Alert brokers, discovery and classification in the LSST era

S. J. Smartt (Oxford)
R. D. Williams, K. W. Smith, G. Francis D. R. Young, A. Lawrence

Starting points:

https://www.lsst.org
https://www.lsst.ac.uk
https://lsst-uk.atlassian.net

lasair.lsst.ac.uk

Legacy Survey of Space and Time (LSST)

LSST:UK consortium
Stephen Smartt (University of Oxford and Queen’s University Belfast)
Project Lead: Bob Mann (University of Edinburgh)
Slides reviewed and last updated: 8 February 2023
https://lsst-uk.atlassian.net
Construction progress: as of Feb 2023

Projected (post-Covid) start of science operations: January 2025
Rubin schedule

Projected science operation start January 2025

Monthly updates (including diagram updates): https://www.lsst.org/about/project-status
When will science data arrive?

Two useful Rubin documents which are continually updated:

- Release Scenarios for Rubin - LSST Commissioning and Survey data
  Marshall et al. RDO-11

- Rubin Observatory Plans for an Early Science Program
  Guy et al. RTN-11
  [https://rtn-011.lsst.io/](https://rtn-011.lsst.io/)

Guy et al. Table 1

![Rubin Early Data Release Scenario](image-url)
Where to point and when?

- **Rubin Observatory**
  - 8m telescope (6.5 m clear aperture) on Cerro Pachon, Chile
  - 3.5 gigapixel camera, impressive detector quality
  - Real time alert stream and multi-colour deep image of the sky

- **Science Requirements**
  - 18,000 square degrees observed 825 times over 10 yrs
  - Multi-Colour deep image of southern sky
  - Parallax and proper motion precision requirements
  - Rapid revisit timescale requirements

Cadence problem in a nutshell:
Can do all southern, visible sky once per night: but we need 2 visits and we have 6 filters
Average return time (in same filter) would be 2 x 6 = 12 days
Figure 4. The LSST bandpasses. The vertical axis shows the total throughput. The computation includes the atmospheric transmission (assuming an airmass of 1.2, dotted line), optics, and the detector sensitivity.
2 example strategies

Baseline

Exgal sky and rolling

Number of observations after 10 years (DDF visits removed)

Year 3.5-4.5

From, Peter Yoachim’s talk August 2020 at Project & Community Workshop 2020:
https://project.lsst.org/meetings/rubin2020/agenda/session/community-evaluation-rubin-survey-strategies
LSST Observing sequence and cadence

- Observe a camera footprint with 2×15 second exposures, taken back-to-back (they are called “snaps”). They will be co-added automatically to make a 30 second image, allowing cosmic ray mitigation.
- Come back on the same night, about 30mins later, and observe exactly the same footprint. Still to be decided if the 2nd visit will be in the same filter as the 1st or a suitable different pair (e.g. $g + r$, $i + z$ .... $u$ and $y$ would not be paired of course)

When does LSST revisit this footprint again?

![Diagram showing median visit gaps](image)

Figure 2. Distribution of median internight visit gaps (the time elapsed between visits to the same field in different nights) at a given location in the sky for two simulated LSST Optsim strategies: baseline nexp2 v1.7.1 10yrs (left) and rolling nm scale0.90 nslice2 fpw0.9 nrw1.0v1.7 10yrs

Bianco et al. 2022: Optimisation of the Observing Cadence for Rubin
LSST Alerts - Key numbers

Goal is 60 seconds to send an alert. Every 60 seconds the following tables give an idea of number of alerts and their types that will be released.

<table>
<thead>
<tr>
<th>Alert numbers : per visit</th>
<th>5σ single visit</th>
<th>10 yr depth</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type</strong></td>
<td><strong>Extragalactic (80% of sky)</strong></td>
<td><strong>Galactic (20% of sky)</strong></td>
</tr>
<tr>
<td>Movers</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>Stars</td>
<td>1800</td>
<td>300000</td>
</tr>
<tr>
<td>AGN</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>Supernovae and extragalactic transients</td>
<td>200</td>
<td>200</td>
</tr>
</tbody>
</table>

u 23.9 26.1
g 25.0 27.4
r 24.7 27.5
i 24.0 26.8
z 23.3 26.1
y 22.1 24.9
Latest ZTF Transient Alerts Map

This skymap shows the most recent, bright (<17 Mag) ZTF transient detections, coloured by their predicted type. The longer ago the transient was last detected, the smaller and fainter its marker. Click on a markers for information about an object, and then on the 'ZTF' transient ID for full information.
What do brokers do?

'SN-like candidates in last 14 days' filter results

SN-like candidates (Sherlock classifications SN, NT and orphans). Rejects Pan-STARRS star matches. The filter is streamed via kafka with the topic name lasair_242SN-likecandidatesinlast14days.

Filter Results

A list of objects passing the 'SN-like candidates in last 14 days' filter.

<table>
<thead>
<tr>
<th>objectid</th>
<th>rmean</th>
<th>decmean</th>
<th>mjdmin</th>
<th>mjdmax</th>
<th>mgmean</th>
<th>magsn</th>
<th>classification</th>
<th>score</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZTF23aadqduf</td>
<td>288.99920</td>
<td>23.877823</td>
<td>60016.4907</td>
<td>60021.5125</td>
<td>19.639</td>
<td>19.639</td>
<td>SN</td>
<td>Not Near PS1 star</td>
</tr>
<tr>
<td>ZTF23aadqcvj</td>
<td>264.48923</td>
<td>22.562881</td>
<td>60016.4887</td>
<td>60021.4948</td>
<td>19.193</td>
<td>19.482</td>
<td>SN</td>
<td>Not Near PS1 star</td>
</tr>
<tr>
<td>ZTF23aadqcx</td>
<td>230.25042</td>
<td>55.953445</td>
<td>60016.4051</td>
<td>60021.4520</td>
<td>19.335</td>
<td>19.335</td>
<td>NT</td>
<td>Not Near PS1 star</td>
</tr>
<tr>
<td>ZTF23aadnhxe</td>
<td>71.55626</td>
<td>71.485326</td>
<td>60013.2388</td>
<td>60021.2037</td>
<td>19.264</td>
<td>19.264</td>
<td>SN</td>
<td>Not Near PS1 star</td>
</tr>
<tr>
<td>ZTF23aadje</td>
<td>249.06923</td>
<td>18.392791</td>
<td>60016.4878</td>
<td>60021.3467</td>
<td>19.759</td>
<td>19.759</td>
<td>SN</td>
<td>Not Near PS1 star</td>
</tr>
<tr>
<td>ZTF23aadjne</td>
<td>214.94754</td>
<td>57.938523</td>
<td>60016.3881</td>
<td>60020.4881</td>
<td>19.544</td>
<td>19.560</td>
<td>SN</td>
<td>Not Near PS1 star</td>
</tr>
<tr>
<td>ZTF23aadjse</td>
<td>190.86160</td>
<td>8.206266</td>
<td>59996.4075</td>
<td>60020.3615</td>
<td>20.178</td>
<td>20.250</td>
<td>SN</td>
<td>Not Near PS1 star</td>
</tr>
<tr>
<td>ZTF23aadfnv</td>
<td>121.50831</td>
<td>-10.232411</td>
<td>60020.1916</td>
<td>60021.1927</td>
<td>19.760</td>
<td>19.760</td>
<td>SN</td>
<td>Not Near PS1 star</td>
</tr>
<tr>
<td>ZTF23aaddehlp</td>
<td>192.17960</td>
<td>-8.584071</td>
<td>60016.3214</td>
<td>60021.3817</td>
<td>18.919</td>
<td>19.008</td>
<td>SN</td>
<td>Not Near PS1 star</td>
</tr>
<tr>
<td>ZTF23aadcvce</td>
<td>122.26069</td>
<td>55.947170</td>
<td>60013.3183</td>
<td>60021.2022</td>
<td>19.177</td>
<td>19.177</td>
<td>NT</td>
<td>Not Near PS1 star</td>
</tr>
</tbody>
</table>
Lasair scalable architecture
The transient was discovered on 4th February 2023 at 08:25:22 UTC (MJD 59979.35) by ZTF as ZTF23aabtfho with a discovery magnitude of \( g = 18.18 \). It was subsequently classified as a SN Ia at \( z = 0.028 \).
ZTF23aabtfho

Discovery date: 2023-02-04 08:25:23.996
Last detection: 2023-03-17 05:18:03.997
Number of detections: 11
Number of low quality alerts: 0
Number of upper limits: 14
ML classification

Potential for major advances
- Improved ML methods
- Better training, with data and models
- Large and expert community - rapidly changing field

Lochner et al. 2016

Muthukrishna et al. 2019
Lasair and lightcurve fitting

\[ f(t) = A \frac{e^{-(t-t_0)/\tau_{\text{fall}}}}{1 + e^{-(t-t_0)/\tau_{\text{rise}}}} + B \]

**Lasair focus**
- Mover/star/galaxy separations (galaxy offset or nuclear transient or AGN)
- Provide trustworthy measurements and values
- Host galaxy match and redshift
- Trust in the data values
- User decides
- Can work with Lasair team on “Annotator”
# Lasair watchlists

Watchlists submitted to the public gallery by other Lasair users. You can view matches or copy individual watchlists into your own collection.

<table>
<thead>
<tr>
<th>Name</th>
<th>Owner</th>
<th>Description</th>
<th>Count</th>
<th>Created</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>TNS</em></td>
<td>Roy Williams</td>
<td>All the sources in the IAU Transient Name Server <code>https://www ... more</code></td>
<td>113,233</td>
<td>2023-03-14 14:18:26</td>
</tr>
<tr>
<td>BL Lac for TeV</td>
<td>Roy Williams</td>
<td>BL Lac candidates for TeV observations (Massaro+, 2013)</td>
<td>42</td>
<td>2023-03-14 14:18:26</td>
</tr>
<tr>
<td>AM CVn</td>
<td>Roy Williams</td>
<td>These are 56 very close binaries of compact objects, from <code>... more</code></td>
<td>55</td>
<td>2023-03-14 14:18:26</td>
</tr>
<tr>
<td>AM Her</td>
<td>Gavin Ramsay</td>
<td>Magnetic CVs (B&gt;10MG), some go into prolonged low states, se <code>... more</code></td>
<td>101</td>
<td>2023-03-14 14:18:26</td>
</tr>
<tr>
<td>Milliquas_1000000</td>
<td>Roy Williams</td>
<td>million</td>
<td>999,998</td>
<td>2023-03-14 14:18:26</td>
</tr>
<tr>
<td>E+A galaxies</td>
<td>Matt Nicholl</td>
<td>French &amp; Zabludoff 2018</td>
<td>51,907</td>
<td>2023-03-14 14:18:26</td>
</tr>
<tr>
<td>Gaia DR2 white dwarfs</td>
<td>Roy Williams</td>
<td>Gaia DR2 white dwarf candidates (Gentile Fusillo+, 2019) <code>MNR ... more</code></td>
<td>486,641</td>
<td>2023-03-14 14:18:26</td>
</tr>
</tbody>
</table>
Lasair Watchmaps

'SDSS' Watchmap Associations

The area of the SDSS footprint the watchmap is active.

Watchmap Results

A list of objects located within the 'SDSS' watchmap

<table>
<thead>
<tr>
<th>objectid</th>
<th>rmean</th>
<th>declmean</th>
<th>mag</th>
<th>gmag</th>
<th>last detected (days ago)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZTF17aaacztjr</td>
<td>80.17868</td>
<td>18.611806</td>
<td>16.679</td>
<td>17.284</td>
<td>716.5</td>
</tr>
<tr>
<td>ZTF17aaaczmn</td>
<td>85.64818</td>
<td>19.564695</td>
<td>17.193</td>
<td>94.3</td>
<td></td>
</tr>
<tr>
<td>ZTF17aaaczqf</td>
<td>83.07144</td>
<td>20.544445</td>
<td>18.327</td>
<td>9.5</td>
<td></td>
</tr>
<tr>
<td>ZTF17aaaczrzg</td>
<td>83.39188</td>
<td>17.899240</td>
<td>18.840</td>
<td>10.338</td>
<td>73.5</td>
</tr>
</tbody>
</table>
Landscape now to 2030

https://observing.docs.ligo.org/plan/
Discussion points

1. Are we taking the right approach with Lasair?
2. Can we facilitate your science, and what extra can we do?
3. A UK strategy for time domain real-time data federation, classification and curation

Roy Williams
Ken Smith
Dave Young
Gareth Francis

All very helpful!
Finally the last word .... the latest on alerts from LSST
7th Feb 2023

The LSST Survey start: 4-7 months after System First Light. Some “near-live” alerts are planned around the time of the LSST Survey start, and then alert production is planned to increase smoothly to "live" during the early months of the LSST Survey, covering more regions over time as the static-sky templates are built up.

Monthly updates (including diagram updates) :
https://www.lsst.org/about/project-status
https://lsst-uk.atlassian.net
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