Las Cumbres Observatory

Target of Opportunity Observing – The Las Cumbres Observatory Experience

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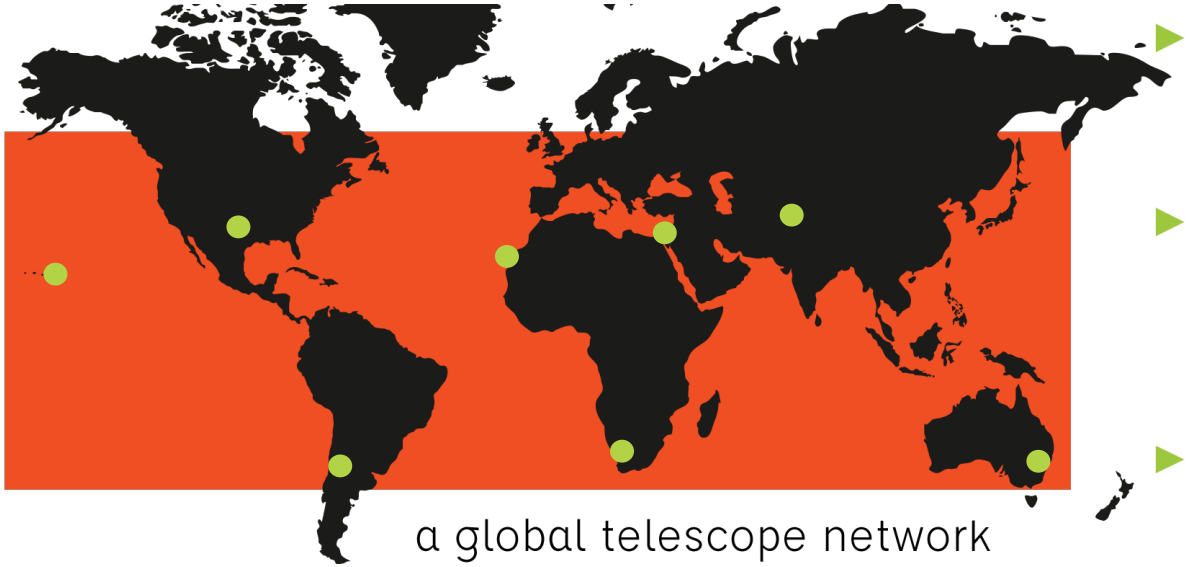
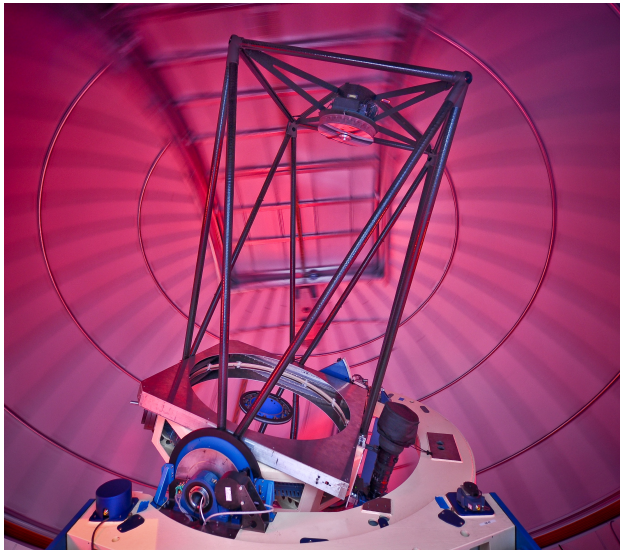
Network Concept



- Twenty robotic telescopes – ultimately ~27
  - 2-meter, 1-meter, 40-cm
- Eight high-quality sites spanning north and south hemispheres
  - Several telescopes per site
- Uniform instrumentation
  - All instruments always available
- Automatic calibration, pipeline processing, archiving
- Operates as single integrated observatory
- Designed and operated to enable time domain observations of all types

LCO telescopes

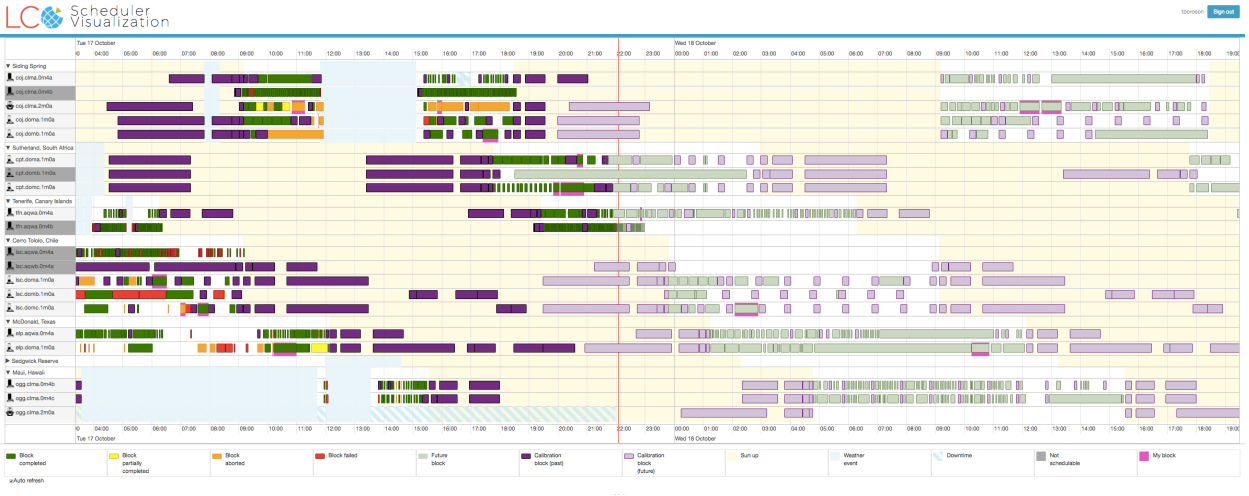
- Two 2m telescopes have optical imagers and low dispersion optical spectrographs
- Nine 1m telescopes have optical imagers. Four sites will also have high-res precision radial velocity spectrographs.
- Several more 1m telescopes planned to complete coverage in northern hemisphere
- Ten 40-cm telescopes have optical imagers



How it works (from the users perspective)

- We allocate hours to successful proposals on a given subnet (2m, 1m, 0.4m)
  - All proposals (other than purchased time) go through peer-review
  - Each approved project has a TAC-assigned rank, which determines its "scientific priority"
- PI and Co-I's submit observation requests either through a web-form interface or through their own software, which addresses an API end-point in our system
  - Requests may be submitted at any time during the semester in which the allocation is active
  - Users specify: pointing trajectory, exposure time, time window, maximum airmass, minimum distance from moon, acquisition and guide modes (as well as instrumental parameters)
  - Cadence-driven requests generate one or more observations within time window
  - Rapid response requests interrupt ongoing observation (median 6 minutes)
- Users can monitor scheduling status and can request email notification of data availability
- Raw data are returned immediately to LCO headquarters and archived
- Immediate pipeline processing produces a "quick-look" reduced data set
- End of night reprocessing produces a final reduced data set
  - Proprietary period for data is 12 months

Network operates as a single facility

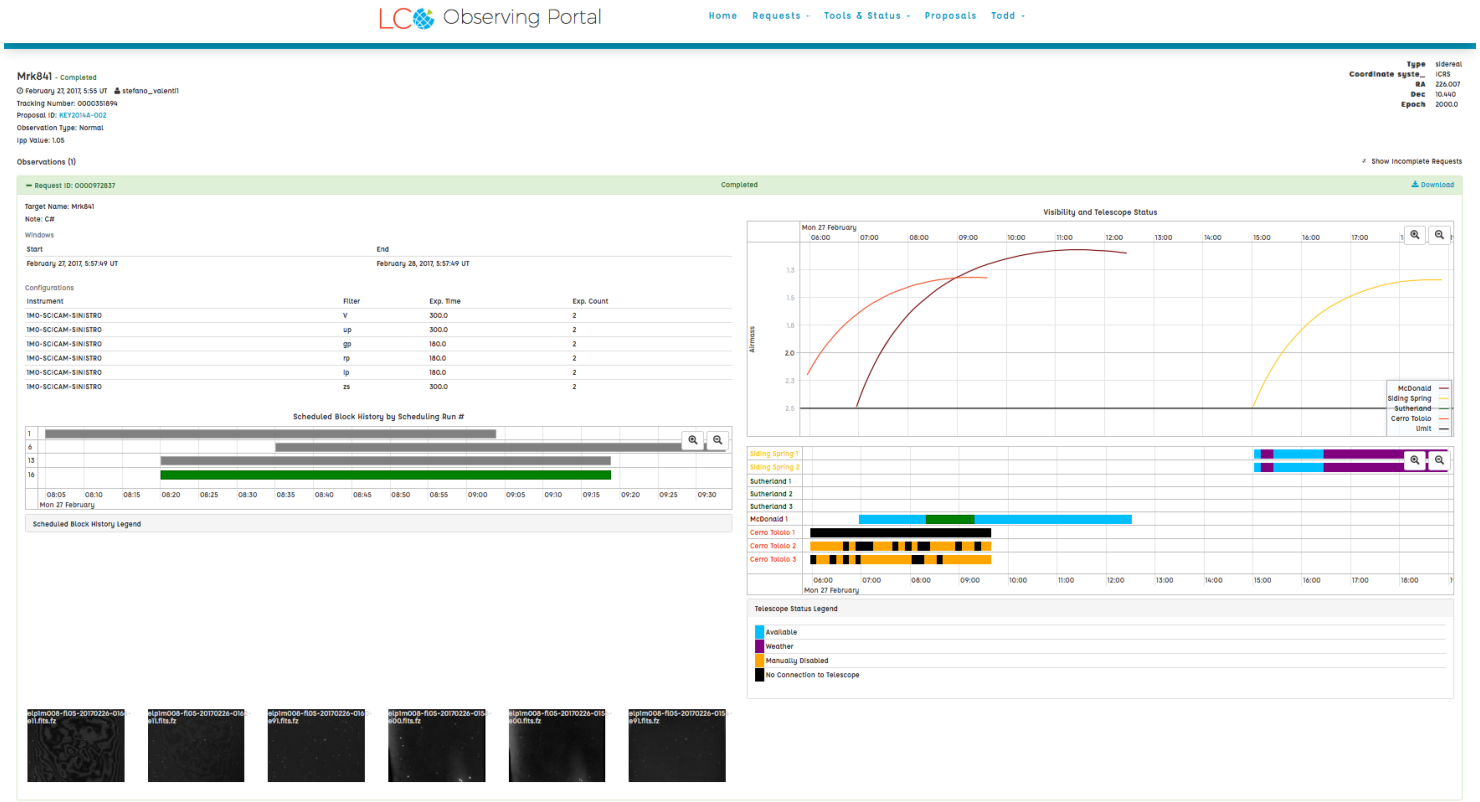


Full science operations continuously since May 1, 2014

We underallocate slightly with the goal of completing a large fraction of programs

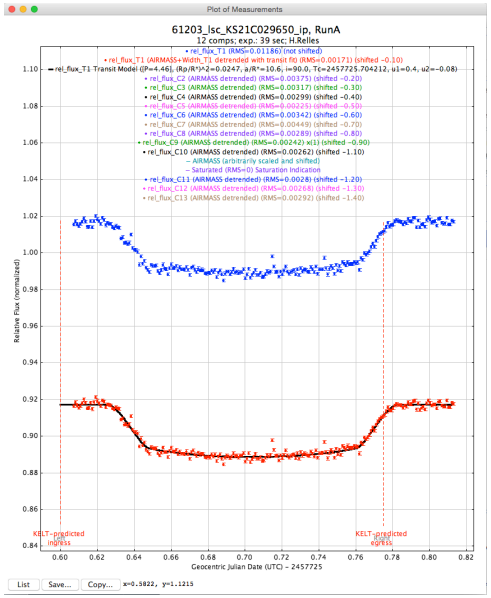
- Single scheduler takes entire set of current requests, produces optimum schedule for network – updates as needed (~10 min runtime)
  - ***All observations are "Targets of Opportunity"***
- Scheduler attempts to optimize global schedule – including factors for TAC priority, network efficiency
- Local weather stations guide robotic decision-making on site operation
- Calibration program runs automatically – biases, darks, skyflats, photometric standards; arcs and flats for spectroscopy
- Telescopes run automatic pointing, focus adjustment sequences several times during each night.

Observing with LCO

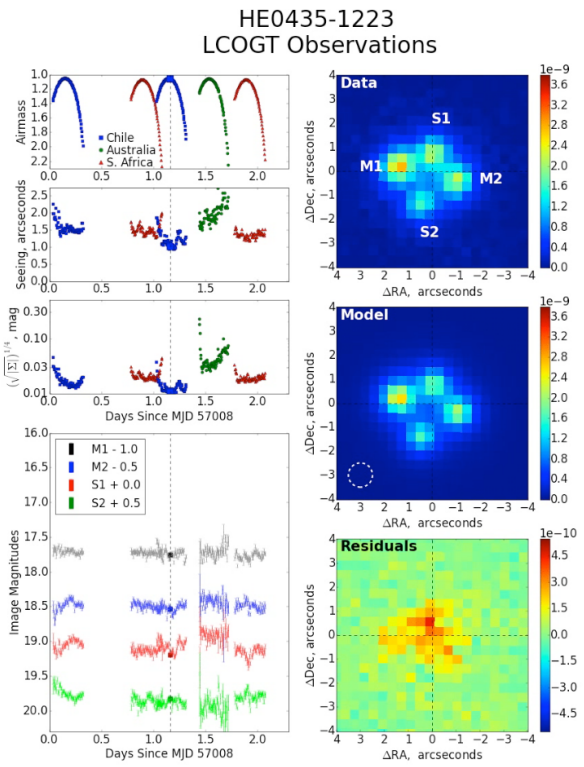


- Feedback page provides information on visibility, facility availability, and scheduling
- Thumbnails provide links to data after observation completes
- Users can select "Email me when my data arrives"

Scientific Performance (imaging)



- Filters include Bessel-Johnson, Pan-STARRS, SDSS, Hα, Hβ
- 1-meter telescopes used to m=20 (imaging)
- 2-meter telescopes used to m=22 (imaging)
- For bright objects, achieve 2 mmag precision
- For faint objects, achieve photon-limited S/N



RESEARCH LETTER

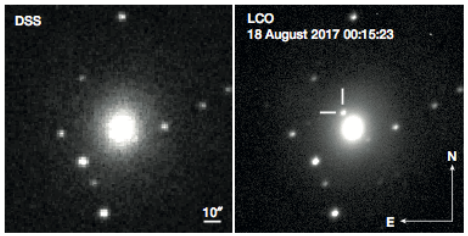
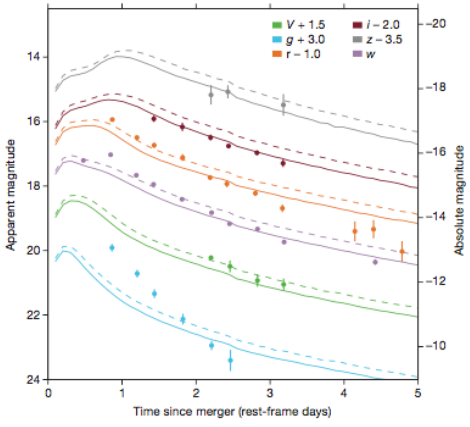


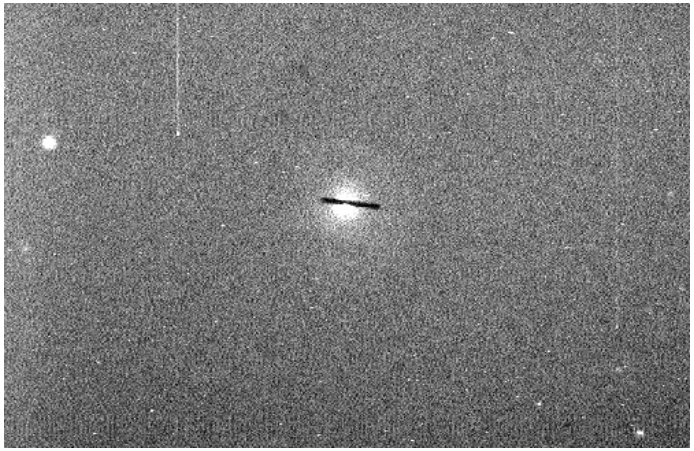
Figure 2 | LCO discovery image of the kilonova AT 2017gfo in the galaxy NGC 4993. The *w*-band LCO image (right), centred on NGC 4993, clearly shows a new source (marked with white ticks) compared to an archival image (left) taken on 9 April 1992 with the RG610 filter as part of the Anglo-Australian Observatory Second Epoch Survey (AAO-SES), retrieved via the Digitized Sky Survey (DSS).

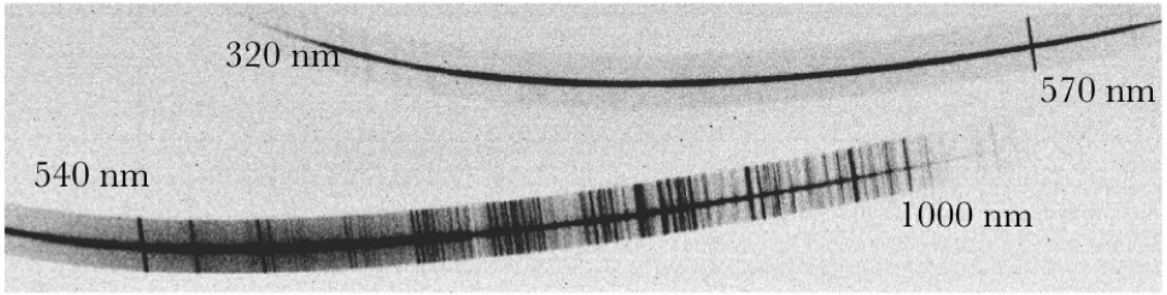
and location area included in the LIGO–Virgo three-dimensional localization[29] (see Methods).

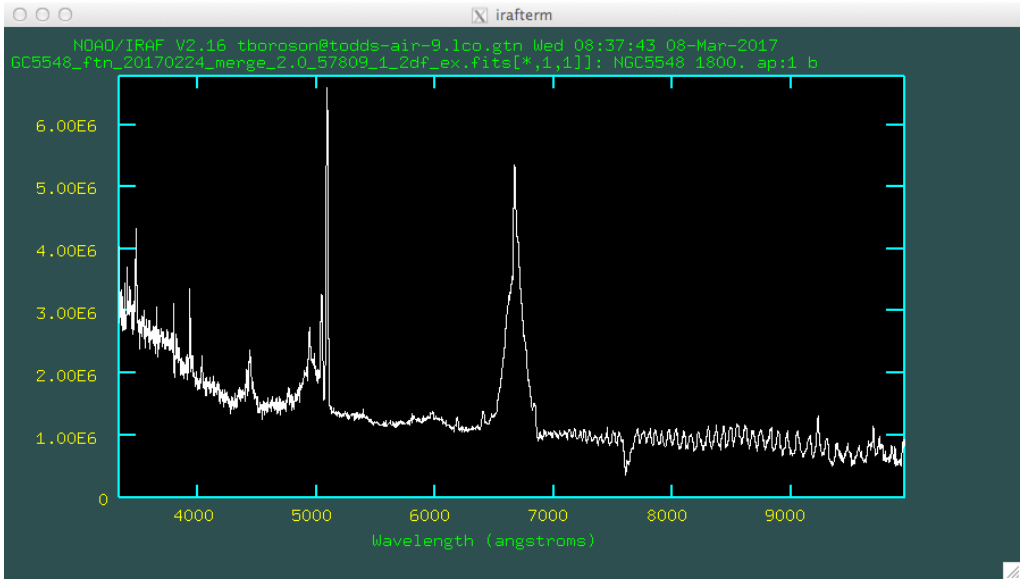


- Multiple longitudes allow more frequent – or even continuous – monitoring than a single site

Scientific Performance (FLOYDS)







- On 2-meter telescopes: Maui & Australia
- 30 arcsec long slit; width selectable (1.2 – 6.0 arcsec)
- Robotically position by coordinates or "brightest within radius"
- 1.6Å/pix in 1st order; 0.8Å/pix in 2nd order
- 1 hr exposure gives S/N ~ 20 for V=19

Notable LCO "Policies"

- By operating 100% of the time as a dynamically-scheduled robotic observatory, we can efficiently fit together many (70) programs with a diverse range of timing requirements (including static)
- Every observation is a "Target of Opportunity"
  - We don't expect observers to know what or when they are going to observe until they submit their requests
  - Our semester boundaries are a management convenience (also have DD time)
- We operate to achieve a high level of completeness for all projects
  - Some idle time is a necessary consequence
- Even though the observatory is robotic, you still have to think about what you are doing
  - Experimentation well before your critical observation needs to start is a good idea
- The goal of producing uniform and consistent data sets requires a coherent calibration program and automatic pipeline processing to remove instrumental signatures
- Monitoring and managing the data flow is important – it makes little sense to make an observation within a few minutes of a request if the data are not available until 24 hours later

NSF MSIP award provides U.S. open access

- ~1200 hrs of 1m time and 200 hrs of 2m time per semester for 8 semesters
- Proposals to NOAO through their regular proposal process
- LCO semesters start Dec 1 and June 1 to synchronize with NOAO TAC
- Next proposals due: March 31, 2018

Priorities for Open Access

(1) Follow up discoveries/samples identified with current surveys

(2) Provide experience for community in time domain techniques

(3) Motivate and enable development of infrastructure for time domain research (for LSST era)

Planned LCO development

- Learn how to integrate other, existing telescopes into our network
  - SOAR under way, Gemini under discussion
  - These external telescopes still allocate their own time – LCO acts as UI and dynamically schedules observations
- Results in a larger set of capabilities that can be used efficiently for time-domain follow-up

- Develop a better, science-based user interface (Target and Observation Manager)
  - Build a toolkit so that research teams can easily assemble their own TOM
  - TOM manages data and provides tools for collaborating team
  - TOM receives discovery alerts, allows filters and algorithms to identify targets for follow-up
  - TOM generates requests to follow-up facilities and tracks new data obtained

Las Cumbres **Observatory**

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