Optimizing Facilities and Infrastructure for Time Domain Science

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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
Time Domain Science

Several major time domain programs coming online or operational

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

- Spectra, multi-band imaging
- ToO alert then Every 1-3d for >month

Near-Earth Asteroids

- Short timeseries imaging
- Rapid-response short (<1hr) series, daily for 1-3d

Microlensing

- Timeseries imaging
- Medium-high cadence continuous monitoring for weeks
### Resources Required

<table>
<thead>
<tr>
<th>Category</th>
<th>Now</th>
<th>LSST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supernovae</td>
<td>~700</td>
<td>307,000</td>
</tr>
<tr>
<td>Solar System</td>
<td>~5400</td>
<td>5.83 million</td>
</tr>
<tr>
<td>Microlensing</td>
<td>~2100</td>
<td>~10,000</td>
</tr>
</tbody>
</table>

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.
Effectively responding to survey alerts requires a number of steps:

1. Receive alert from survey
2. Analyze available data
3. Select targets, decide observations required
4. Have suitable facility in the right place to take data
5. Have time allocation which can be used when you need it
6. Conduct observation in time
7. Get new data from facility
8. Reduce new data

Joining the dots
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

Alert Broker must...

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

Several specialized broker/observation manager systems already

Share common tools, protocols
Communication between brokers

‘Ecosystem’ of brokers

ANTARES

ExoFOP
Skymap
SNEx
NEO Exchange
Skylet
Gaia Marshall
NEOCP
PTF Marshall
Spitzer Microlensing Portal
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

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

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

Observation management

Frequency of observation as function of time
Managing targets & observations

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

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

- Survey
- Alert Broker
- Target & Observation Manager
- Follow-up Telescopes

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

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
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
Wide range of observing resources required will...

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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

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

- New alert
- Initial classification
- Follow-up observation/analysis
- Project 1
- Project 2
- Project 3
- Re-classification

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 BQ Peg [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?