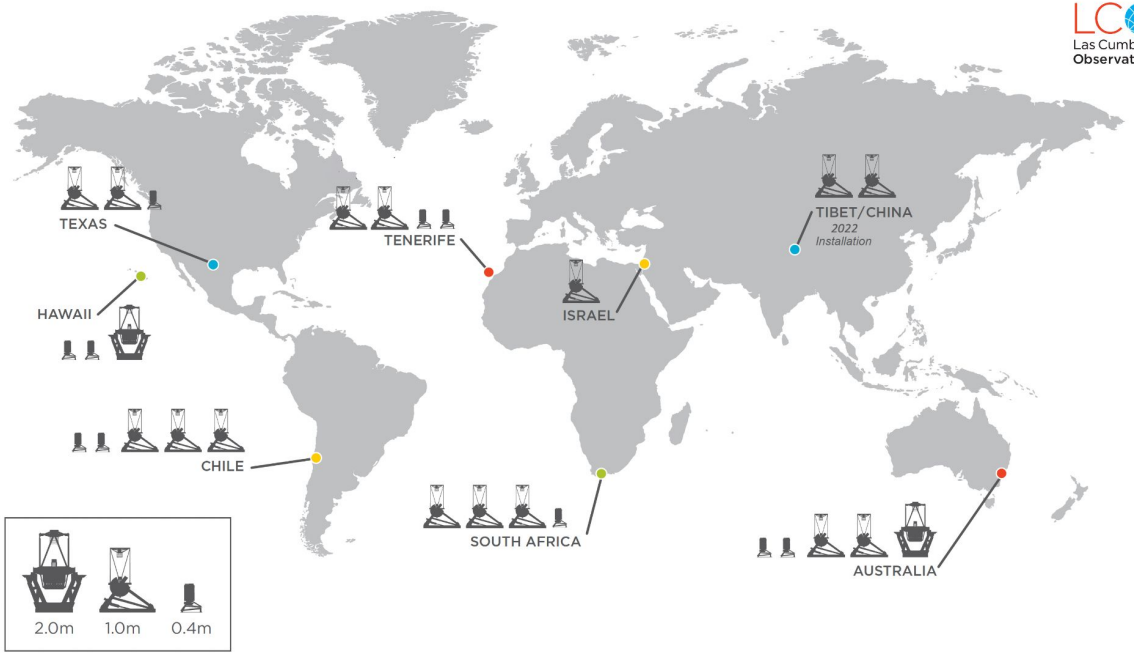
LCO resources to aid astronomy in the big data era

Nikolaus Volgenau
with contributions from Rachel Street, Jon Nation, Lisa Storrie-Lombardi

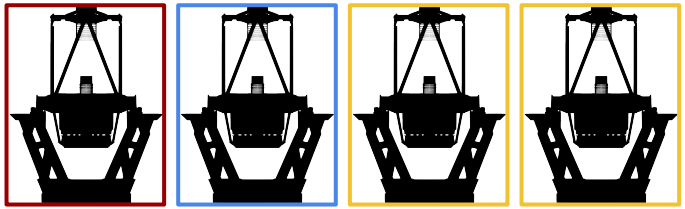
Las Cumbres Observatory in 2023

A unique **follow-up** facility for the astronomy community:

- **A global network** of 2m, 1m and 0.4m robotically controlled telescopes.
- **Uniform instrumentation** on each telescope class.
- Globally-optimized, **dynamic scheduling**. (New schedule every 5 min)
- **Specialized observing modes** for science programs that need them.
- **Rapid delivery of data products**. (Archived 10 min after shutter close)

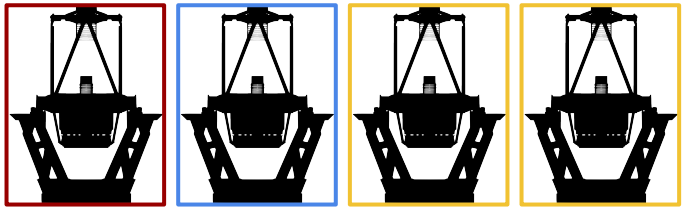


LCO's instrument inventory

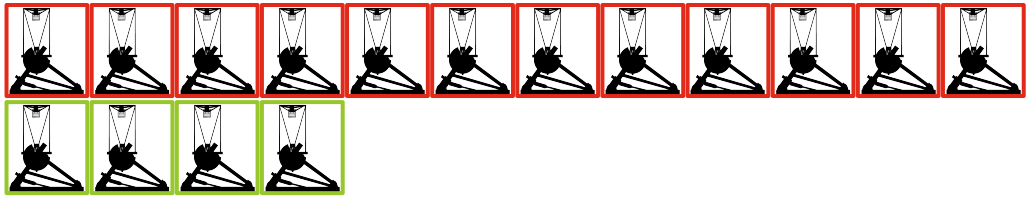


1 MuSCAT imager | 1 Spectral imager | 2 FLOYDS spectrographs

LCO's instrument inventory

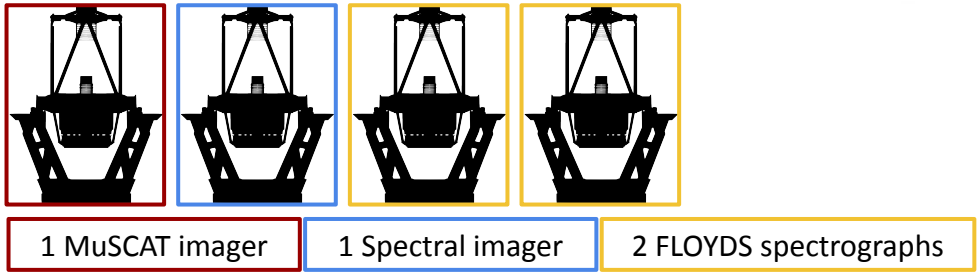


1 MuSCAT imager | 1 Spectral imager | 2 FLOYDS spectrographs

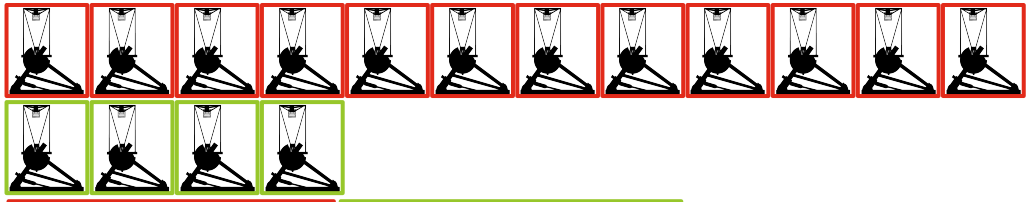


12 Sinistro imagers | 4 NRES spectrographs

LCO's instrument inventory



1 MuSCAT imager | 1 Spectral imager | 2 FLOYDS spectrographs

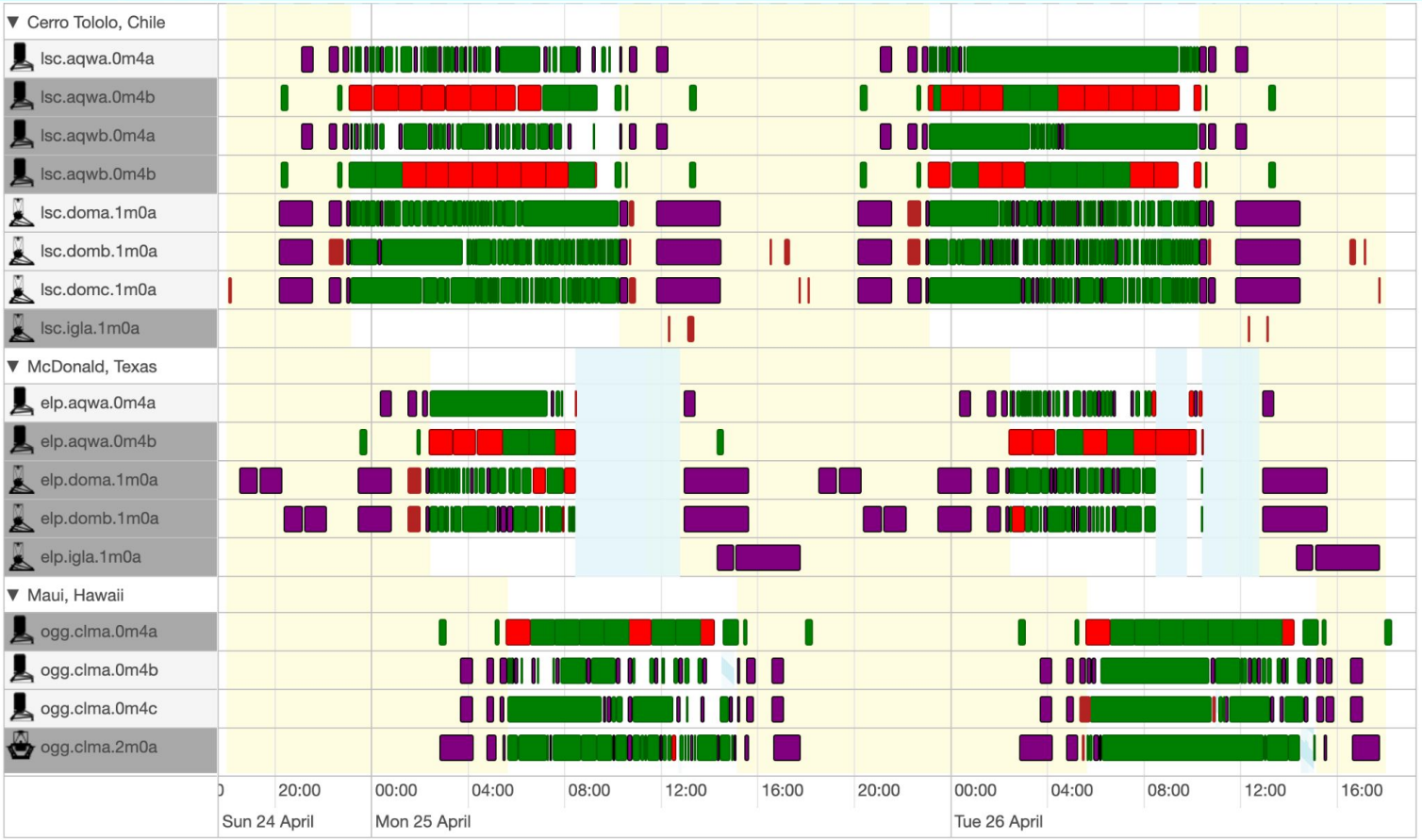


12 Sinistro imagers | 4 NRES spectrographs

7 SBIG imagers | 3 QHY imagers

That's 30 instruments!

Dynamic Scheduling



Science Collaboration, Global Sky Partners

Science Collaboration institutions have guaranteed observing time on the LCO network. (https://lco.global/observatory/science-collaboration/)

- National Science Foundation (for NOIR Lab)
- St. Andrews University (Scotland)
- Wise Observatory/I-CORE (Israel)
- Instituto de Astrofisica de Canarias (Spain)
- Australian National University
- AURA (for the Chilean National TAC)
- South African Astronomical Observatory
- Institute for Astronomy, University of Hawaii
- University of Texas
- Faulkes Telescope Project (UK)
- National Astronomical Observatories of China

LCO Global Sky Partners (https://lco.global/education/partners/): currently supporting 28 education programs from institutions around the world with >1000 hours of observing time.

- Supported by the Simons Foundation and the Gordon & Betty Moore Foundation.
- Deadline for new 2023 partners was May 26.

Key Projects

"Large, coherent observing programs designed to take maximum advantage of the unique capabilities of the global telescope network." (https://lco.global/science/keyprojects/)

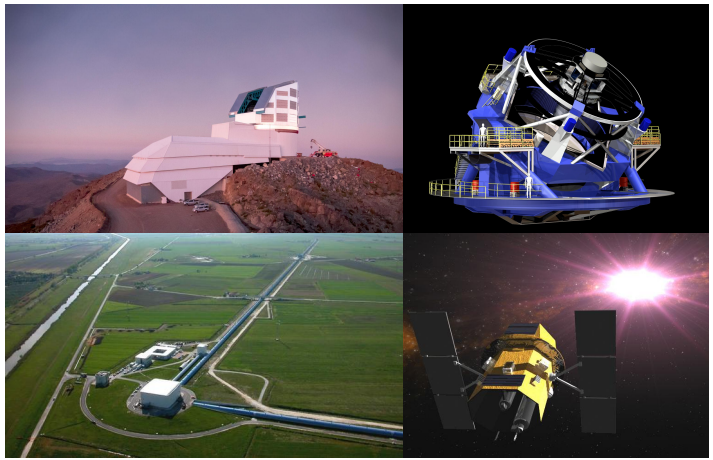
Key projects for 2023-2026:

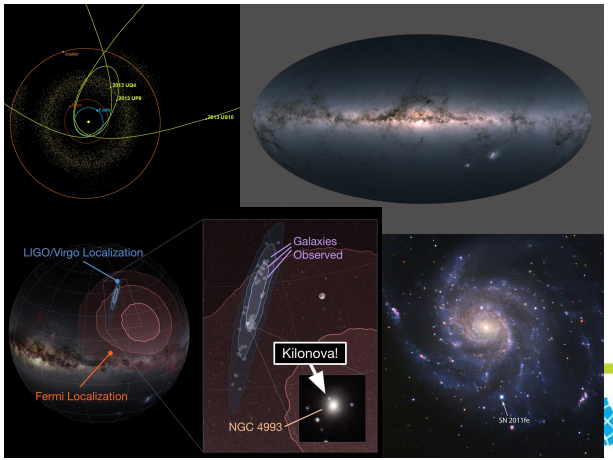
- Discovery and Follow-up of Optical Counterparts to Gravitational-wave Events (Tel Aviv U.)
- Characterizing the Milky Way's Hidden Populations (LCO)
- Intensive Broadband Reverberation Mapping of Nearby Active Galactic Nuclei (U. St Andrews)
- The Global Supernova Project (LCO)
- Follow up of TESS transiting planet candidates (MIT)
- Determining the Mass-Ratio Function and the Multiplicity Distribution for Cold Planets with Microlensing (Tsinghua U., Harvard-Smithsonian CfA)
- Constraining the Structure and Evolution of Massive Stars through Multi-Band Asteroseismology (Tel Aviv U.)

Astronomy in the Big Data Era

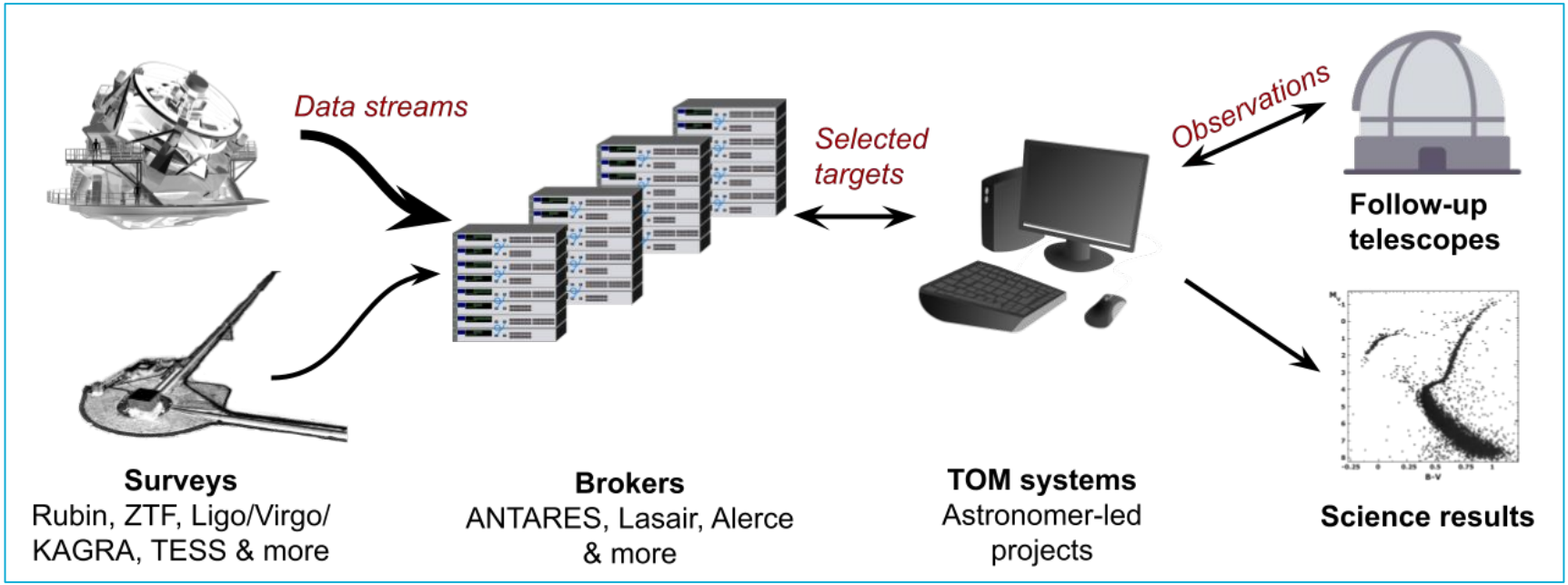
What does the astronomy community demand to maximize science yield when technology enables an unprecedented increase in data volume and delivery rate?

- Process/filter continuous streams of new targets.
- Monitor many targets in different states simultaneously.
- Select and prioritize targets in real time.
- Observe targets on a range of timescales, cadences.
- Coordinate observations across multiple facilities.
- Manage thousands of observations, TB of data.
- Communicate efficiently with collaborators worldwide.

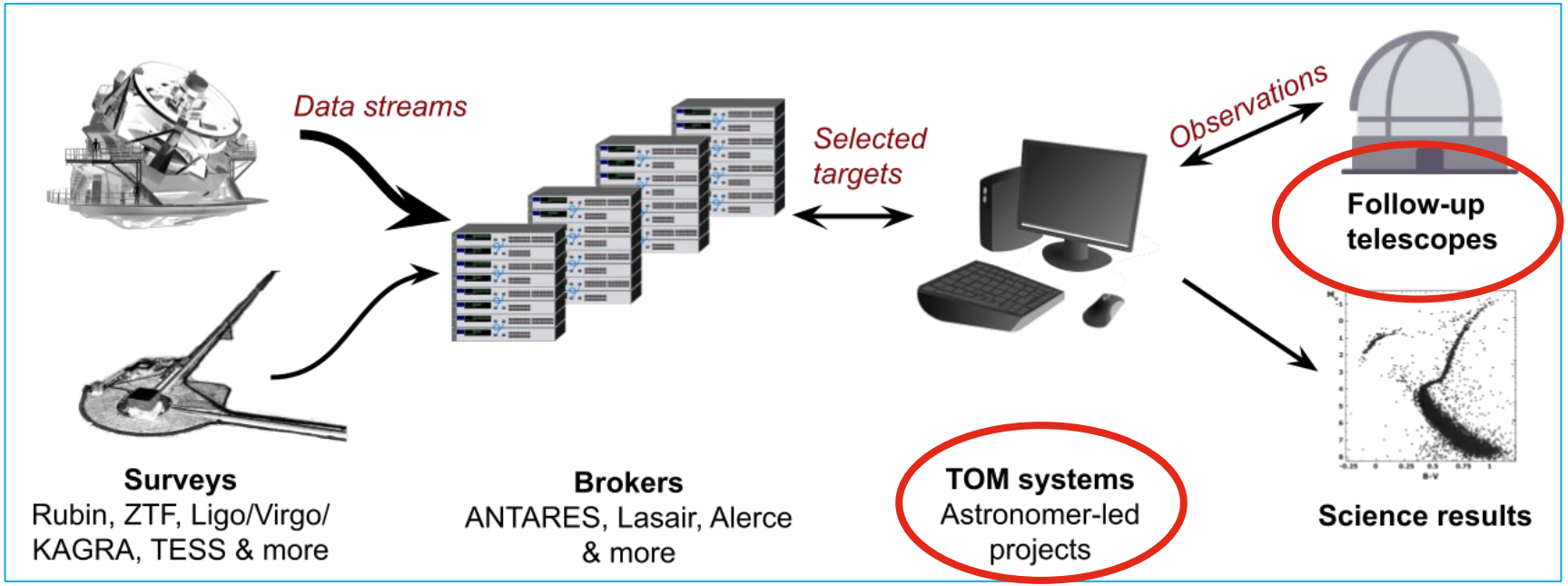




The ecosystem of infrastructure for astronomy

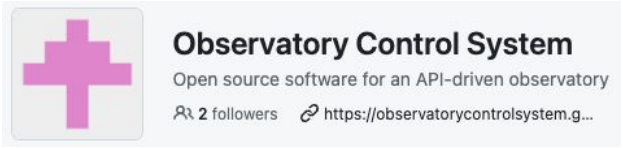


The ecosystem of infrastructure for astronomy



LCO Support for follow-up observations

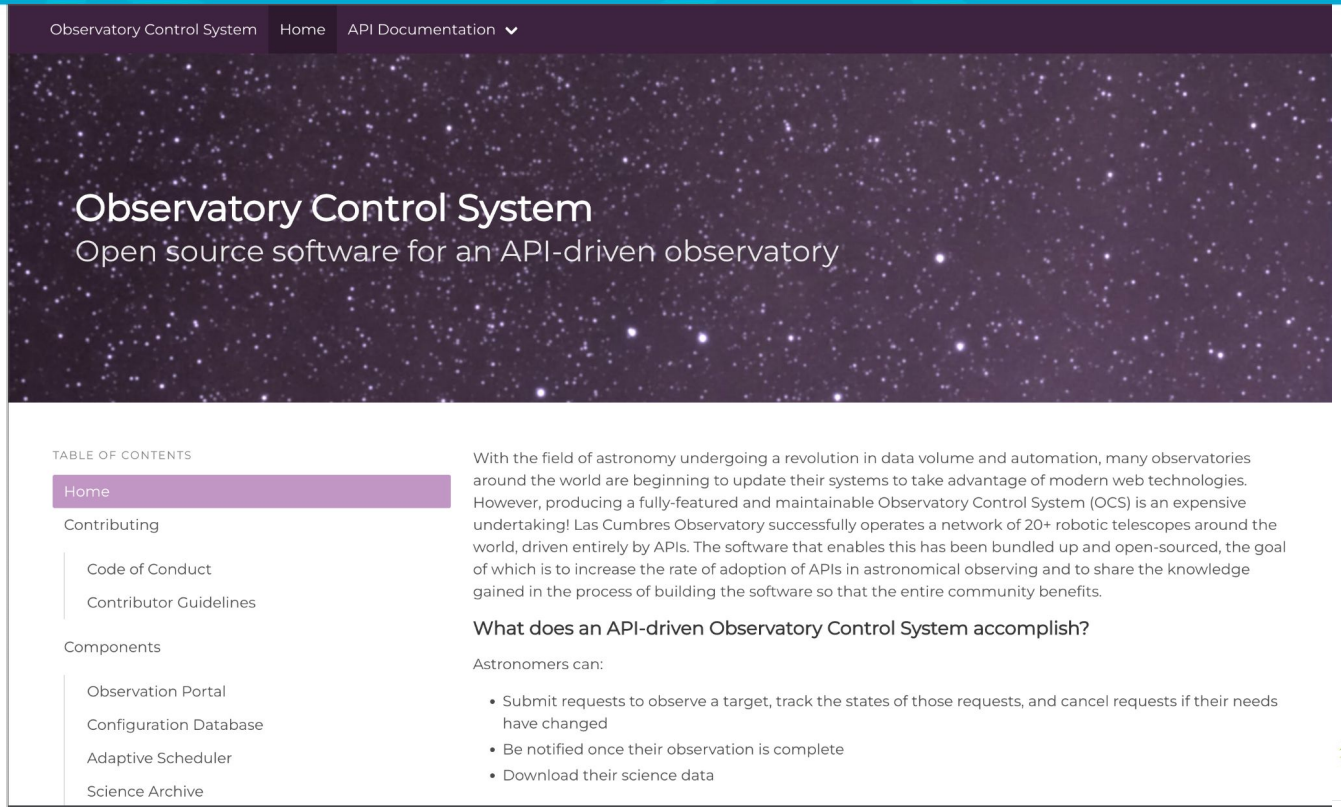
AEON



TOM TOOLKIT Las Cumbres Observatory LCO

HERMES

Open Observatory Control System



https://observatorycontrolsystem.github.io/

HEISING-SIMONS FOUNDATION

LCO

OpenOCS Goals

Provide a fully customizable "out of the box" observatory management system.

Make all software open-source and provide extensive documentation.

Enable management of:

- user accounts,
- science proposals,
- observation requests and scheduling,
- data product storage and retrieval.

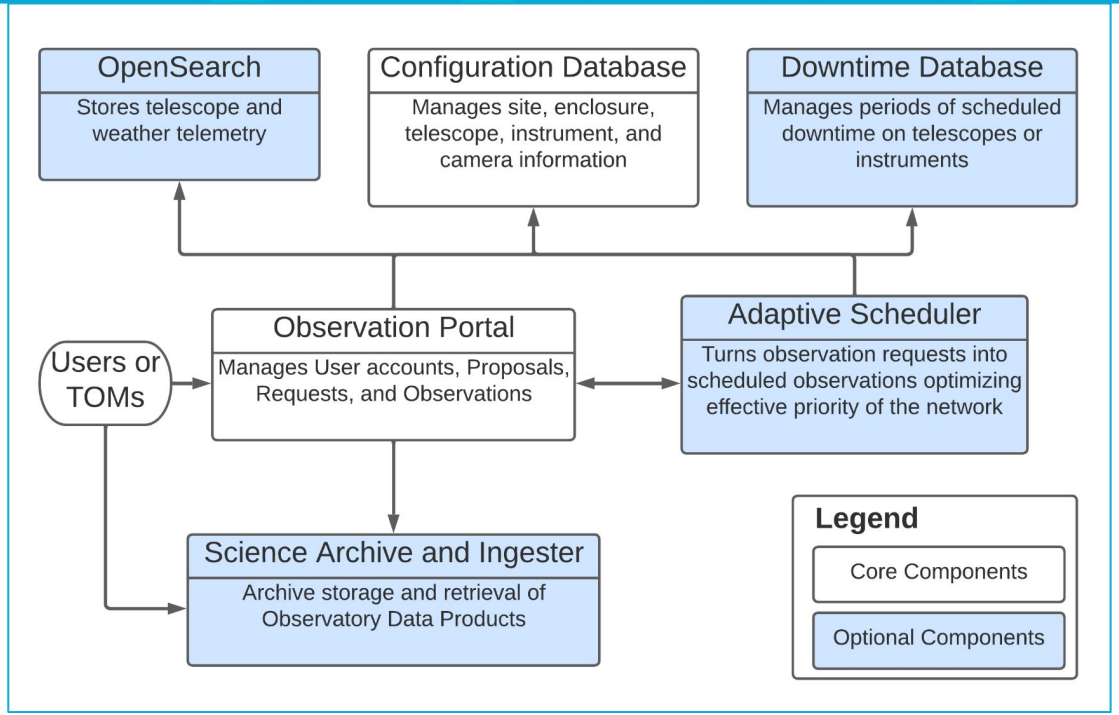
Separate observatory management from site (telescope, instrument) management.

OpenOCS Overview

Python libraries; Django backends.

VueJS component library and sample frontends.

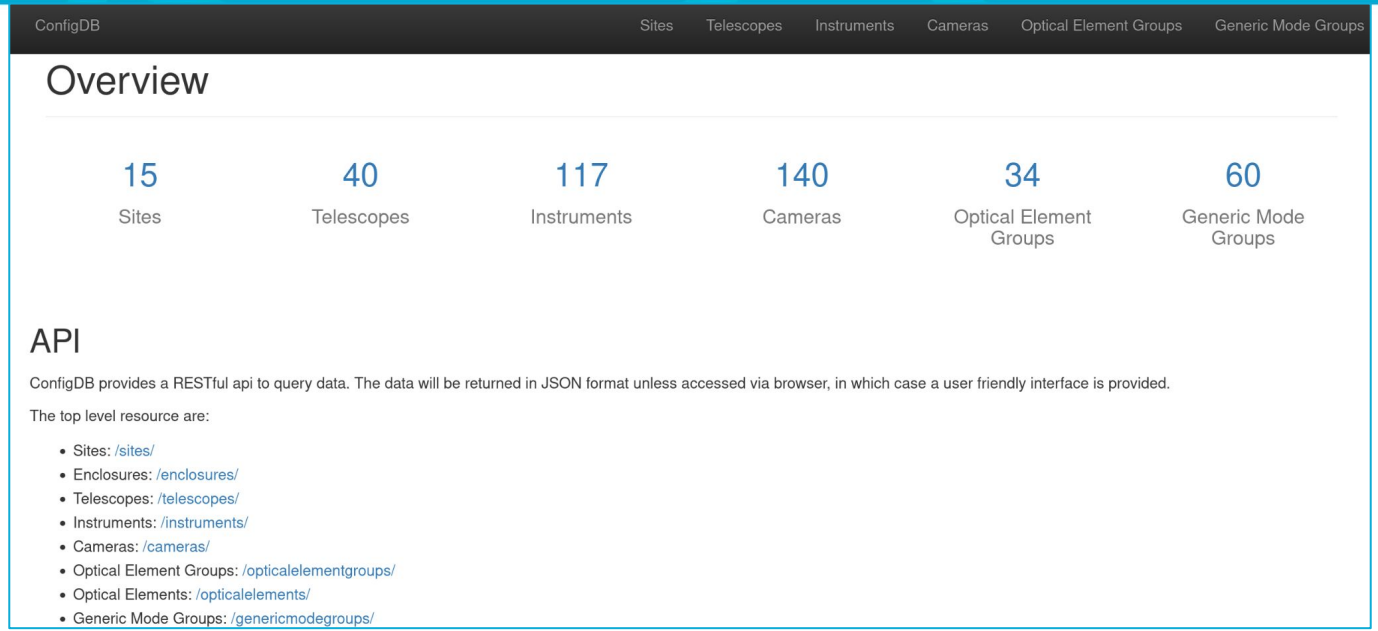
Flexible architecture of mandatory and optional components.



HEISING-SIMONS FOUNDATION

LCO

OpenOCS Configuration Database



Example nodes:

- instrument states
- instrument configurations
- instrument binning/readout modes
- overheads

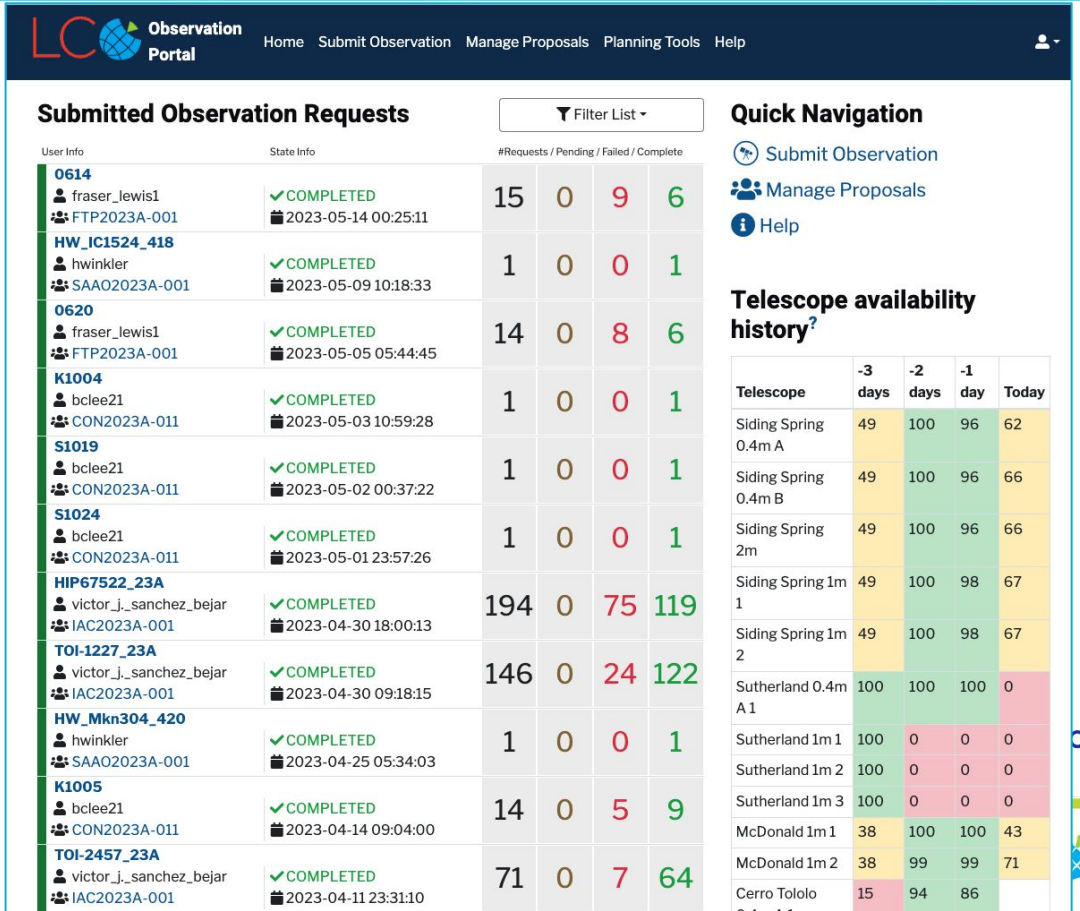
HEISING-SIMONS FOUNDATION

LCO

OpenOCS Observation Portal

Functions:

- Login to accounts
- Submit, manage science proposals
- Manage co-investigator permissions
- Compose, submit observation requests
- View observation request results
- Link to data archive



LCO Observation Portal — Home | Submit Observation | Manage Proposals | Planning Tools | Help

Submitted Observation Requests

Filter List

User Info	State Info	#Requests	Pending	Failed	Complete
0614 fraser_lewis1 FTP2023A-001	COMPLETED 2023-05-14 00:25:11	15	0	9	6
HW_IC1524_418 hwinkler SAAO2023A-001	COMPLETED 2023-05-09 10:18:33	1	0	0	1
0620 fraser_lewis1 FTP2023A-001	COMPLETED 2023-05-05 05:44:45	14	0	8	6
K1004 bclee21 CON2023A-011	COMPLETED 2023-05-03 10:59:28	1	0	0	1
S1019 bclee21 CON2023A-011	COMPLETED 2023-05-02 00:37:22	1	0	0	1
S1024 bclee21 CON2023A-011	COMPLETED 2023-05-01 23:57:26	1	0	0	1
HIP67522_23A victor_j._sanchez_bejar IAC2023A-001	COMPLETED 2023-04-30 18:00:13	194	0	75	119
TOI-1227_23A victor_j._sanchez_bejar IAC2023A-001	COMPLETED 2023-04-30 09:18:15	146	0	24	122
HW_Mkn304_420 hwinkler SAAO2023A-001	COMPLETED 2023-04-25 05:34:03	1	0	0	1
K1005 bclee21 CON2023A-011	COMPLETED 2023-04-14 09:04:00	14	0	5	9
TOI-2457_23A victor_j._sanchez_bejar IAC2023A-001	COMPLETED 2023-04-11 23:31:10	71	0	7	64

Quick Navigation

- Submit Observation
- Manage Proposals
- Help

Telescope availability history[?]

Telescope	-3 days	-2 days	-1 day	Today
Siding Spring 0.4m A	49	100	96	62
Siding Spring 0.4m B	49	100	96	66
Siding Spring 2m	49	100	96	66
Siding Spring 1m 1	49	100	98	67
Siding Spring 1m 2	49	100	98	67
Sutherland 0.4m A 1	100	100	100	0
Sutherland 1m 1	100	0	0	0
Sutherland 1m 2	100	0	0	0
Sutherland 1m 3	100	0	0	0
McDonald 1m 1	38	100	100	43
McDonald 1m 2	38	99	99	71
Cerro Tololo	15	94	86	

OpenOCS in the community

LCO uses all OpenOCS applications running in AWS. In 2022:

- > 27 telescopes
- > 8000 user accounts
- > 2000 proposals
- Millions of requests submitted; millions of observations scheduled
- > 33 million data products served

SOAR instruments are supported for AEON.

Other observatories using OpenOCS:

- MONET 1.2-meter telescopes

Other organizations testing OpenOCS applications:

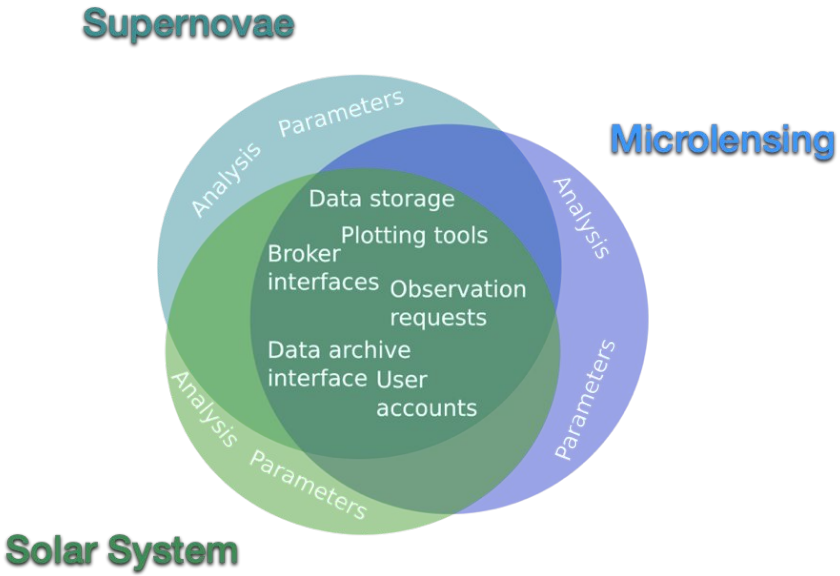
- Yunnan Observatory (2.4m telescope)
- South African Astronomical Observatory
- Instituto de Astrofisica de Andalucia

HEISING-SIMONS FOUNDATION

LCO

Target (and) Observation Managers

Target Observation Managers (TOMs) are software packages that expedite the administration of (science) campaigns by automating a variety of useful functions: filtering alert streams, submitting new observation requests, etc.

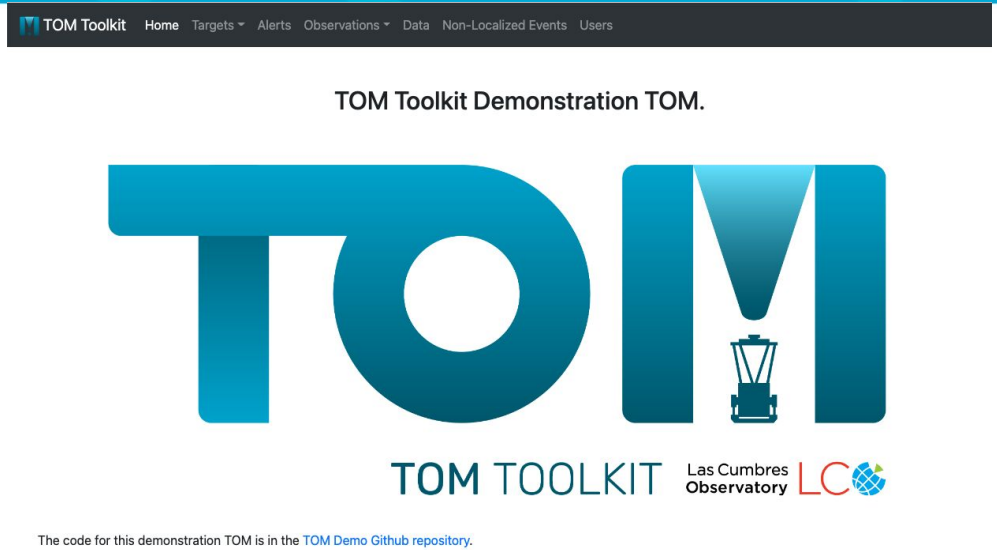


Motivations for a universal "tool kit":

- Although different science campaigns require *different* analysis tools, they require *common* basic functions.
- Many code-writing astronomers do not have advanced database or software engineering skills.
- The cost (in time and effort) for each science campaign to write its own TOM is high.

The TOM Toolkit

- An open-source, professionally developed software package that enables astronomers to build TOMs easily and customize them for their science needs.
  - Minimal prior knowledge.
  - Python based.
- Provides a set of commonly-used functions.
- Provides well-defined interfaces to science-specific code.
- Creates a community of TOM Toolkit users who develop their own plugins.

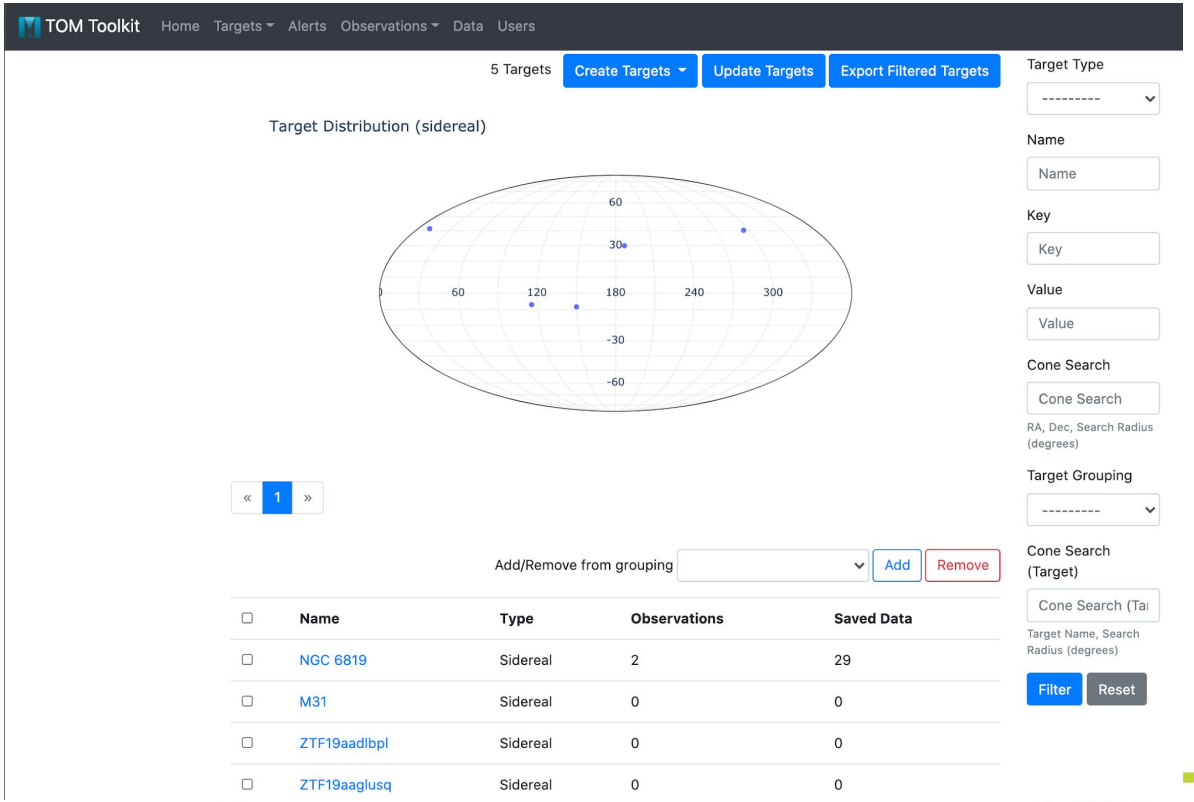


ZEGAR FAMILY FOUNDATION

HEISING-SIMONS FOUNDATION

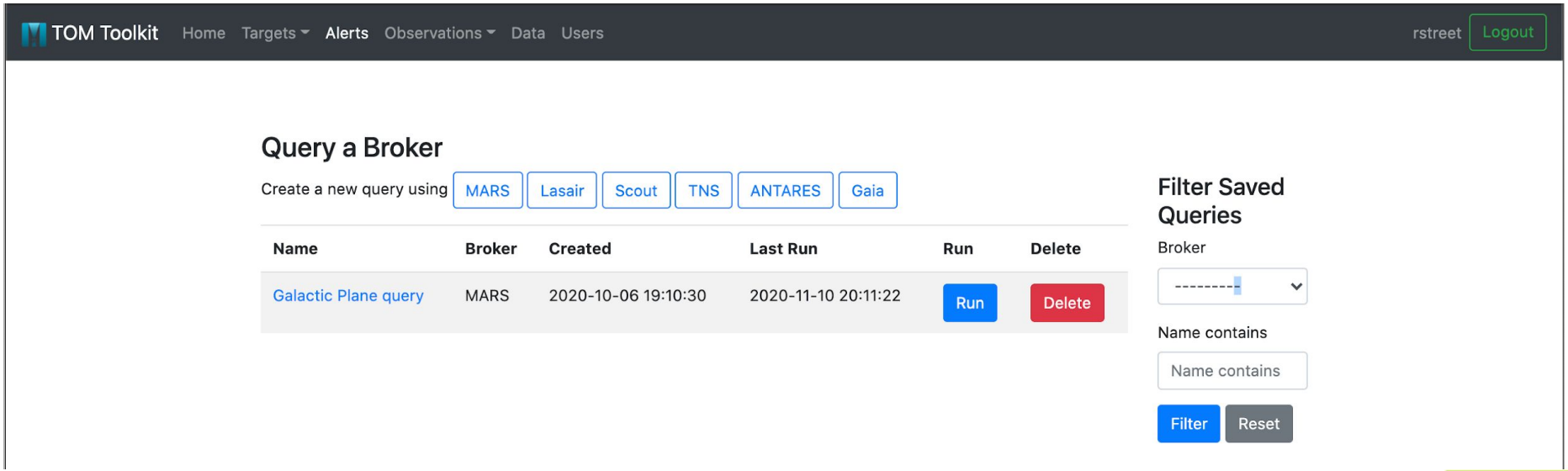
TOM Toolkit Functions 1

- Central database designed for astronomical programs.



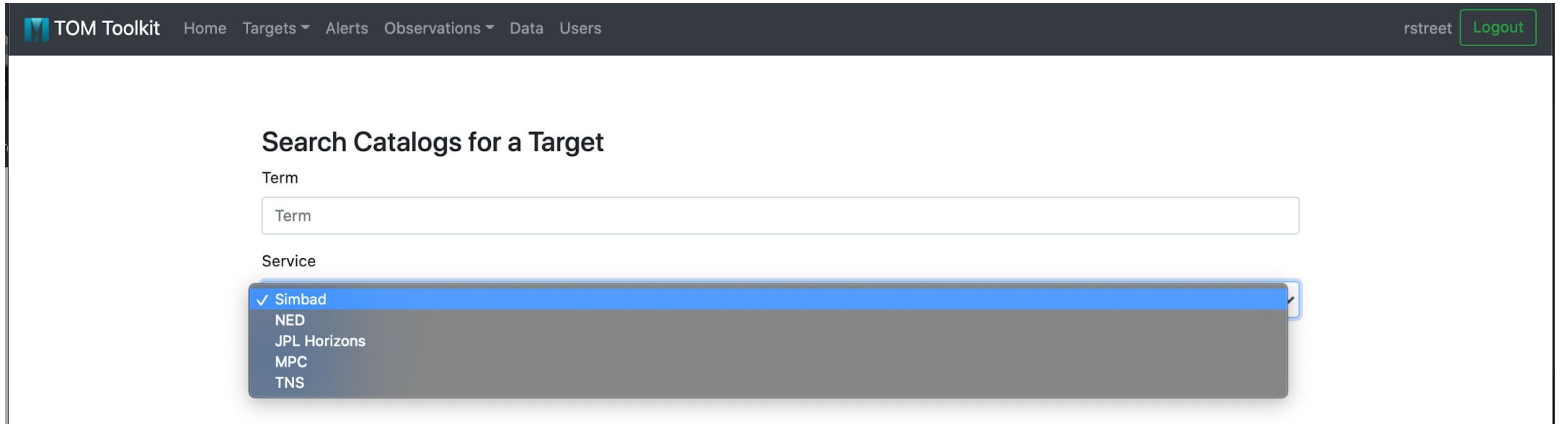
TOM Toolkit Functions 2

- Central database designed for astronomical programs.
- Interfaces to alert brokers.



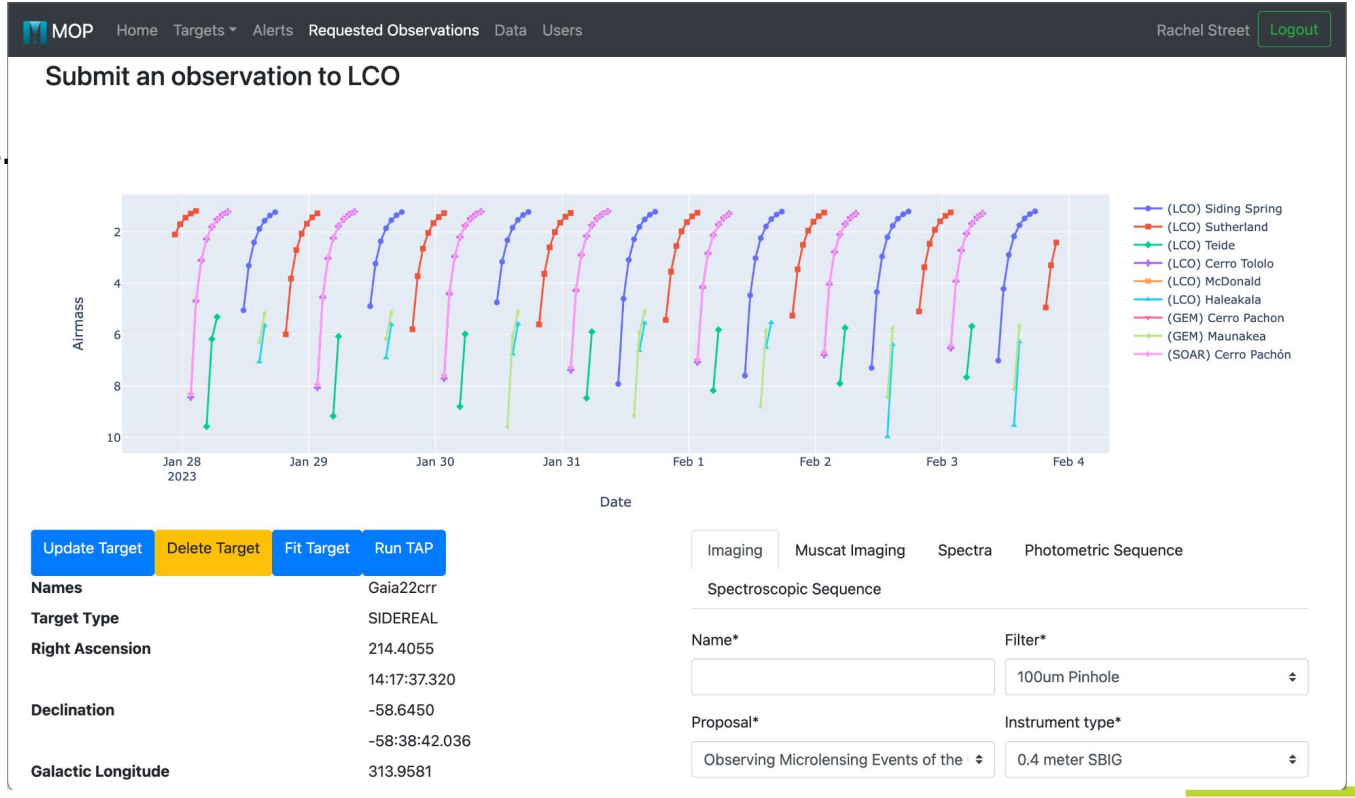
TOM Toolkit Functions 3

- Central database designed for astronomical programs.
- Interfaces to alert brokers.
- Interface to data archives.



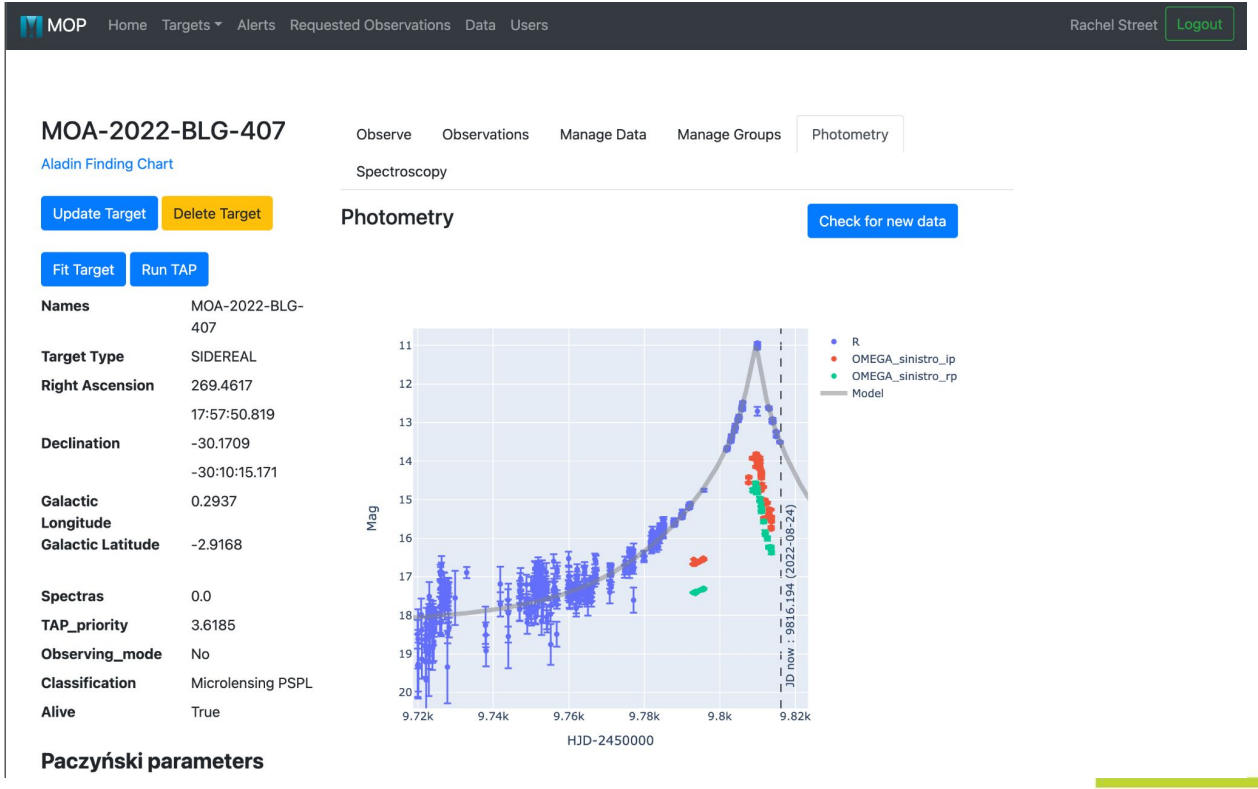
TOM Toolkit Functions 4

- Central database designed for astronomical programs.
- Interfaces to alert brokers.
- Interface to data archives.
- Submit observations.



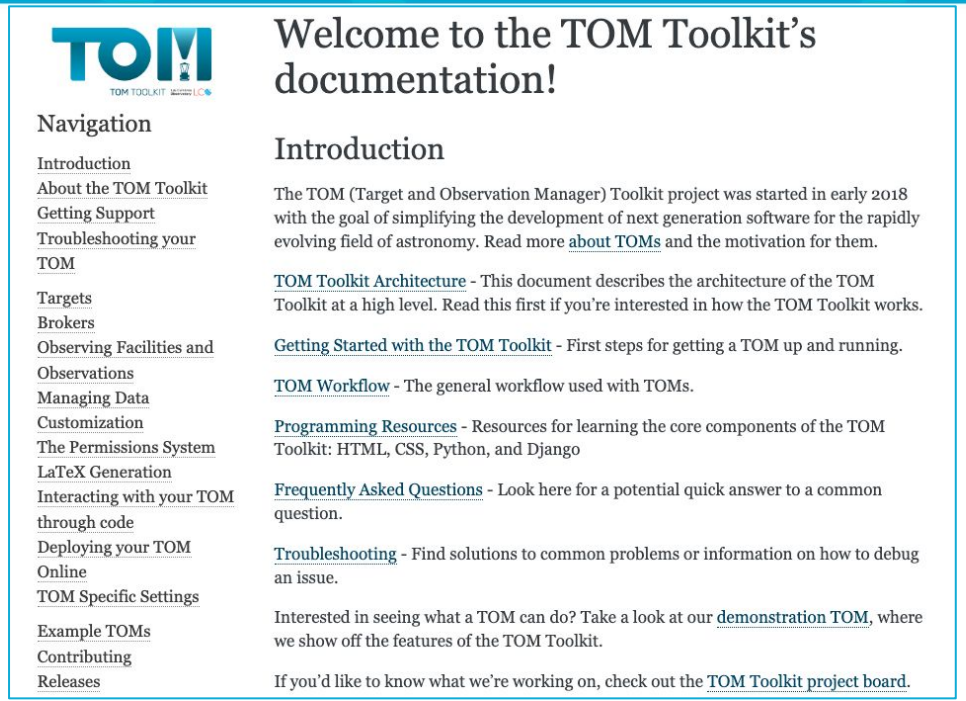
TOM Toolkit Functions 5

- Central database designed for astronomical programs.
- Interfaces to alert brokers.
- Interface to data archives.
- Submit observations.
- Modules for common astronomical displays.



TOM Toolkit documentation

- Low barrier to entry: https://tom-toolkit.readthedocs.io/



TOM TOOLKIT

Navigation

Introduction
About the TOM Toolkit
Getting Support
Troubleshooting your TOM

Targets
Brokers
Observing Facilities and Observations
Managing Data
Customization
The Permissions System
LaTeX Generation
Interacting with your TOM through code
Deploying your TOM Online
TOM Specific Settings

Example TOMs
Contributing
Releases

Welcome to the TOM Toolkit's documentation!

Introduction

The TOM (Target and Observation Manager) 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.

TOM Toolkit Architecture - This document describes the architecture of the TOM Toolkit at a high level. Read this first if you're interested in how the TOM Toolkit works.

Getting Started with the TOM Toolkit - First steps for getting a TOM up and running.

TOM Workflow - The general workflow used with TOMs.

Programming Resources - Resources for learning the core components of the TOM Toolkit: HTML, CSS, Python, and Django

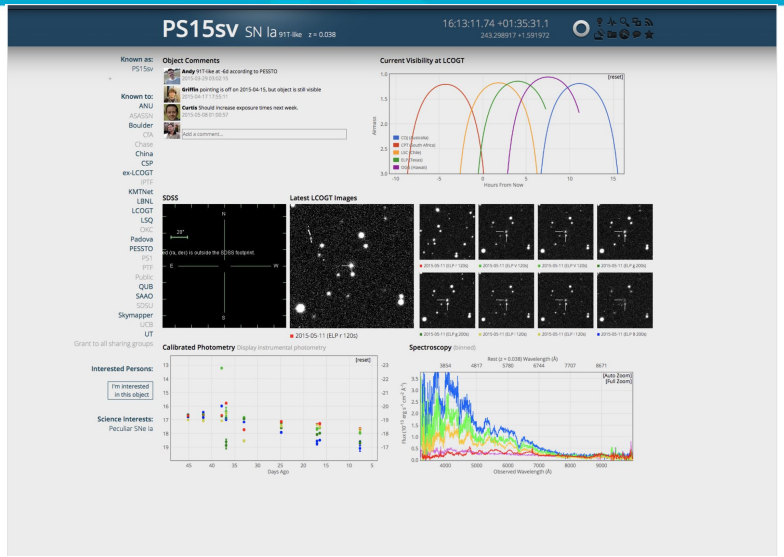
Frequently Asked Questions - Look here for a potential quick answer to a common question.

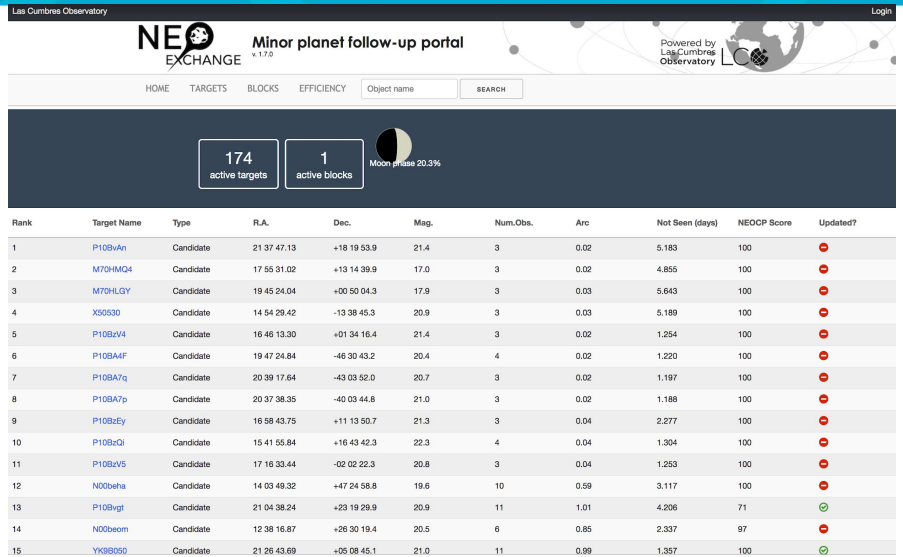
Troubleshooting - Find solutions to common problems or information on how to debug an issue.

Interested in seeing what a TOM can do? Take a look at our demonstration TOM, where we show off the features of the TOM Toolkit.

If you'd like to know what we're working on, check out the TOM Toolkit project board.

TOMs everywhere





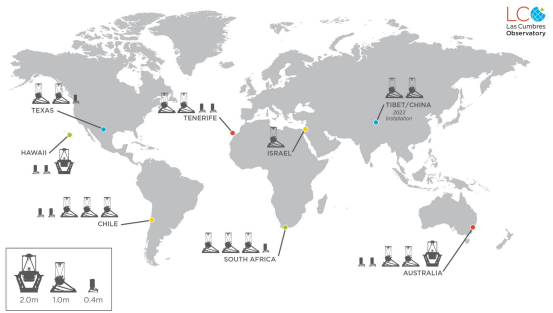
Rank	Target Name	Type	R.A.	Dec.	Mag.	Num.Obs.	Arc	Not Seen (days)	NEOCP Score	Updated?
1	P10BvAn	Candidate	21 37 47.13	+18 19 53.9	21.4	3	0.02	5.183	100	
2	M70HMQ4	Candidate	17 55 31.02	+13 14 39.9	17.0	3	0.02	4.855	100	
3	M70HLGY	Candidate	19 45 24.04	+00 50 04.3	17.9	3	0.03	5.643	100	
4	X50530	Candidate	14 54 29.42	-13 38 45.3	20.9	3	0.03	5.189	100	
5	P10BzV4	Candidate	16 46 13.30	+01 34 16.4	21.4	3	0.02	1.254	100	
6	P10BA4F	Candidate	19 47 24.84	-46 30 43.2	20.4	4	0.02	1.220	100	
7	P10BA7q	Candidate	20 39 17.64	-43 03 52.0	20.7	3	0.02	1.197	100	
8	P10BA7p	Candidate	20 37 38.35	-40 03 44.8	21.0	3	0.02	1.188	100	
9	P10BzEy	Candidate	16 58 43.75	+11 13 50.7	21.3	3	0.04	2.277	100	
10	P10BzQI	Candidate	15 41 55.84	+16 43 42.3	22.3	4	0.04	1.304	100	
11	P10BzV5	Candidate	17 16 33.44	-02 02 22.3	20.8	3	0.04	1.253	100	
12	N00beha	Candidate	14 03 49.32	+47 24 58.8	19.6	10	0.59	3.117	100	
13	P10Bvgt	Candidate	21 04 38.24	+23 19 29.9	20.9	11	1.01	4.206	71	
14	N00beom	Candidate	12 38 16.87	+26 30 19.4	20.5	6	0.85	2.337	97	
15	YK9B050	Candidate	21 26 43.69	+05 08 45.1	21.0	11	0.99	1.357	100	

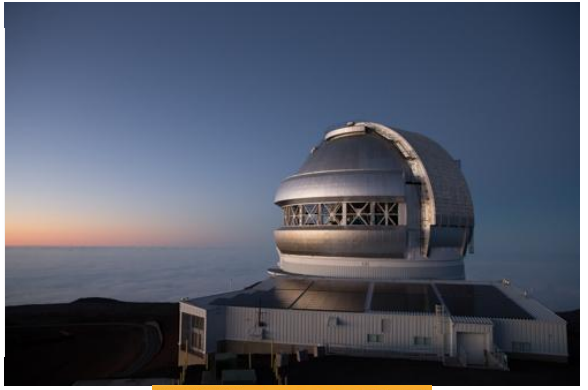
TOMs in 2022:

- SuperNova EXchange (SNEx)
- MOP (Microlensing Observing Project)
- ANTARES TOM
- ExoTOM
- NEO Exchange
- AleRCE TOM
- BlackHole TOM
- Calibration-TOM

Astronomical Event Observatory Network

A partnership to build an extended network of observing facilities to provide greater flexibility and efficiency in follow-up observations.





SOAR NOIR Lab

LCO

GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders

LCO

AEON Guiding principles

Partner observatories retain control of their own time allocations.

Partner observatories do not have to be automated, i.e. robotically controlled.

Partner inclusion should be as simple and as inexpensive as possible.

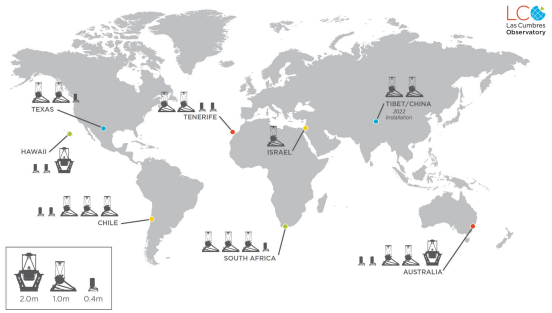
Partner observatories should adopt a common (software) protocol for requesting observations and sharing information about weather, telescope status, observation status.

- The observation request interface can be UI or API.

Partner observatories can use custom software, the OpenOCS, or the LCO system to enable queue scheduling.

- Compatible with various observing modes: flexible, fixed, long-term monitoring, etc.

Operations model 1

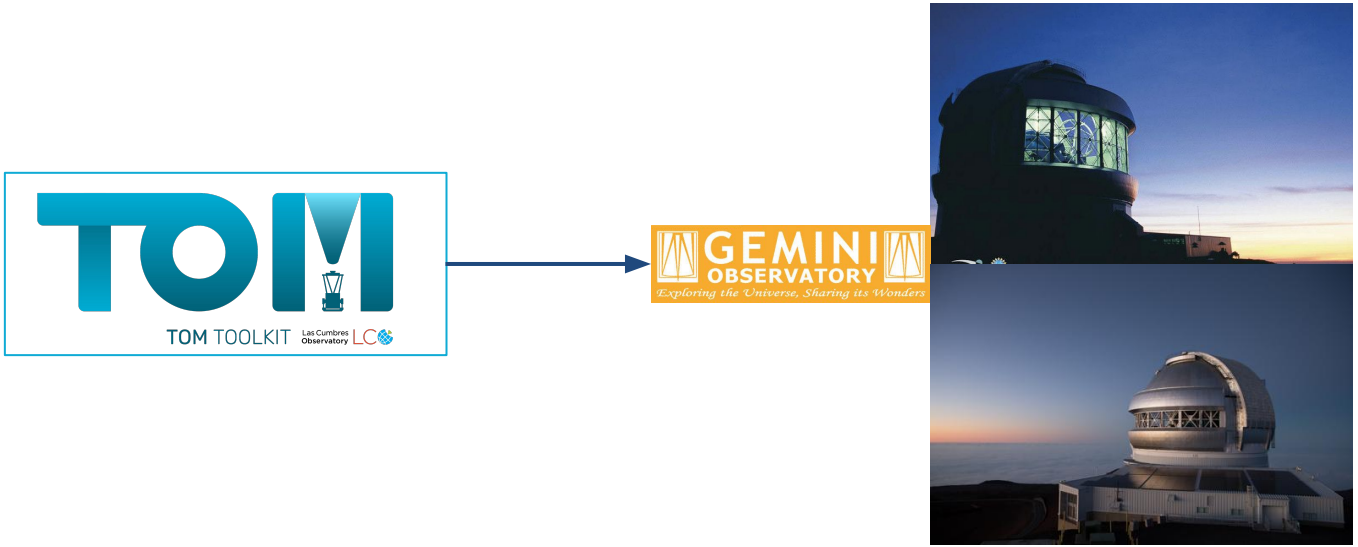


SOAR TELESCOPE

Partner observatories (SOAR-LCO) interface via a programmatic portal.

- When in AEON mode, SOAR is a node on the LCO network.
- Submission of observations and TOM compatibility provided by LCO portal.
- When not in AEON mode, SOAR is traditionally scheduled.
- SOAR has operators on-site.
- SOAR maintains the GHTS, TSpec data pipelines.

AEON Operations model 2



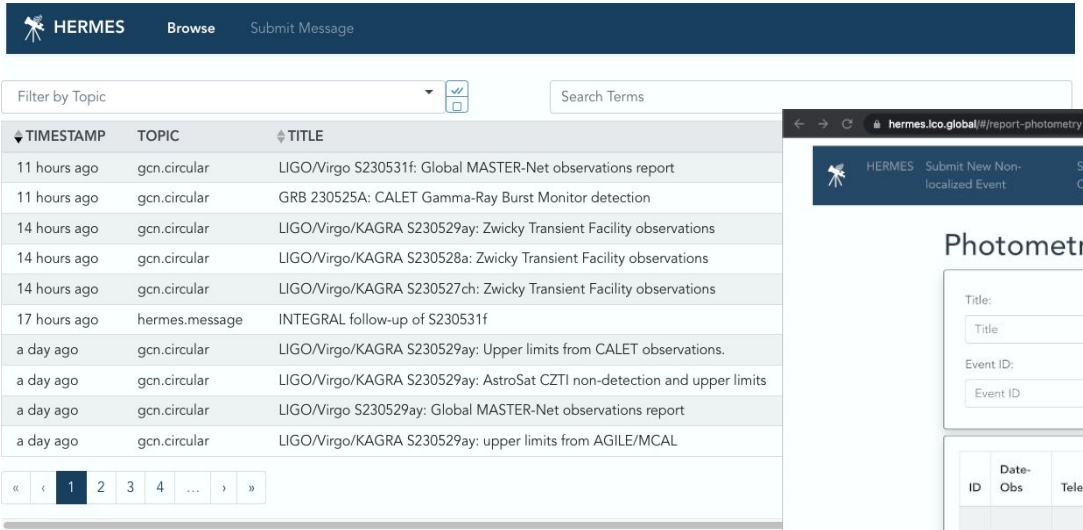
Partner observatory (Gemini) uses its own scheduling system.

- Observations are queue-scheduled.
- Programmatic submission of observation requests through an API.
- Gemini observing module plugin for the TOM Toolkit built by Bryan Miller.
- Gemini operations software being redesigned to accommodate AEON.

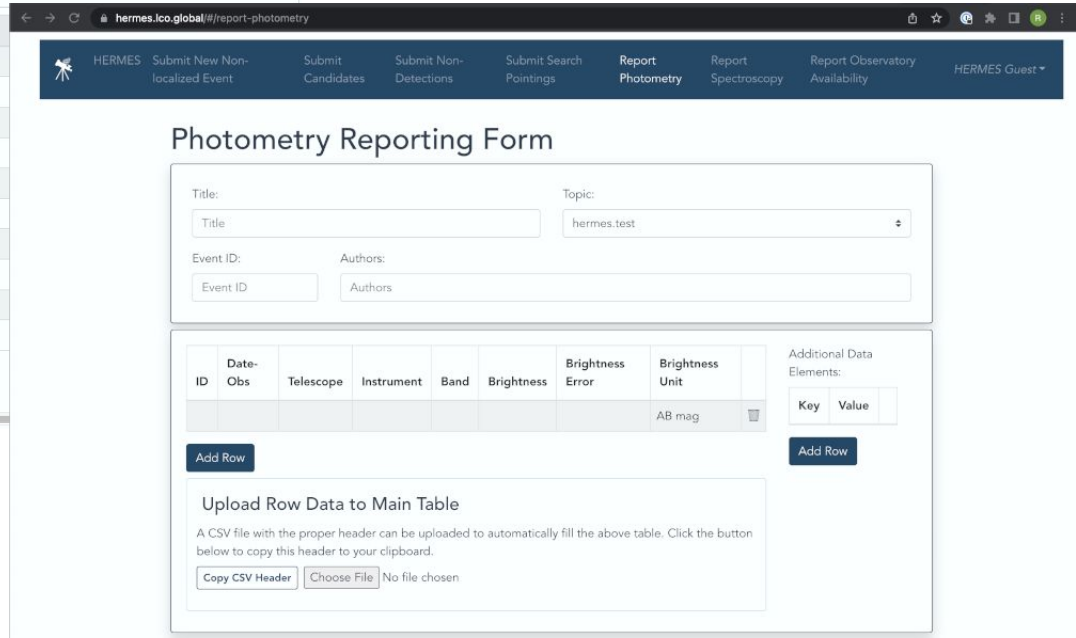
HERMES

Hopskotch Enabled Rapid Message Exchange Service (https://hermes.lco.global):

- Hopskotch: "scalable, high-throughput, low-latency platform for handling real-time data streams"
- Any type of astronomical data can be shared.



Collaboration between LCO & SCiMMA



Las Cumbres **Observatory**

6740 Cortona Drive, Suite 102, Goleta, CA 93117
805 880 1600 | www.lco.global

Nikolaus Volgenau
805 880 1642
nvolgenau@lco.global

Thank you!