Optimizing Facilities and Infrastructure for Time Domain Science

Rachel Street

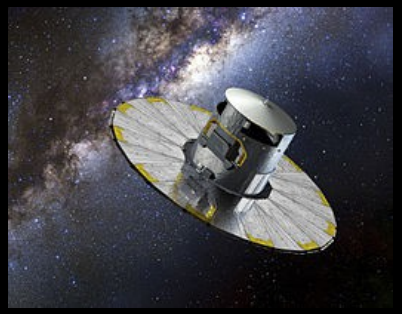
With thanks to
The LSST Time Domain Splinter Group: Adam Bolton, Dave Ciardi, Jay Elias, Tom Matheson, Bryan Miller, Steve Ridgway, Chad Schafer, Erik Tollerud and LCOGT Science Team

Las Cumbres Observatory

Hot-Wiring the Transient Universe

Time Domain Science

Several major time domain programs coming online or operational



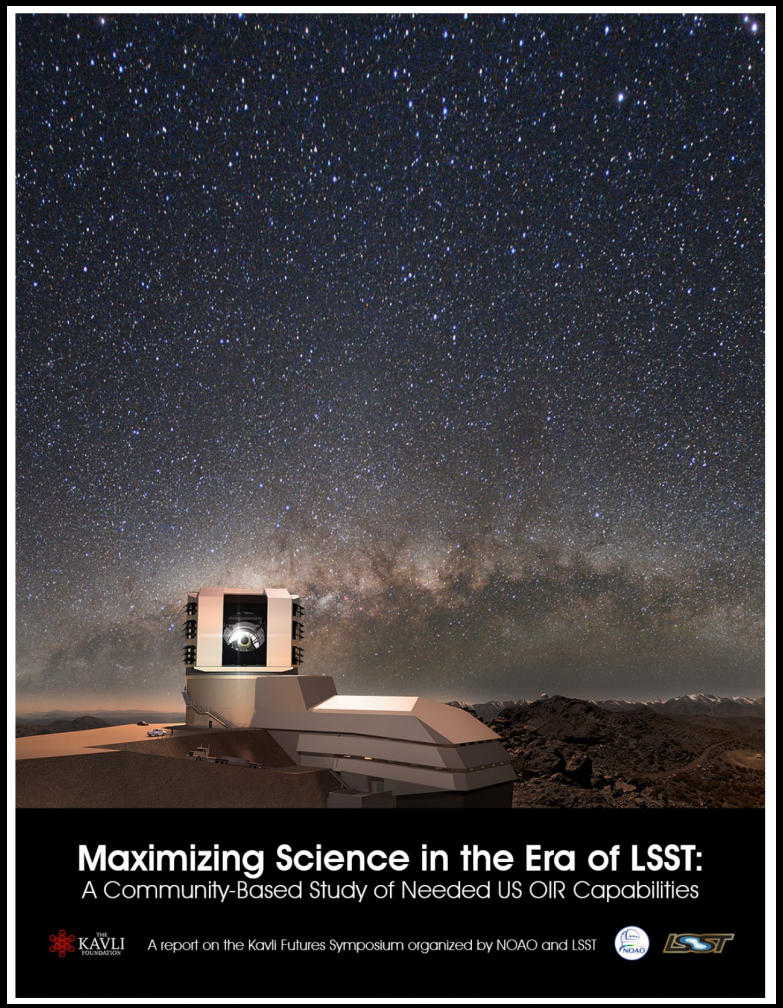
ATLAS

LIGO

Some science goals require additional observations from a range of other facilities

Supernovae
Trans-Neptunian Objects
Gravitational wave detections
Kuiper belt occultations
Pulsating stars
Microlensing events
Eclipsing/transiting targets
...

Time Domain Science



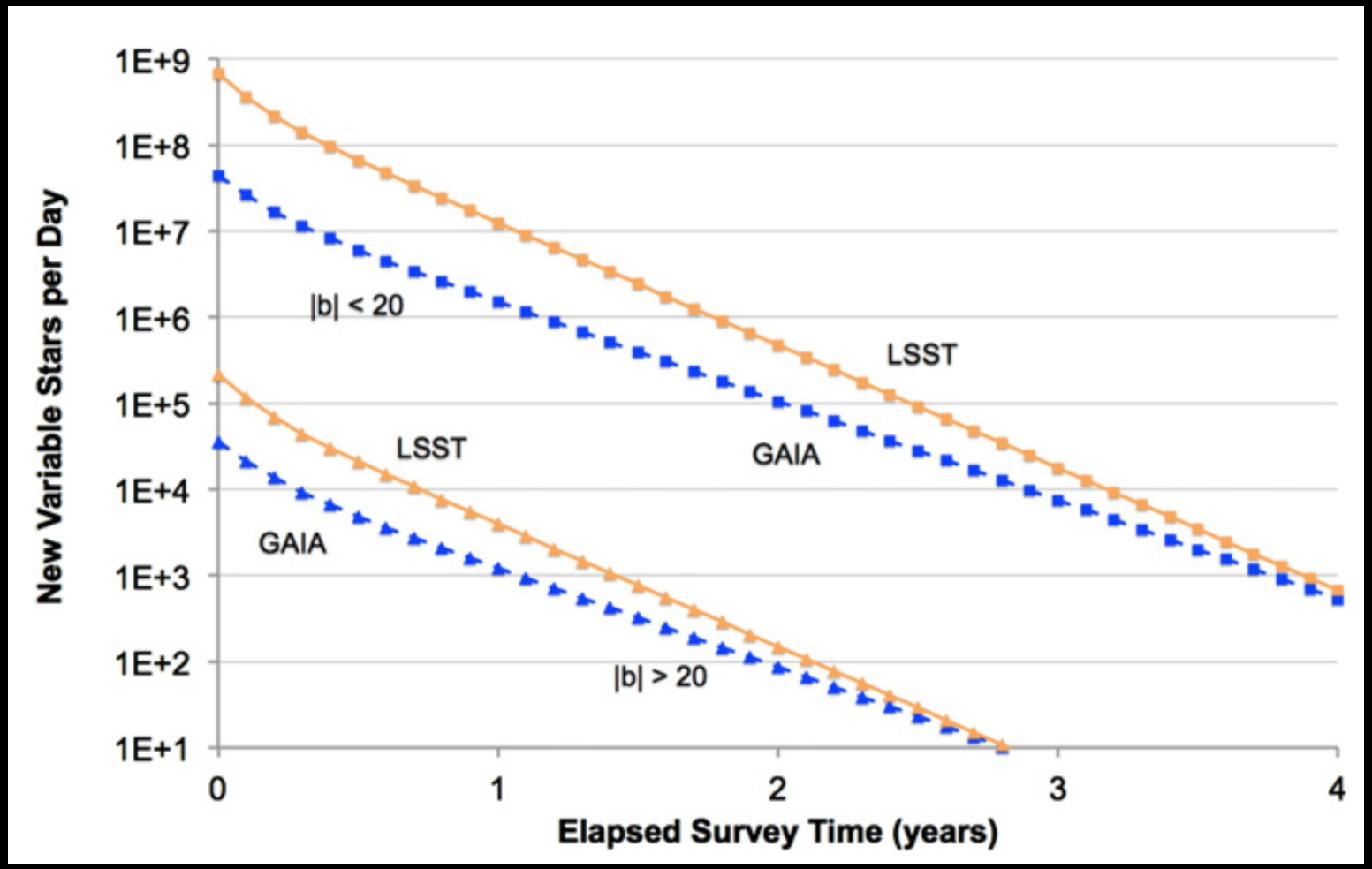
LSST/Kavli study asked:
"What additional facilities will you need to do your science?"

arXiv:1610.01661
www.noao.edu/meetings/lsst-oir-study/

But effective follow-up requires more than instrumentation

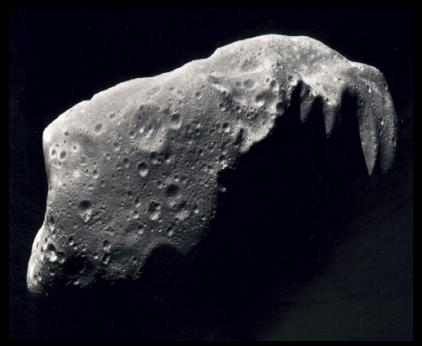
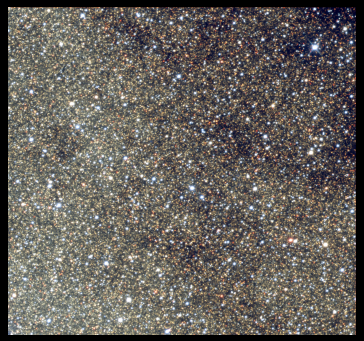
Alert Rate

Lots at first... though fewer later on

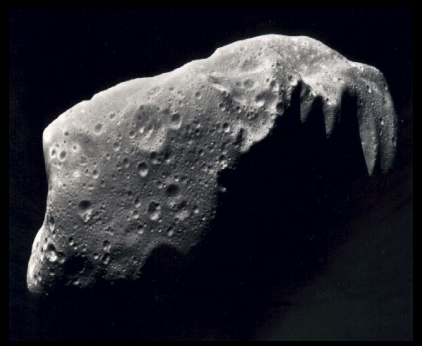
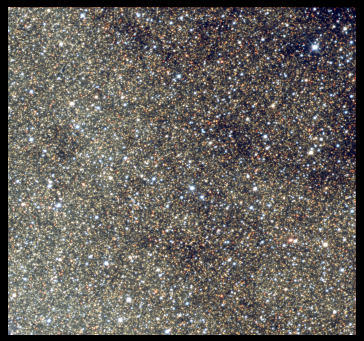


From: Ridgway+2014

Resources Required

	Supernovae	Near-Earth Asteroids	Microlensing
			
Observations	Spectra, multi-band imaging	Short timeseries imaging	Timeseries imaging
Cadence	ToO alert then Every 1-3d for >month	Rapid-response short (<1hr) series, daily for 1-3d	Medium-high cadence continuous monitoring for weeks

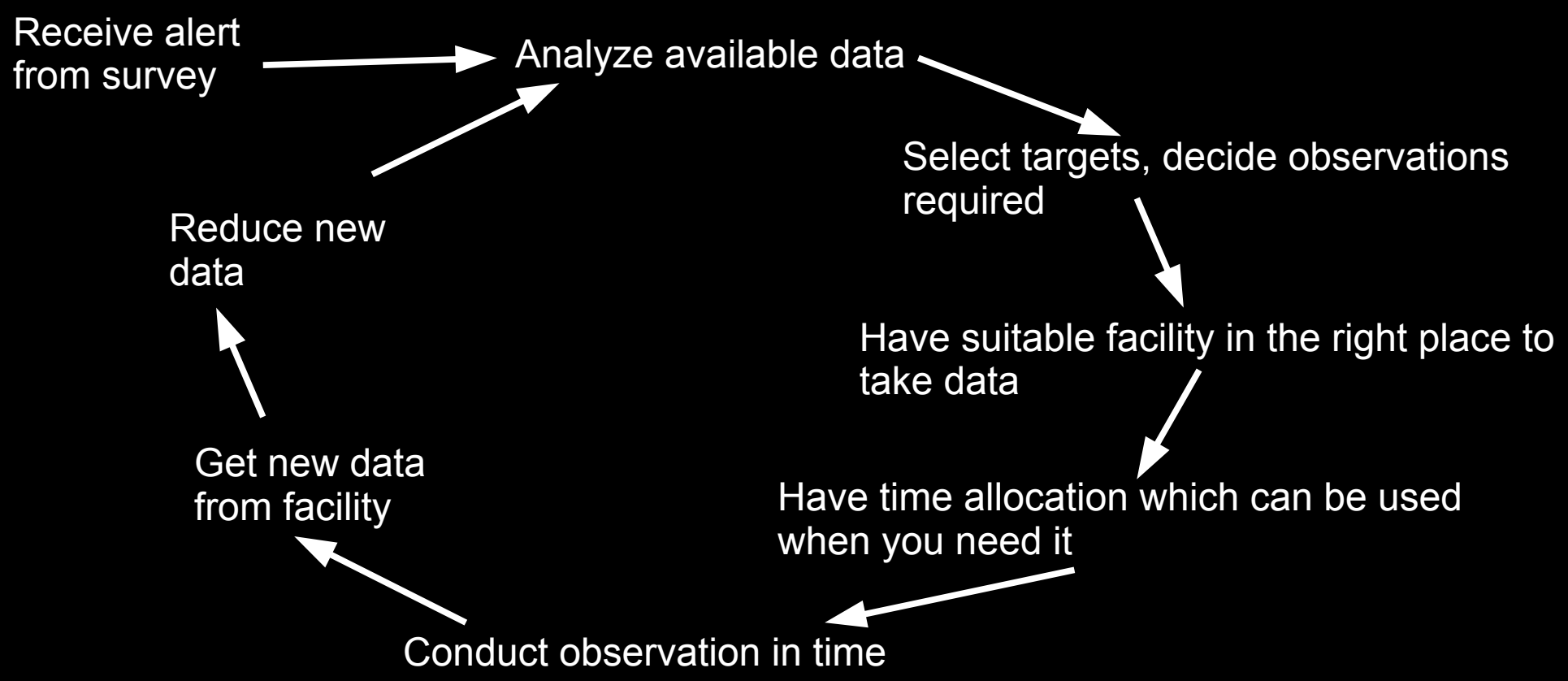
Resources Required

	Supernovae		Solar System		Microlensing	
						
	Now	LSST	Now	LSST	Now	LSST
Total alerts/year	~700	307,000	~5400	5.83 million	~2100	~10,000
New alerts/day	~2		~100		~8	
Followed/day	40-60		~10		~10	

Already have more alerts than we can follow!
Tools developed for target selection and observations.
Efficiency in follow-up is vital; resources could be saturated

Joining the dots

Effectively responding to survey alerts requires a number of steps:

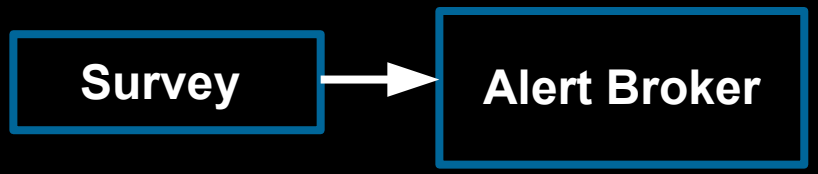


So as well as instruments, we also need to consider...

- Distribution of alerts
- Selection and prioritization of targets
- Geographic distribution of facilities
- Observation coordination
- Telescope access & scheduling
- Data processing and distribution
- Real-time data analysis

Distribution of Alerts

Broker functions



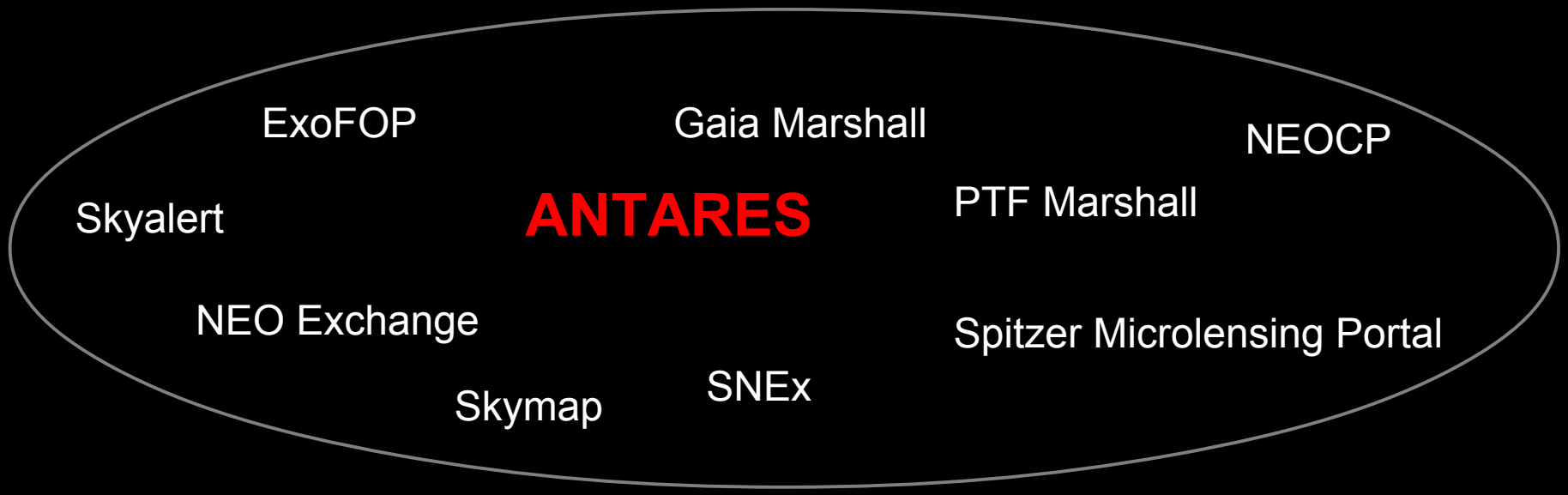
Alert Broker must...

- Serve alerts promptly and publicly
- Aggregate all available information
- Enable filtering to identify targets of interest

Distribution of Alerts

'Ecosystem' of brokers

Several specialized broker/observation manager systems already



Share common tools, protocols
Communication between brokers

Responding to Alerts

Project functions

Project-side software must...

- Filter targets of interest from Broker(s)
- Assess and prioritize targets
- Determine what (if any) follow-up data is required
- Interface with observatories to request observations

Responding to Alerts

Target Selection

Highly project-specific

Algorithms constantly being developed

Role for general-purpose classifiers
→ common metrics

Expect high traffic

Targets evolve → classification needs reevaluation

- Enable user-configurable filters
- Brokers can ingest user classifier metrics
- Handle high traffic of search queries
- More work needed on classifiers for a range of science purposes, particularly early-time classification

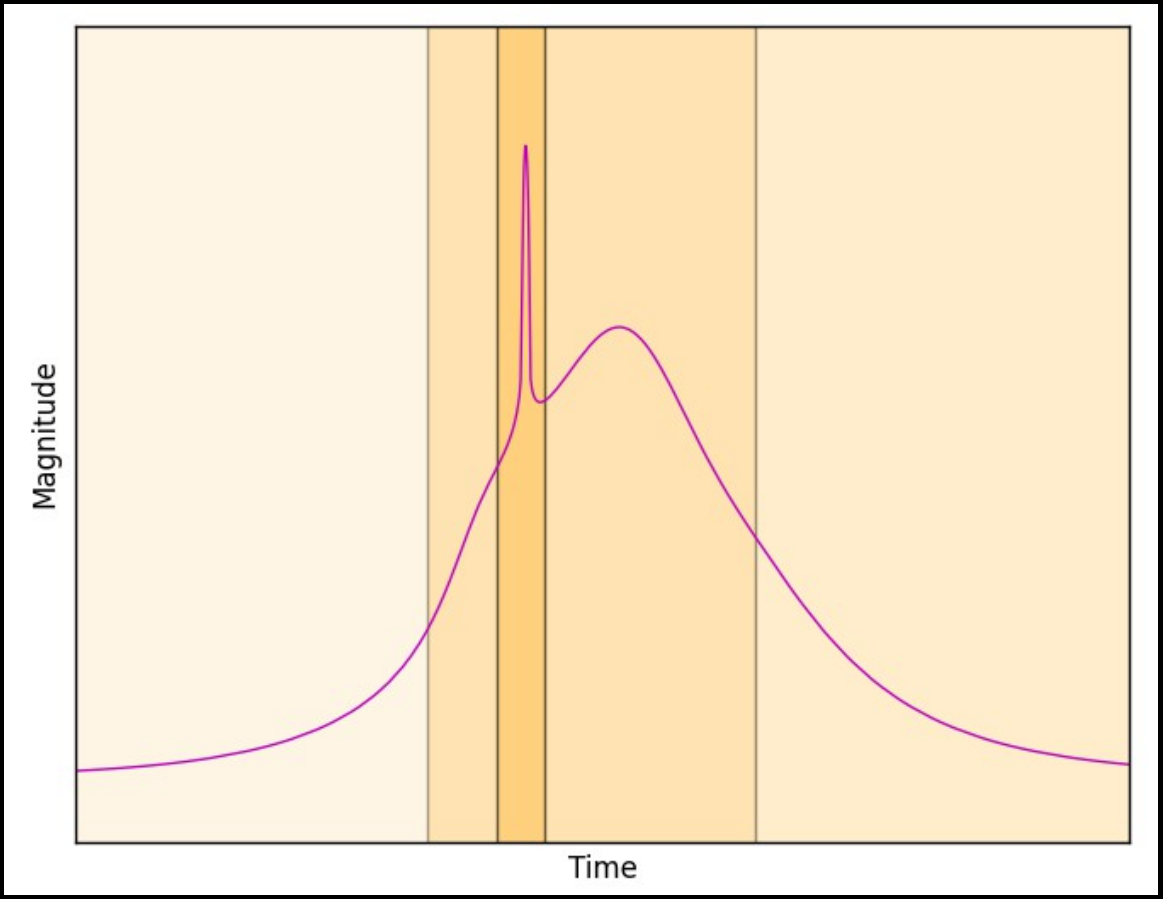
Responding to Alerts

Observation management

Observation strategies and target priority can vary over the lifetime of each target

...phase
...position
...brightness
...time
...proximity to Earth

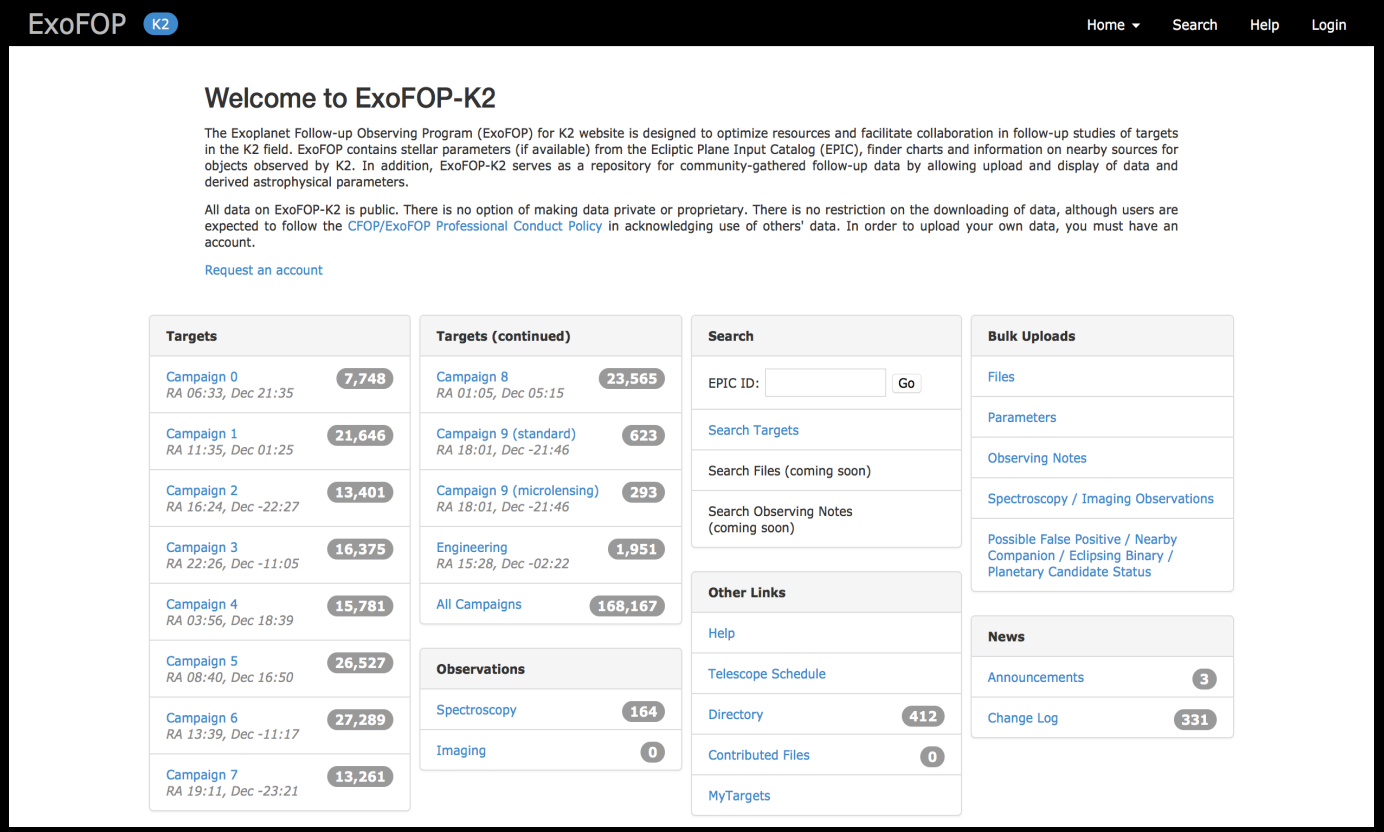
Frequency of observation as function of time



Responding to Alerts

Managing targets & observations

Searchable databases are a big advantage, but database skills uncommon among astronomers

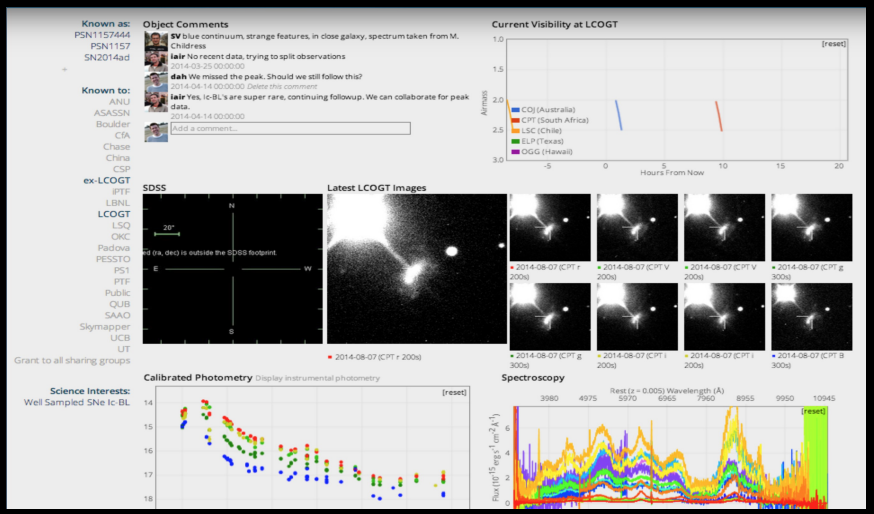


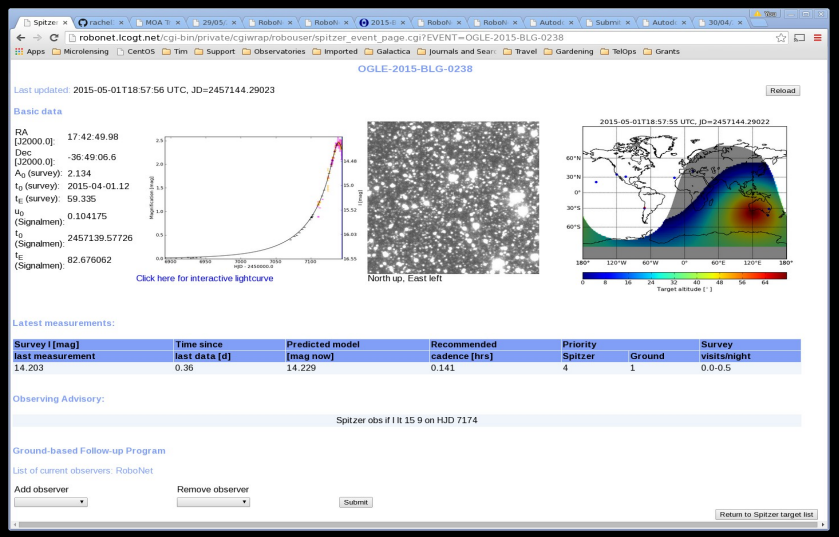
Responding to Alerts

Managing targets & observations

Many projects require similar functionality...

Subscribe to multiple alert feeds
Track evolving status of lots of targets
Cross-match catalogs
Searchable
Process updates
...

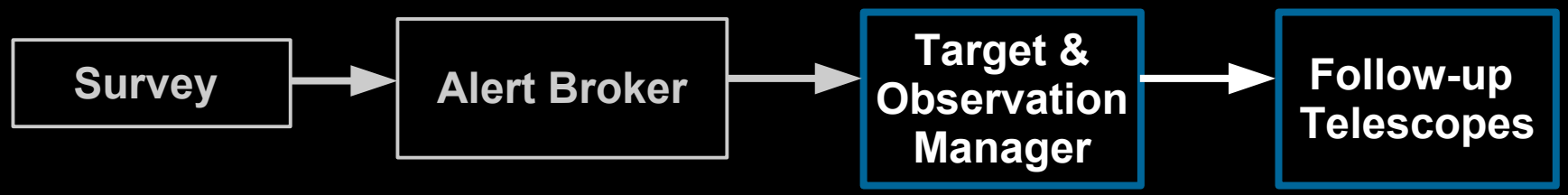




...but highly configurable access & display

Different data products
Different display requirements
Different selection filters
Different collaborator access requirements

Coordinating Observations



Wide range of observing resources required will...

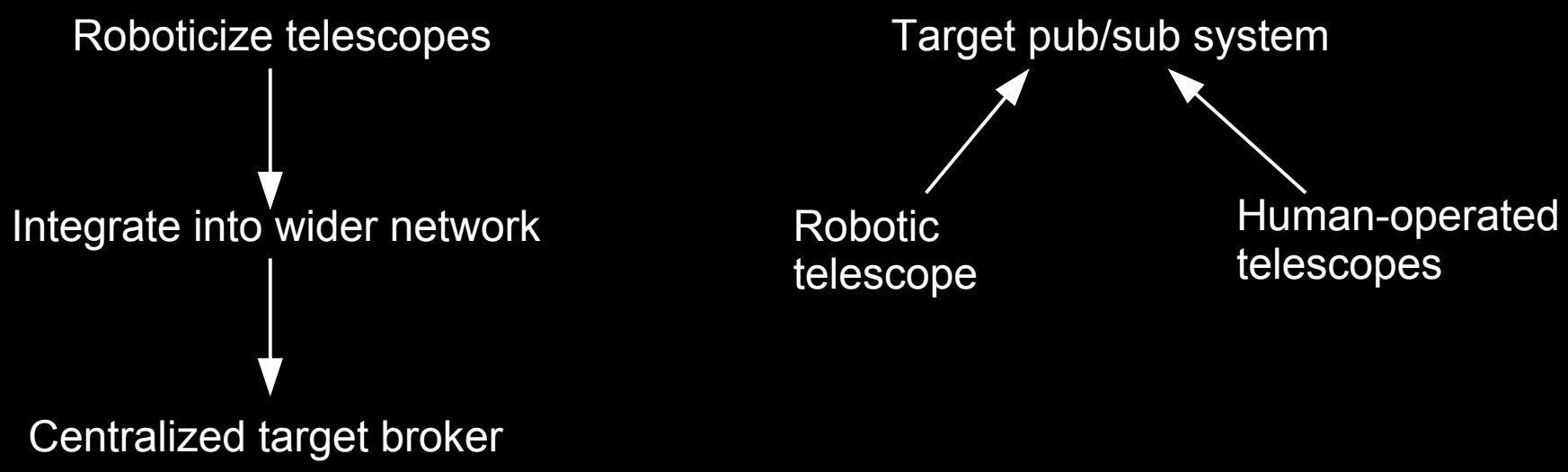
- Be manual, remote-controlled and robotic
- Need to be geographically distributed
- Need to be accessible
- Need to respond on a range of timescales
- Need to deliver data products promptly

Interface to different control systems

Coordinating Observations

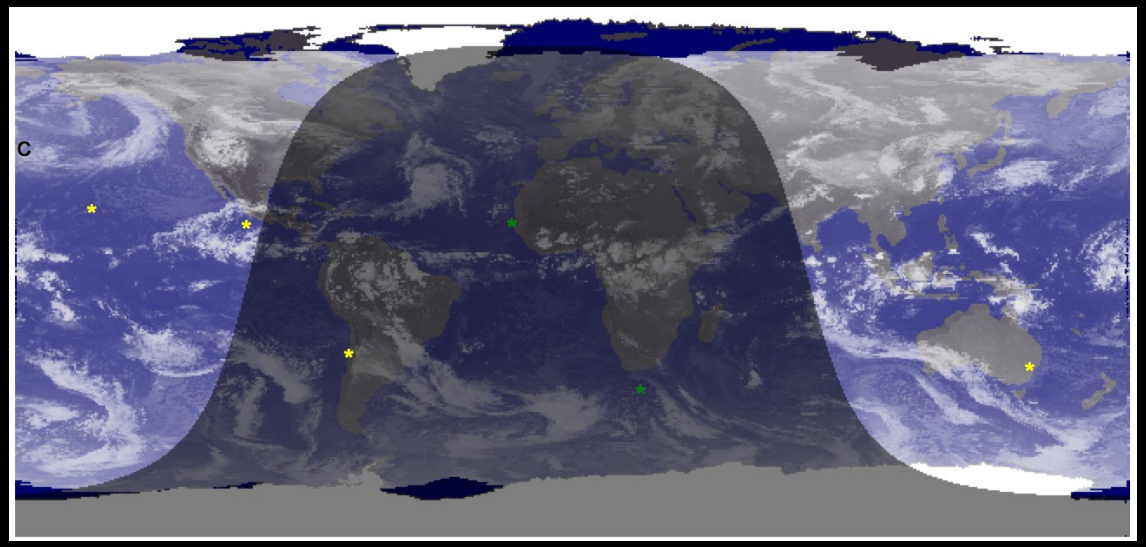
Humans & robots

Astronomy is increasingly robotic, but many telescopes will remain human-operated



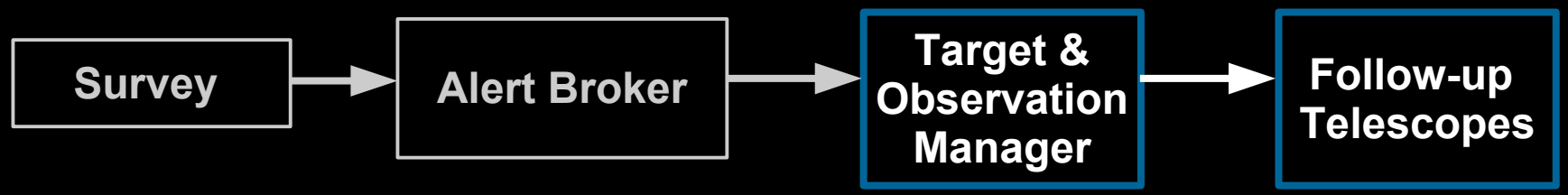
Resource availability

Geographic location



- Instrumentation/aperture facilities needed at multiple locations
- Will often need to combine data gathered from multiple locations
- Similar instrumentation ideal for ease of calibration/analysis
- Access agreements with foreign observatories?

Coordinating Observations



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Can we get time on the instruments we need?
Is it allocated appropriately?

Resource availability

Time Domain Targets Vary Widely

Transients, periodic, aperiodic, outbursts, moving...

→ Require follow-up for a variety of science goals

Higher cadence timeseries for fast features
Spectroscopic classification/evolution
Orbital parameter determination...

→ Require follow-up on a wide range of timescales

10 mins every week for 4 years
4 hours once every 3.4 days
1.5hr every 3 days for 2 months
5 mins every 15min for 4 days...

→ Require observations from a range of instruments

→ Require follow-up from both hemispheres

Moving objects
Around-the-clock monitoring
Resource distribution...

Resource availability

Scheduling

Time domain targets demand a range of observation types

- Need to observe when phenomena occur, not at TAC convenience
- More facilities need more flexible, queue-mode time allocation
- Rapid-response ≠ ToO! “Rapid” is often sufficient but ToO needed also
- More facilities need “open” time available e.g. Swift ToO

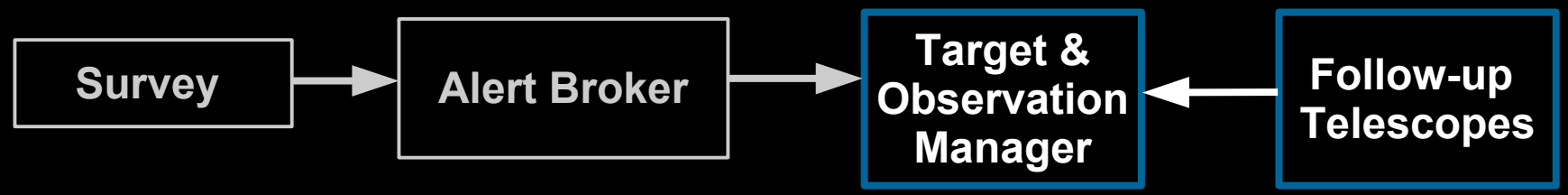
Resource availability

Scheduling

Optimize scheduling over multiple facilities

- Request observations of a specific type & required S/N
  → schedule on most appropriate facility
- Dovetailing observations of multiple projects is a hard problem!
  → but tractable: e.g. LCO scheduler
- Scheduling of shared MOS fibers needs development

Delivering Data



Wide range of observing resources required will...

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Data reduction pipelines
Data archives
Data scientists

Parallel Data Acquisition/Analysis

"I take my data over a few nights then go away and analyze it"

Static target list

→

"New targets every day, observations ongoing, existing targets re-evaluated in light of new data"

Dynamic target list

- Observatories serve data online on rapid timescales

- Development of automated reduction pipelines
- Requires long-term support for data scientists, software developers
- Requires support for the recognition of software contributions, data processing

- Encourage adoption of common data formats/protocols

Computing Resources

Download propriety data,
analyze on local machine

Current data model

→

Move algorithm to data
Tools for data query, analysis
Access remotely

Big data model

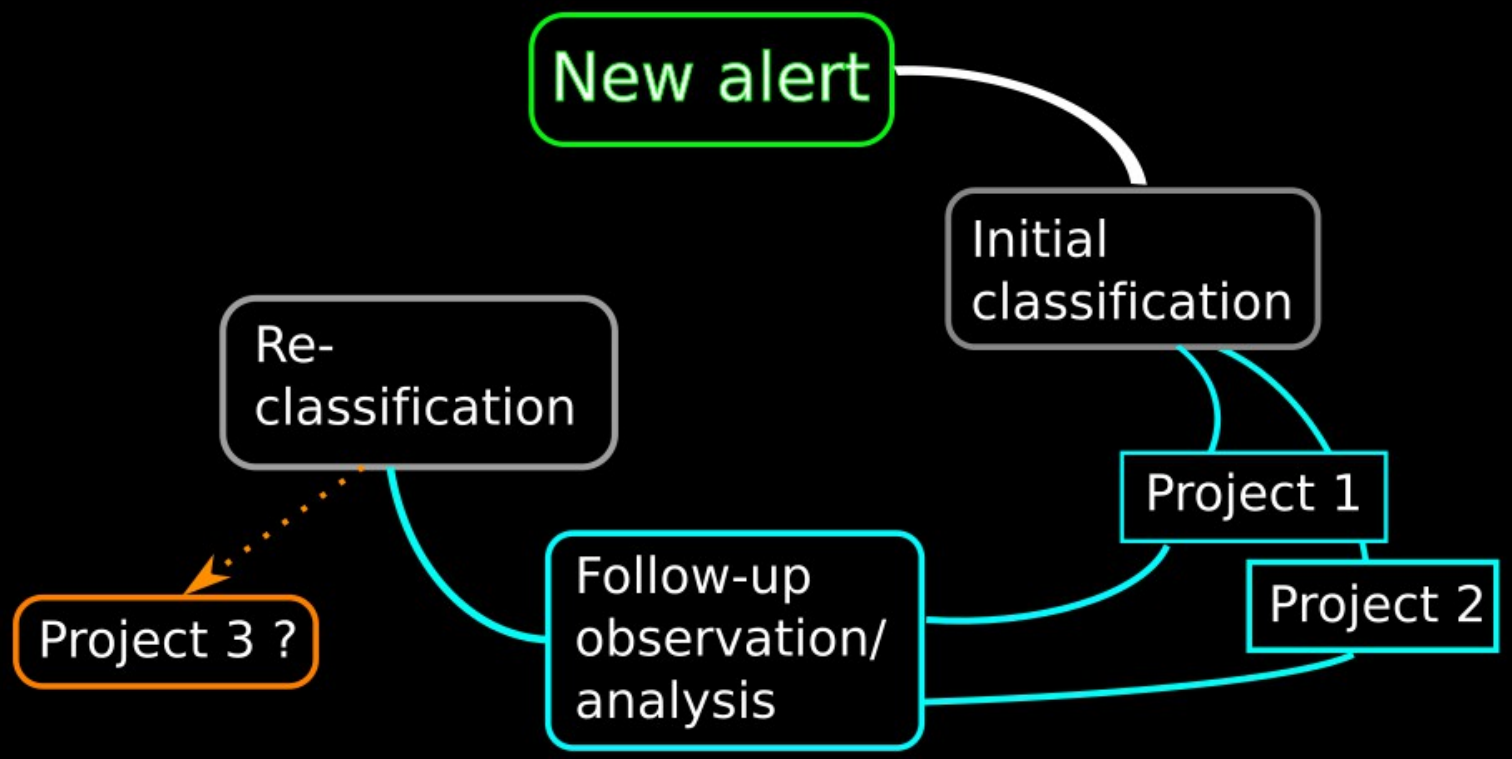
Future data catalogs very large, immobile

Analysis tools under development LSST Suite

Large-scale analyses will require access to big computing facilities

Requirements of science projects unclear, need to resolve!

Life cycle of an alert



False positives to one program are targets to another

Target deconfliction (by observatories? By brokers?)

Data sharing maximizes efficient use of limited resources

Paradigm shift

"I do my thing and publish my few targets"

Projects operate independently

Scarce target model

→

"More candidate targets than resources, some false alarms"

Obs of candidates+false alarms overwhelm resources

Projects want independence

Resource-limited model

- Flexible, coordinated response most efficient
- Sociological change against data/target protectionism but careers can depend on data, discoveries
- Encourage data sharing for targets AND false positives – make it easier
- Funding for public archiving of data products

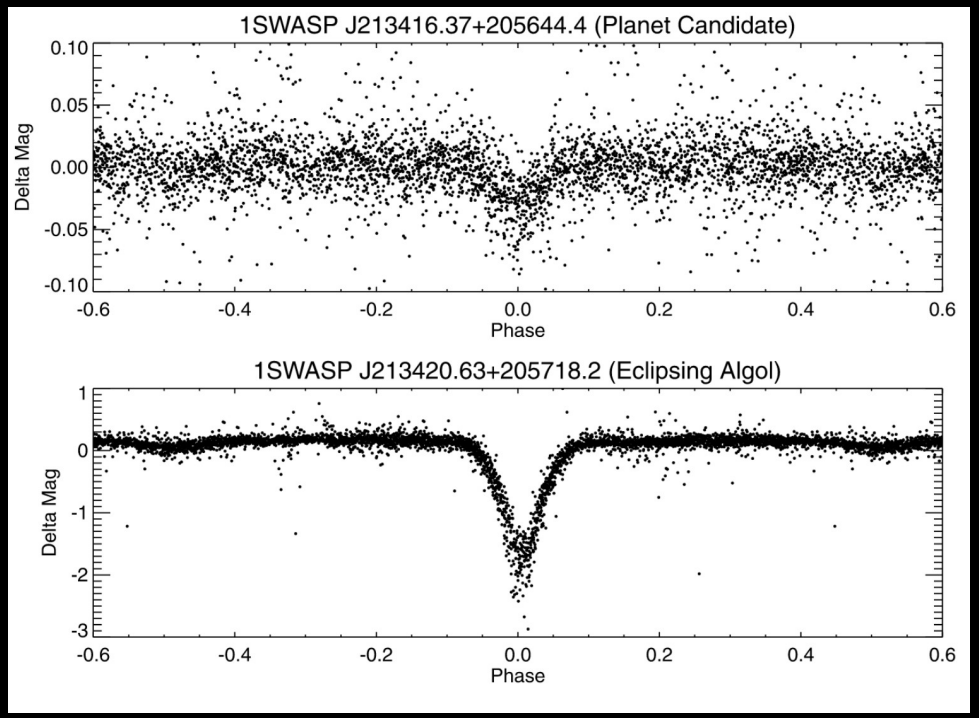
Alert Triage

Different science drivers suffer a range of false positives and rates

→ Triage may be valuable to wider community

→ Observations taken will depend on initial classification

SuperWASP false positive caused by nearby BQPeg [Collier Cameron+2007]



Alert Triage

Triage observations could be valuable to the whole community

***But**...*it's a thankless task
- difficult to publish results
- no support from TAC
- punishing on early-career researchers

- Consider allocating open-access time on workhorse resources
- Support for triage teams

LCO Open-Access Program

US community can apply for LCO 1m, 2m time from next semester

→ Aimed at follow-up programs for current surveys

→ Goal is to develop tools, experience which will scale for LSST

AAS Splinter Session
Fri Jan 6th, 6:30pm

NOAO/LCO Workshop
May 2017

See poster for details!

Summary

- Lots of great science will depend on responding effectively to alerts
- Plan carefully to avoid saturating resources
- Use current surveys as testing grounds.

    Do existing tools, systems, allocation mechanisms scale?

    What resources will your science need?

    How will you get access to them?