Las Cumbres Observatory

LCO Global Telescope Network:
Operations and policies for a time-domain facility

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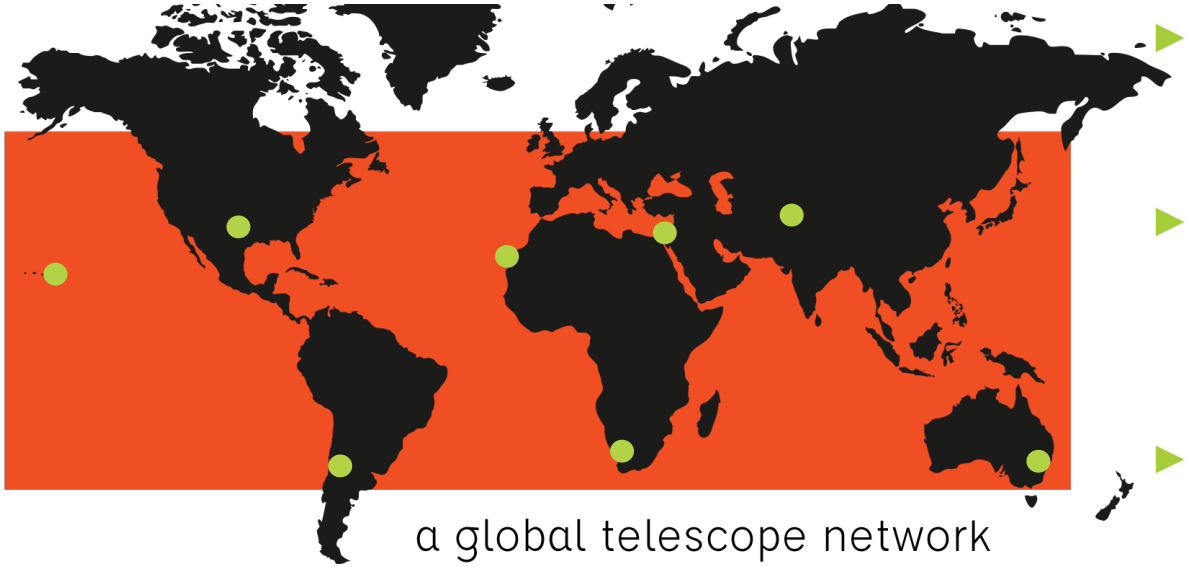
Network Concept

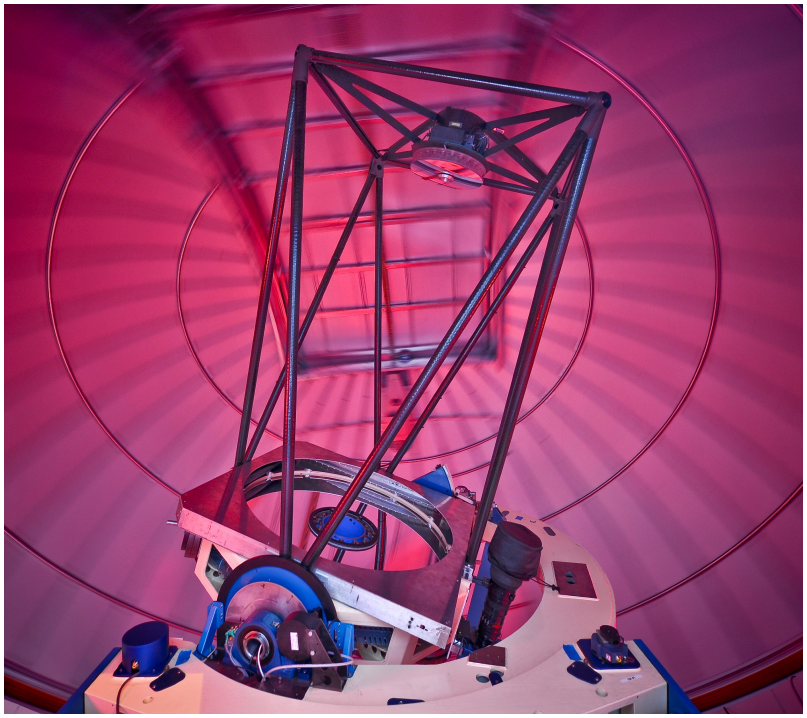


- Eighteen robotic telescopes – ultimately ~27
  - 2-meter, 1-meter, 40-cm
- Eight high-quality sites spanning north and south hemispheres
  - Several telescopes per site
- Uniform instrumentation
  - All instruments always available
- Automatic calibration, pipeline processing, archiving
- Operates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

2-meter telescopes

- Two telescopes in network (Maui and Australia)
- 10 arcmin FOV optical imager w/ many filters
- Low-res (R=500) optical spectrograph (FLOYDS)

1-meter telescopes



- Nine telescopes in network (Chile, South Africa, Australia, Texas)
- Two in production (China) and three more planned (Canary Islands, Texas)
- 30 arcmin FOV optical imager w/ many filters
- High-resolution (R=50,000) optical spectrograph - NRES
  - Optimized for high precision RV work on bright stars

40-cm telescopes

- Seven telescopes in network (Chile, Canary Islands, Maui, Australia)
- Three more in production (Chile, Texas, South Africa)
- 20 X 30 arcmin FOV optical imager w/ many filters

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

LCO

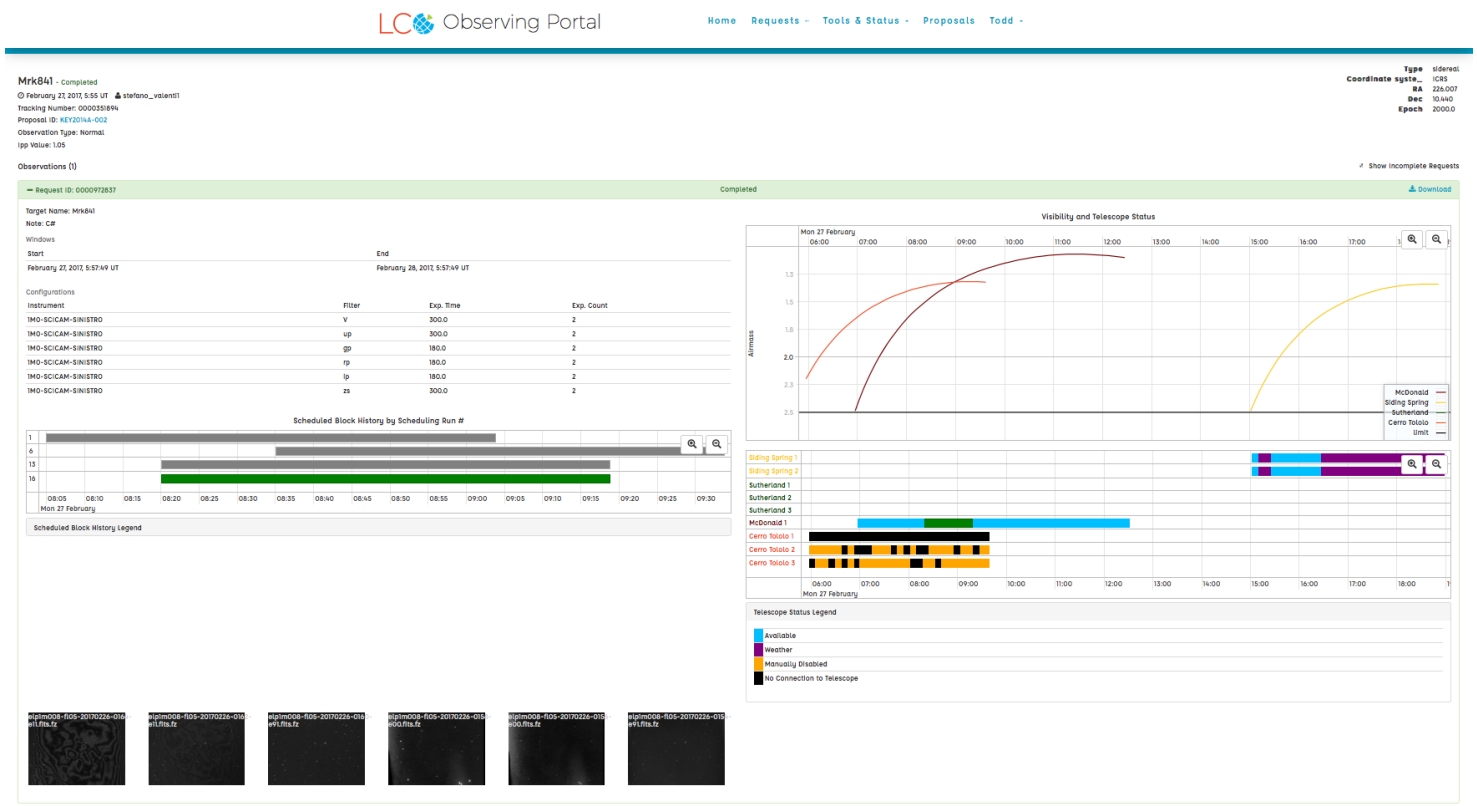
Network operates as a single facility

- Single scheduler takes entire set of current requests, produces optimum schedule for network – updates as needed (5-10 min runtime)
- 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.

Full science operations continuously since May 1, 2014

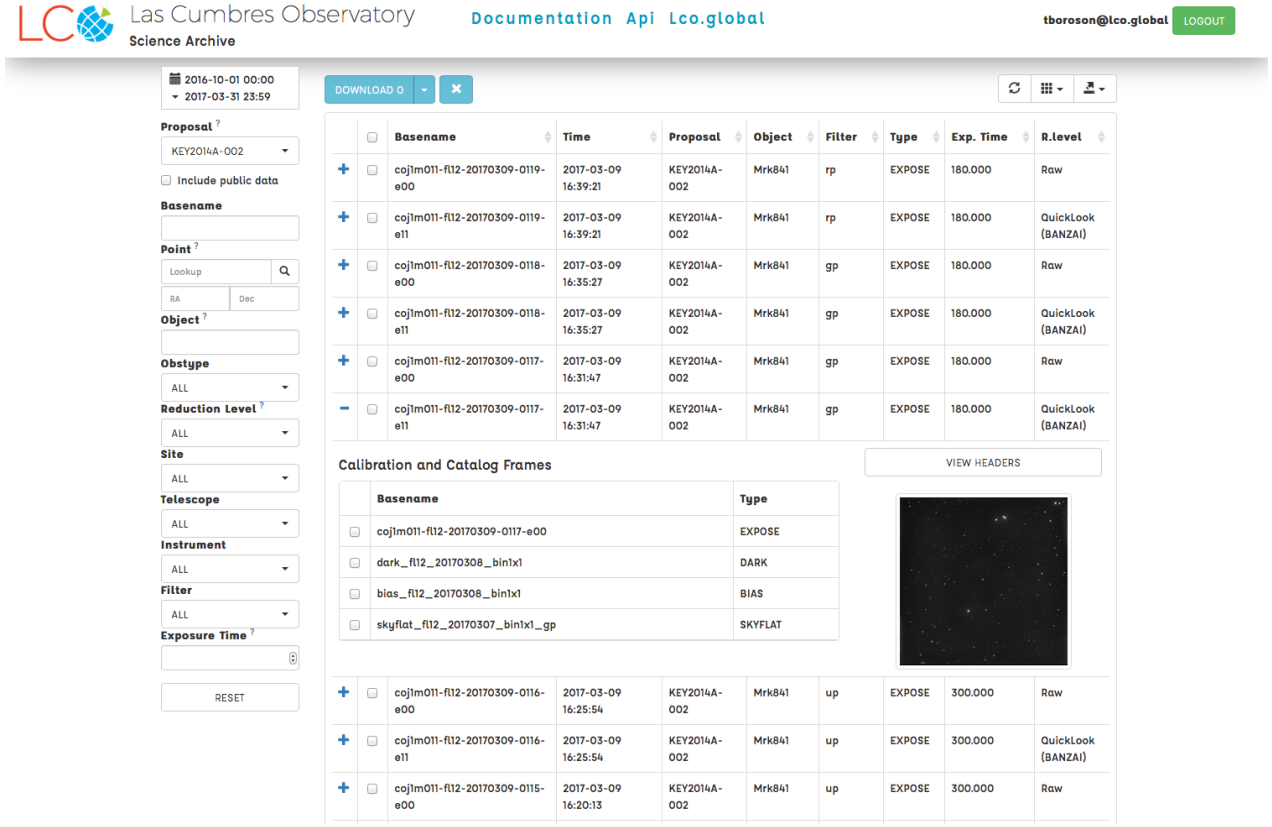
We underallocate slightly with the goal of completing a large fraction of programs

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"

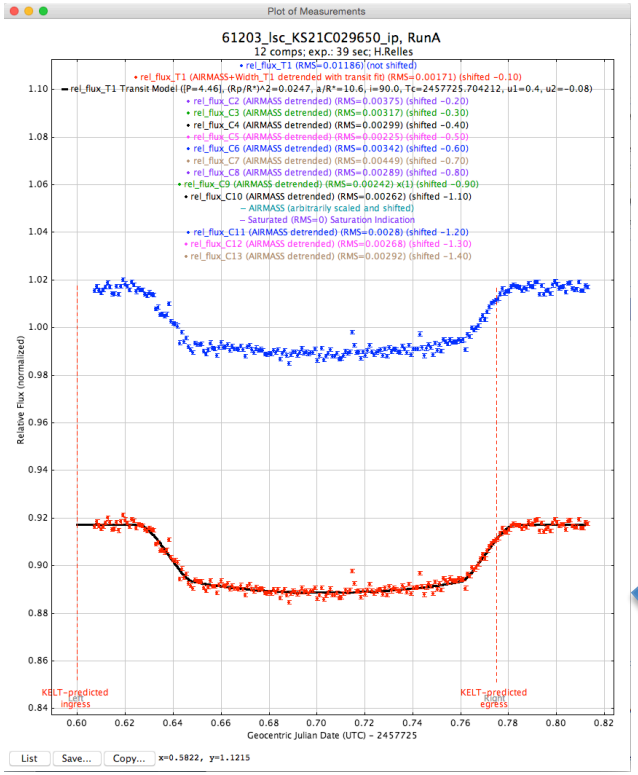
Pipeline processing and Archive



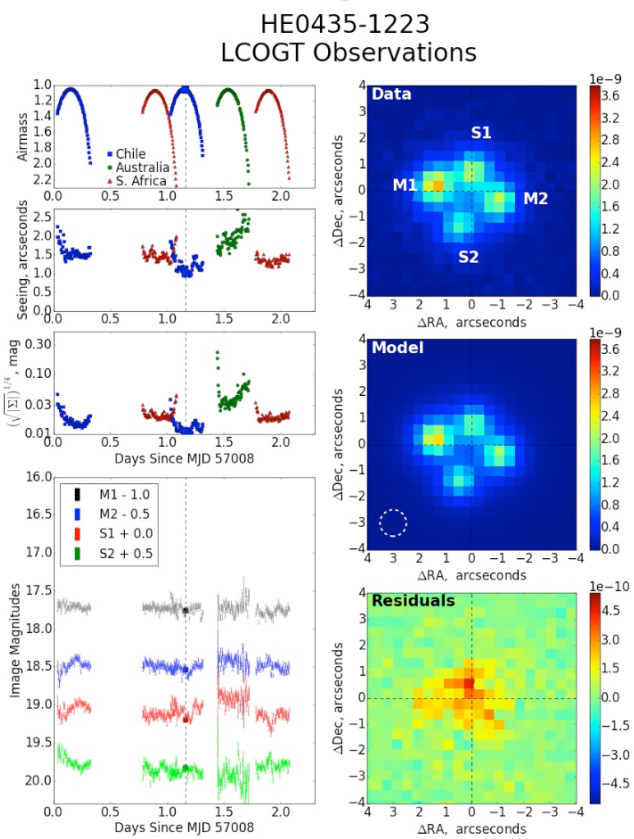
- Data immediately transferred to headquarters over internet
- Python pipeline uses daily bias/dark/flat calibrations
- Reduced data product includes instrumental-signature-removed image and source catalog
- "quicklook" available within 15 minutes; "final" at end of night
- FLOYDS data completely reduced to flux/wavelength-calibrated 1D spectra

- Archive based in (Amazon S3) cloud
- Allows identification of relevant data including public
- Simple download of selected data sets

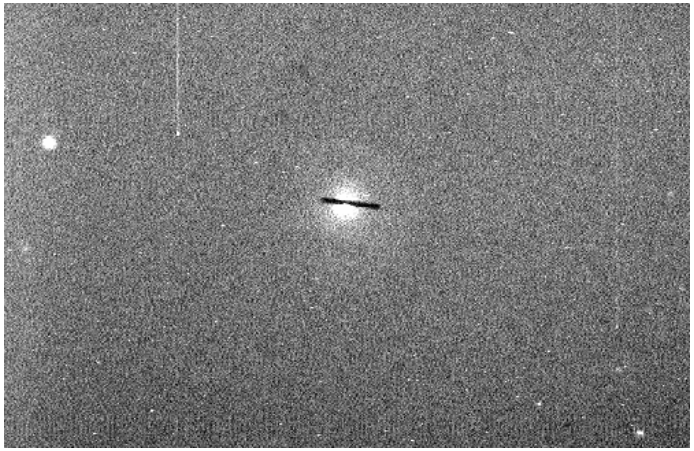
Scientific Performance (imaging)

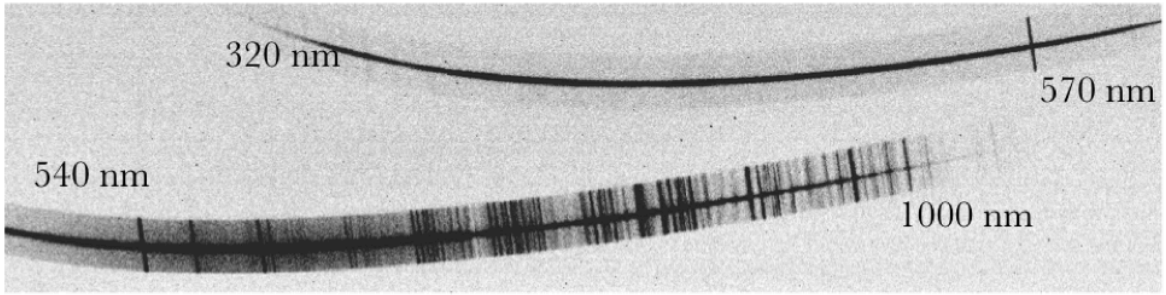


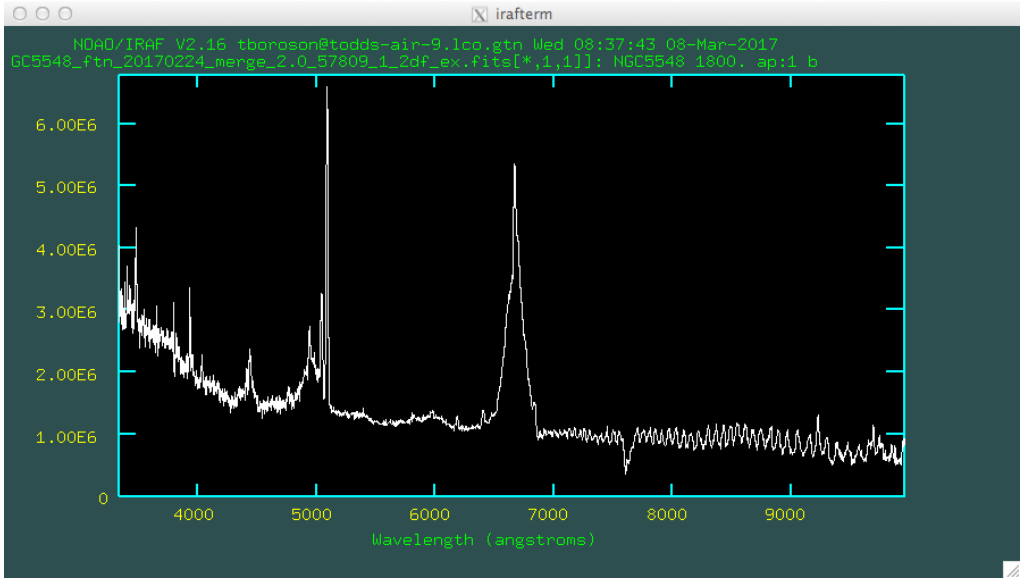
- Filters include Bessel-Johnson, Pan-STARRS, SDSS, Hα, Hβ
- Continuous (24 hr) monitoring – limited by weather
- 1-meter telescopes used to m=20 (imaging)
- 2-meter telescopes used to m=22 (imaging)
- For bright objects, achieve 2 mmag precision
- For faint objects, achieve photon-limited S/N



Scientific Performance (FLOYDS)

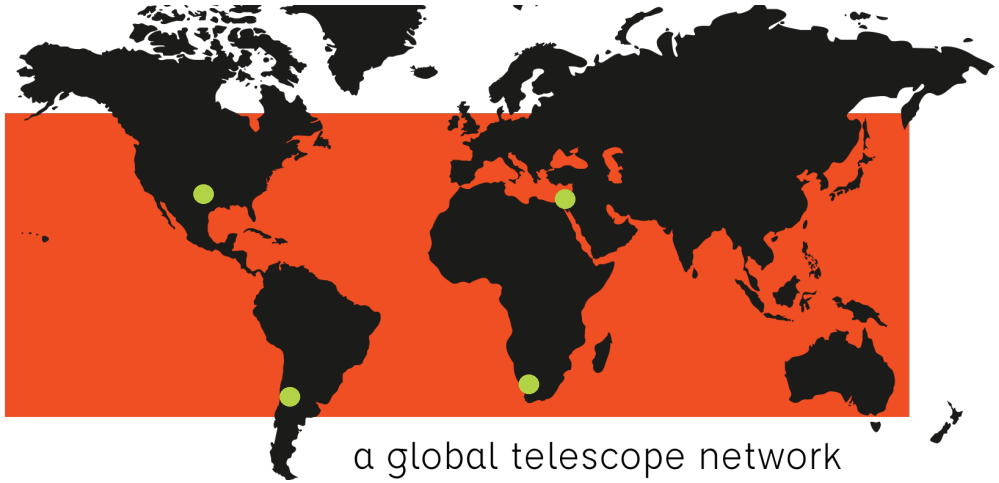




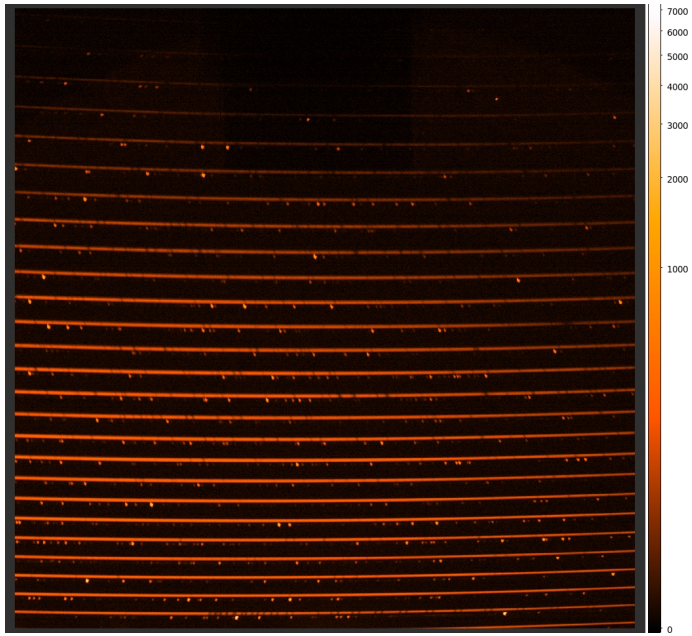


- On 2-meter telescopes: Maui & Australia
- 30 arcsec long slit; width selectable (1.2 – 6.0 arcsec)
- Robotically position by coordinates or "brightest within radius"
- 1.6Å/pix in 1st order; 0.8Å/pix in 2nd order
- 1 hr exposure gives S/N ~ 20 for V=19

Scientific Performance (NRES)



- Planned for 4 sites by mid-2018
- Fed by optical fibers from 2 1-m telescopes (2.6 arcsec diam)
- R=50,000; λλ3800-8600
- Ultimate precision/stability: 3 m/s for V=12 in 1 hr



- Exposure can be limited by time or counts
- Pipeline (in development) will provide radial velocity and stellar parameters

Notable LCO "Policies"

- By operating 100% of the time as a dynamically-scheduled robotic observatory, we can efficiently mesh 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

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)

- ~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 shifting to start Dec 1 and June 1 to synchronize with NOAO TAC
- First round: 30 proposals
  - Mix of solar system, stellar, galactic, and extragalactic research areas
  - ~2X oversubscribed
- Next proposals due: September 30, 2017
- Next call for key projects (to start June 2018) early 2018

Las Cumbres **Observatory**

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