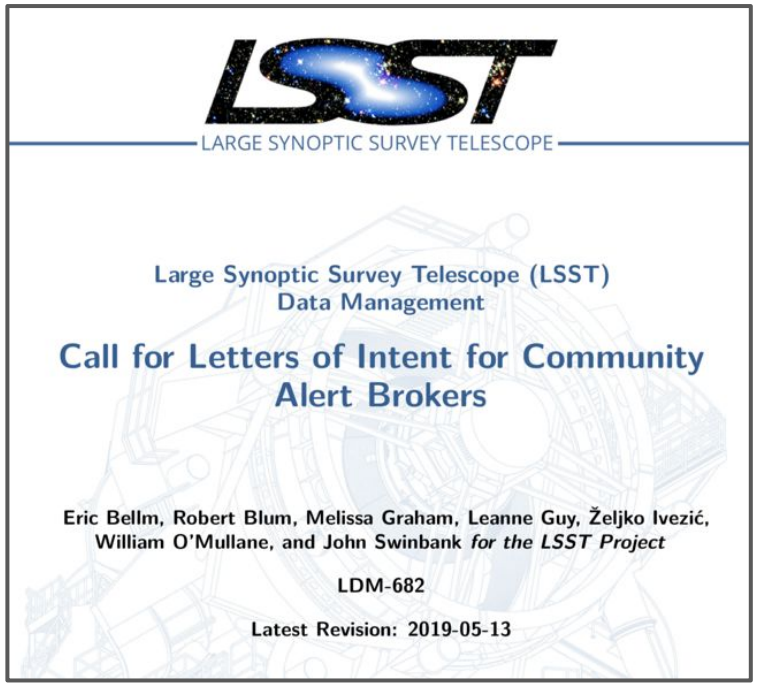
- Under development

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

- Filtering ZTF alerts

Lasair

Due to bandwidth limitations, LSST will only distribute the full alert stream to only ~5 brokers


LARGE SYNOPTIC SURVEY TELESCOPE

Large Synoptic Survey Telescope (LSST)
Data Management

Call for Letters of Intent for Community Alert Brokers

Eric Bellm, Robert Blum, Melissa Graham, Leanne Guy, Željko Ivezić, William O'Mullane, and John Swinbank *for the LSST Project*

LDM-682

Latest Revision: 2019-05-13

LSST will provide an Alert Filtering Service for simple alert filtering

A selection process is underway to choose the community brokers

https://ls.st/ldm-612

Recently ~12 teams pitched their projects at the LSST Community Broker Workshop

https://ls.st/cbw

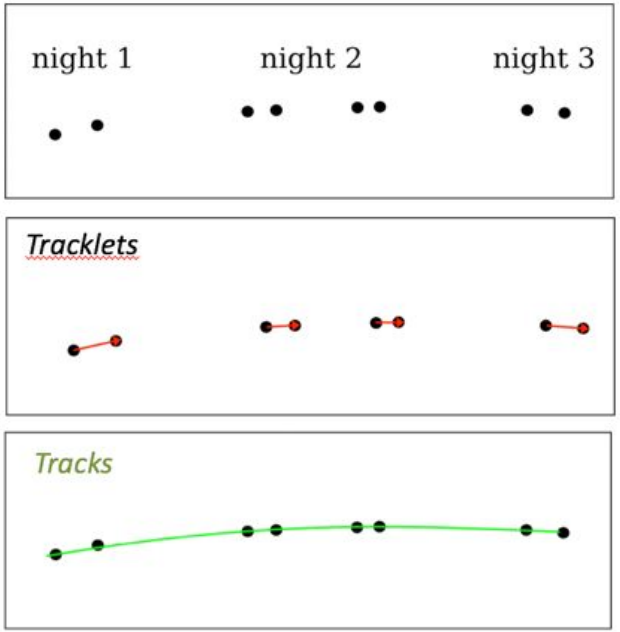
Alerts will contain all detected, known solar-system objects (SSOs) and many unknown objects as single detections

The Moving Object Pipeline (MOPS) will run daily to link single detections into tracks and eventually orbits.

New SSOs will be sent to the Minor Planet Center (MPC)

“Brokers” for SSOs may include

- Minor Planet Center (MPC)
- NOAO/NCOA DataLab
- Community broker software (e.g. NEOfixer)



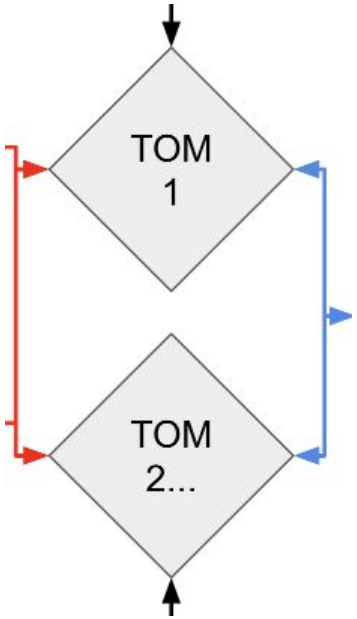
Target/Observation Managers match targets with telescopes, coordinate observations, and manage data.

TOMs make up the main science layer:

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

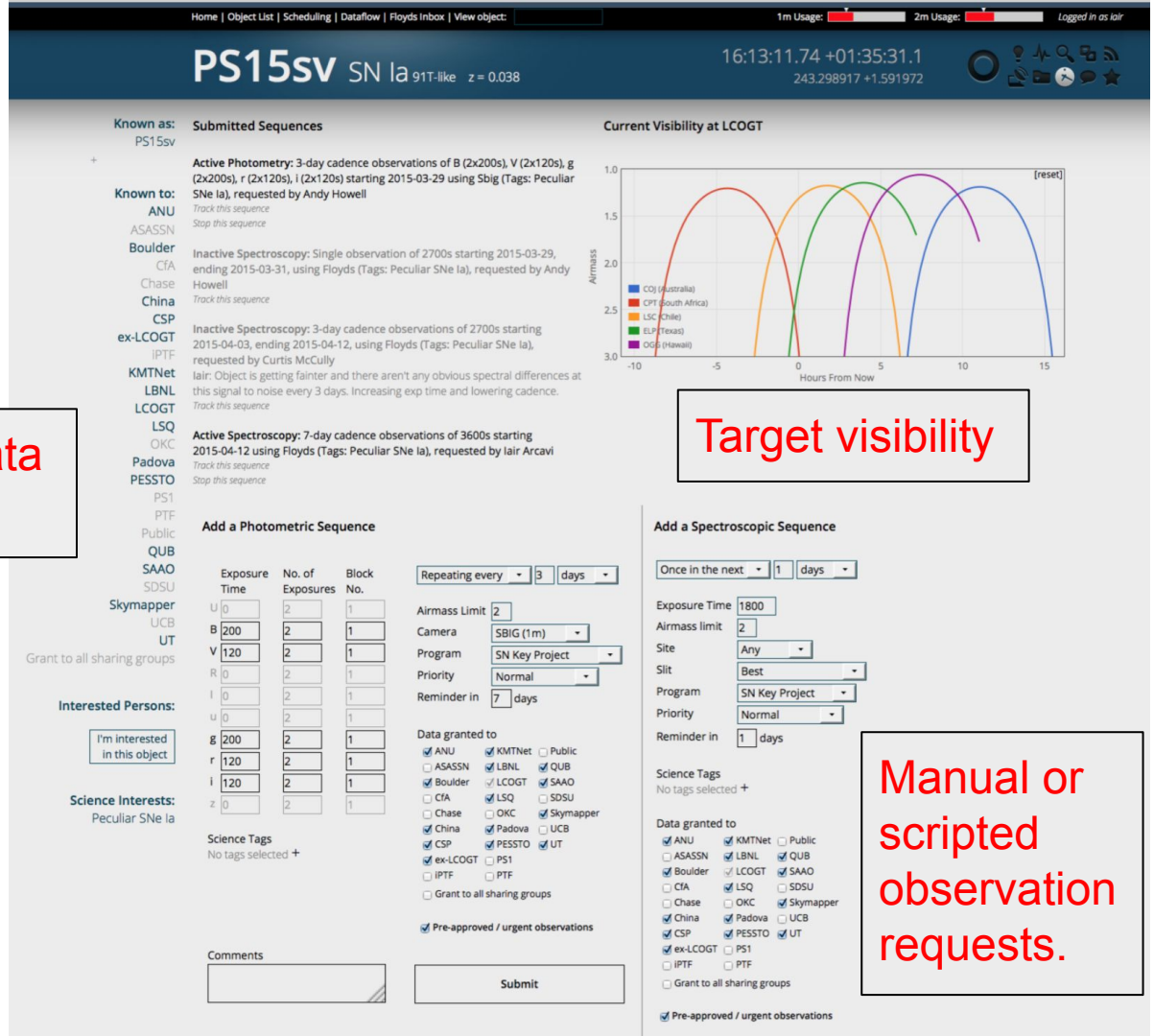
In use by SNe, exoplanet, NEO, AGN, and microlensing teams.

"Request everything matching these criteria"
"Here is what I learned"



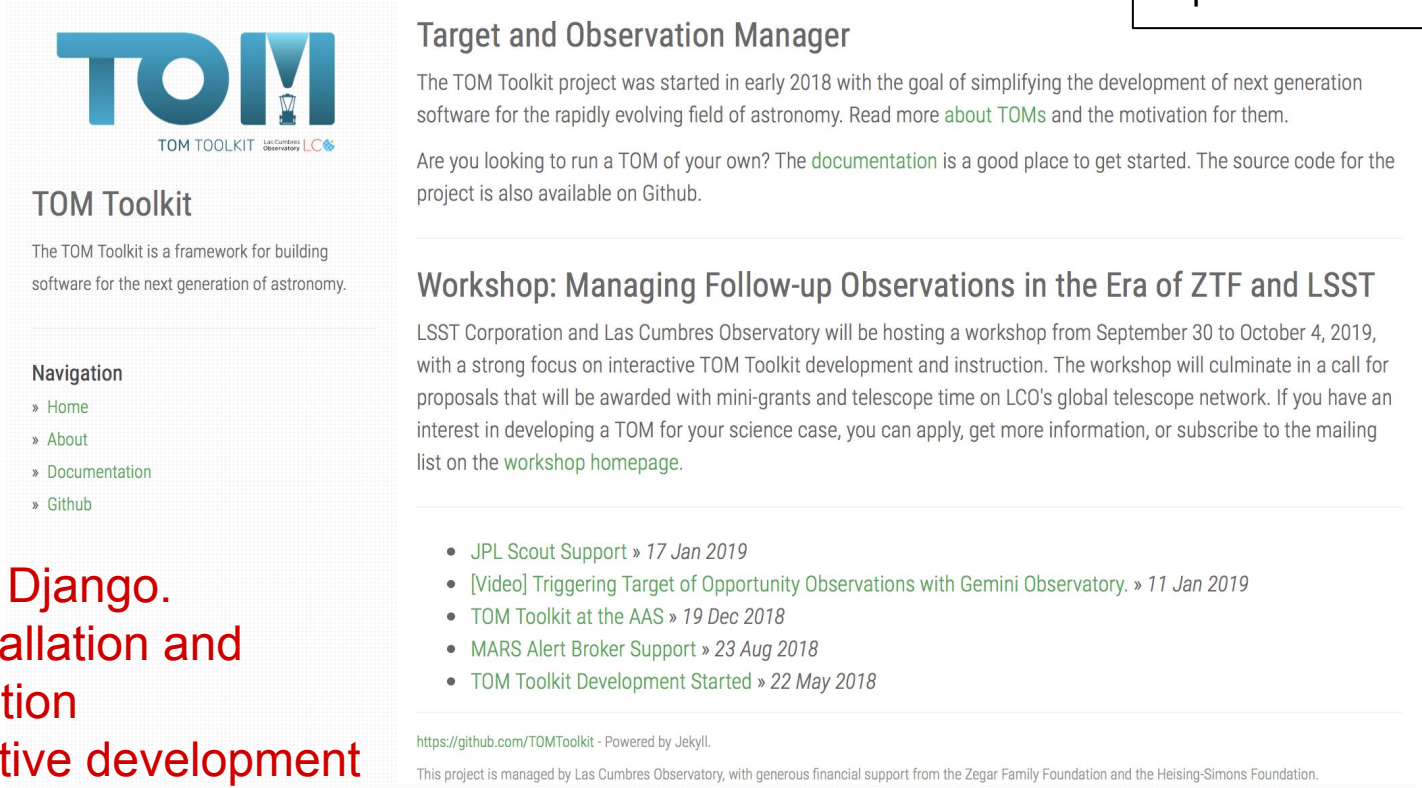
Supernova Exchange TOM

Target/data access



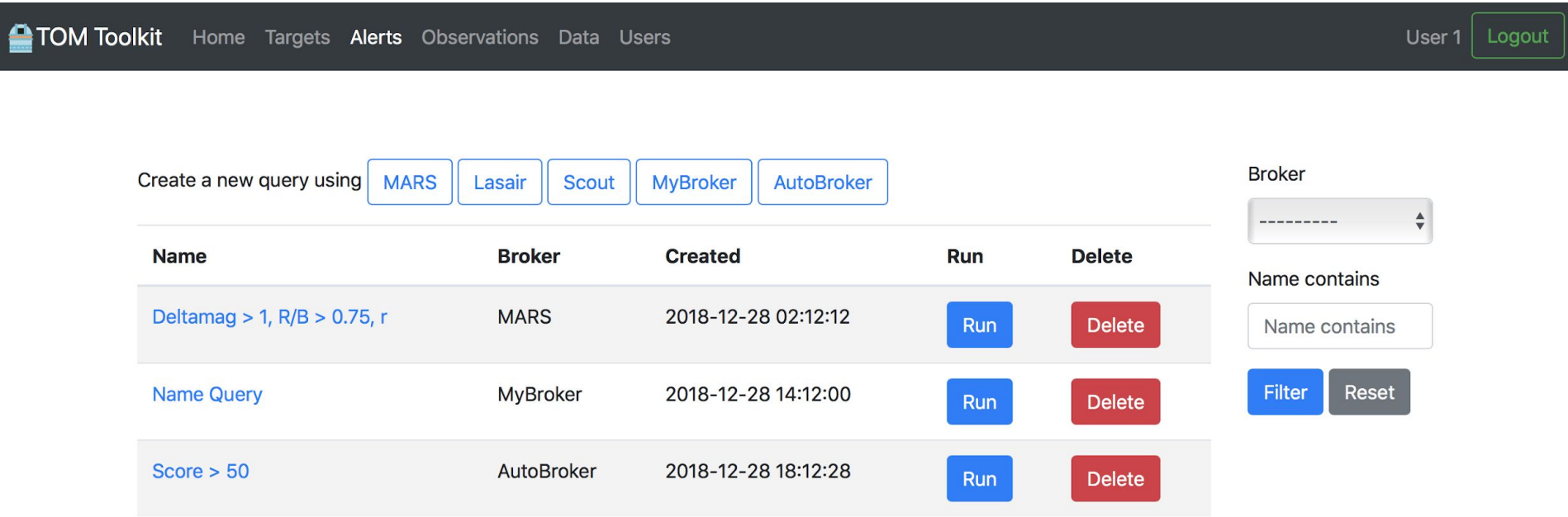
Las Cumbres Observatory is developing a “toolkit” to make these easier to create.

https://tomtoolkit.github.io

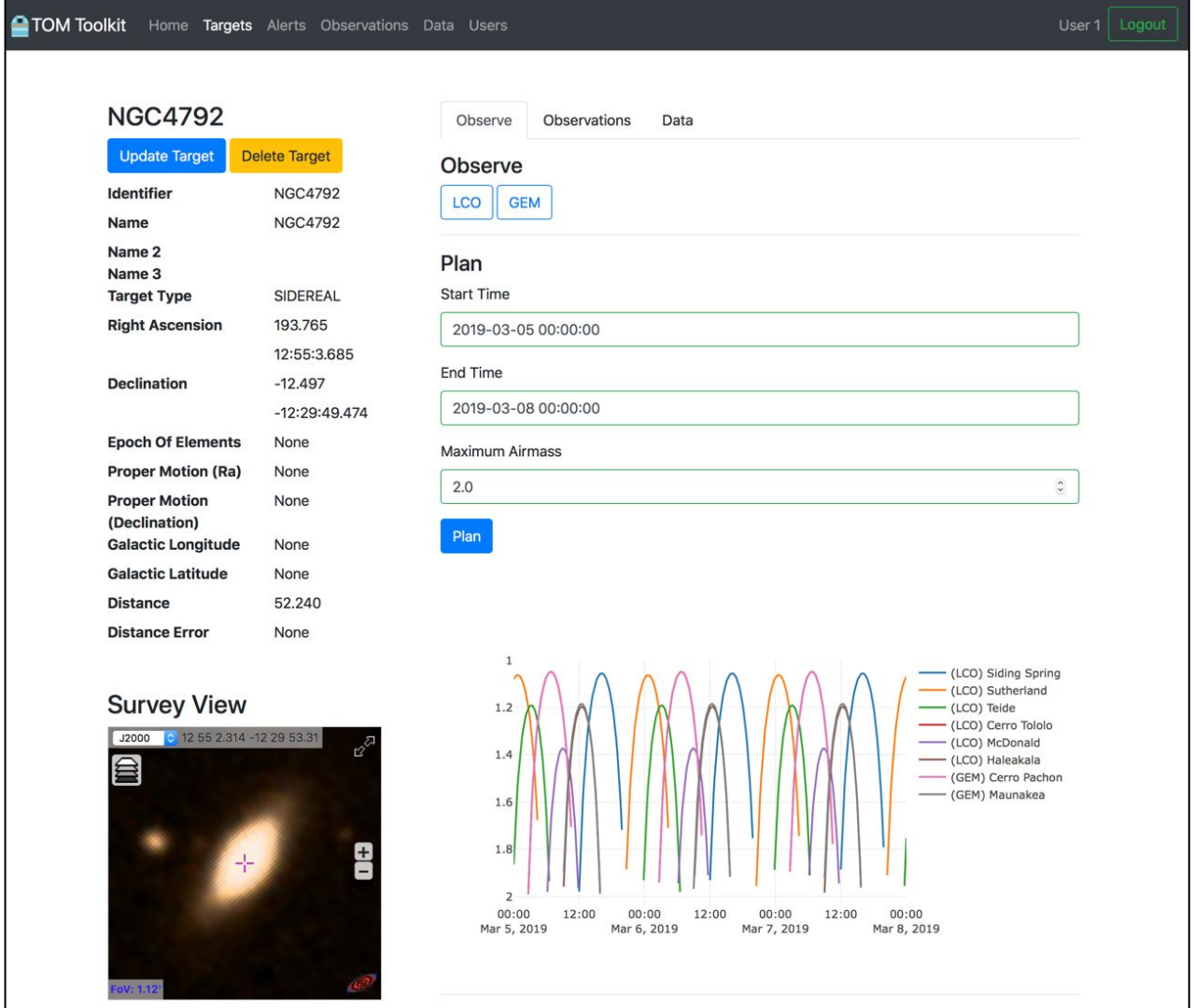


Python + Django.
Easy installation and configuration
Under active development

You can define broker queries,



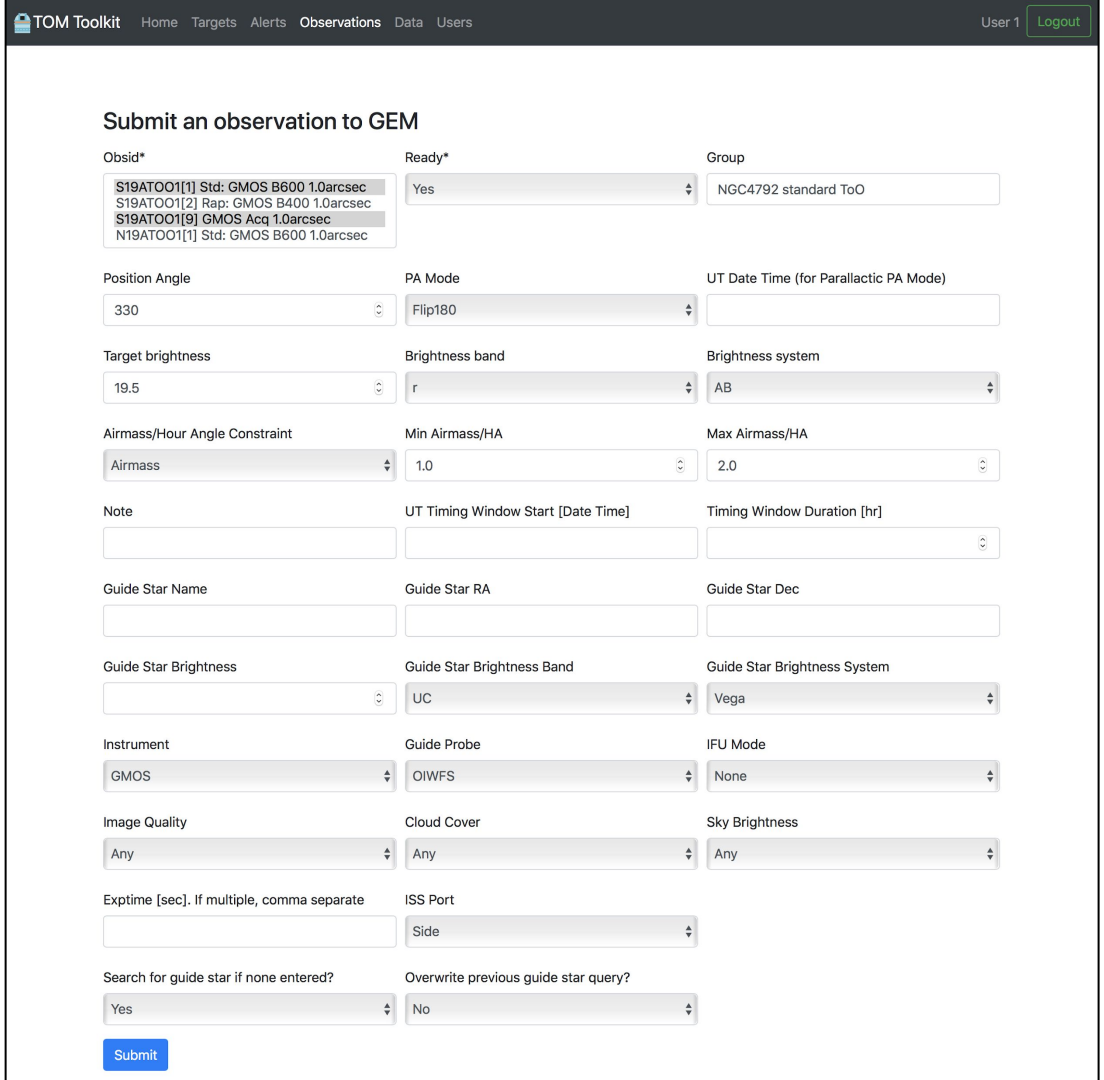
… manage targets and check visibilities,

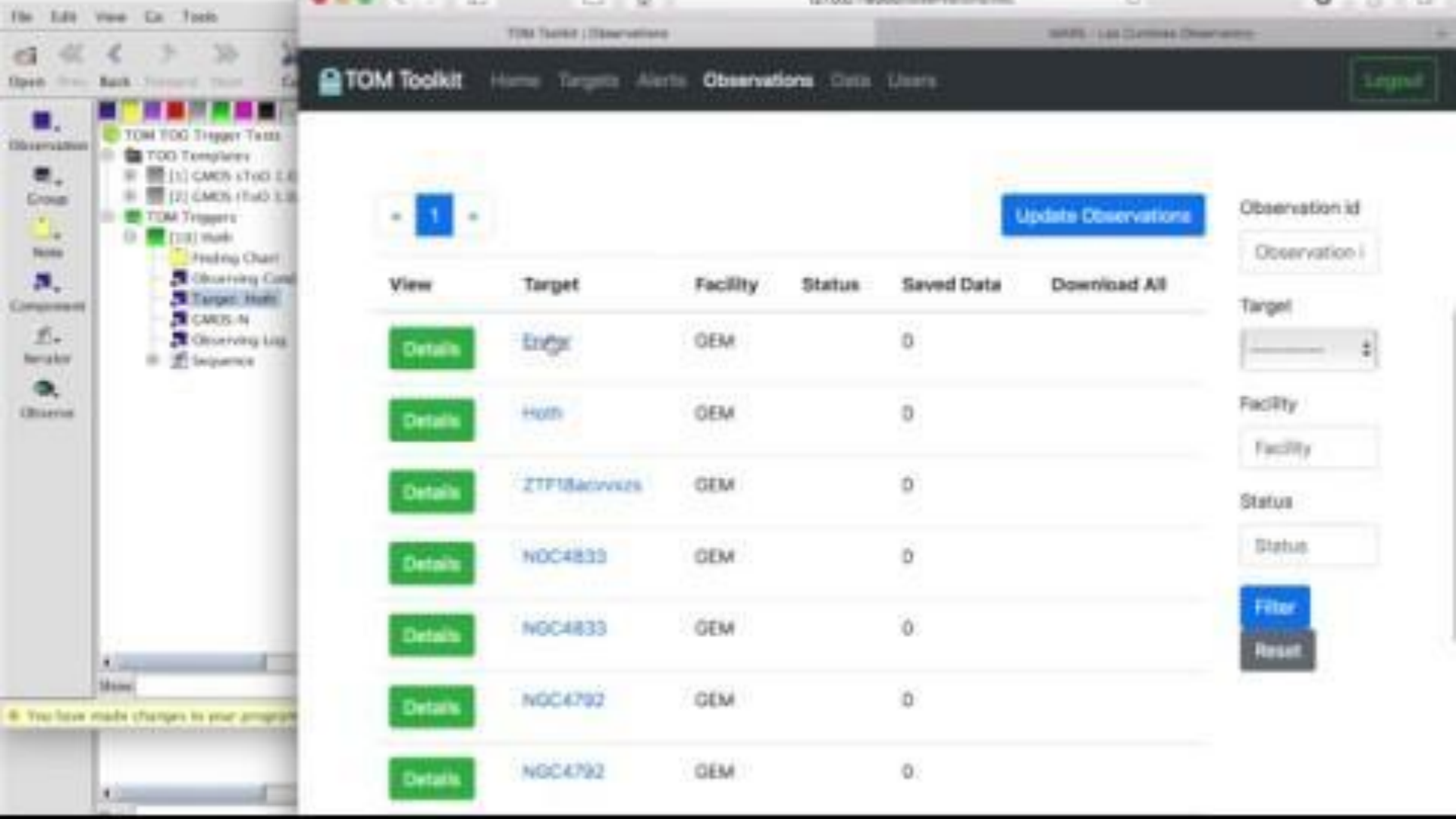


… and submit observations.

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

See the video at
https://youtu.be/PC_5kmSdZBU




TOM Toolkit
Home
Targets
Alerts
Observations
Data
Users
Logout
1
Update Observations
Observation id
Target
Facility
Status
Filter
Reset
View
Target
Facility
Status
Saved Data
Download All
Details
GEM
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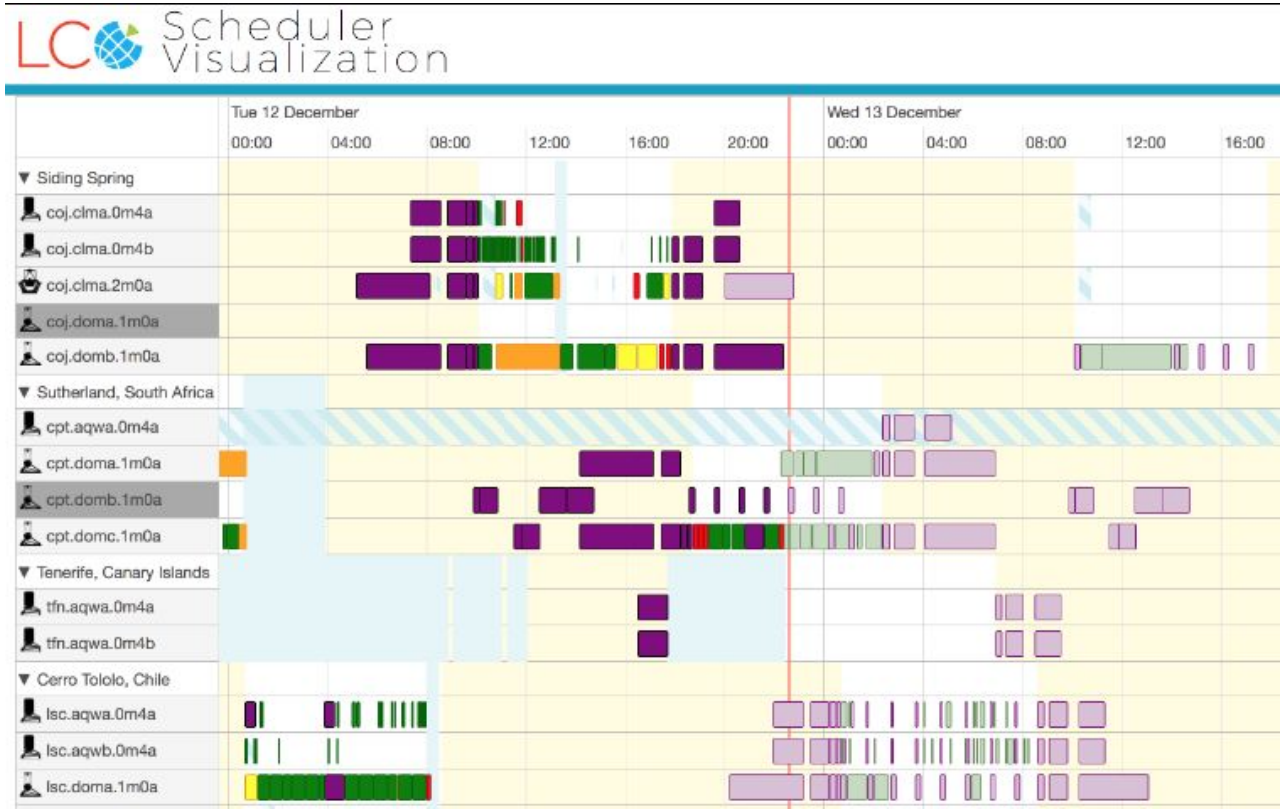
TOMs request observations from the appropriate network resource, then a scheduler takes over

Scheduling needs to be automatic, update frequently or as new observations arrive.

Targets assigned to nodes based on site conditions, target visibility, requested resource, etc.



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)
Joanna Thomas-Osip (Gemini)

Las Cumbres Observatory (LCOGT) is an example of an operating telescope network

22 robotic telescopes: 0.4m, 1m, 2m

Imaging and spectroscopy (on 1m and 2m)

Both hemispheres and nearly complete longitudinal coverage

Open access time is now available via NOAO due to a NSF MSIP award.

SOAR will start by offering limited modes of the Goodman spectrograph for time-domain projects

4.1 meter telescope on Cerro Pachón, Chile

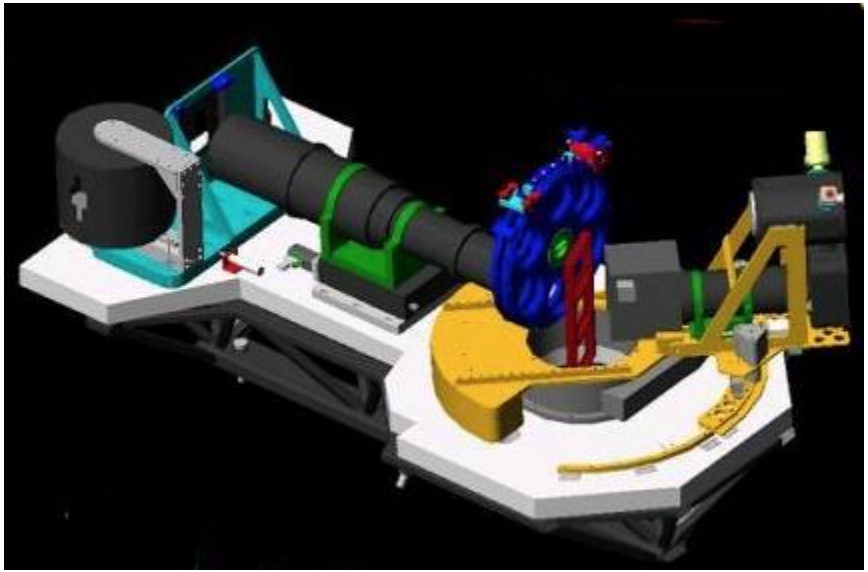
Red camera and 400 l/mm grating

R ~ 1000 with 1 arcsec slit

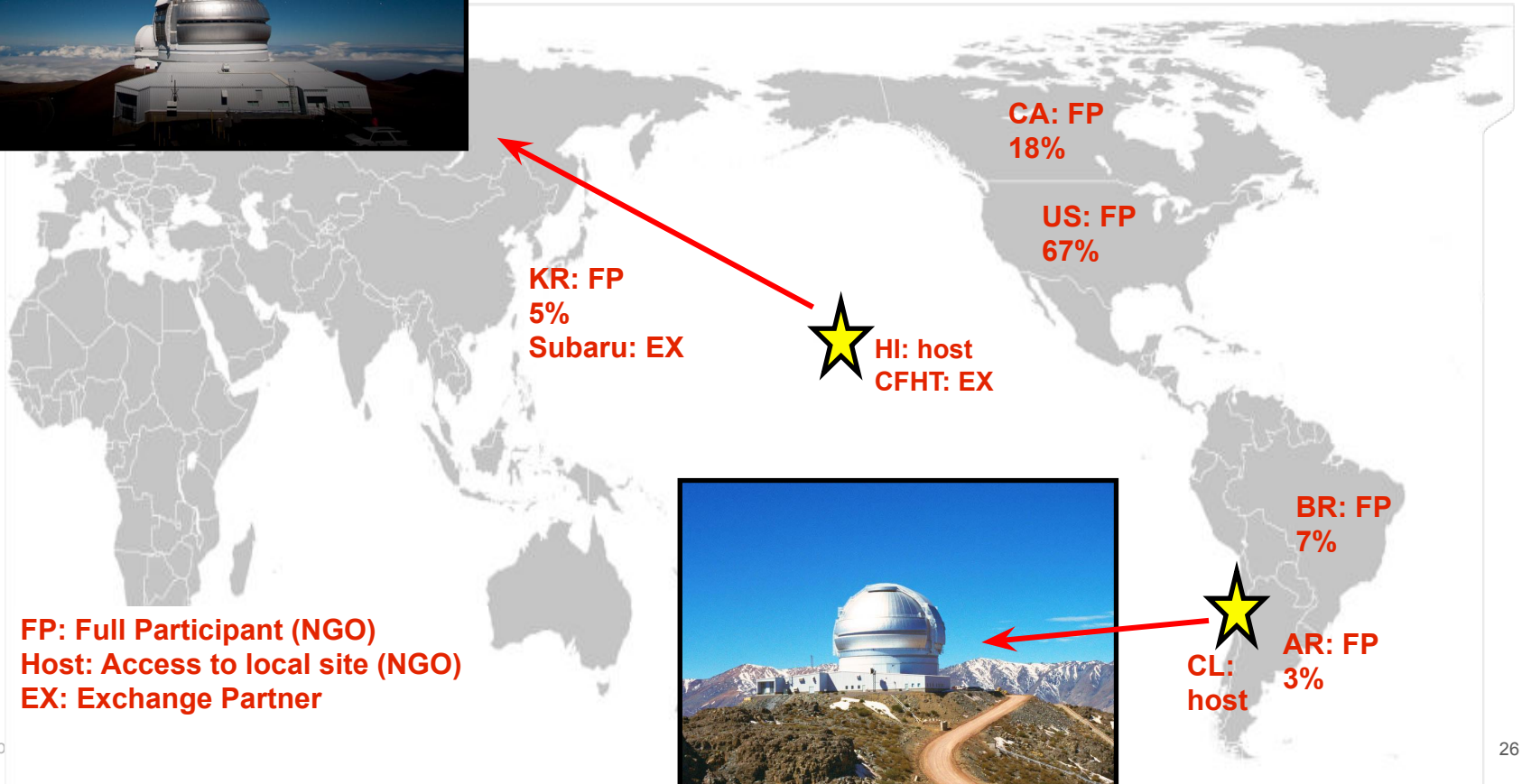
Imaging

7.2 arcmin FoV

SDSS and Bessel filters



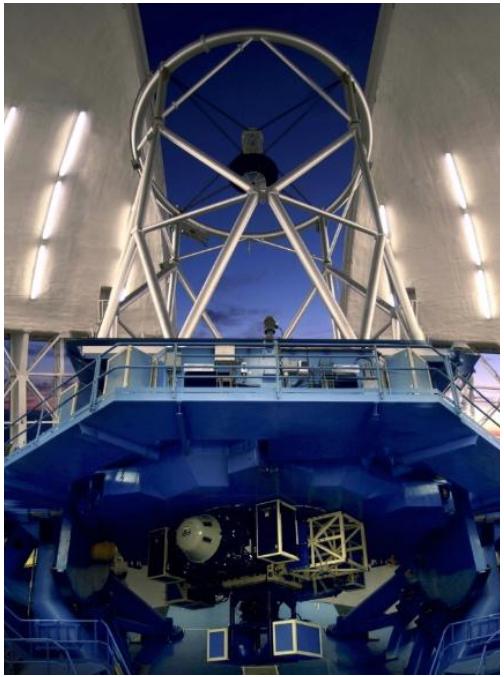
Gemini: twin 8-meter telescopes with coverage of both hemispheres



FP: Full Participant (NGO)
Host: Access to local site (NGO)
EX: Exchange Partner

Gemini supports four facility instruments + AO at each site. Up to three + AO at a time in queue.

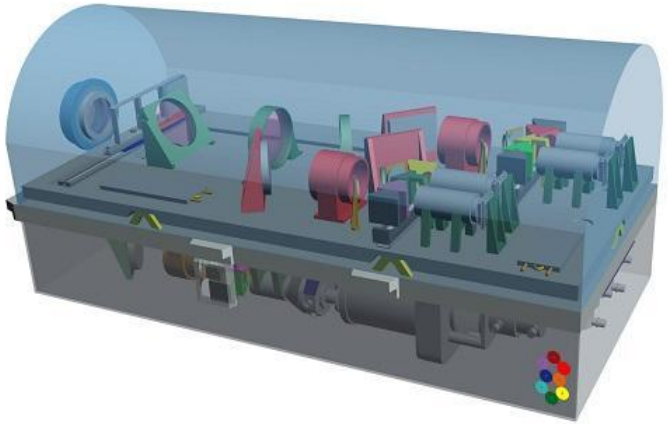
	Gemini North	Gemini South
Optical	GMOS-N	GMOS-S
Near-IR	GNIRS	FLAMINGOS-2
	NIFS	GPI (ExtAO)
	NIRI	GSAOI
AO	ALTAIR NGS & LGS	GeMS (MCAO) LGS (5)

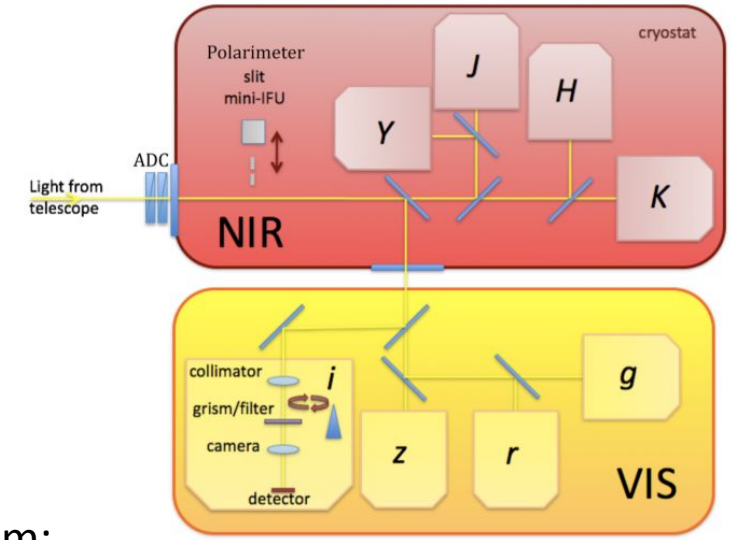


Visitor instruments

SCORPIO will be a new broad-wavelength LSST follow-up machine.

- g – K_s coverage using 7 dichroics
- Simultaneous 8-band imaging over a 3’ x 3’ field
- Single-object longslit, IFU upgrade option
- R ~ 4000
- Must be operational by 2023



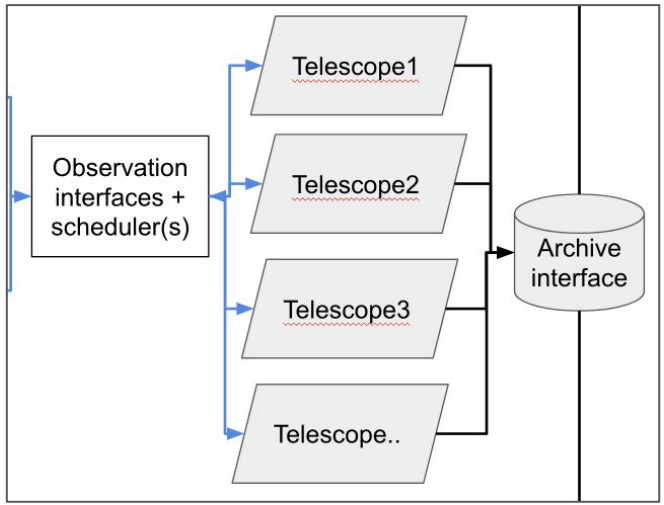


Team:

- PI: Massimo Robberto, JHU & STScI
- Project Manager, Co-PI: P. Roming
  Southwest Research Institute
- Project Scientist: A. van der Horst
  George Washington University

The AURA/LCOGT follow-up effort is called the 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, implement APIs and an automated queue scheduler
5. Be ready to incorporate other facilities (Blanco, etc)



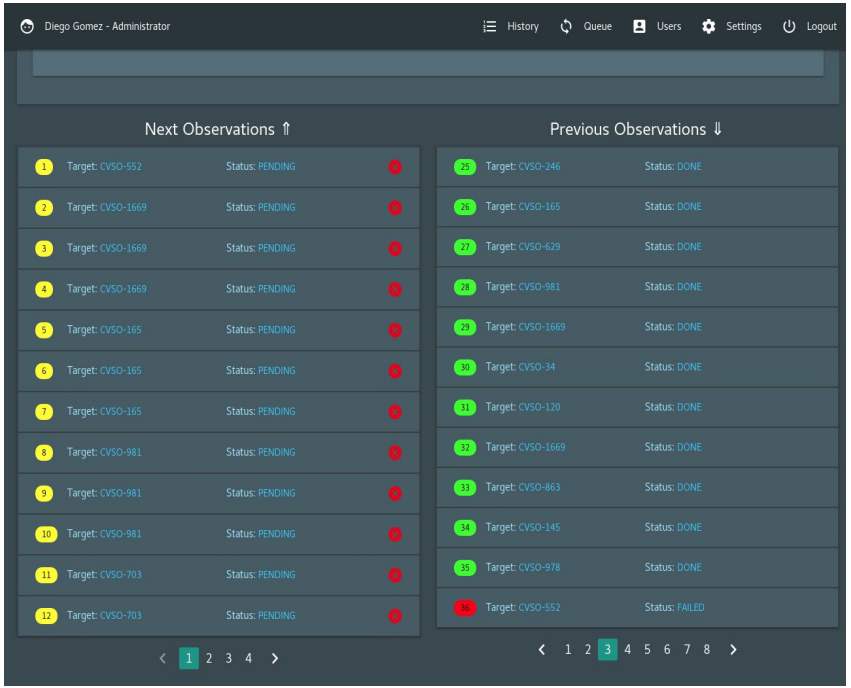
https://lco.global/aeon/

AEON Status

1. Updates to the LCOGT APIs for scheduling/telemetry defined
2. SOAR Goodman scripting capabilities implemented
3. Full end-to-end tests between scheduler@LCOGT and SOAR, executed observations (May 2019)

Shared-risk “AEON”-mode nights will be run in 2019B
https://lco.global/aeon/soar-aeon-schedule/

Expecting to offer the mode in 2020A

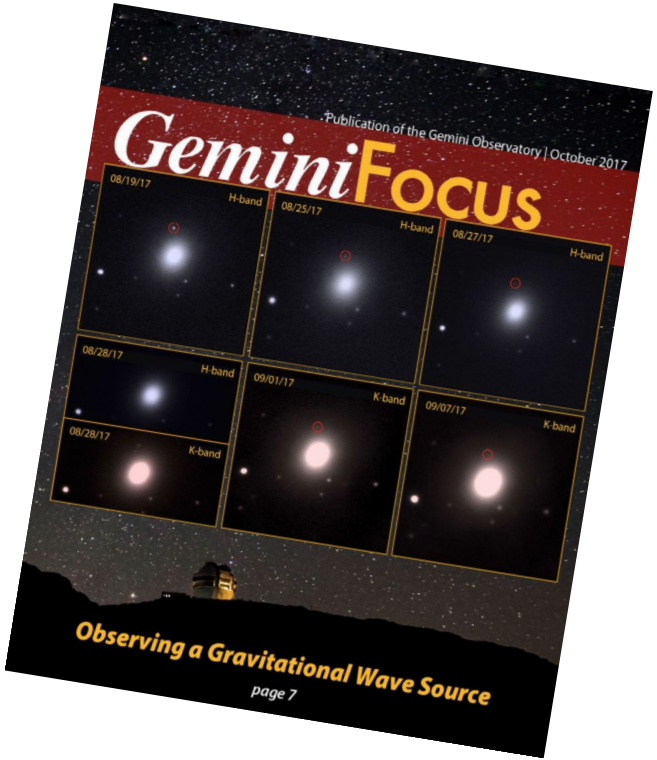


SOAR Queue Manager

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

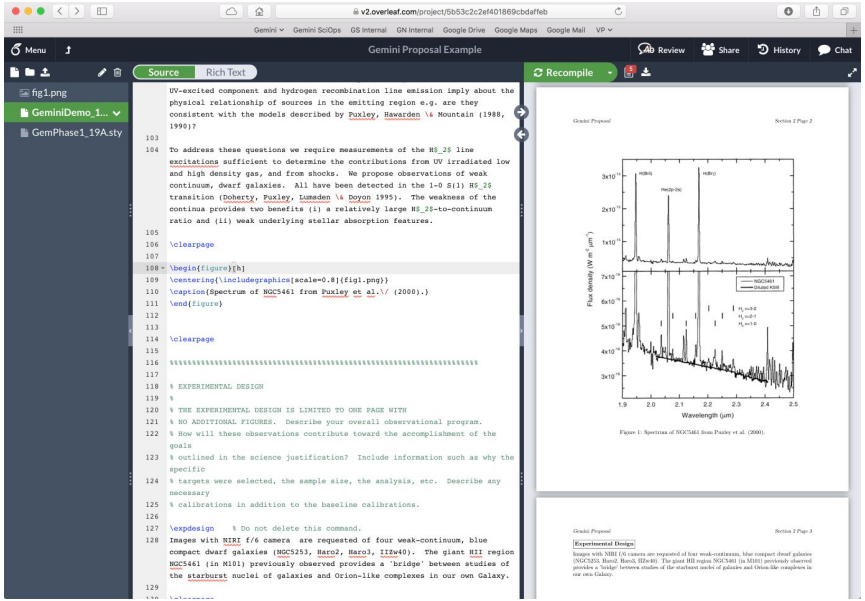


See Oct 2017 Gemini Focus, pg. 20

The proposal process should provide assistance with finding the right instrument and be collaborative

Have a Phase “0” tool for discovery of the appropriate instrument/mode for a project

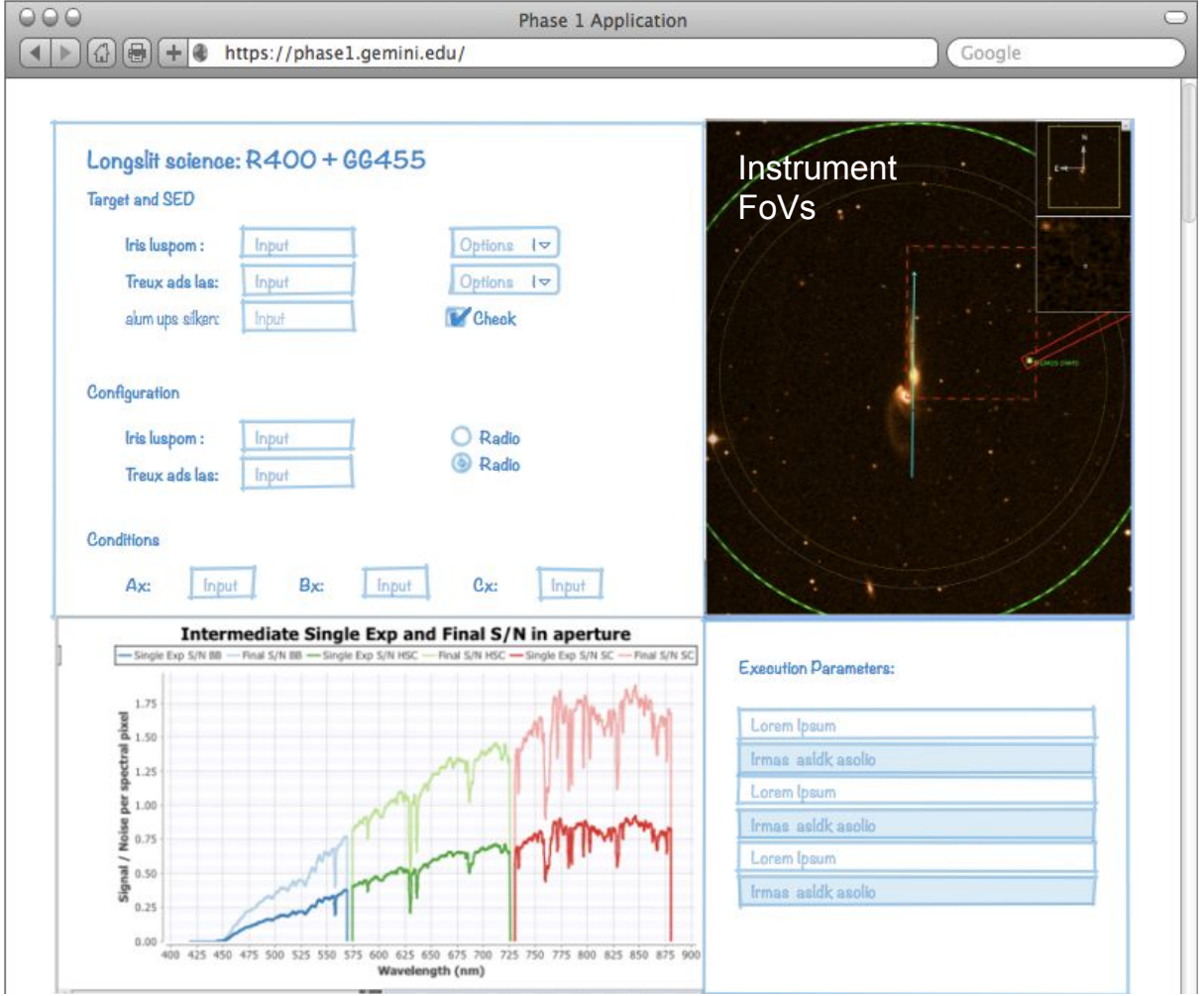
- Near-IR spec, R~2000
  ⇒ F2, GNIRS
- Optical spec, R > 20000
  ⇒ GHOST, GRACES
- Imaging, FWHM < 0.1”
  ⇒ GSAOI, NIRI+LGS



Collaborative editing using templates (e.g. Overleaf, Authorea, Google Drive, Github, …)

Physical conditions on target (FWHM)

Build around the ITCs



Web interface - single ODB

Calculate overheads, execution probability

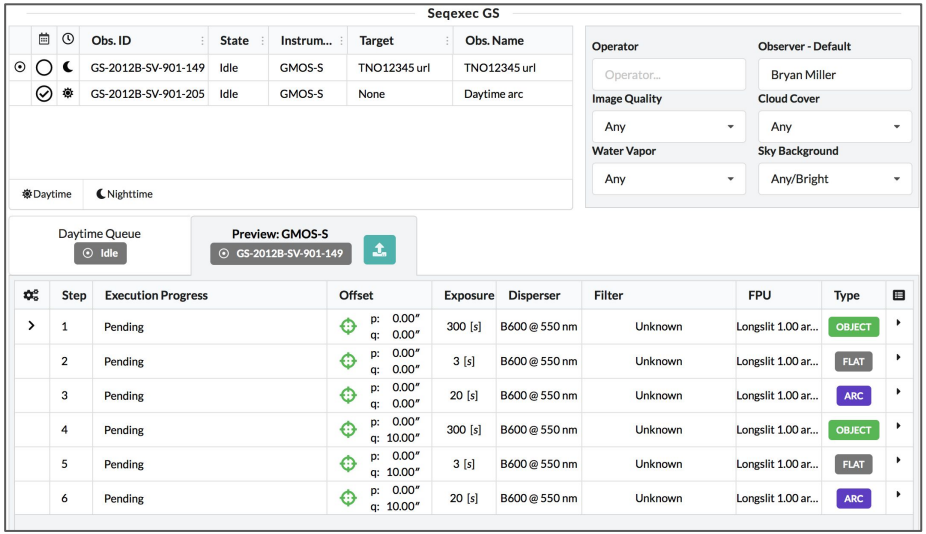
Calibration steps and observations automatically added, configurations linked

The OCS Upgrades Program operations concepts and requirements are being refined.

The Conceptual Design Review is scheduled for the week of August 26.

User stories/requirements updated based on iterative reviews

Developers are prototyping APIs, sequence models, observation creation, and producing the development plan.

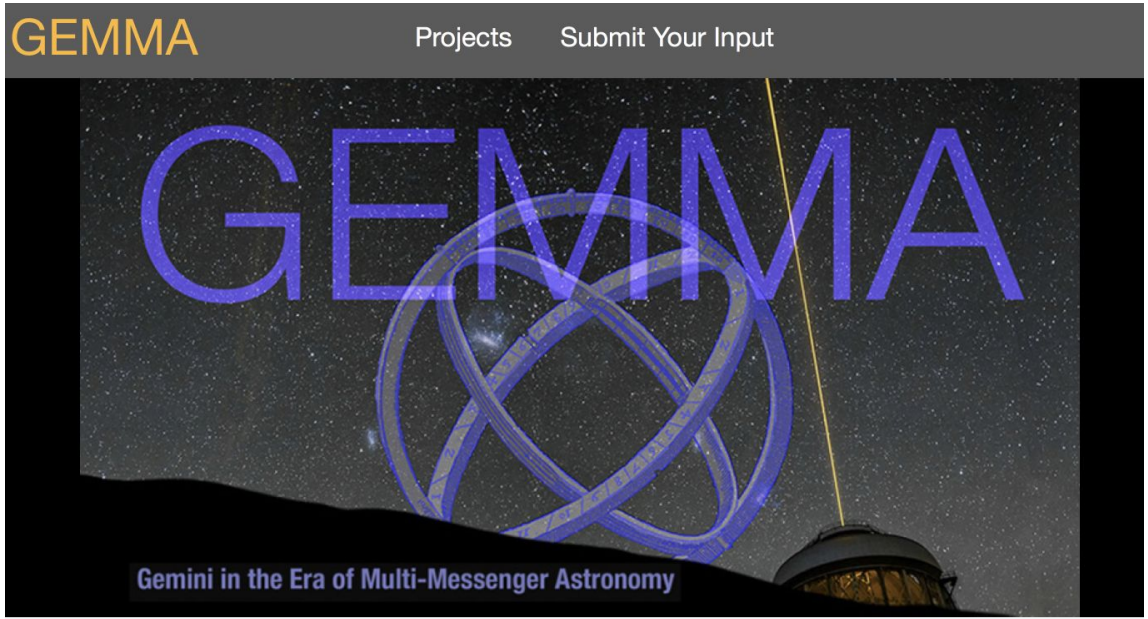


New web-app seqexec from the OCS Upgrades Program

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



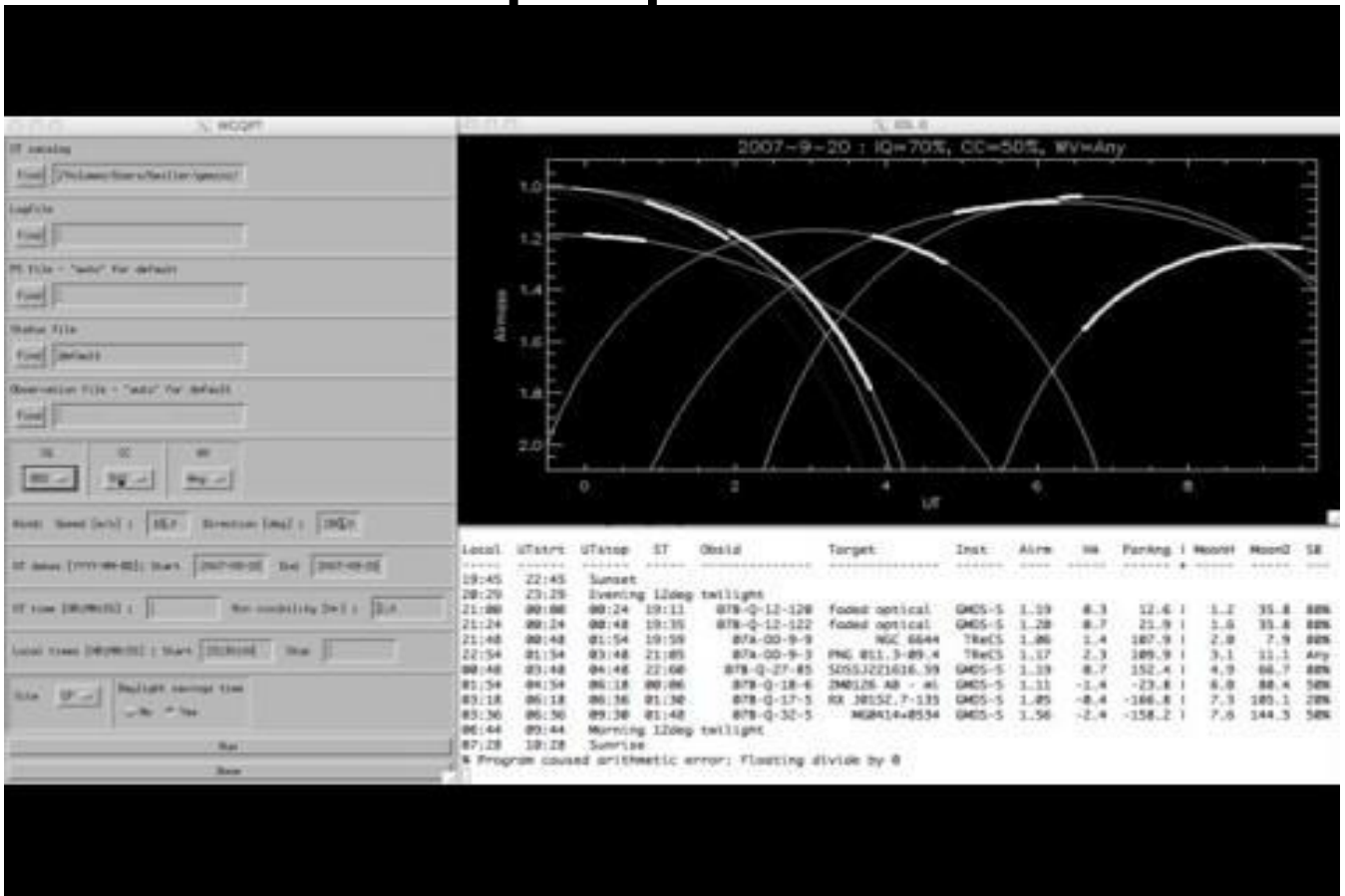
https://www.gemini.edu/gemma/

We are working with a prototype scheduler to gain experience and develop requirements

New python version

Derive observation weighting algorithm and schedule metric

Can simulate ToOs - varying ToO fractions, etc



Lots of user input and involvement will be needed to make these projects successful

Participate in focus or working groups to discuss specific aspects.

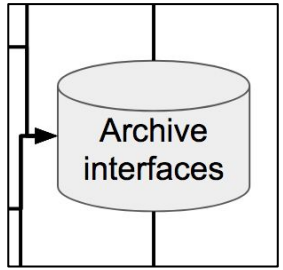
Fill in surveys or questionnaires

Experiment with and use the tools

Testing, testing, testing

The development process will be iterative, so user feedback will be essential.

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).

An important issue in TDA is how to coordinate observations

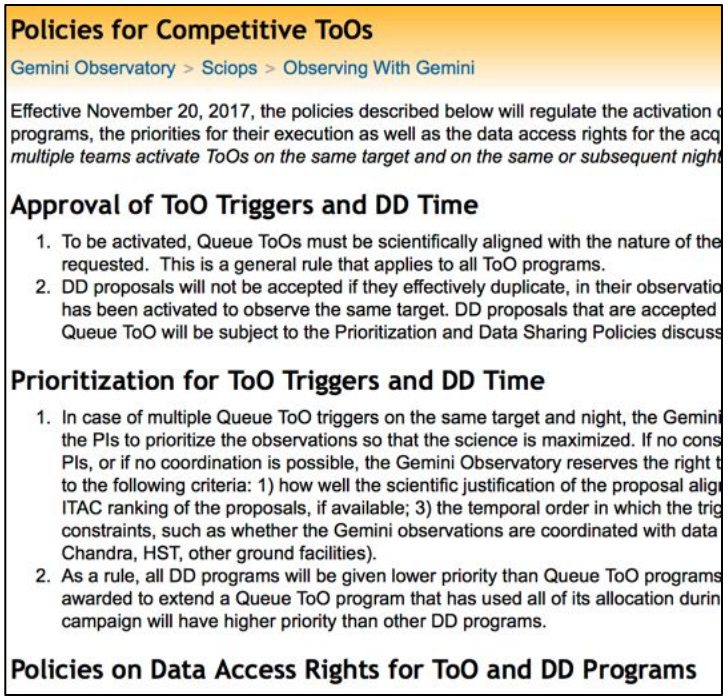
It is a waste of resources to duplicate observations.
How do we avoid this?

Also, there is a general need to coordinate simultaneous observations between facilities (e.g. VLA, Chandra, optical telescopes)

Possible solutions:

- Policies
- Software systems

Gemini's 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
programs, the priorities for their execution as well as the data access rights for the acq
multiple teams activate ToOs on the same target and on the same or subsequent night

Approval of ToO Triggers and DD Time

1. To be activated, Queue ToOs must be scientifically aligned with the nature of the 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 observatio has been activated to observe the same target. DD proposals that are accepted Queue ToO will be subject to the Prioritization and Data Sharing Policies discuss

Prioritization for ToO Triggers and DD Time

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

Policies on Data Access Rights for ToO and DD Programs

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

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.

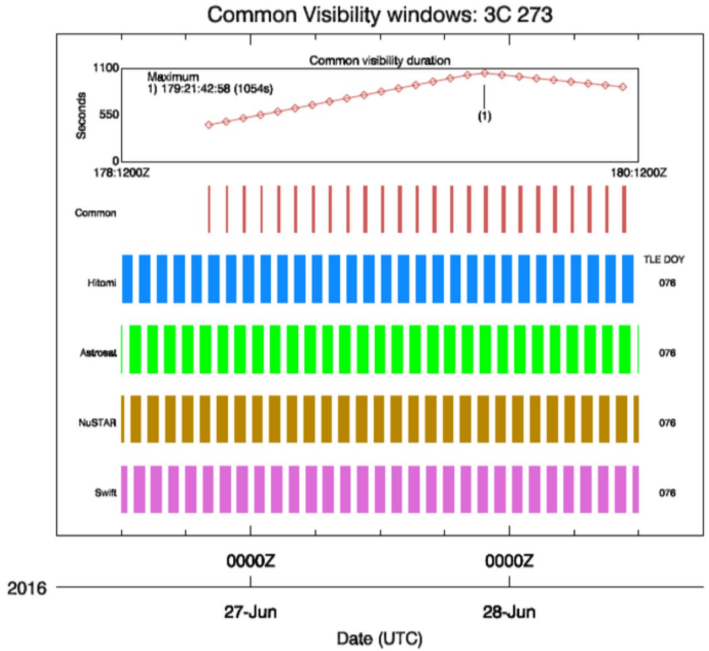
We can also build tools for allowing projects to communicate schedules and facilitate coordination

Virtual Observatory standards for observation coordination (see Kuulkers et al. 2019, arXiv:1901.05390)

- ObjVisSAP - Object Visibility Simple Access Protocol
  - When is a coordinate visible from a given site/facility?
- ObsLocTAP : Observation Locator Table Access Protocol
  - When are observations scheduled?

These or similar standards can be used to develop apps for coordinating observations.

APIs could also be used by TOMs to communicate with each other...



The community should also consider how to best allocate time on these networks

Many follow-up projects require time on multiple facilities

How to get the best science and avoid multiple jeopardy in proposal evaluation?

The Gemini TDA Advisory Committee has been considering options.
Members contribute time to a common pool. Then:

- A single TDA TAC assigns this time to proposals that need multiple resources on the network. Analogous to the current Gemini Large/Long Program TAC.
- Network member TACs forward proposals that require multiple resources to a merging process, like the Gemini ITAC.

Summary

Las Cumbres/NOAO/SOAR/Gemini is re-imagining and rebuilding our observing systems to create a TDA/MMA follow-up network that will consist of:

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

This will enhance the science from LSST and will benefit all users.