

New Infrastructure and Processes for Time-Domain Follow-up

Bryan Miller

Gemini Observatory

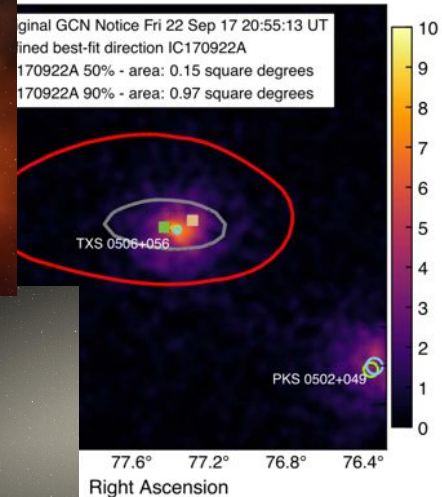
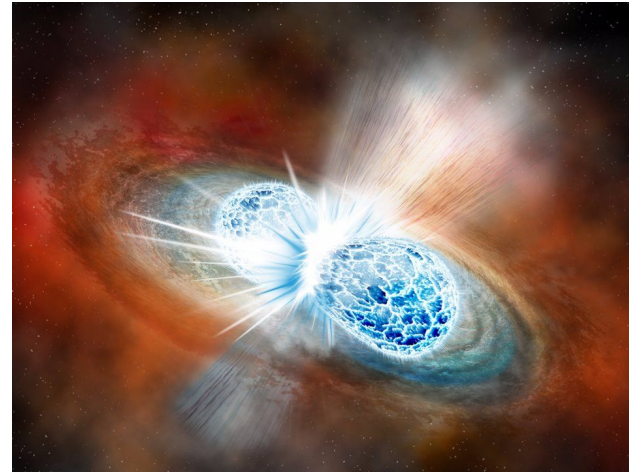


In 2017 it was clear that we were in a new era of Time Domain (TDA) and Multi-messenger Astrophysics (MMA)

In short succession

- GW170817
- IceCube-170922A
- 'Oumuamua

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

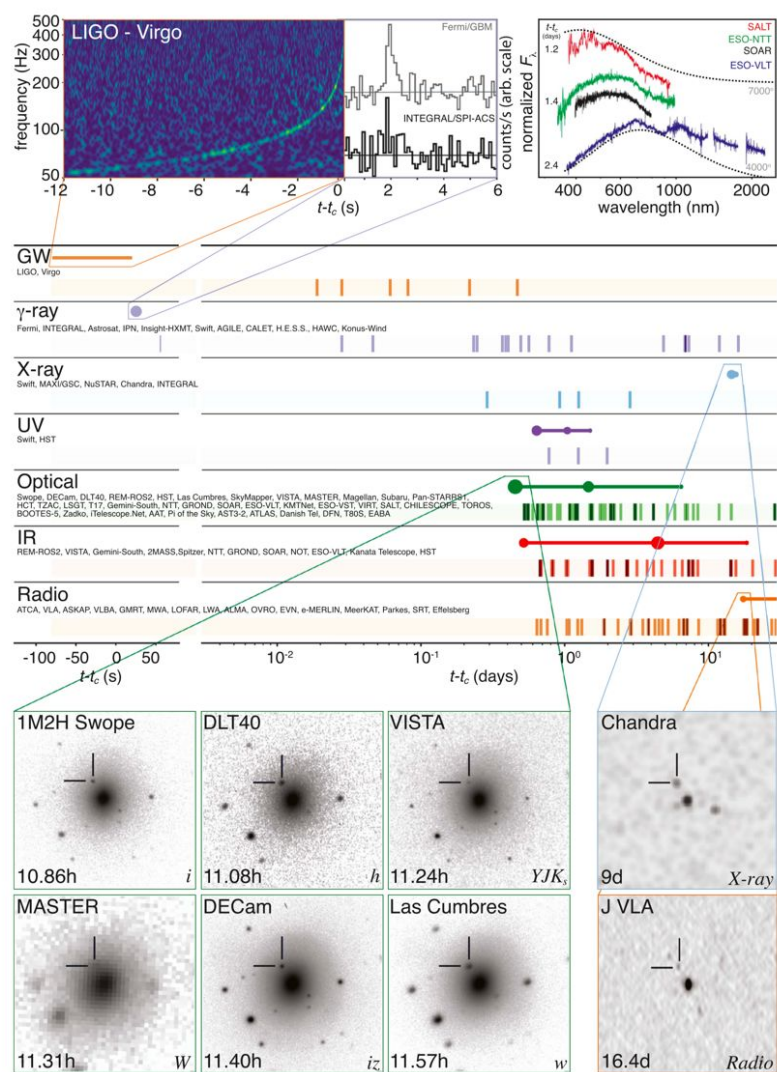


GW170817

Merger of two, $\sim 1 M_{\text{sun}}$ neutron stars

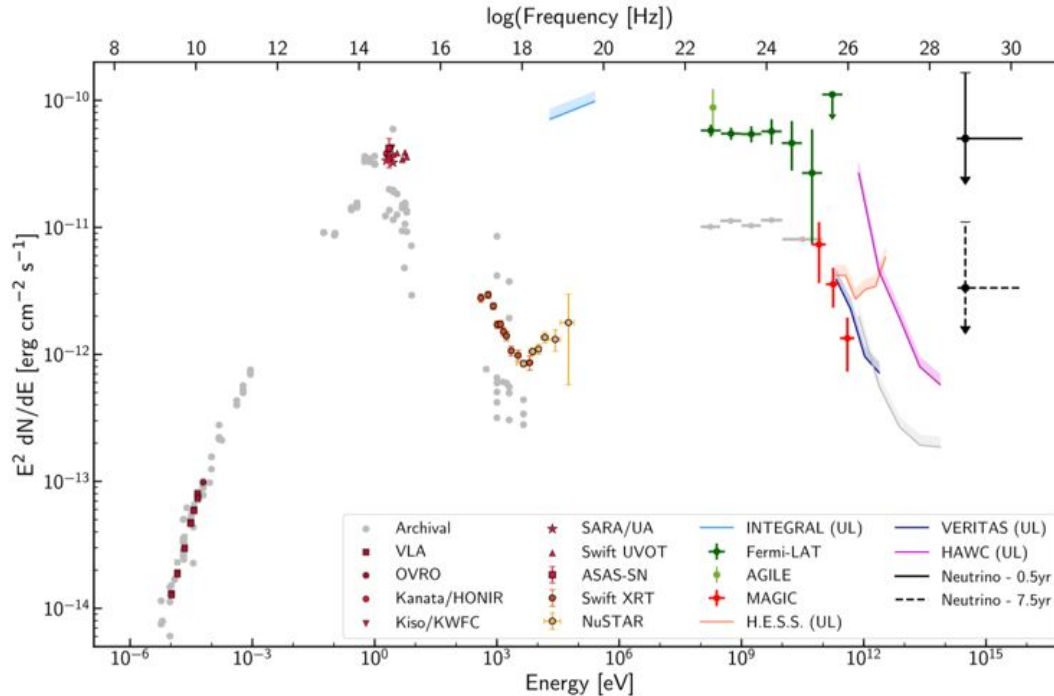
The resulting “kilonovae” was observed at all EM frequencies within a day.

Coordinating all the requests was chaotic, stressful.



Abbott et al. (2017)

IceCube-170922A and TXS 0506+056



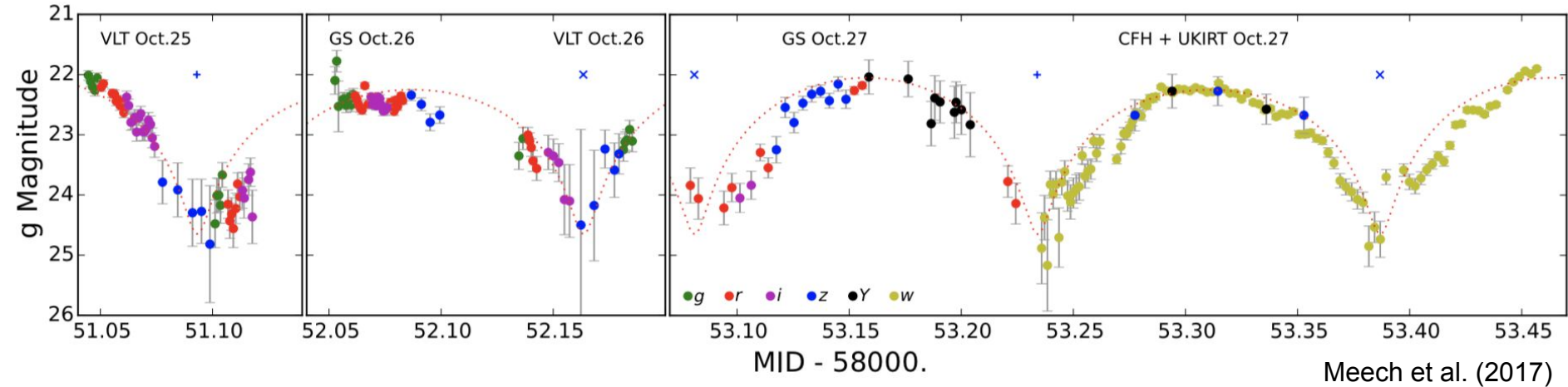
IceCube Collaboration (2018)

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



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



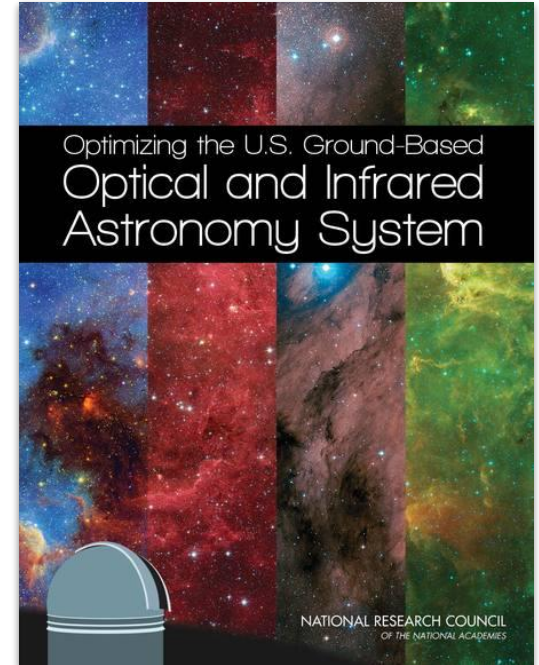
Large Synoptic Survey Telescope (LSST)

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

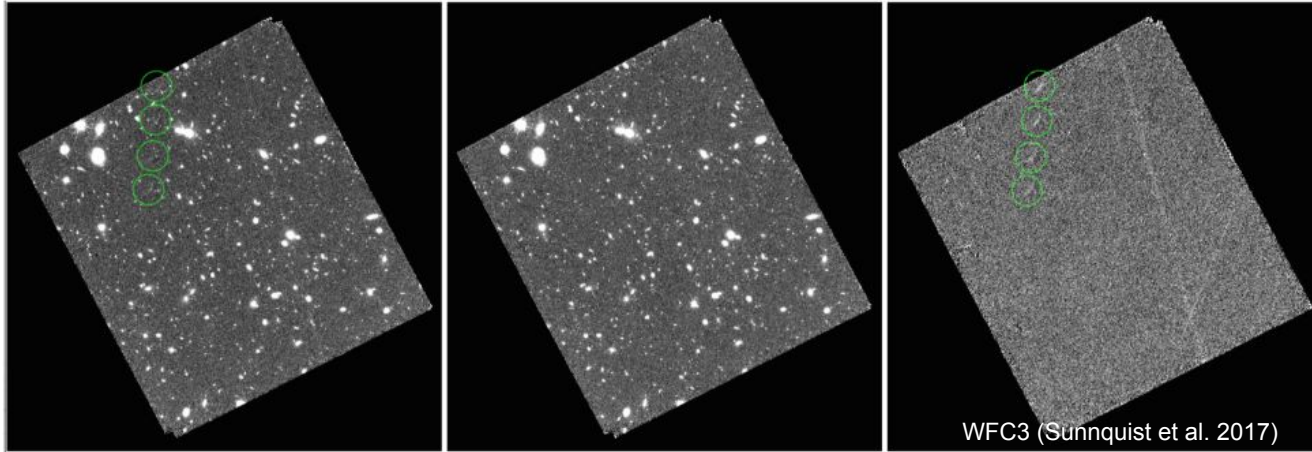
Maximizing the science return from LSST/LIGO/IceCube/etc is a high priority for the US NSF

Recommendations of the 2015 “Elmegreen” report:

- Recommendation 3: Event broker development
- Recommendation 4b: high throughput, broad wavelength spectrograph
 - ➔ SCORPIO (0.4-2.4 μm , $R \sim 4\text{K}$, 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 $\sim 10^7$ transient alerts (~ 1500 new solar system objects) per night!



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

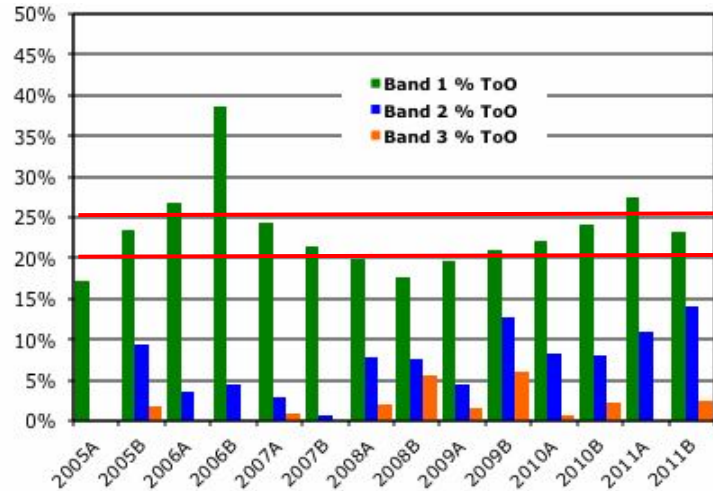
Updates are needed to handle the expected increases in ToOs from LSST and MMA.

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

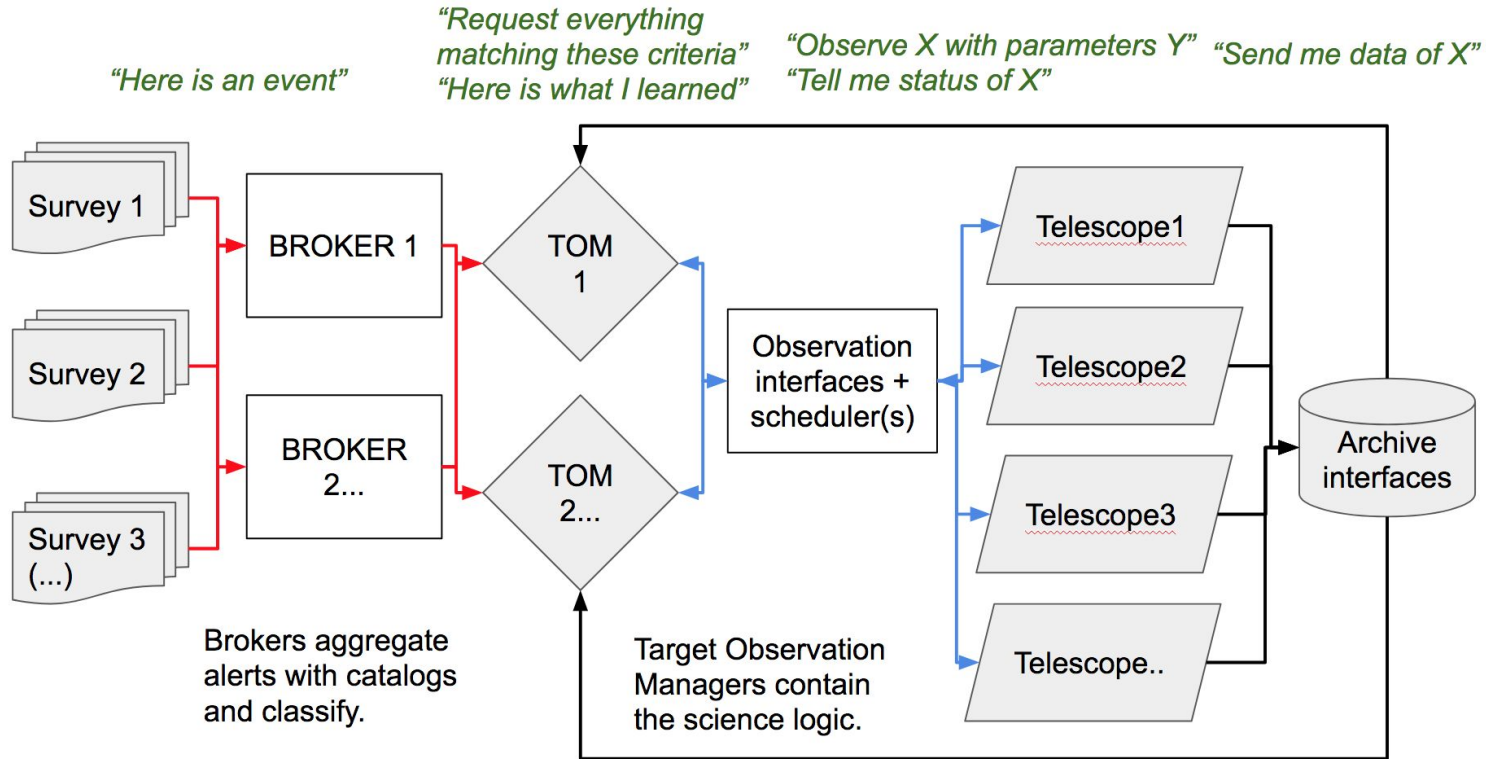


At CTIO/SOAR, ToOs interrupt visitor nights. More will be disruptive.



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/lstt-tds/>)

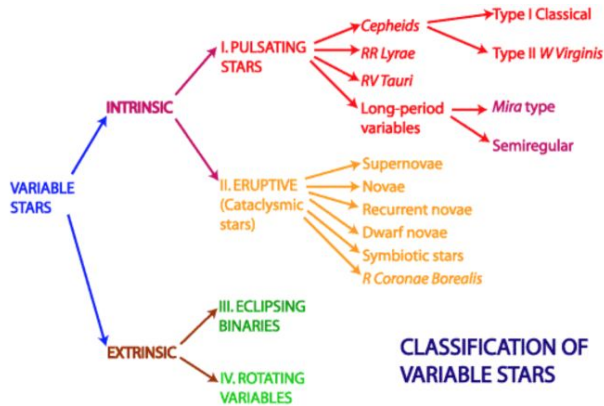
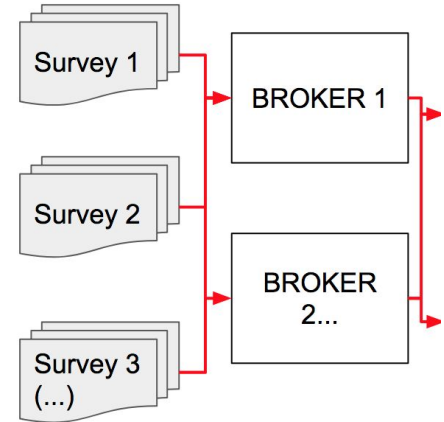
Brokers aggregate and classify alerts

Cross-matches with available catalogs

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

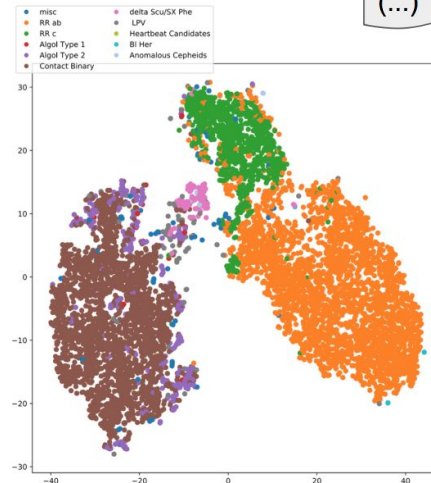
Estimates rarity

Applies filters to select a particular kind of object



CLASSIFICATION OF VARIABLE STARS

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



Light curve basis vector decomposition

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



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



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>

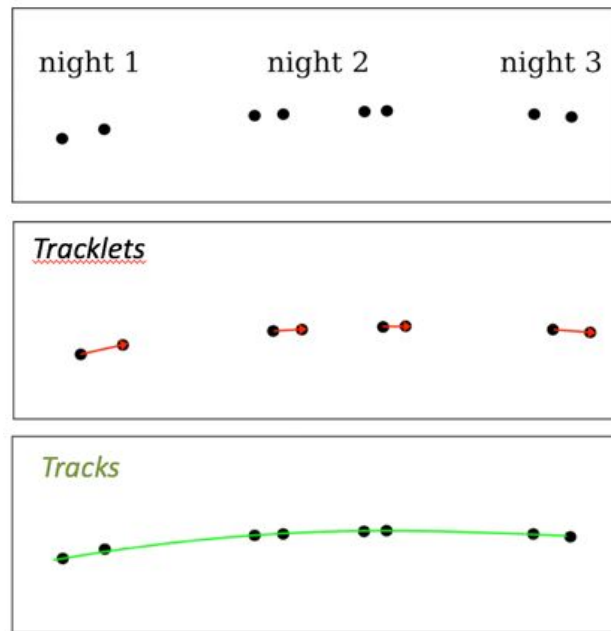
Alerts will contain all detected, known solar-system objects (SSOs) and many unknown objects as single detections

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)



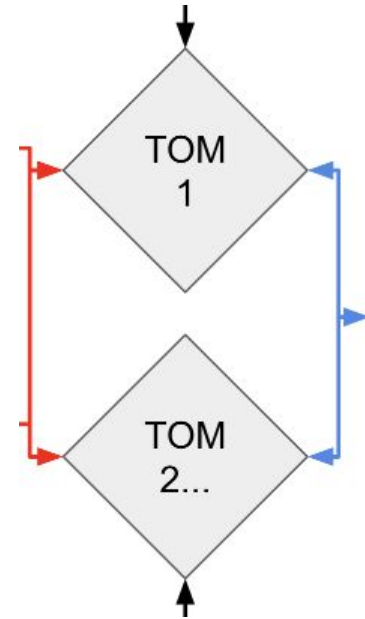
Target/Observation Managers match targets with telescopes, coordinate observations, and manage data.

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

Home | Object List | Scheduling | Dataflow | Floyds Inbox | View object

PS15sv SN Ia 91T-like z = 0.038

16:13:11.74 +01:35:31.1
243.298917 +1.591972

Known as: PS15sv

Known to: ANU, ASASSN, Boulder, CIA, Chase, China, CSP, ex-LCOGT, IPTF, KMTNet, LBNL, LCOGT, LSQ, OKC, Padova, PESSTO, PS1, PTF, Public, QUB, SAAO, SDSU, Skymapper, UCB, UT

Grant to all sharing groups

Interested Persons: I'm interested in this object

Science Interests: Peculiar SNe Ia

Submitted Sequences

Active Photometry: 3-day cadence observations of B (2x200s), V (2x120s), g (2x200s), r (2x120s), i (2x120s) starting 2015-03-29 using Sbig (Tags: Peculiar SNe Ia), requested by Andy Howell
Track this sequence
Stop this sequence

Inactive Spectroscopy: Single observation of 2700s starting 2015-03-29, ending 2015-03-31, using Floyds (Tags: Peculiar SNe Ia), requested by Andy Howell
Track this sequence

Inactive Spectroscopy: 3-day cadence observations of 2700s starting 2015-04-03, ending 2015-04-12, using Floyds (Tags: Peculiar SNe Ia), requested by Curtis McCully
Track this sequence

lair: Object is getting fainter and there aren't any obvious spectral differences at this signal to noise every 3 days. Increasing exp time and lowering cadence.
Track this sequence

Active Spectroscopy: 7-day cadence observations of 3600s starting 2015-04-12 using Floyds (Tags: Peculiar SNe Ia), requested by lair Arcavi
Track this sequence
Stop this sequence

Current Visibility at LCOGT

Add a Photometric Sequence

Repeating every 3 days

| Filter | Exposure Time | No. of Exposures | Block No. |
|--------|---------------|------------------|-----------|
| U | 0 | 2 | 1 |
| B | 200 | 2 | 1 |
| V | 120 | 2 | 1 |
| R | 0 | 2 | 1 |
| I | 0 | 2 | 1 |
| U | 0 | 2 | 1 |
| B | 200 | 2 | 1 |
| r | 120 | 2 | 1 |
| i | 120 | 2 | 1 |
| z | 0 | 2 | 1 |

Airmass Limit 2
Camera SBIG (1m)
Program SN Key Project
Priority Normal
Reminder in 7 days

Data granted to:
 ANU KMTNet Public
 ASASSN LBNL QUB
 Boulder LCOGT SAAO
 CIA LSQ SDSU
 Chase OKC Skymapper
 China Padova UCB
 CSP PESSTO UT
 ex-LCOGT PS1
 IPTF PTF
 Grant to all sharing groups

Pre-approved / urgent observations

Comments

Submit

Add a Spectroscopic Sequence

Once in the next 1 days

Exposure Time 1800
Airmass limit 2
Site Any
Slit Best
Program SN Key Project
Priority Normal
Reminder in 1 days

Science Tags
No tags selected +

Data granted to:
 ANU KMTNet Public
 ASASSN LBNL QUB
 Boulder LCOGT SAAO
 CIA LSQ SDSU
 Chase OKC Skymapper
 China Padova UCB
 CSP PESSTO UT
 ex-LCOGT PS1
 IPTF PTF
 Grant to all sharing groups

Pre-approved / urgent observations

Target visibility

Manual or scripted observation requests.

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

<https://tomtoolkit.github.io>



TOM Toolkit

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

Navigation

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

Python + Django.
Easy installation and
configuration
Under active development

Target and Observation Manager

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.

Workshop: Managing Follow-up Observations in the Era of ZTF and LSST

LSST Corporation and Las Cumbres Observatory will be hosting a workshop from September 30 to October 4, 2019, with a strong focus on interactive TOM Toolkit development and instruction. The workshop will culminate in a call for proposals that will be awarded with mini-grants and telescope time on LCO's global telescope network. If you have an interest in developing a TOM for your science case, you can apply, get more information, or subscribe to the mailing list on the [workshop homepage](#).

- [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.



You can define broker queries,

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

| Name | Broker | Created | Run | Delete |
|---|------------|---------------------|---------------------|------------------------|
| Deltamag > 1, R/B > 0.75, r | MARS | 2018-12-28 02:12:12 | Run | Delete |
| Name Query | MyBroker | 2018-12-28 14:12:00 | Run | Delete |
| Score > 50 | AutoBroker | 2018-12-28 18:12:28 | Run | Delete |

Broker

Name contains

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

... manage targets and check visibilities,

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 |

Observe Observations Data

Observe

[LCO](#) [GEM](#)

Plan

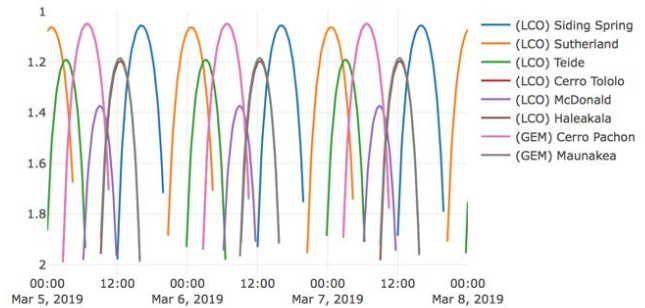
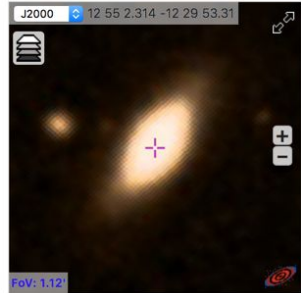
Start Time

End Time

Maximum Airmass

[Plan](#)

Survey View



... 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 User 1 Logout

Submit an observation to GEM

| | | |
|--|--------------------------------------|--|
| Obsid* | Ready* | Group |
| S19ATOO1[1] Std: GMOS B600 1.0arcsec S19ATOO1[2] Rap: GMOS B400 1.0arcsec S19ATOO1[9] GMOS Acq 1.0arcsec N19ATOO1[1] Std: GMOS B600 1.0arcsec | Yes | NGC4792 standard ToO |
| Position Angle | PA Mode | UT Date Time (for Parallactic PA Mode) |
| 330 | Flip180 | |
| Target brightness | Brightness band | Brightness system |
| 19.5 | r | AB |
| Airmass/Hour Angle Constraint | Min Airmass/HA | Max Airmass/HA |
| Airmass | 1.0 | 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 | Guide Star Brightness System |
| | UC | Vega |
| Instrument | Guide Probe | IFU Mode |
| GMOS | OIWFS | None |
| Image Quality | Cloud Cover | Sky Brightness |
| Any | Any | Any |
| Exptime [sec]. If multiple, comma separate | ISS Port | |
| | Side | |
| Search for guide star if none entered? | Overwrite previous guide star query? | |
| Yes | No | |

Submit

File Edit View Go Tools

Open Home Back Forward Stop

Observation

- TOM TOO Trigger Tests
- TOO Templates
 - [1] CAMS sToD 3.0
 - [2] CAMS rToD 3.0
- TOM Triggers
 - [10] Wash
 - Feeding Chart
 - Observing Core
 - Target: Hoth
 - CAMS-N
 - Observing List
 - [11] Sequence

Group

Note

Component

Smaller

Observer

- 1 - [Update Observations](#)

| View | Target | Facility | Status | Saved Data | Download All |
|-------------------------|--------------|----------|--------|------------|--------------|
| Details | Engel | GEM | | 0 | |
| Details | Hoth | GEM | | 0 | |
| Details | ZTF18acovvcs | GEM | | 0 | |
| Details | NGC4833 | GEM | | 0 | |
| Details | NGC4833 | GEM | | 0 | |
| Details | NGC4792 | GEM | | 0 | |
| Details | NGC4792 | GEM | | 0 | |

Observation id

Observation i

Target

Facility

Facility

Status

Status

[Filter](#)

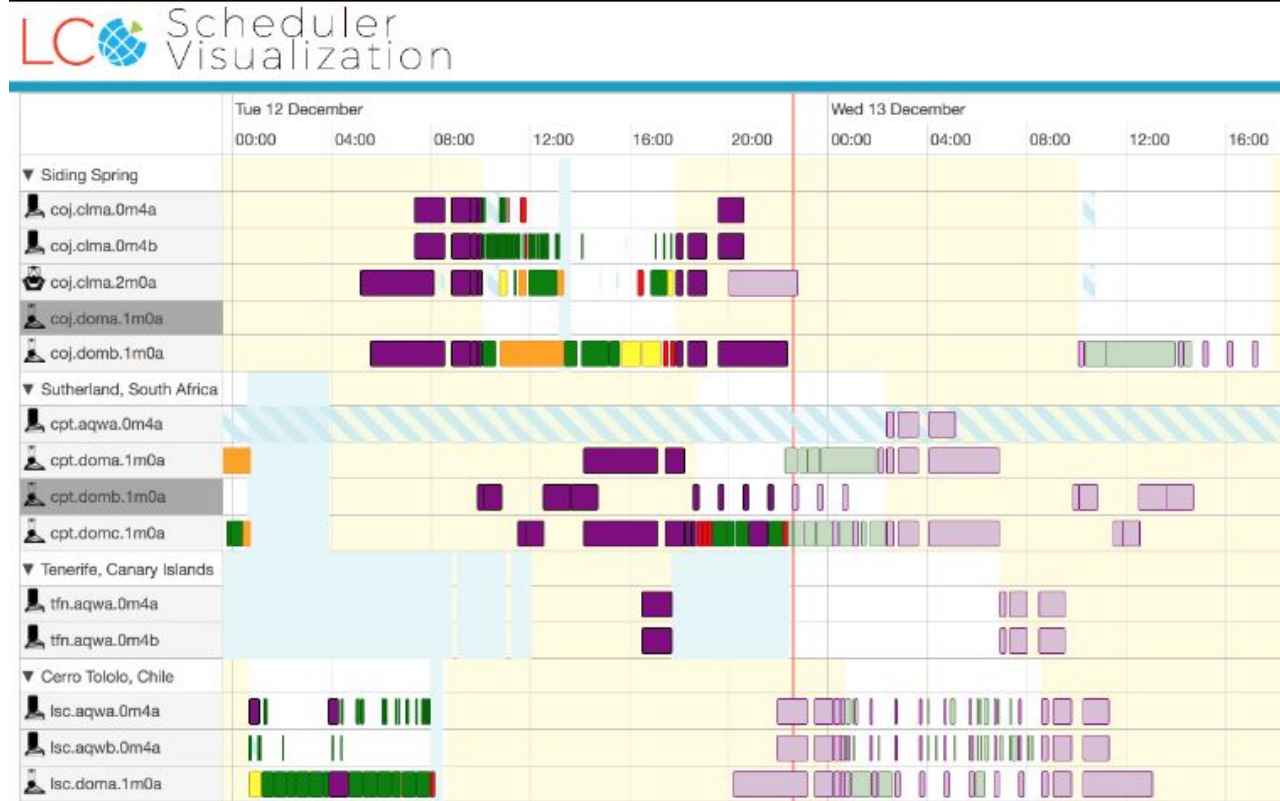
[Reset](#)

You have made changes to your program

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.



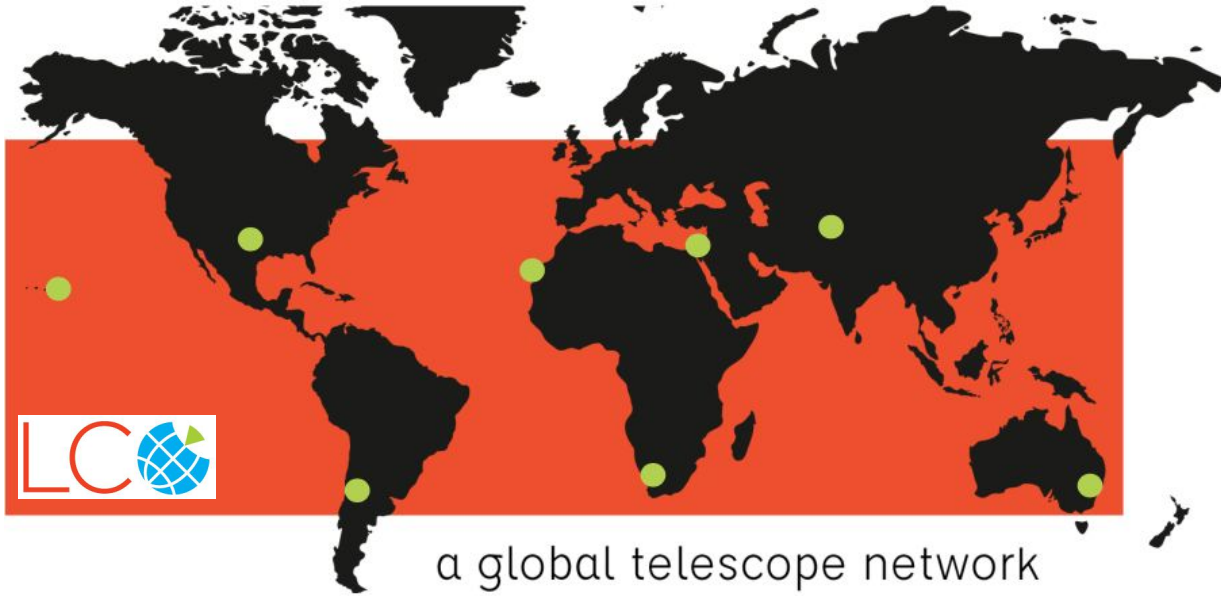
NOAO/SOAR/Las Cumbres/Gemini are working to dynamically schedule requests from TOMs on SOAR, Gemini, Blanco, others...



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



a global 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

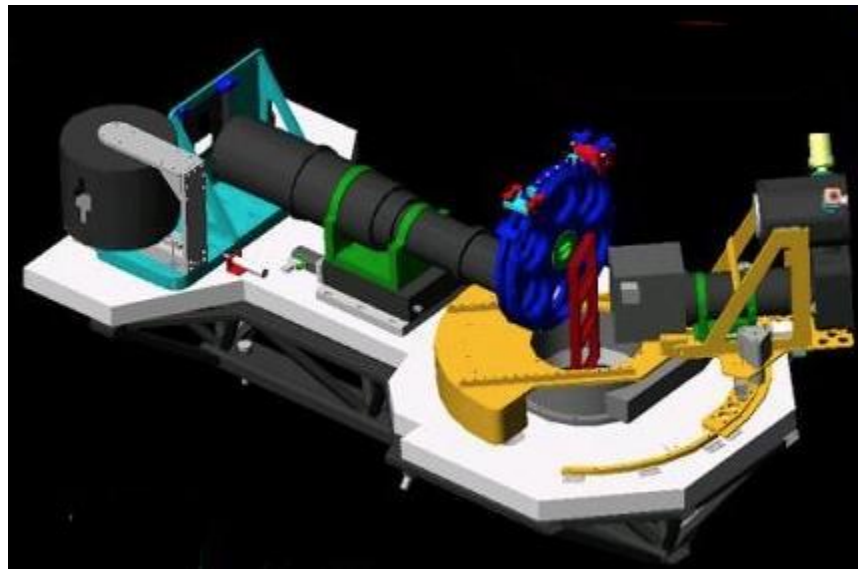
Red camera and 400 l/mm grating

$R \sim 1000$ with 1 arcsec slit

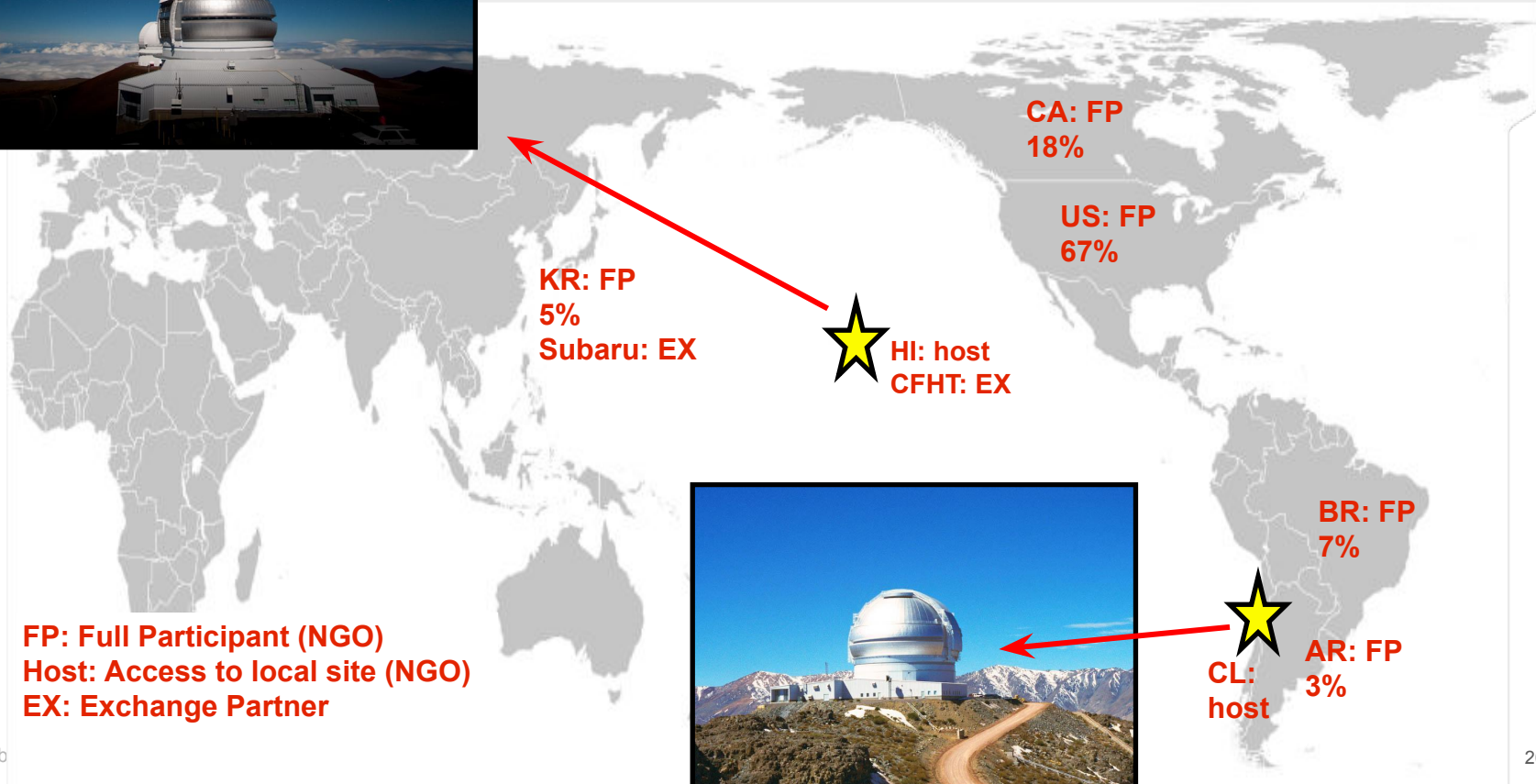
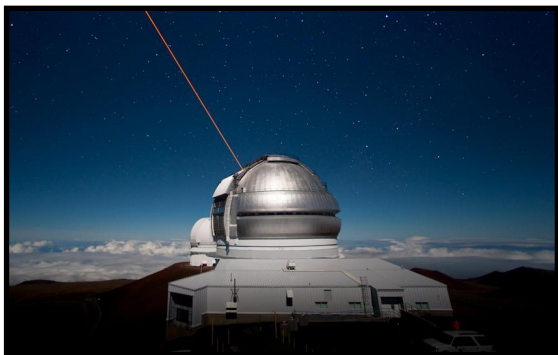
Imaging

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

Optical

GMOS-N

GNIRS

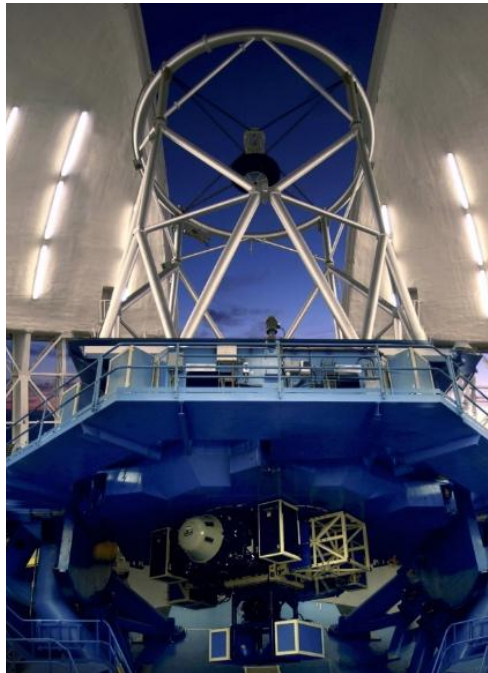
Near-IR

NIFS

NIRI

AO

ALTAIR
NGS & LGS



Visitor instruments

Gemini South

GMOS-S

FLAMINGOS-2

GPI (ExtAO)

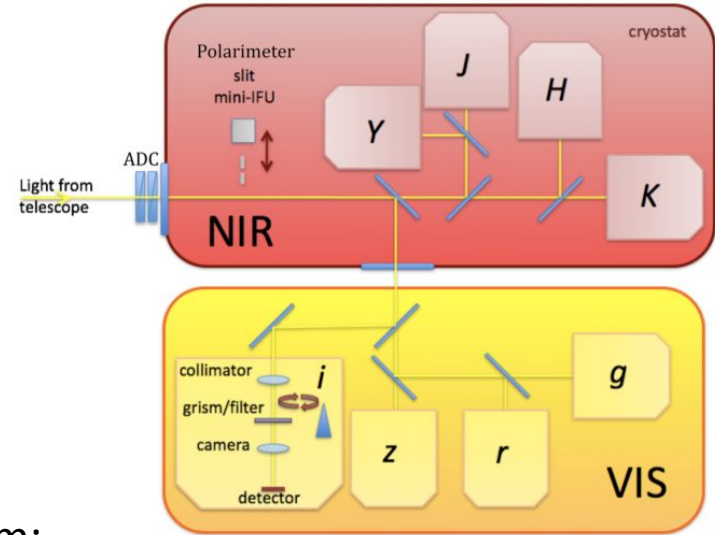
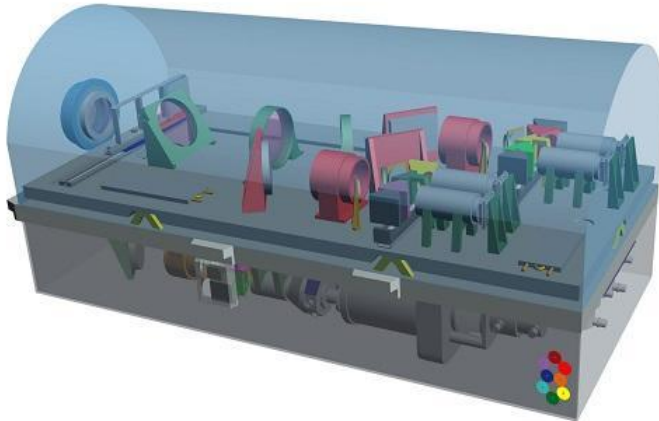
GSAOI

GeMS (MCAO)

LGS (5)

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

- $g - K_s$ coverage using 7 dichroics
- Simultaneous 8-band imaging over a $3' \times 3'$ field
- Single-object longslit, IFU upgrade option
- $R \sim 4000$
- Must be operational by 2023

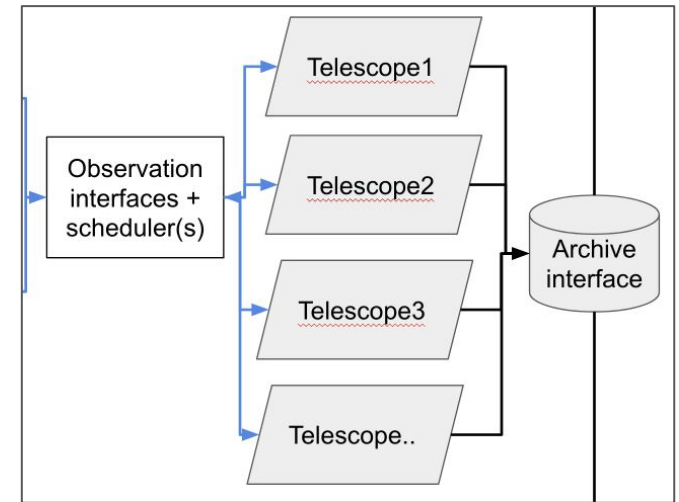


Team:

- 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/>

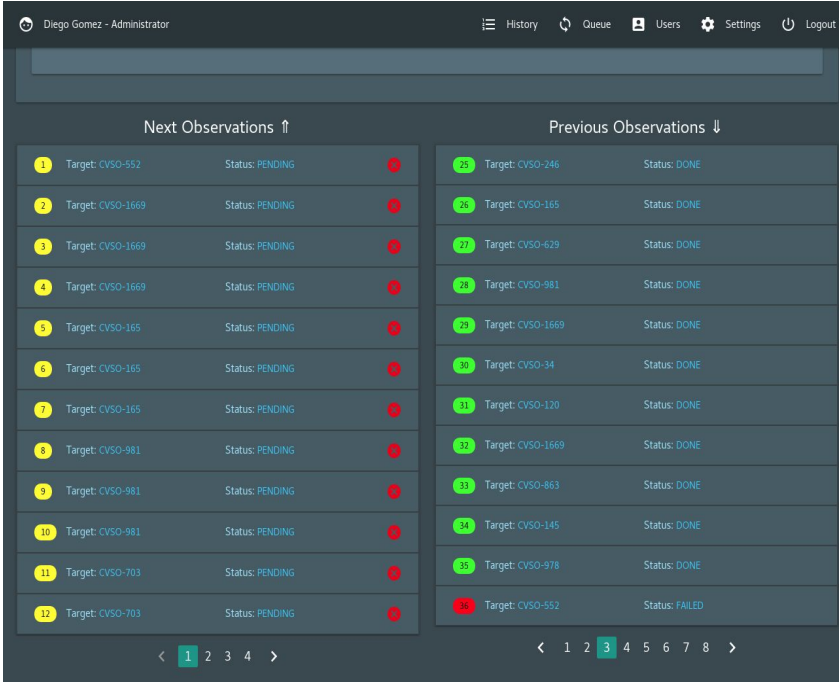
AEON Status

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



The screenshot shows the SOAR Queue Manager interface. At the top, it displays 'Diego Gomez - Administrator' and navigation options: History, Queue, Users, Settings, and Logout. The main area is divided into two columns: 'Next Observations ↑' and 'Previous Observations ↓'. Each column contains a list of observations with their target IDs and status. The 'Next Observations' column shows 12 observations, all with a 'PENDING' status and a red circle icon. The 'Previous Observations' column shows 18 observations, all with a 'DONE' status and a green circle icon. At the bottom of each column, there are pagination controls with a highlighted page number (1 for Next, 3 for Previous) and arrows for navigation.

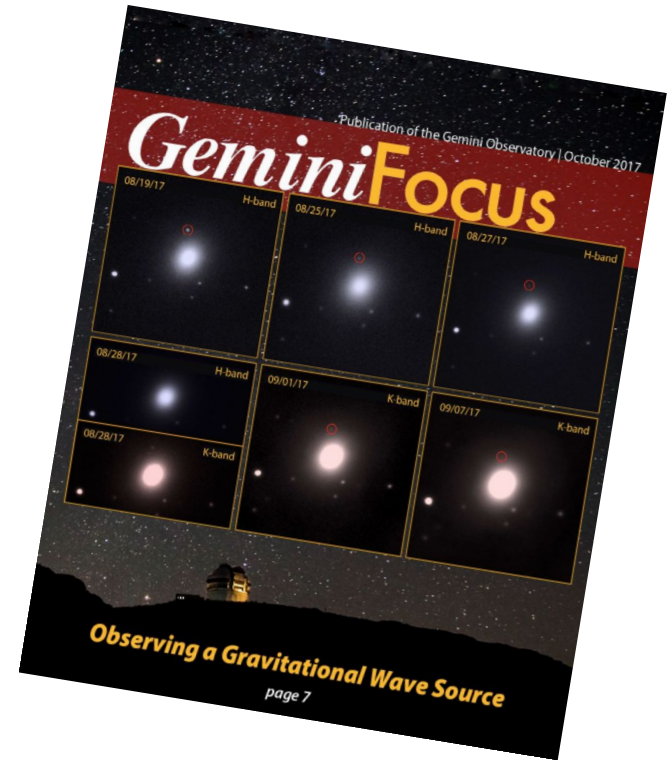
| Next Observations ↑ | | Previous Observations ↓ | |
|---------------------|-----------------------------------|-------------------------|---------------------------------|
| 1 | Target: CVSO-552 Status: PENDING | 25 | Target: CVSO-246 Status: DONE |
| 2 | Target: CVSO-1669 Status: PENDING | 26 | Target: 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

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, $R \sim 2000$
⇒ F2, GNIRS
- Optical spec, $R > 20000$
⇒ GHOST, GRACES
- Imaging, $\text{FWHM} < 0.1''$
⇒ GSAOI, NIRI+LGS

The screenshot shows a Gemini Proposal Example document in Overleaf. The document is a LaTeX source file for a proposal section titled "EXPERIMENTAL DESIGN". It contains text describing the scientific goals and instrument requirements for observing dwarf galaxies. A figure is included, showing the spectrum of NGC5461 from Puxley et al. (2009). The figure plots Flux density (W m^{-2}) versus Wavelength (μm) from 1.8 to 2.5. The spectrum shows several emission lines, with the H-alpha line being the most prominent. The text in the proposal discusses the need for measurements of the H-alpha line and the importance of observing weak continuum dwarf galaxies.

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

Phase 1 Application

https://phase1.gemini.edu/

Google

Longslit science: R400 + GG455

Target and SED

Iris luspom : Options: I ▾

Treux ads las: Options: I ▾

alum ups silker: Check

Configuration

Iris luspom : Radio

Treux ads las: Radio

Conditions

Ax: Bx: Cx:

Instrument FoVs

Intermediate Single Exp and Final S/N in aperture

Execution Parameters:

Physical conditions on target (FWHM)

Build around the ITCs

Web interface - single ODB

Calculate overheads, execution probability

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.

The screenshot displays the Seqexec GS web application interface. At the top, there is a table with columns: Obs. ID, State, Instrum..., Target, and Obs. Name. Below this, there are controls for Daytime and Nighttime. A 'Preview: GMOS-5' section shows a 'Daytime Queue' with an 'Idle' button and a 'GS-2012B-SV-901-149' button. The main table below has columns: Step, Execution Progress, Offset, Exposure, Disperser, Filter, FPU, and Type. The table contains 6 rows of pending observations.

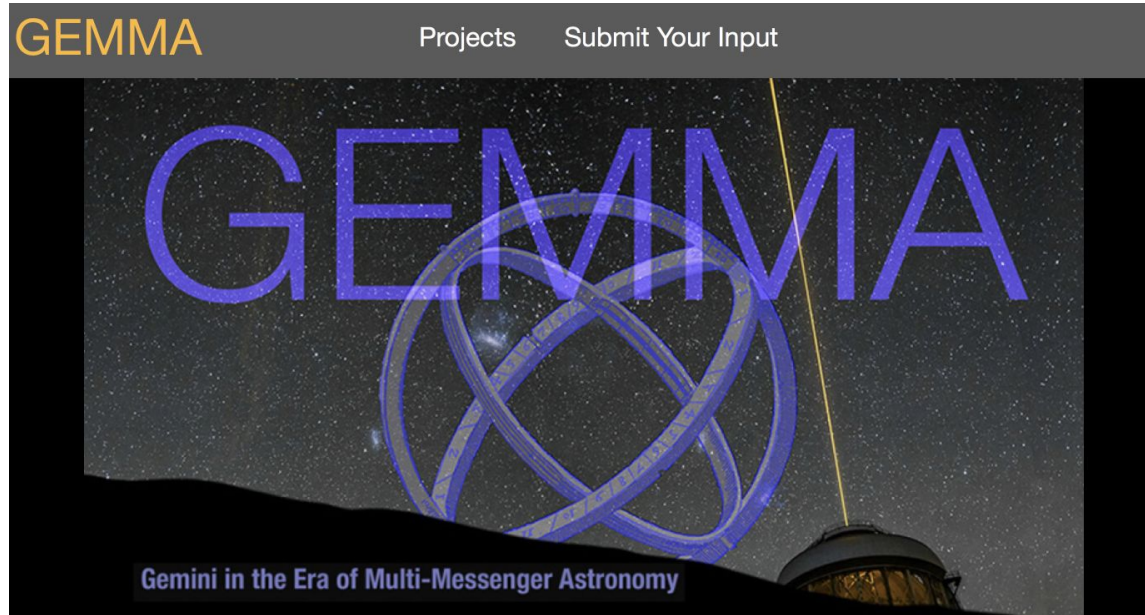
| Step | Execution Progress | Offset | Exposure | Disperser | Filter | FPU | Type |
|------|--------------------|-----------------------|----------|---------------|---------|---------------------|--------|
| 1 | Pending | p: 0.00* q: 0.00* | 300 [s] | B600 @ 550 nm | Unknown | Longslit 1.00 ar... | OBJECT |
| 2 | Pending | p: 0.00* q: 0.00* | 3 [s] | B600 @ 550 nm | Unknown | Longslit 1.00 ar... | FLAT |
| 3 | Pending | p: 0.00* q: 0.00* | 20 [s] | B600 @ 550 nm | Unknown | Longslit 1.00 ar... | ARC |
| 4 | Pending | p: 0.00* q: 10.00* | 300 [s] | B600 @ 550 nm | Unknown | Longslit 1.00 ar... | OBJECT |
| 5 | Pending | p: 0.00* q: 10.00* | 3 [s] | B600 @ 550 nm | Unknown | Longslit 1.00 ar... | FLAT |
| 6 | Pending | p: 0.00* q: 10.00* | 20 [s] | B600 @ 550 nm | Unknown | Longslit 1.00 ar... | ARC |

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



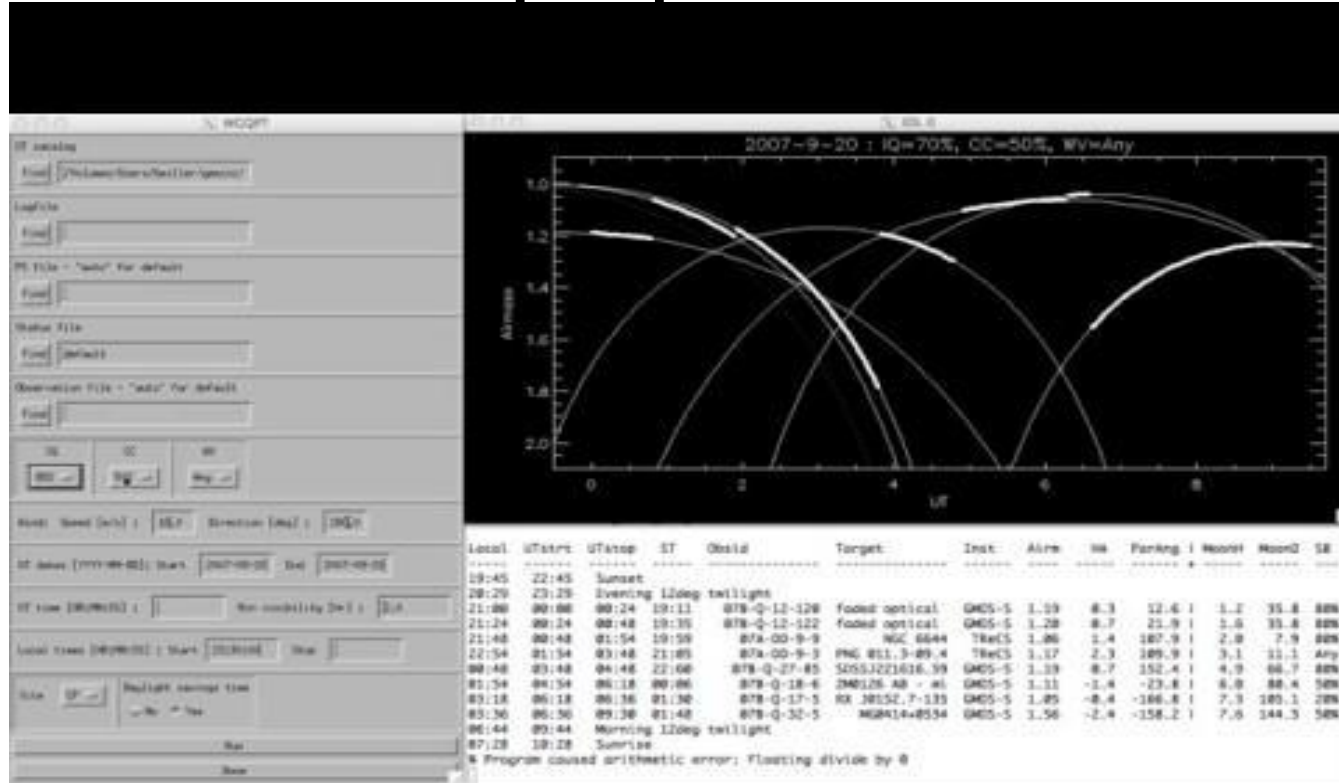
<https://www.gemini.edu/gemma/>

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

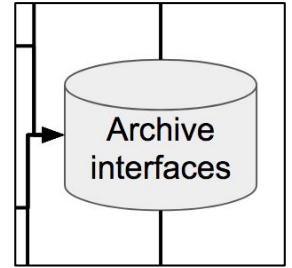
Experiment with and use the tools



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 of programs, the priorities for their execution as well as the data access rights for the acquisition. *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 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 to observe the same target as 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 other facilities (e.g., Chandra, HST, other ground facilities).
2. As a rule, all DD programs will be given lower priority than Queue ToO programs. DD programs awarded to extend a Queue ToO program that has used all of its allocation during the current 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.

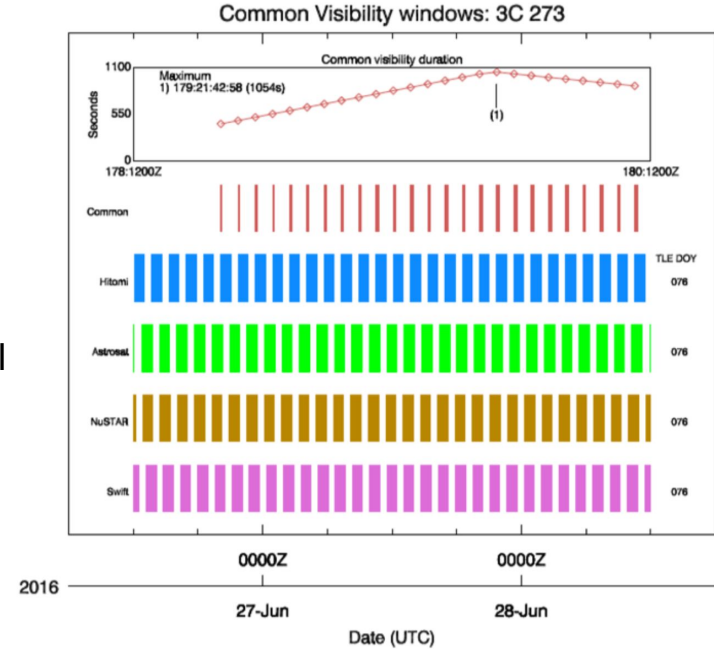
We can also build tools for allowing projects to communicate schedules and facilitate coordination

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.