



Las Cumbres **Observatory**

LCO resources to aid astronomy in the big data era

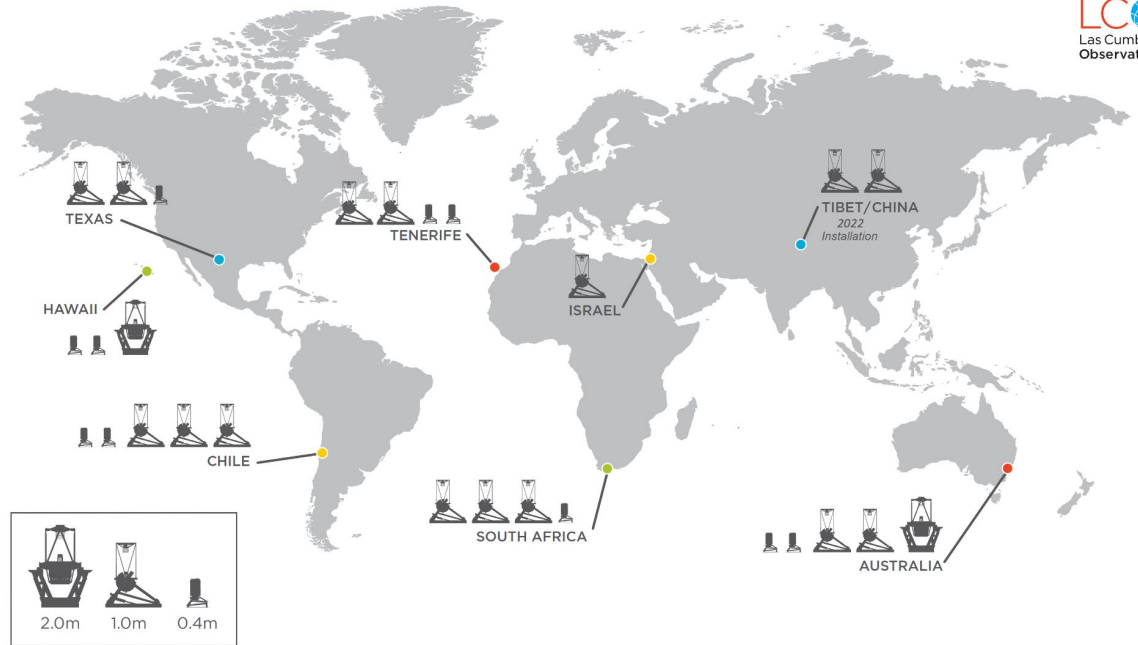
Nikolaus Volgenau

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

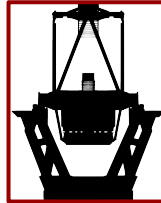
Las Cumbres Observatory in 2023

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

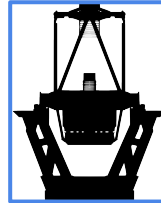
- ▶ **A global network** of 2m, 1m and 0.4m robotically controlled telescopes.
- ▶ **Uniform instrumentation** on each telescope class.
- ▶ Globally-optimized, **dynamic scheduling**. (New schedule every 5 min)
- ▶ **Specialized observing modes** for science programs that need them.
- ▶ **Rapid delivery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



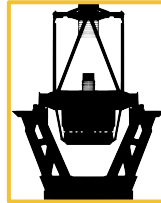
LCO's instrument inventory



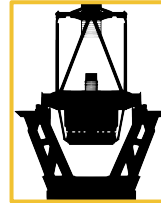
1 MuSCAT imager



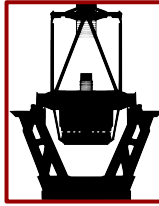
1 Spectral imager



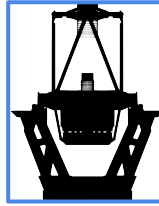
2 FLOYDS spectrographs



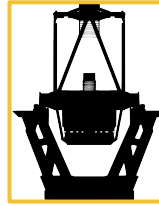
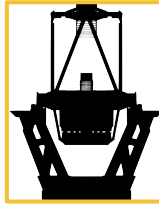
LCO's instrument inventory



1 MuSCAT imager



1 Spectral imager



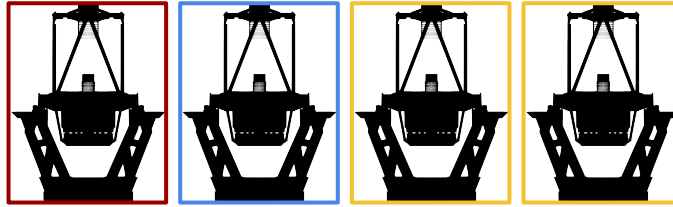
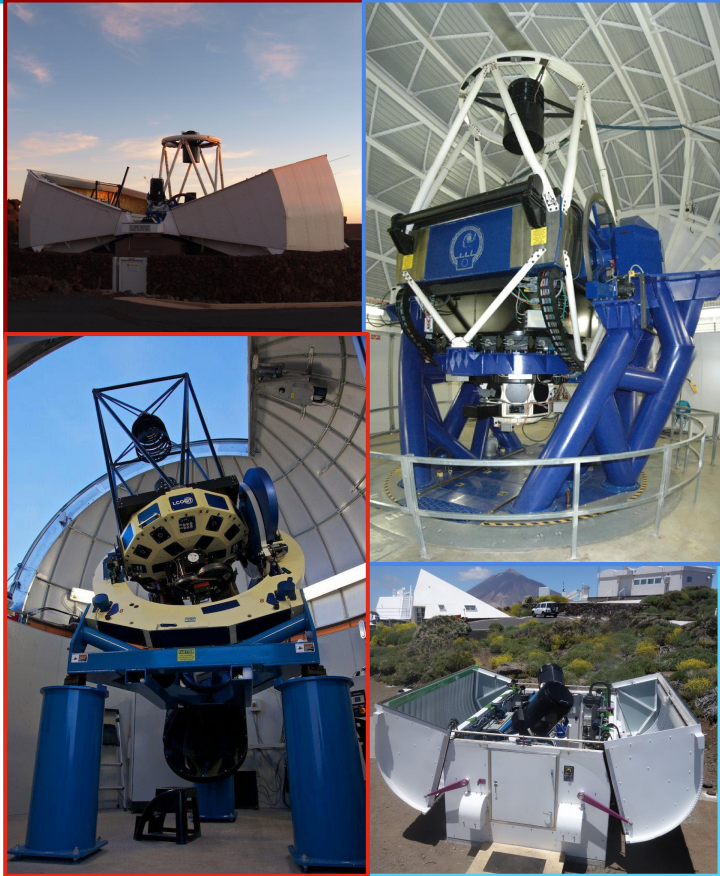
2 FLOYDS spectrographs



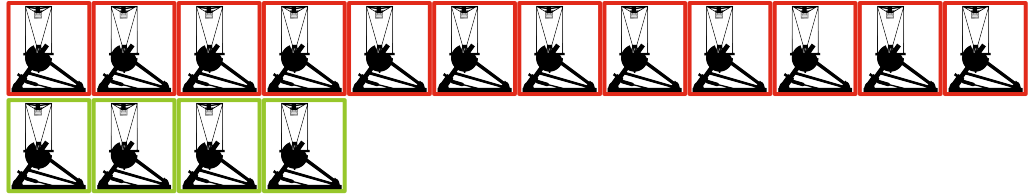
12 Sinistro imagers

4 NRES spectrographs

LCO's instrument inventory



1 MuSCAT imager 1 Spectral imager 2 FLOYDS spectrographs



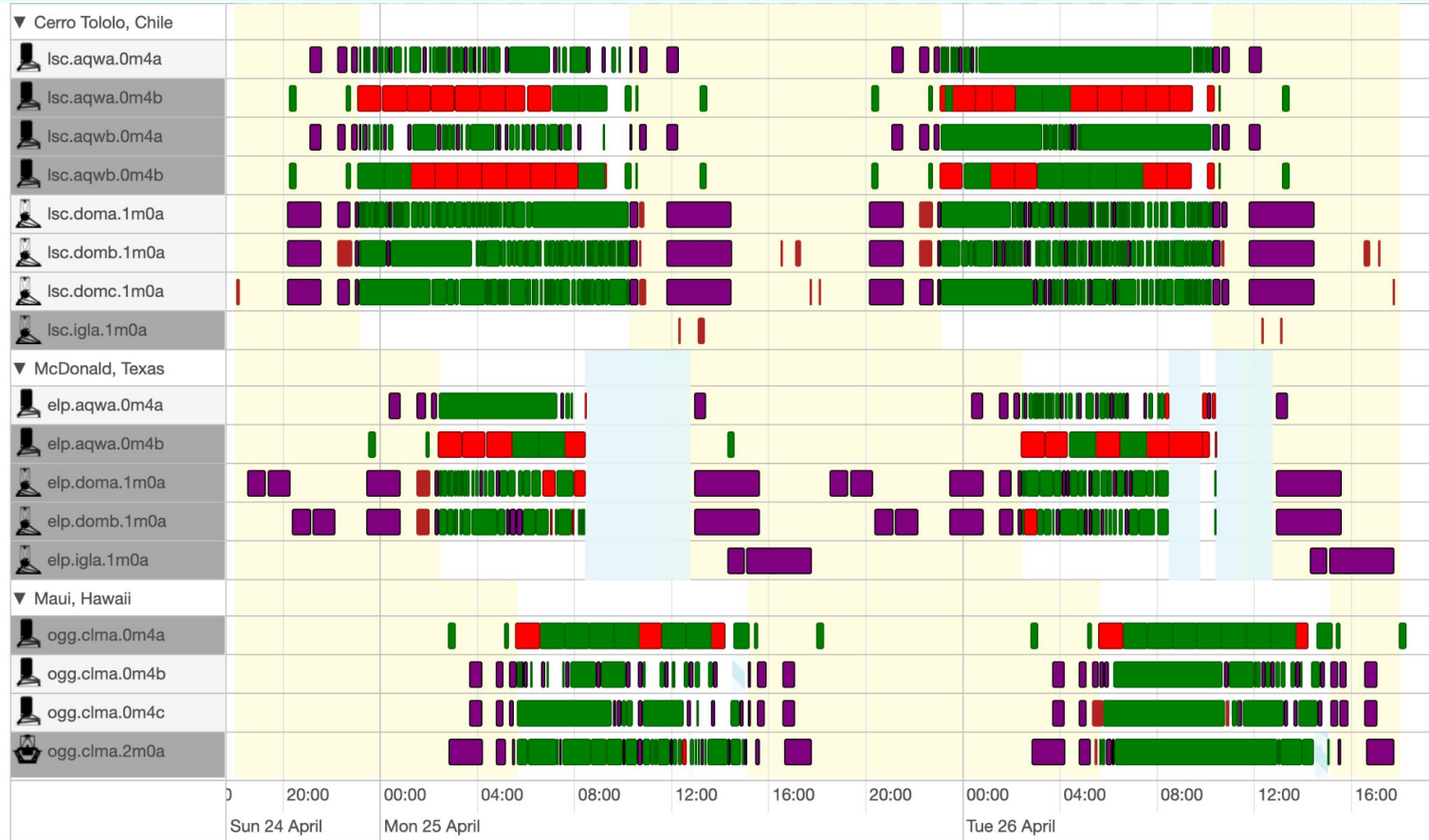
12 Sinistro imagers 4 NRES spectrographs



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/>)

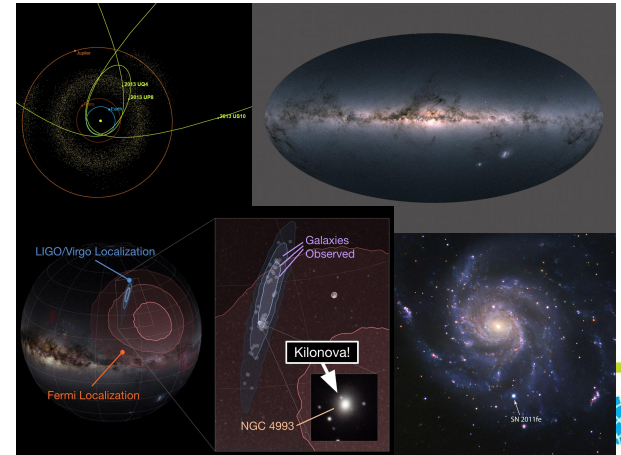
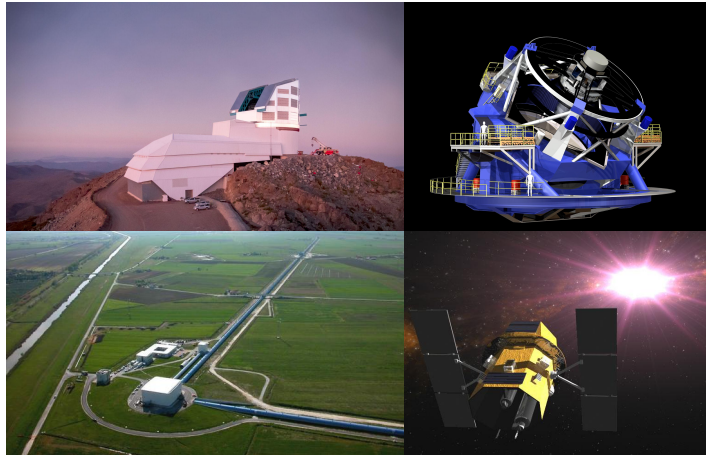
Key projects for 2023-2026:

- ▶ 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.)

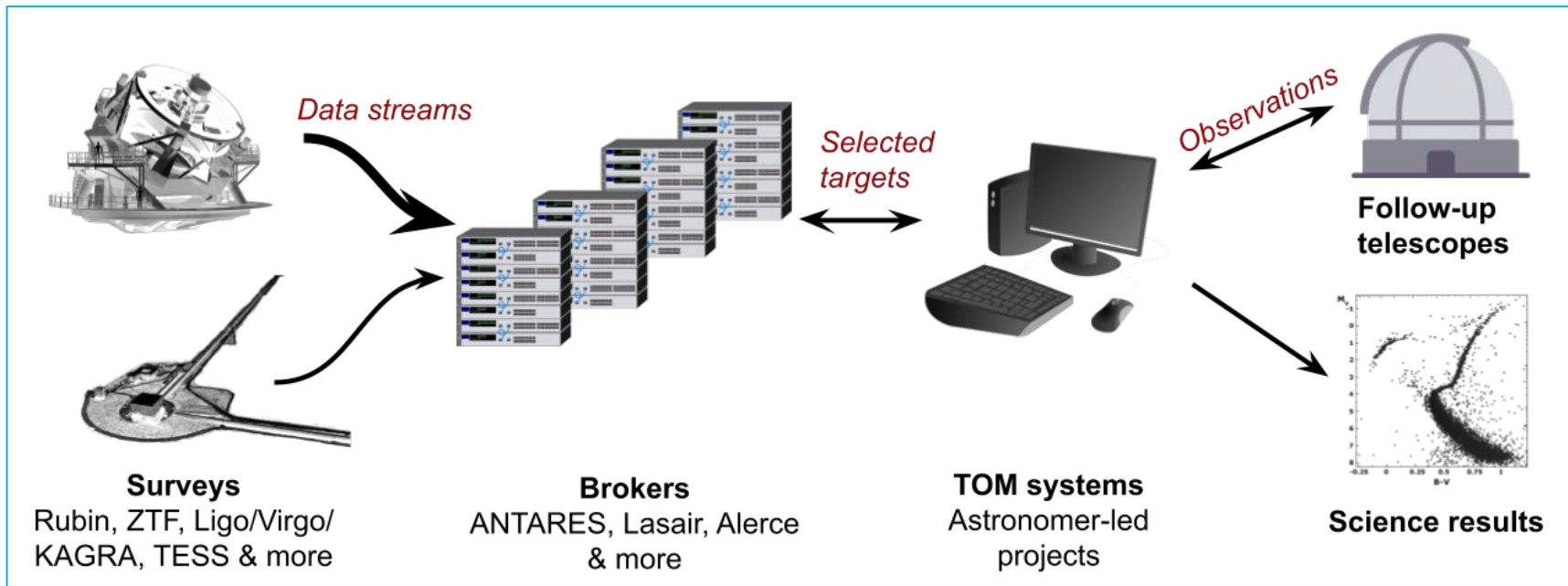
Astronomy in the Big Data Era

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

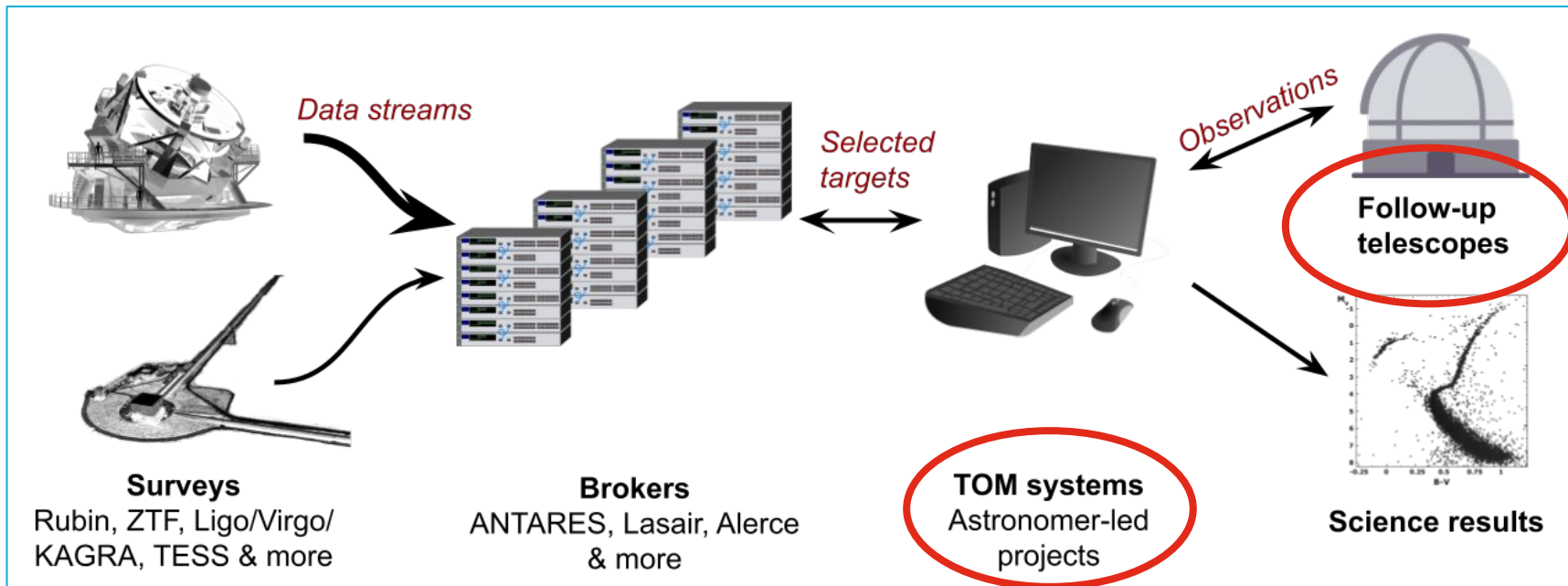
- ▶ Process/filter continuous streams of new targets.
- ▶ Monitor many targets in different states simultaneously.
- ▶ Select and prioritize targets in real time.
- ▶ Observe targets on a range of timescales, cadences.
- ▶ Coordinate observations across multiple facilities.
- ▶ Manage thousands of observations,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



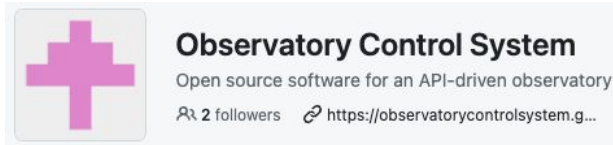
The ecosystem of infrastructure for astronomy



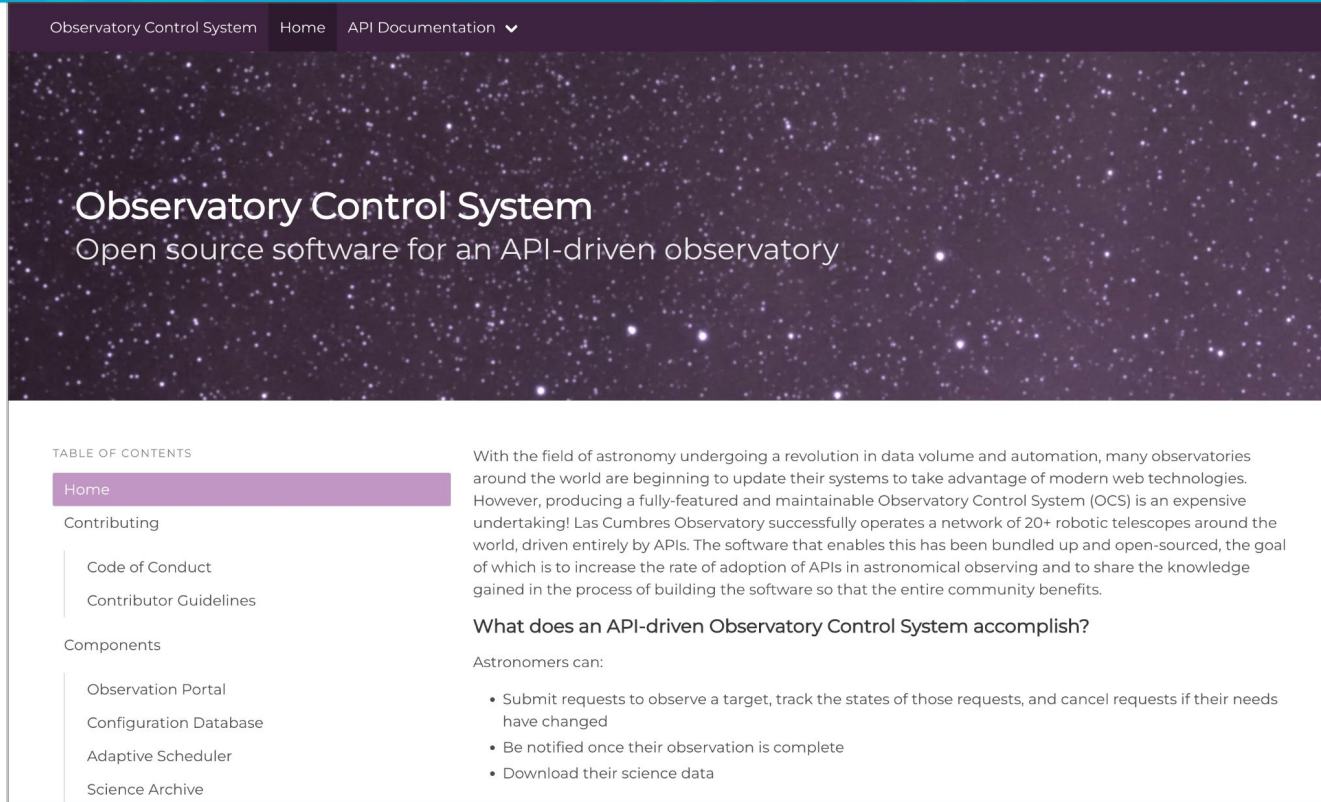
The ecosystem of infrastructure for astronomy



LCO Support for follow-up observations



Open Observatory Control System



Observatory Control System Home API Documentation

Observatory Control System

Open source software for an API-driven observatory

TABLE OF CONTENTS

- Home
- Contributing
 - Code of Conduct
 - Contributor Guidelines
- Components
 - Observation Portal
 - Configuration Database
 - Adaptive Scheduler
 - Science Archive

With the field of astronomy undergoing a revolution in data volume and automation, many observatories around the world are beginning to update their systems to take advantage of modern web technologies. However, producing a fully-featured and maintainable Observatory Control System (OCS) is an expensive undertaking! Las Cumbres Observatory successfully operates a network of 20+ robotic telescopes around the world, driven entirely by APIs. The software that enables this has been bundled up and open-sourced, the goal of which is to increase the rate of adoption of APIs in astronomical observing and to share the knowledge gained in the process of building the software so that the entire community benefits.

What does an API-driven Observatory Control System accomplish?

Astronomers can:

- Submit requests to observe a target, track the states of those requests, and cancel requests if their needs have changed
- Be notified once their observation is complete
- Download their science data

<https://observatorycontrolsystem.github.io/>

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.

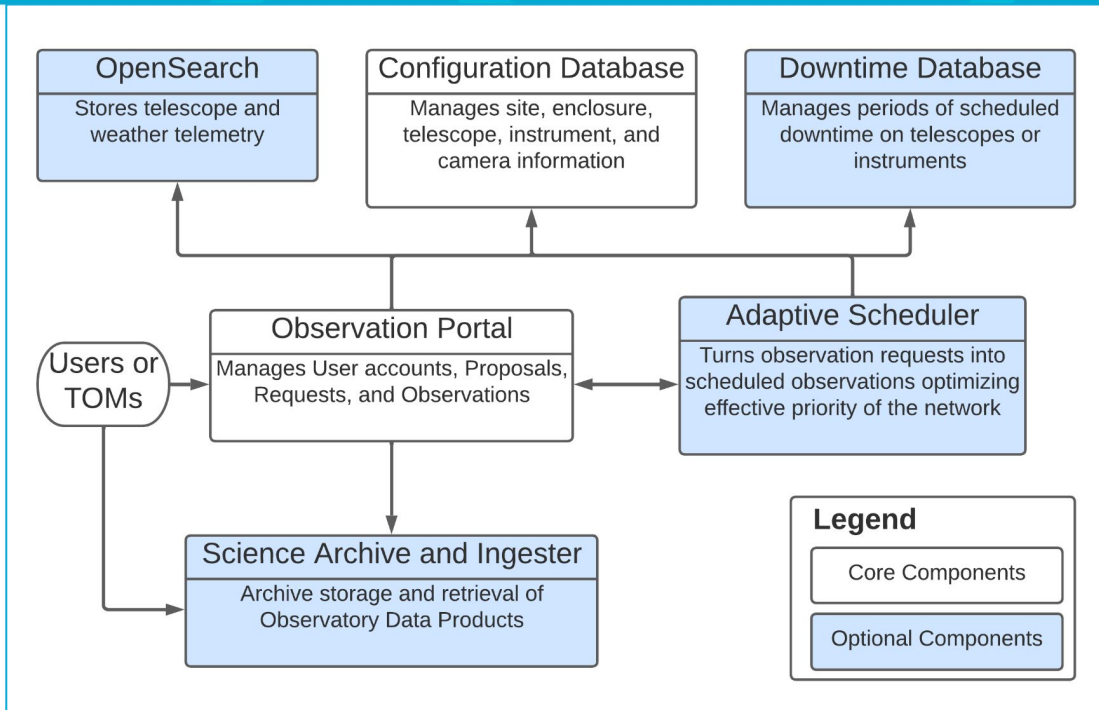
Separate observatory management from site (telescope, instrument) management.

OpenOCS Overview

Python libraries; Django backends.

VueJS component library and sample frontends.

Flexible architecture of mandatory and optional components.



OpenOCS Configuration Database

The screenshot shows the 'Overview' page of the OpenOCS Configuration Database. At the top, there is a navigation bar with the following items: ConfigDB, Sites, Telescopes, Instruments, Cameras, Optical Element Groups, and Generic Mode Groups. The main content area is titled 'Overview' and features six large blue numbers representing counts for different categories: 15 Sites, 40 Telescopes, 117 Instruments, 140 Cameras, 34 Optical Element Groups, and 60 Generic Mode Groups. Below this, there is an 'API' section with a brief description and a list of RESTful endpoints.

ConfigDB

Sites Telescopes Instruments Cameras Optical Element Groups Generic Mode Groups

Overview

15	40	117	140	34	60
Sites	Telescopes	Instruments	Cameras	Optical Element Groups	Generic Mode Groups

API

ConfigDB provides a RESTful api to query data. The data will be returned in JSON format unless accessed via browser, in which case a user friendly interface is provided.

The top level resource are:

- Sites: [/sites/](#)
- Enclosures: [/enclosures/](#)
- Telescopes: [/telescopes/](#)
- Instruments: [/instruments/](#)
- Cameras: [/cameras/](#)
- Optical Element Groups: [/opticalelementgroups/](#)
- Optical Elements: [/opticalelements/](#)
- Generic Mode Groups: [/genericmodegroups/](#)

Example nodes:

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

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

LC
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	

ONS

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:

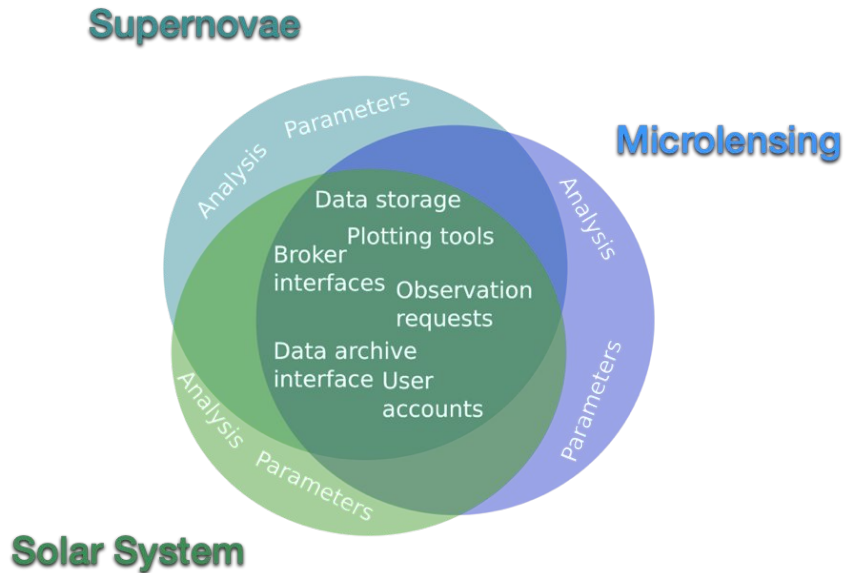
- ▶ MONET 1.2-meter telescopes

Other organizations testing OpenOCS applications:

- ▶ Yunnan Observatory (2.4m telescope)
- ▶ South African Astronomical Observatory
- ▶ Instituto de Astrofísica de Andalucía

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.

TOM Toolkit Demonstration TOM.



TOM TOOLKIT Las Cumbres Observatory LCO

The code for this demonstration TOM is in the [TOM Demo Github repository](#).

ZEGAR
FAMILY FOUNDATION

 **HEISING-SIMONS**
FOUNDATION

TOM Toolkit Functions 1

- ▶ Central database designed for astronomical programs.

The screenshot displays the TOM Toolkit interface. At the top, there is a navigation bar with links for Home, Targets, Alerts, Observations, Data, and Users. Below this, there are three main buttons: 'Create Targets', 'Update Targets', and 'Export Filtered Targets'. The central part of the interface features a 'Target Distribution (sidereal)' plot, which is a Mollweide projection map showing the distribution of 5 targets. The plot includes a grid of right ascension (0 to 300) and declination (-60 to 60) coordinates. Below the plot is a pagination control showing '1' of 1 pages. To the right of the plot is a table with columns for Name, Type, Observations, and Saved Data. The table lists five targets: NGC 6819, M31, ZTF19aadlbpl, and ZTF19aaglusq. On the far right, there is a sidebar with various search and filter options, including 'Target Type', 'Name', 'Key', 'Value', 'Cone Search', and 'Target Grouping'. The 'Cone Search' section includes input fields for 'Cone Search', 'RA, Dec, Search Radius (degrees)', and 'Cone Search (Target)'. There are also 'Filter' and 'Reset' buttons at the bottom of the sidebar.

5 Targets [Create Targets](#) [Update Targets](#) [Export Filtered Targets](#)

Target Distribution (sidereal)

« 1 »

<input type="checkbox"/>	Name	Type	Observations	Saved Data
<input type="checkbox"/>	NGC 6819	Sidereal	2	29
<input type="checkbox"/>	M31	Sidereal	0	0
<input type="checkbox"/>	ZTF19aadlbpl	Sidereal	0	0
<input type="checkbox"/>	ZTF19aaglusq	Sidereal	0	0

Add/Remove from grouping [Add](#) [Remove](#)

Target Type: ----- v

Name:

Key:

Value:

Cone Search:

RA, Dec, Search Radius (degrees)

Target Grouping: ----- v


Cone Search (Target):

Target Name, Search Radius (degrees)

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

TOM Toolkit Functions 2

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

 TOM Toolkit [Home](#) [Targets](#) [Alerts](#) [Observations](#) [Data](#) [Users](#) rstreet [Logout](#)

Query a Broker

Create a new query using [MARS](#) [Lasair](#) [Scout](#) [TNS](#) [ANTARES](#) [Gaia](#)

Name	Broker	Created	Last Run	Run	Delete
Galactic Plane query	MARS	2020-10-06 19:10:30	2020-11-10 20:11:22	Run	Delete

Filter Saved Queries

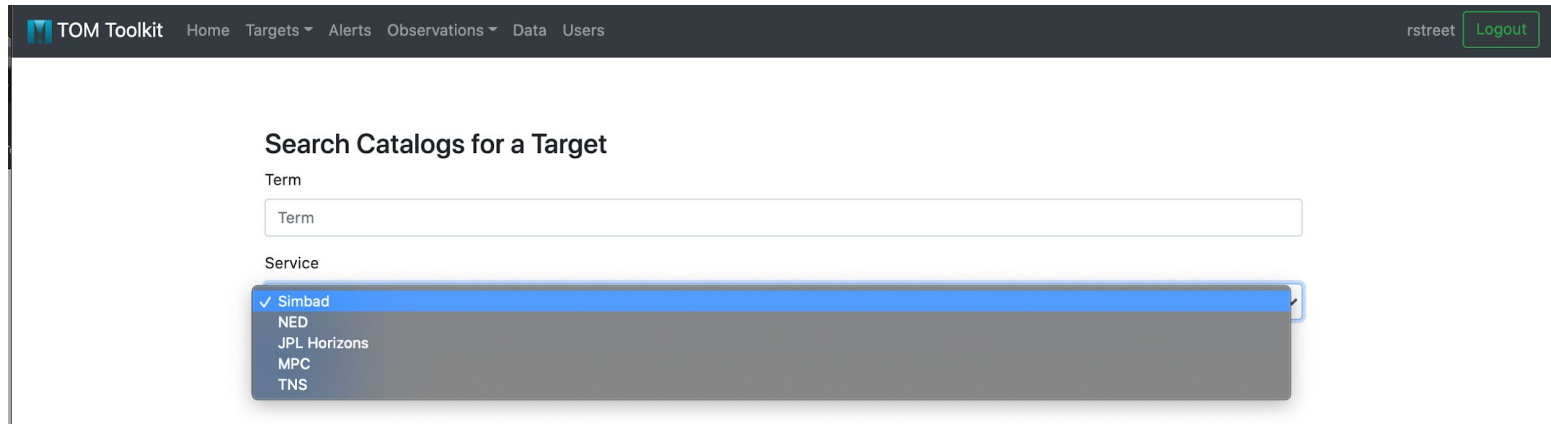
Broker

Name contains

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

TOM Toolkit Functions 3

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



The screenshot displays the TOM Toolkit web interface. At the top, there is a dark navigation bar with the TOM Toolkit logo and menu items: Home, Targets, Alerts, Observations, Data, and Users. On the right side of the navigation bar, the user 'rstreet' is logged in, with a 'Logout' button. The main content area features a section titled 'Search Catalogs for a Target'. Below this title, there is a 'Term' label and a text input field containing the word 'Term'. Underneath the input field is a 'Service' label and a dropdown menu. The dropdown menu is open, showing a list of services: Simbad (selected with a checkmark), NED, JPL Horizons, MPC, and TNS.

TOM Toolkit Functions 4

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

MOP Home Targets Alerts Requested Observations Data Users Rachel Street Logout

Submit an observation to LCO

Legend:

- (LCO) Siding Spring
- (LCO) Sutherland
- (LCO) Teide
- (LCO) Cerro Tololo
- (LCO) McDonald
- (LCO) Haleakala
- (GEM) Cerro Pachon
- (GEM) Maunakea
- (SOAR) Cerro Pachón

Buttons: Update Target Delete Target Fit Target Run TAP

Names	Gaia22crr
Target Type	SIDEREAL
Right Ascension	214.4055
Declination	14:17:37.320
Galactic Longitude	-58.6450
	-58:38:42.036
	313.9581

Imaging Muscat Imaging Spectra Photometric Sequence

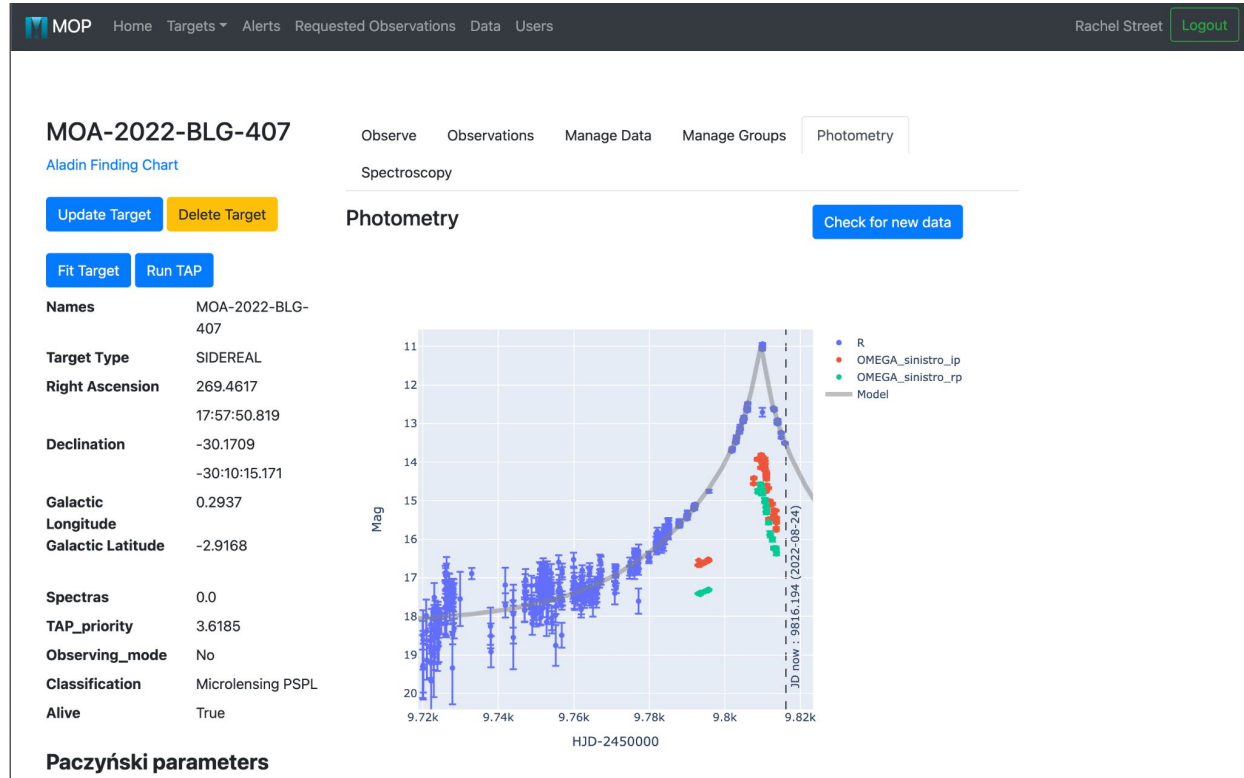
Spectroscopic Sequence

Name* Filter*
 100um Pinhole

Proposal* Instrument type*
Observing Microlensing Events of the 0.4 meter SBIG

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/>



Navigation

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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

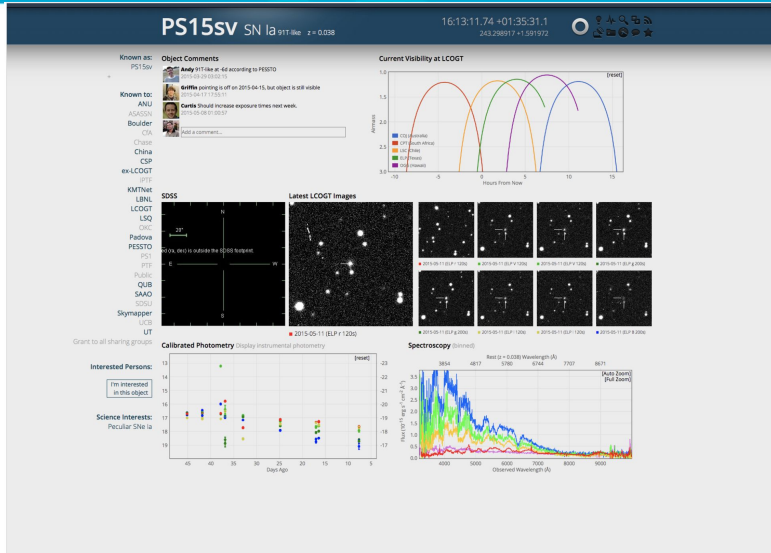
[Frequently Asked Questions](#) - Look here for a potential quick answer to a common question.

[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



Las Cumbres Observatory

NEO EXCHANGE v.1.0.0 Minor planet follow-up portal

Powered by Las Cumbres Observatory

HOME TARGETS BLOCKS EFFICIENCY Object name SEARCH

174 active targets 1 active blocks Moon phase 20.3%

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	M7OHMQ4	Candidate	17 55 31.02	+13 14 39.9	17.0	3	0.02	4,855	100	🔴
3	M7OHLGY	Candidate	19 45 24.04	+00 50 04.3	17.9	3	0.03	5,643	100	🔴
4	X5G530	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 56.8	19.6	10	0.59	3,117	100	🔴
13	P10BvgI	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	YK08060	Candidate	21 26 43.69	+06 08 45.1	21.0	11	0.99	1,357	100	🟢

TOMs in 2022:

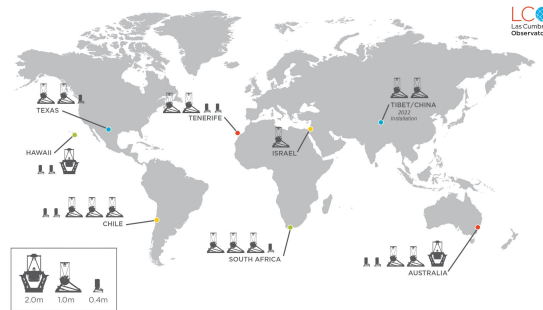
- ▶ SuperNova EXchange (SNEx)
- ▶ MOP (Microlensing Observing Project)
- ▶ ANTARES TOM
- ▶ ExoTOM

- ▶ 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.



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.

AEON Operations model 1



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.



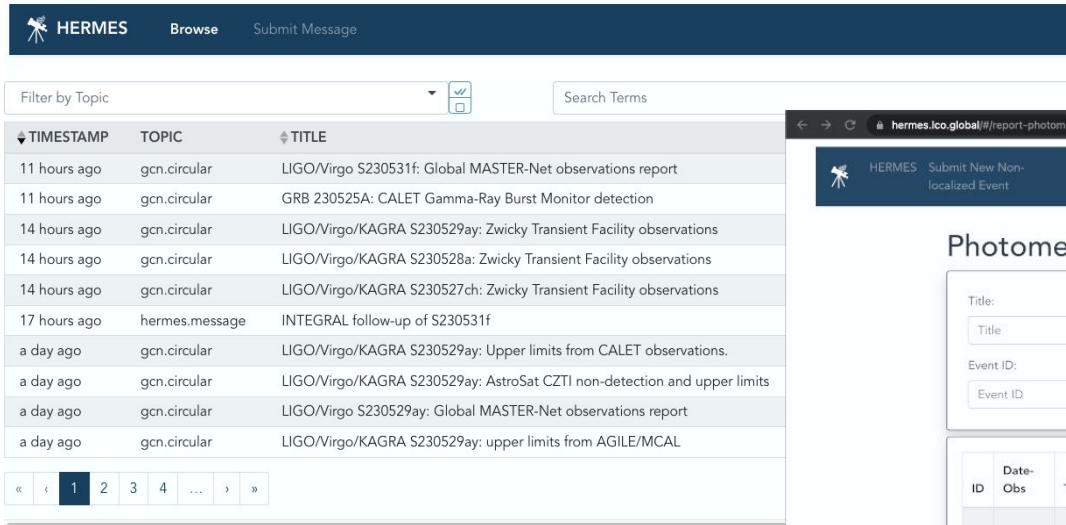
Partner observatory (Gemini) uses its own scheduling system.

- ▶ 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.

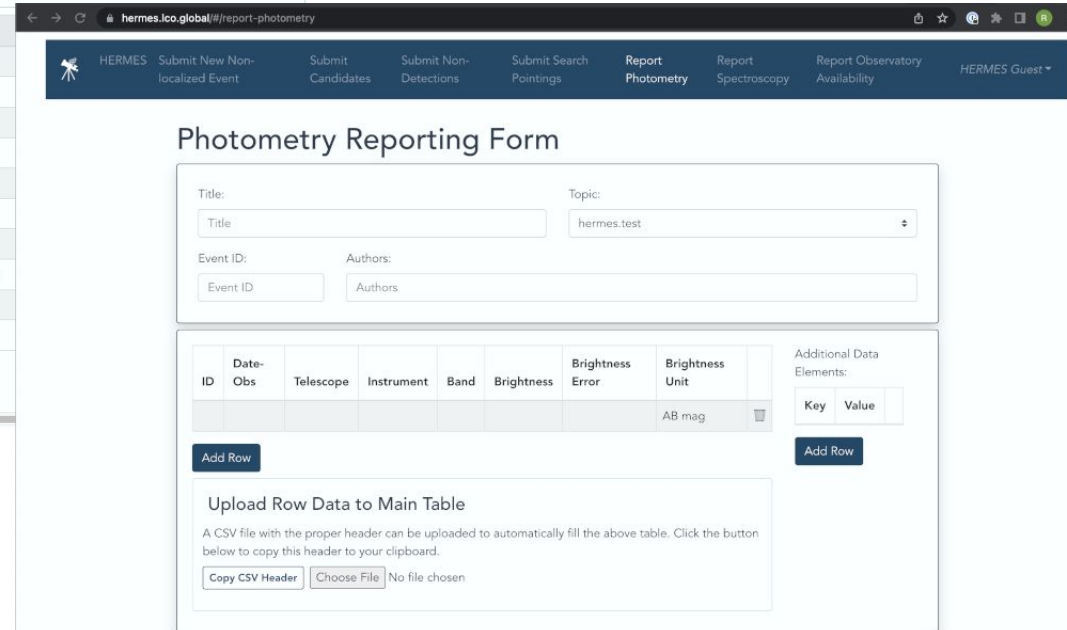


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Date- ID	Obs	Telescope	Instrument	Band	Brightness	Brightness Error	Brightness Unit	Additional Data Elements:
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Collaboration between LCO & SCiMMA



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Thank you!