

General-purpose Tools for Alert-based Science and Observing Programs

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Rachel Street, Las Cumbres Observatory
Representing the TOM Toolkit and AEON Teams



Core team: David Collom, William Lindstrom, Austin Ribas, Rachel Street, Curtis McCully, Elizabeth Heinrich-Josties, Mark Bowman

+ LCO Science Team

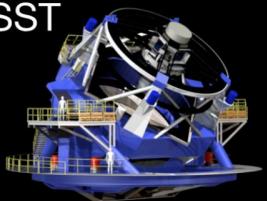
+ Many collaborators - thank you!

Andy Adamson, John Blakeslee, Bob Blum, Adam Bolton, Todd Boroson, Mark Bowman, César Briceño, Jay Elias, Edward Gomez, Steve Heathcote, Elizabeth Heinrich-Josties, Alice Hopkinson, Chien-Hsiu Lee, Bryan Millar, Jon Nation, Steve Ridgeway, David Silva, Lisa Storrie-Lombardi, Rachel Street



Follow-up Ecosystem

LSST



ZTF



TESS



+ many others

Discovery engines

Broker services

Target & Observation
Manager Systems

Observing facilities



Target and Observation Manager Systems (TOMs)

Database-driven tools to address common challenges for astronomical programs

- Continuous stream of new targets
- Target selection and prioritization
- Evaluate many targets in different states simultaneously
- Explore, visualize & share data
- Coordinate observations across a range of facilities
- Manage project data
- Accessible to project members worldwide



Credit: LCO, BJ Fulton, NASA Goddard, NASA/JPL Caltech/T. Pyle,



<https://github.com/TOMToolkit>

Build an open-source, professionally developed, software package that will enable astronomers to build TOM systems easily and customize them for their science goals

- Python-based
- Minimal prior knowledge required

Provide large set of core functions for commonly-used components

Provide well-defined interfaces to allow science-specific code to interact with the TOM

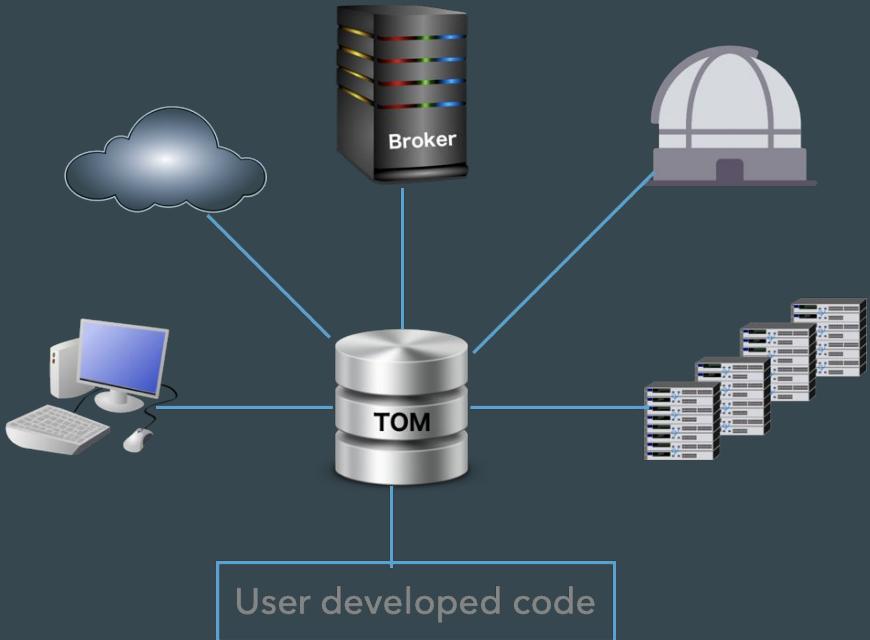
Support the science community, welcome community contributors



TOM Toolkit

<https://github.com/TOMToolkit>

- Database designed for astronomical programs, can be extended for user parameters
- Built-in interfaces to brokers, catalog servers, observing facilities
- Built-in target displays, data visualization, observation planning tools
- Easily customized and extended (Python)
- User accounts, Groups & authentication
- RESTful API for interfacing with user-developed code



Recent Developments

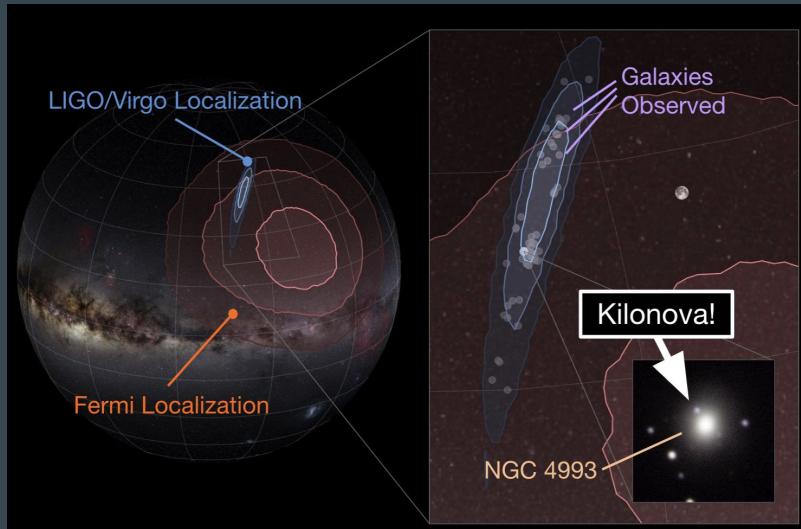
SCiMMA - Scalable Infrastructure to support Multi-Messenger Astrophysics

tom_scimma broker module

Support for Skip and Hopskotch

TOMs can query alerts submitted to the Hopskotch stream, *and* publish alerts to Hopskotch.

See demo by David Collom, Curtis McCully



Recent Developments

Vue.JS tools, DASH apps

Implementing more reactive table and plotting tools

Sort and search options, in-browser plotting controls

The screenshot shows a web application interface for the TOM Toolkit. At the top, there is a navigation bar with links for Home, Targets, Alerts, Observations, Data, and Users. On the far right, it shows the user's name (David Collom) and a Logout button. Below the navigation bar, a green success message box displays "Successfully created View Target". The main content area is titled "MARS Alerts" and contains a "MARS" search form with fields for Object Name Search, Magnitude Maximum, Real-Bogus Minimum, Right Ascension, Declination, and Radius. A blue button labeled "Create targets from selected" is visible. Below the form is a table listing 15 alert entries. The table has columns for Name, Right Ascension, Declination, Magnitude, and Real-Bogus Score. Each entry includes a checkbox and a link to "View Target".

Name	Right Ascension	Declination	Magnitude	Real-Bogus Score
ZTF18aaazxcec	15:42:44.963	+01:00:9.745	17.7284	0.5257
ZTF18abavqem	15:42:55.648	+01:00:8.292	18.4514	0.3643
ZTF18aaxkspk	15:45:30.640	+04:05:0.601	13.8956	0.5371
ZTF18aaxktos	15:37:22.151	+02:21:34.359	16.6066	0.5471
ZTF20acymkhf	15:27:8.432	+02:06:17.080	18.7361	0.4514
ZTF20acymkhg	15:27:1.460	+02:05:46.599	19.0641	0.2443
ZTF20acymkha	15:27:59.156	+02:12:15.262	18.4571	0.2771
ZTF20acymkhb	15:29:8.573	+02:22:11.582	18.5261	0.1786
ZTF20acymkhc	15:27:48.960	+02:27:58.169	18.5001	0.4214
ZTF20acymkhd	15:29:5.861	+01:55:37.365	18.5031	0.2786

Recent Developments

Calibration TOM

TOM designed to automatically perform routine calibration observations on the LCO network

Phase 1 operational: spectrographic standard observations for NRES spectrographs at multiple sites

Phase 2 under development: photometric standards

Open Observatory Control System
<https://observatorycontrolsystem.github.io/>

Fully open-source observatory control and observation scheduling system

TOM Toolkit compatible

NRES Cadences									
Cadence Information							Observation Information		
Site	Calibration Type	Frequency	Target	Active	Last modified	Latest Observation	Next Observation	History	
cpt	FLUX	72	HR5501	Active		1 week, 4 days ago	HR5501 at 2021-03-22 01:03:47	HR5501 at 2021-03-24 21:03:38	HR5501 NRES FLUX calibration cpt
cpt	RV	72	HD76151	Active		2 weeks, 4 days ago	HD76151 at 2021-03-11 21:03:00	HD76151 at 2021-03-23 19:03:00	HD76151 NRES RV Standard CPT
elp	FLUX	72	HR5501	Active		18 hours ago	None	HR5501 at 2021-03-26 05:03:17	NRES FLUX calibration for ELP
elp	RV	72	HD76151	Active		18 hours ago	None	HD76151 at 2021-03-27 02:03:57	NRES RV calibration for ELP
tlv	FLUX	24	HR5501	Active		2 weeks, 4 days ago	HR5501 at 2021-03-20 02:03:25	HR5501, not scheduled	NRES FLUX calibrations for tlv
tlv	RV	24	HD76151	Active		2 weeks, 4 days ago	HD76151 at 2021-03-20 18:03:22	HD76151, not scheduled	HD76151 NRES RV Standard TLV

Community Support

Public repository: <https://github.com/TOMToolkit>

Public Slack channel for users: tom-toolkit.slack.com
To join the channel, go to: <https://tom-toolkit-invite.lco.global/>

Documentation, tutorials, plugins: <https://tom-toolkit.readthedocs.io/en/stable/>

Workshop training materials:
<https://lco.global/workshops/tom-toolkit-community-workshop/training-materials/>

Demonstration system: <https://tom-demo.lco.global/>

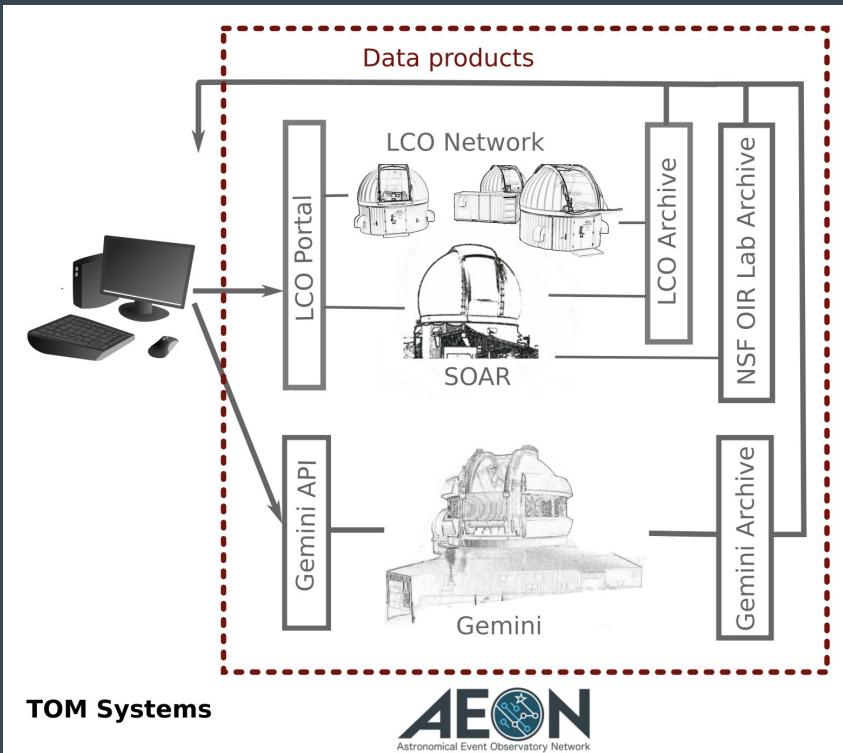
Minimal integration requirements:

- Queue-schedulable at least part of the time, two alternative channels:

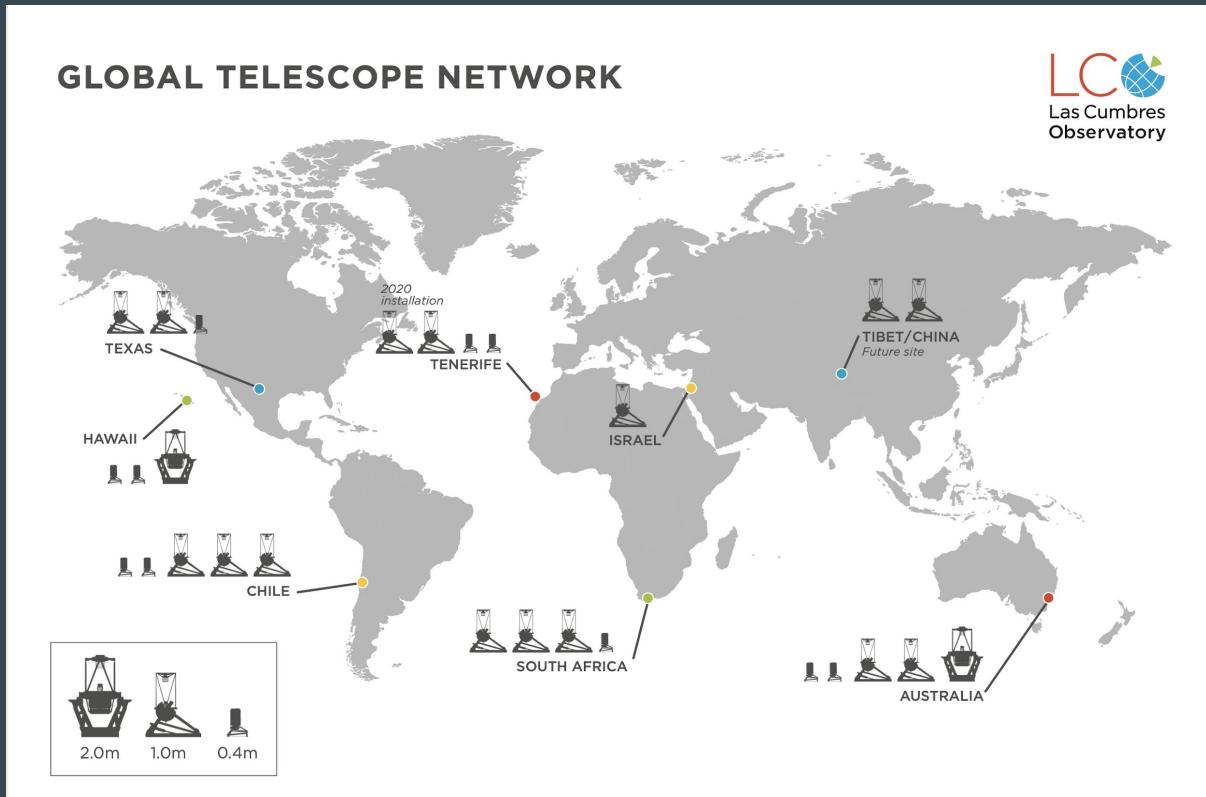
EITHER: by integration with the LCO Network scheduler

OR: through facility's own interface and scheduler

- Programmably-accessible, compatible with the TOM Toolkit



AEON Las Cumbres Observatory



Robotic network of 2m, 1m
and 0.4m telescopes at 7 sites
worldwide
Fully automated, reactive
scheduling system
Queue-scheduled
observations
Programmatic observation
submission/reporting

Brown, et al., 2013, PASP, 125,
1031,
Lampoudi, Saunders & Eastman,
2015, arXiv:1503.07170
Saunders et al., 2018, SPIE:
Observatory Operations, 107040Z

AEON SOAR Observatory

AEON Option 1: Interface via existing programmatic portal when they choose



Available as a queue-scheduled node on LCO network when in AEON-mode

Traditionally scheduled the rest of the time - SOAR controls the schedule

Human operators on-site

Goodman spectrograph pipeline

First successful semester of observations 2019B

Programmatic submission of observations provided by LCO portal

Automatic TOM compatibility provided through LCO portal

Elias et al. 2018, SPIE,
107040B

Nation et al. 2020,
SPIE, Saunders et al. 2018,
SPIE, 107040Z



AEON Option 2: Facility's own scheduling system with compatible interface



Queue-scheduled observations

Programmatic submission of observations with an existing API

Gemini observing module plugin for TOM Toolkit available,
built by Bryan Miller, Gemini

Ongoing re-design of operations software designed with AEON in mind

Designing automated scheduling system

AEON Future Expansion

Infrastructure designed to be easily extended to include additional facilities

TOM interfaces available for other compatible facilities

- Liverpool Telescope (with thanks to the LJMU team)

Simple, low-barrier-to-entry APIs

Exploring collaborations with additional facilities

Questions and comments

Interfaces are key

- Science capabilities are most robust when brokers/TOMs/observing facilities can interface seamlessly
- Need a common system for notify interfacing services of upgrades

Community Partners

- Many teams have collaborated with the TOM/AEON teams to build interfaces - thank you!
- We welcome partnerships with other service providers and science teams