

# The first Rubin Target-of-Opportunity search for a ~~neutron star~~ subsolar mass merger candidate counterpart

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on behalf of the Rubin ToO team, including:

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RAPID Hotwiring Conference - IPAC/Caltech  
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# Rubin ToO workflow

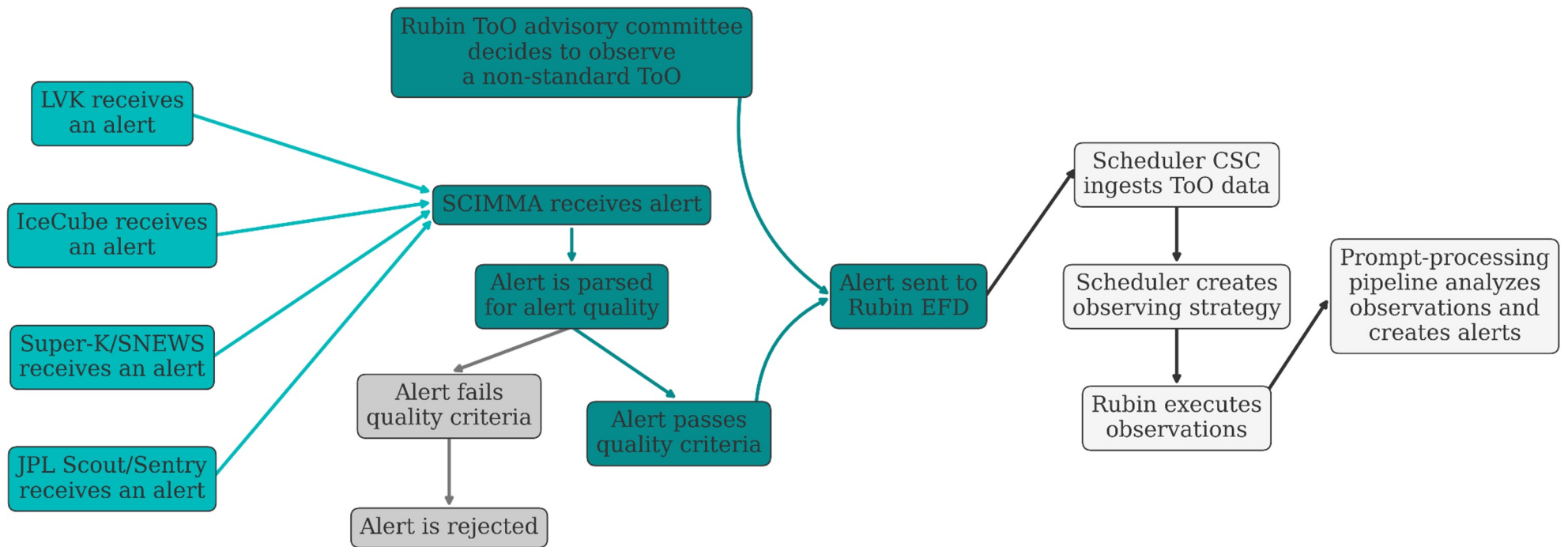
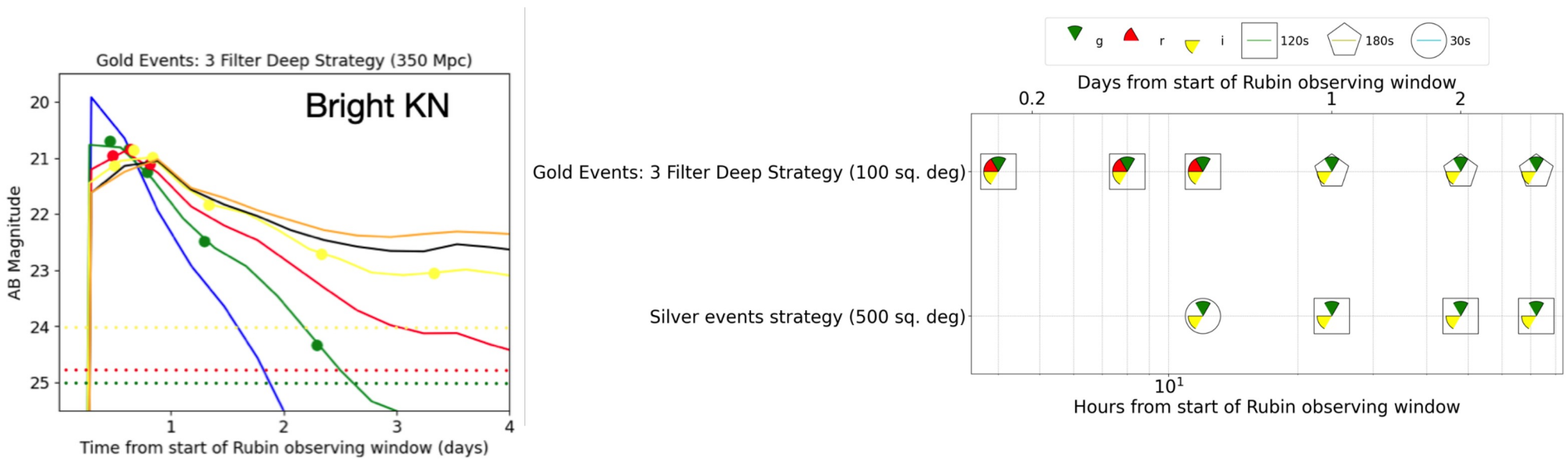
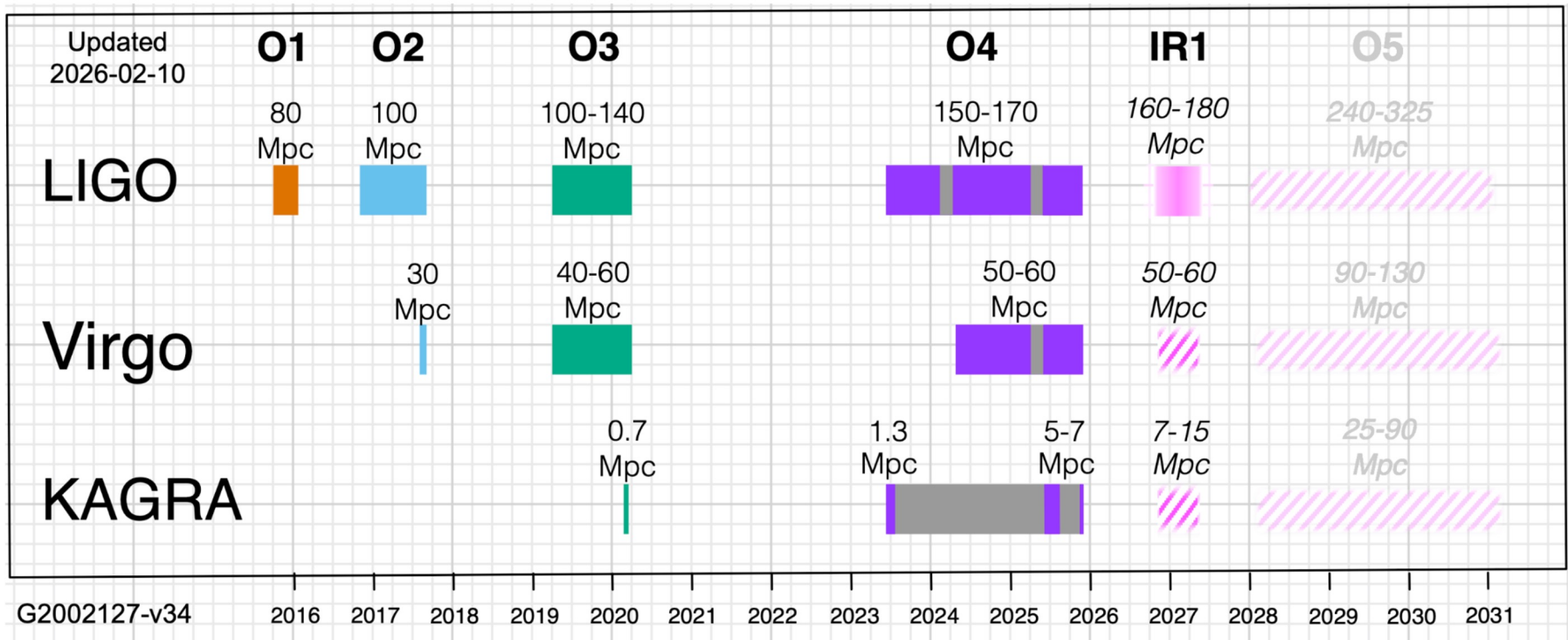


Figure credit: S. MacBride; see <https://rtn-098.lsst.io/> for more details

# Rubin is capable of finding EM counterparts to GW events!

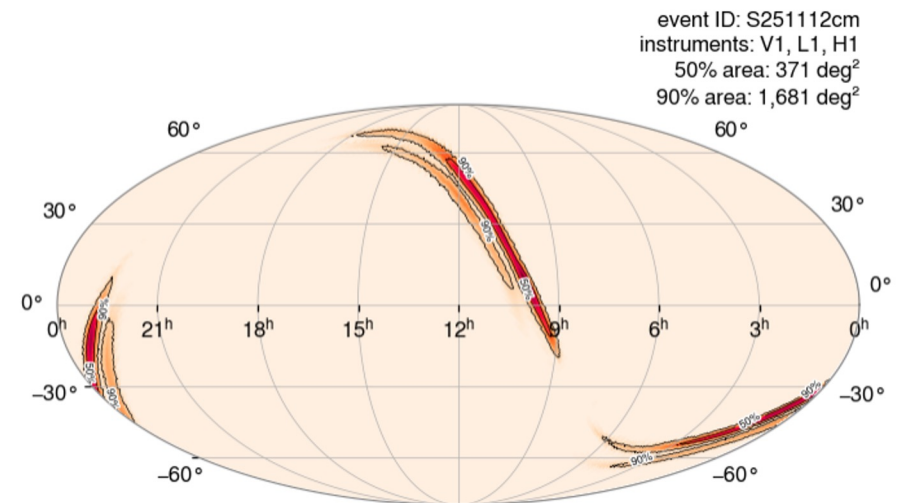


# LVK observing run plans

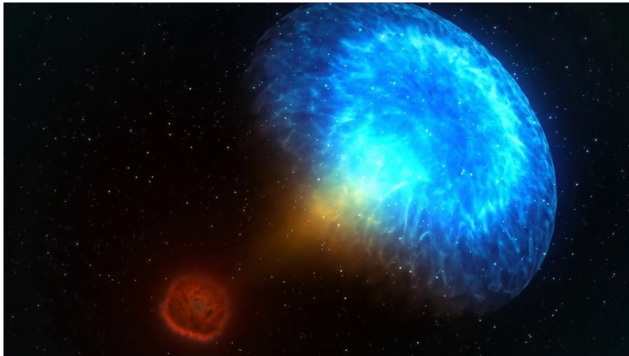


# S251112cm discovery

- On 2025-11-12 LVK detected a sub-solar mass merger candidate, **S251112cm**
- **HasSSM > 99%** and **Mchirp** between **[0.1, 0.87] Msun**
- False Alarm Rate: 1 per 4 yrs
- Localized to **1681 sq. deg** at a distance of **93 +/- 27 Mpc**
- Many teams followed up the event, including GO-TO, BlackGEM, ZTF (GCN 42677; SA+2025) and DECam



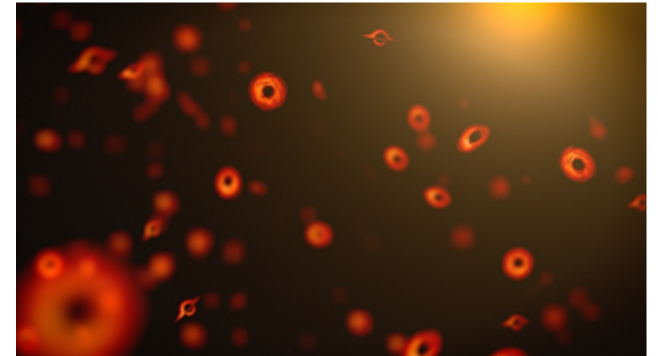
# Subsolar mass (SSM) merger?!



Kilonova from a binary neutron star merger (NASA GSFC / CI Lab)



Super-kilonova (Caltech / K. Miller and R. Hurt (IPAC))



Primordial black holes (NASA GSFC)

# S251112cm: summary statistics

- Given exceptional nature of event, Rubin decided to trigger!
- Cumulative probability coverage: ~39%
- 30s images taken in g- and i-bands
- Four epochs of observations taken on nights 0, 2, 4, and 6 after 2025-11-14
- Median depth: ~24.4 mag (g) and ~23.6 mag (i)

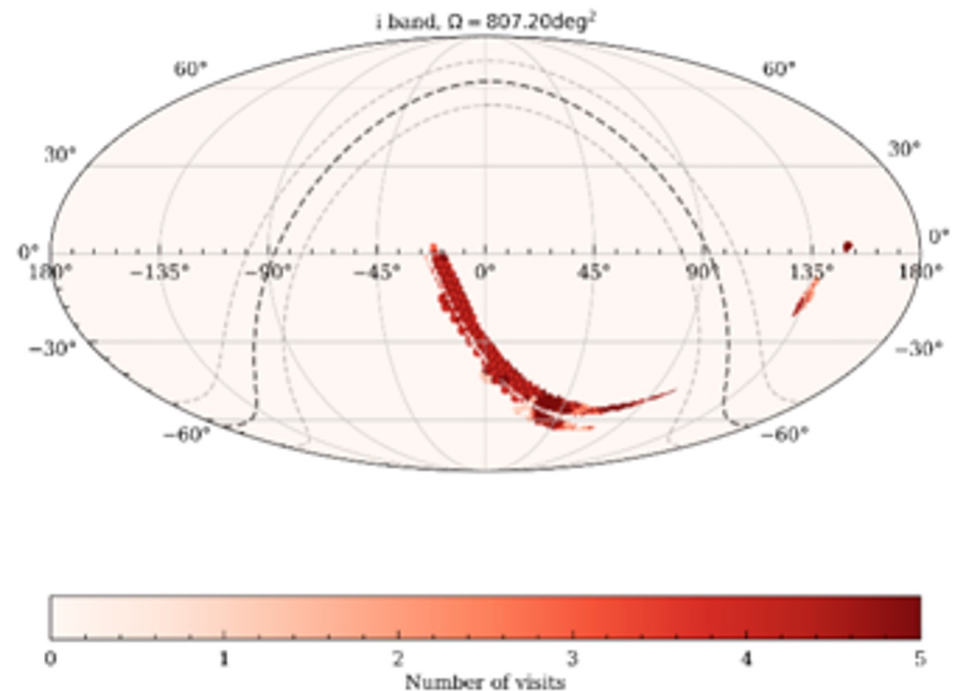


Figure courtesy S. MacBride

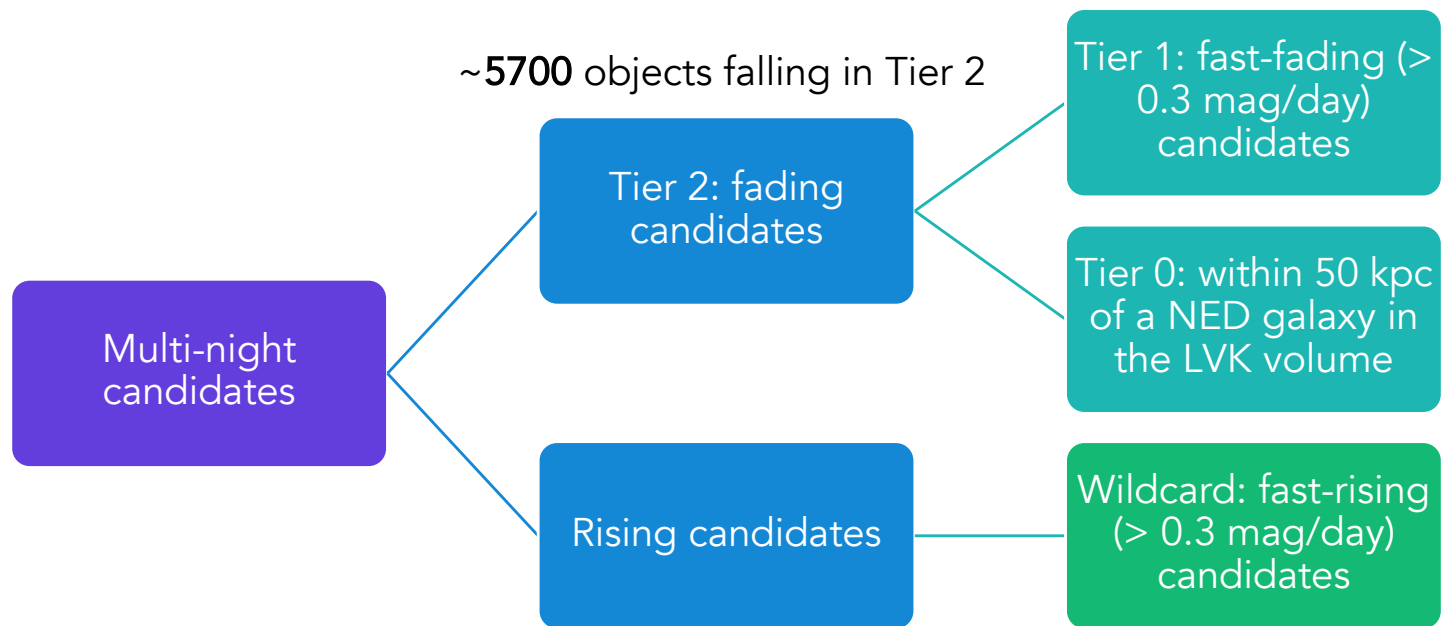
# Image processing

- Challenge: no existing templates!
- Used custom image processing task (developed by Bob Armstrong and Erin Howard) to create DECam templates from DES, DELVE and DECADE datasets
- LSST's standard data release production pipeline used to get difference images and photometry

## Candidate filtering – basic cuts and image quality

- **8.7 million** diaObjects produced from DECam difference imaging!!
- Quality cuts: dipole artifacts, negative sources, and require reliability  $> 0.1$
- Require at least 3 detections in two filters, multi-night detection
- Reject candidates that fall outside the skymap 95% probability contour
- ~**160,000** diaObjects left after basic cuts

# Filtering on lightcurve metrics: Tiers



More info on the NED Gravitational Wave Follow-up service:  
<https://ned.ipac.caltech.edu/NED::GWFOverview/>

# Filtering out impostors

Not nuclear and AGN-like (WISE, Milliquas XMatch)

~1400 remaining

Not stellar (Gaia XMatch)

~1320 remaining

Not galaxy-like (extendedness < 1)

~1290 remaining

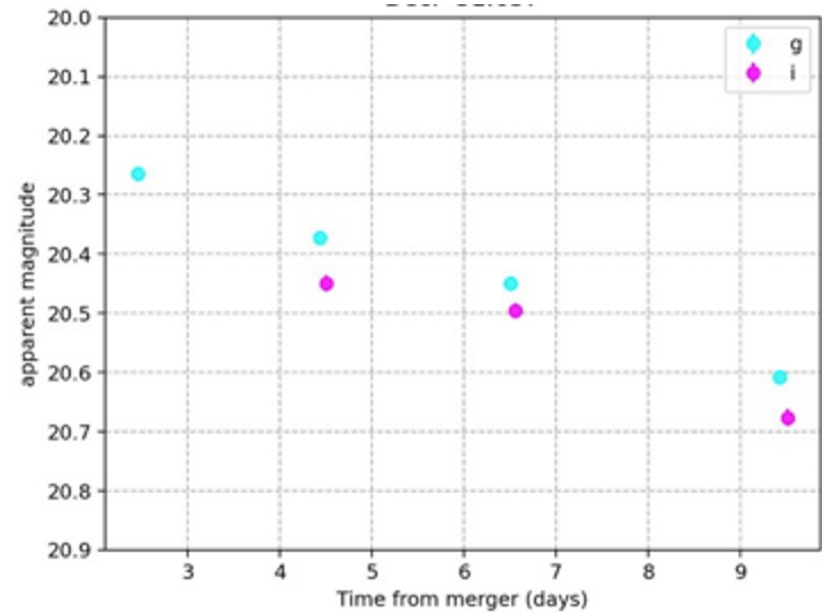
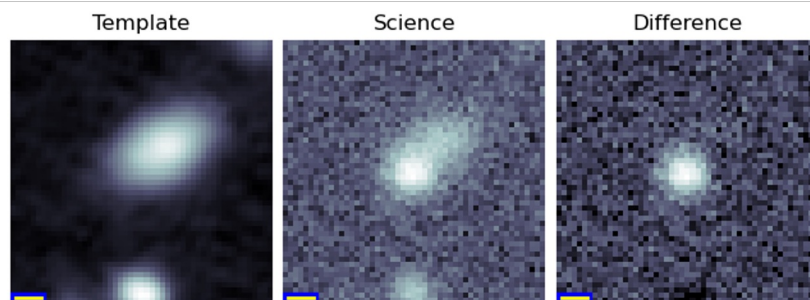
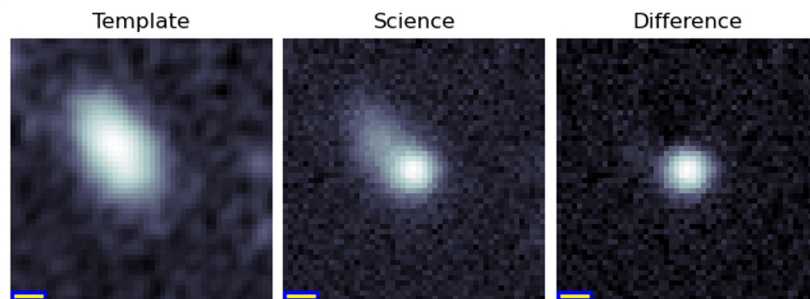
Visual inspection

~70 remaining

Not too far away (Legacy Survey photo-z < 0.3)

# We found real transients...

After visually inspecting ~7000 cutouts!



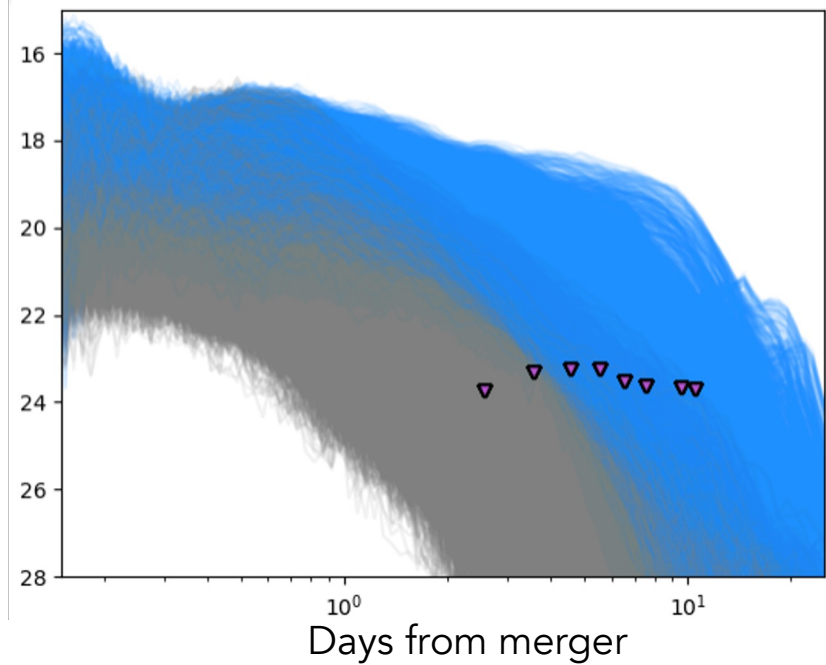
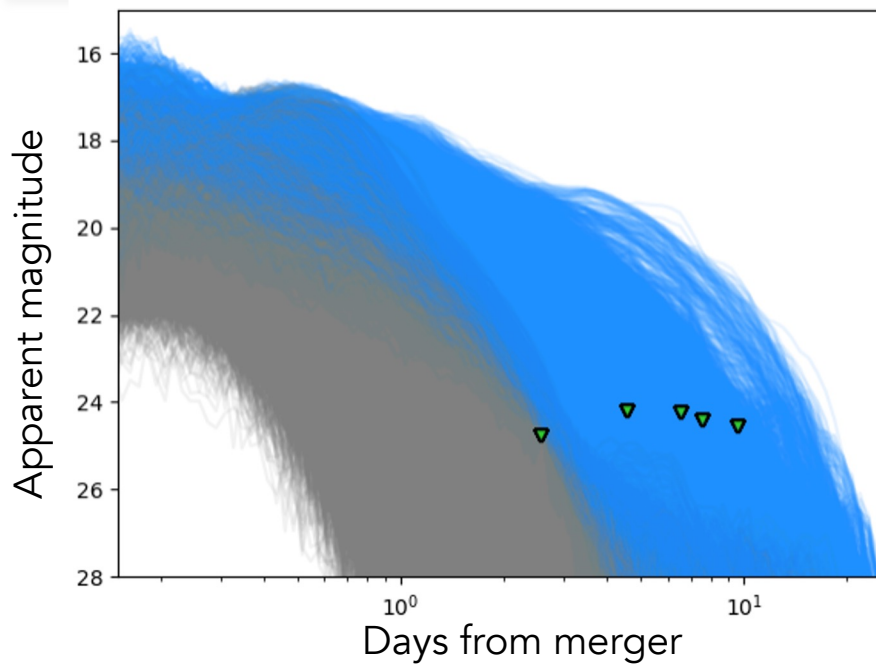
[AT2025adin](#), 30" away from a NED galaxy within the GW volume; first seen by GOTO<sup>13</sup>

## Summary: transient-like candidates from search

- ~70 candidates in our final shortlist
  - 32 candidates with high photo-z (photo-z > 0.3) from Legacy Survey
  - 15 of these candidates were detected by other surveys
  - No kilonova-like candidates

Systematic filtering yields a digestible number of Rubin candidates!

# Constraints on kilonova models



>45% of the kilonova models in the POSSIS KN model grid are ruled out by Rubin non-detections (requiring 3 detections in 2 filters).

## Summary and future work

- Conducted the first comprehensive search for an EM counterpart to a GW event with Rubin
  - GCNs 42707 (MacBride+2025) and 43257 (**SA**+2025)
  - Photometry released on transient name server
- Subsolar mass merger - MMA searches can probe new physics!
- Additional analyses in progress; paper to be released in advance of IR1
- Observations will be released in Rubin's Data Preview 2

## How do we, as a community, find the next MMA counterpart with Rubin and Roman?

- Past experience shows us that systematic filtering yields tens of viable KN candidates from Rubin that can be released to the community.
- To maximize counterpart discovery, we need community standards and broker integration for KN candidate ranking
  - Developing tiered ranking criteria at the LSST TVS-MMA telecons
  - Join us for Rubin ToO 2026 @ Berkeley for more related discussion!