



The Multi-messenger Treasure TROVE: a Tool for Rapid Object Vetting and Examination

Northwestern



**NSERC
CRSNG**



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TROVE is
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for multi-
messenger
programs.



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Multi-messenger?

LIGHT

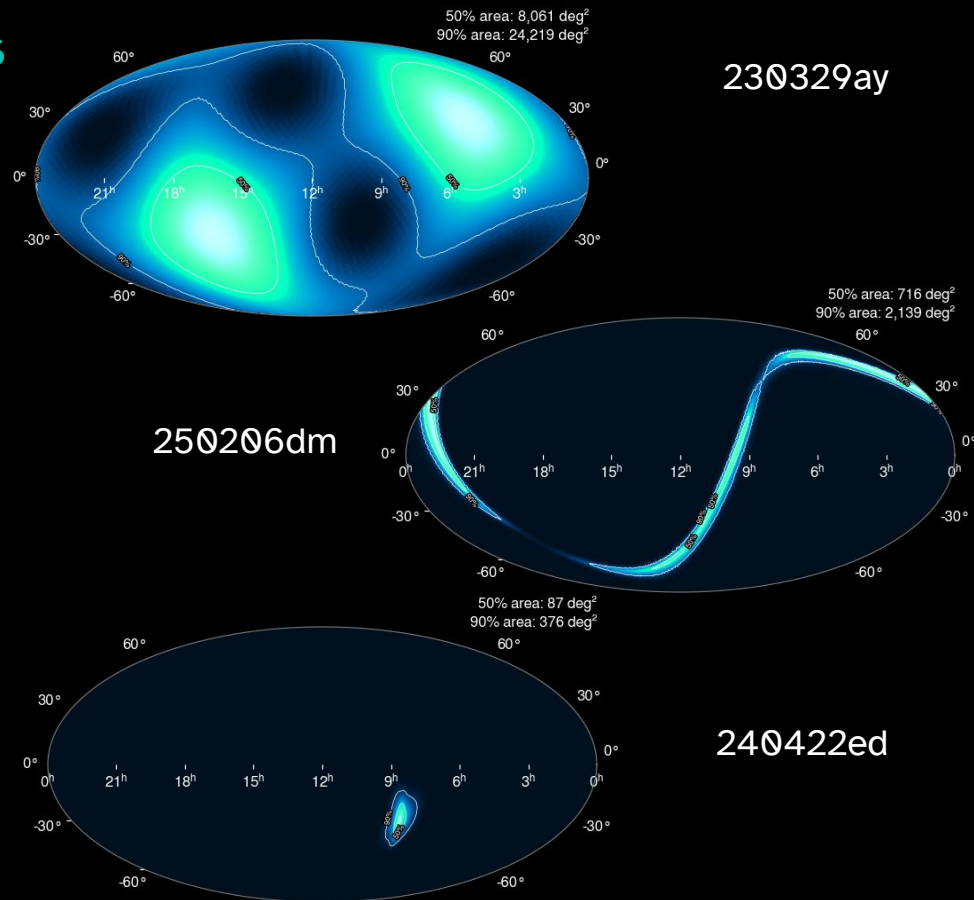
GRAVITATIONAL
WAVES

NEUTRINOS

COSMIC RAYS

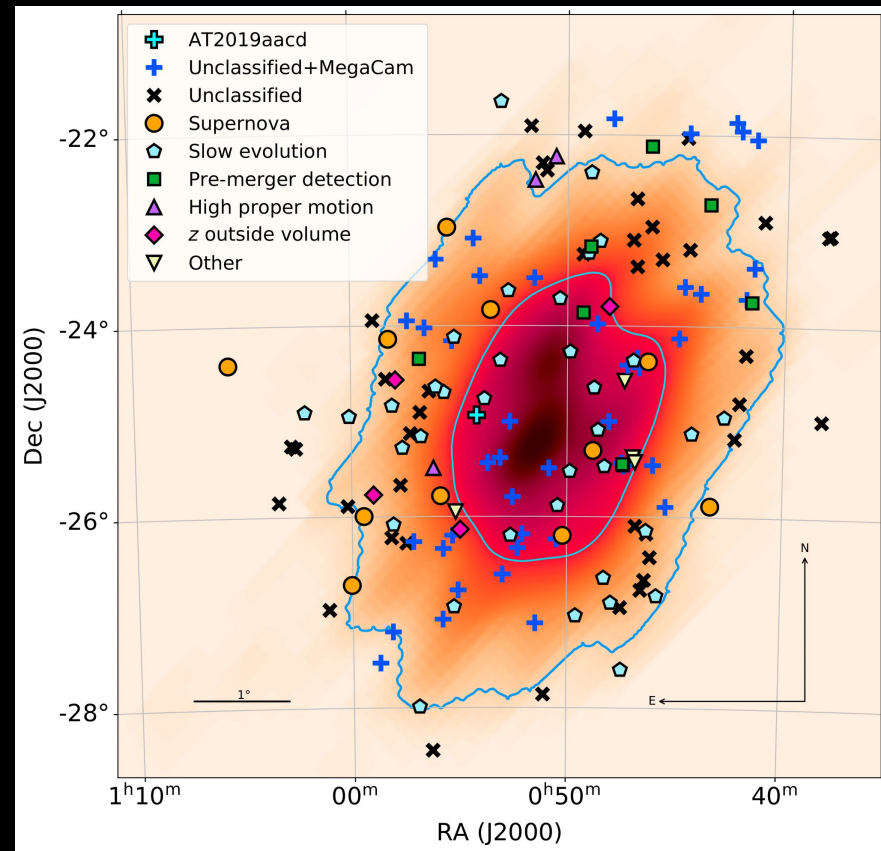
Multi-messenger astrophysics is challenging

Gravitational waves from binary neutron star / neutron star + black hole mergers produce large localization regions with confidence regions $\sim 10^2 - 10^3$ deg



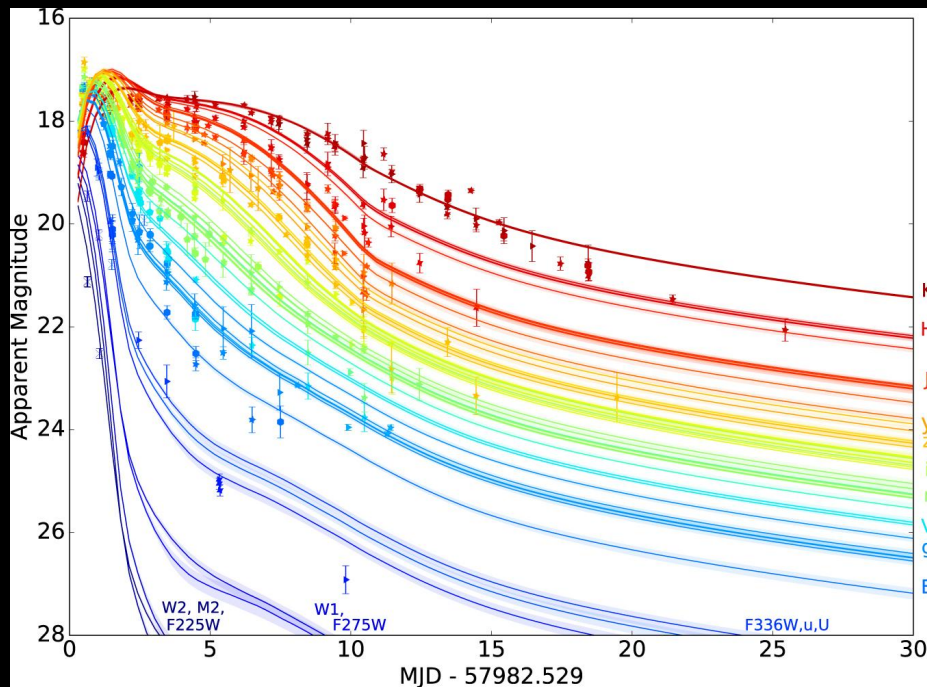
Multi-messenger astrophysics is challenging

Even exceptionally well-localized events like GW190814 will have dozens of candidate counterparts in their localization region—many never classified!



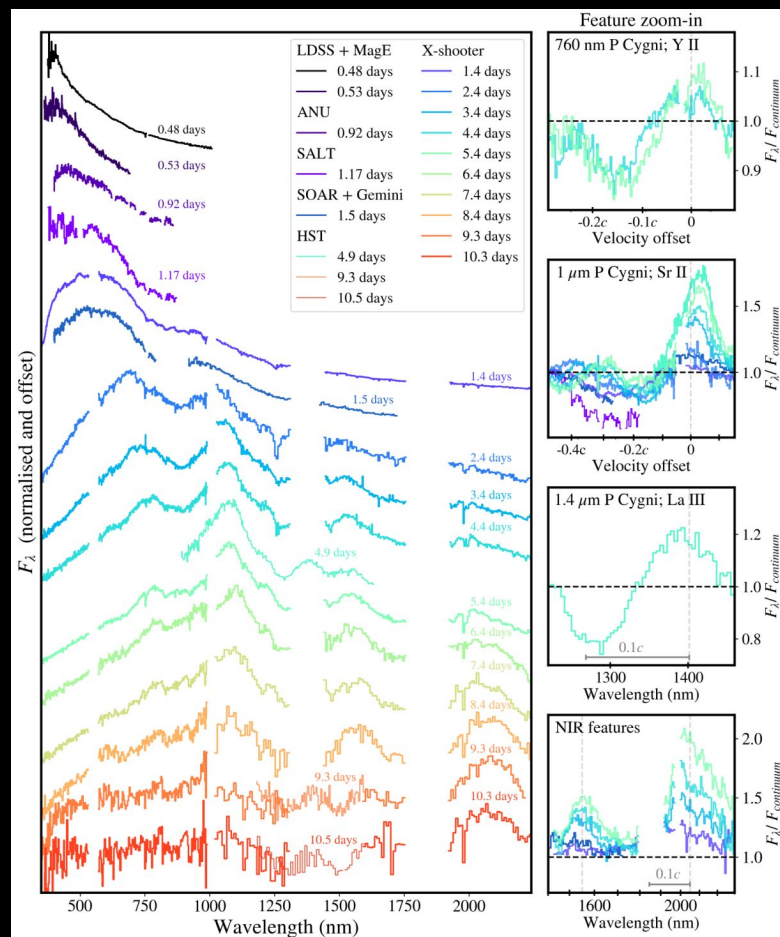
Vieira+20

...but worth it!



Villar+17

Sneppen+24



Multimessenger tools

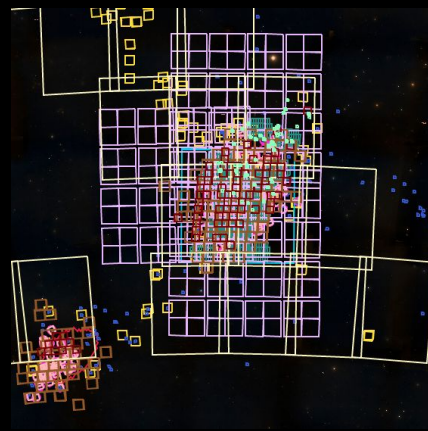
Welcome to TNS Version 2.0.

Please do not hesitate to contact the TNS admins if encountering any issues.

Search by name or coordinates (within 10")

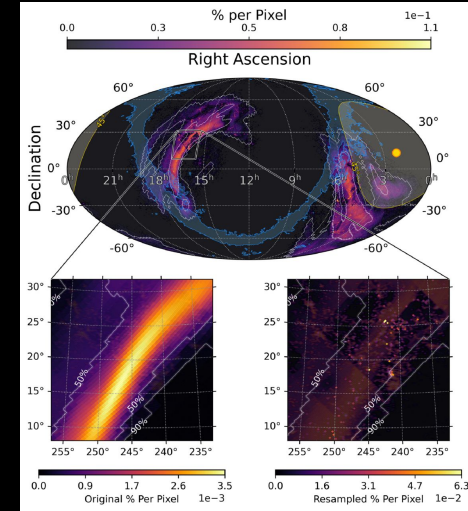
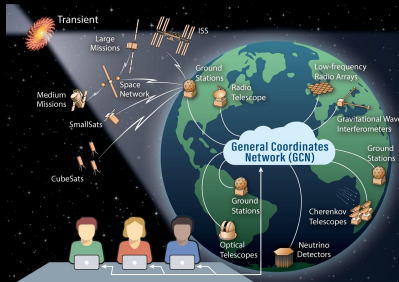
Submit

Transient Name Server



GW Treasure Map

General Coordinates Network



teglon



Target and Observation Managers

Nick Vieira

CosmicExplosions26

REGISTER: datatrove.as.arizona.edu/accounts/register/

Rubin brokers + tools you all are working on!



ALeRCE
Automatic Learning for the
Rapid Classification of Events



Babamul



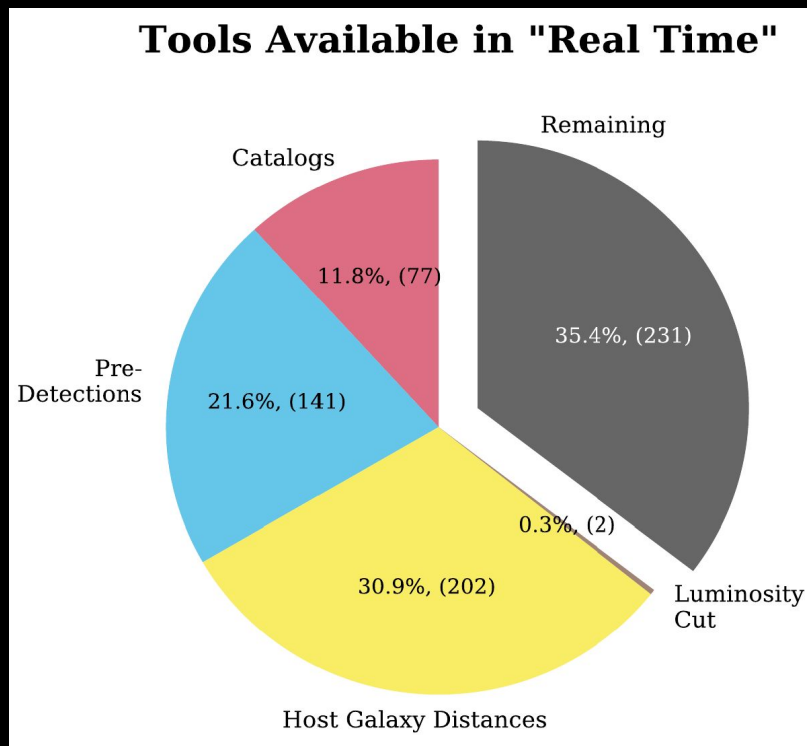
Ampel

Lasair



Pitt-Google-Broker

Vetting can disqualify counterparts to an event



Rastinejad+22

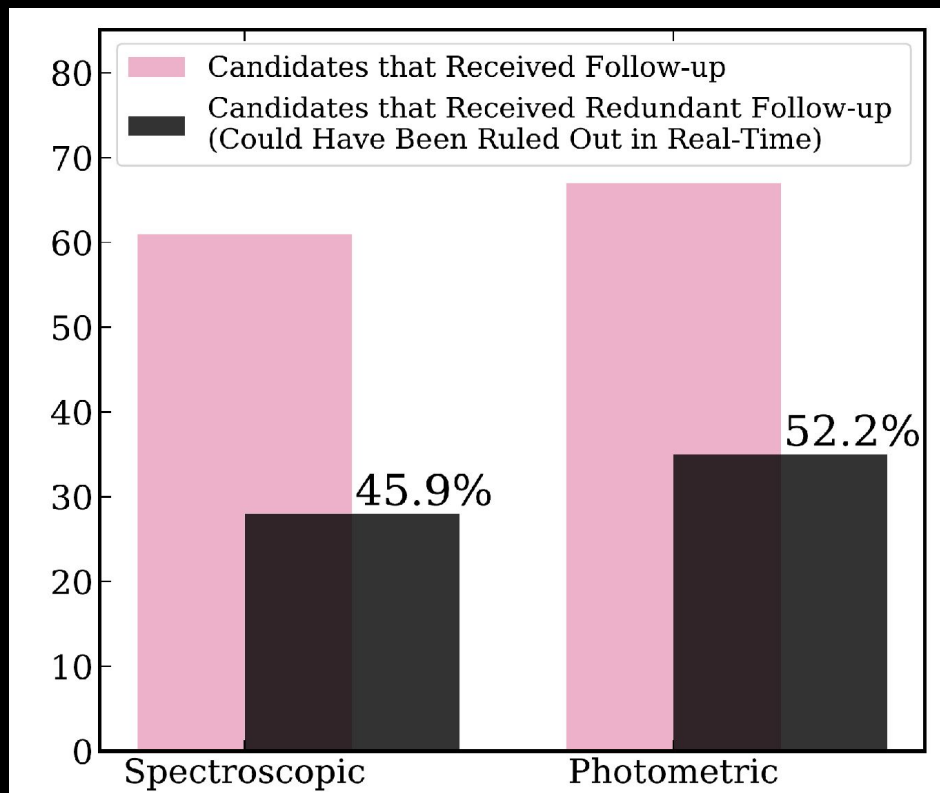
Possible to disqualify counterparts to an event using archival/real-time information (e.g., Anand+21, Kilpatrick+21, Rastinejad+22).

The viability of a candidate also evolves with time:

- classification
- spec-z of host
- photometry

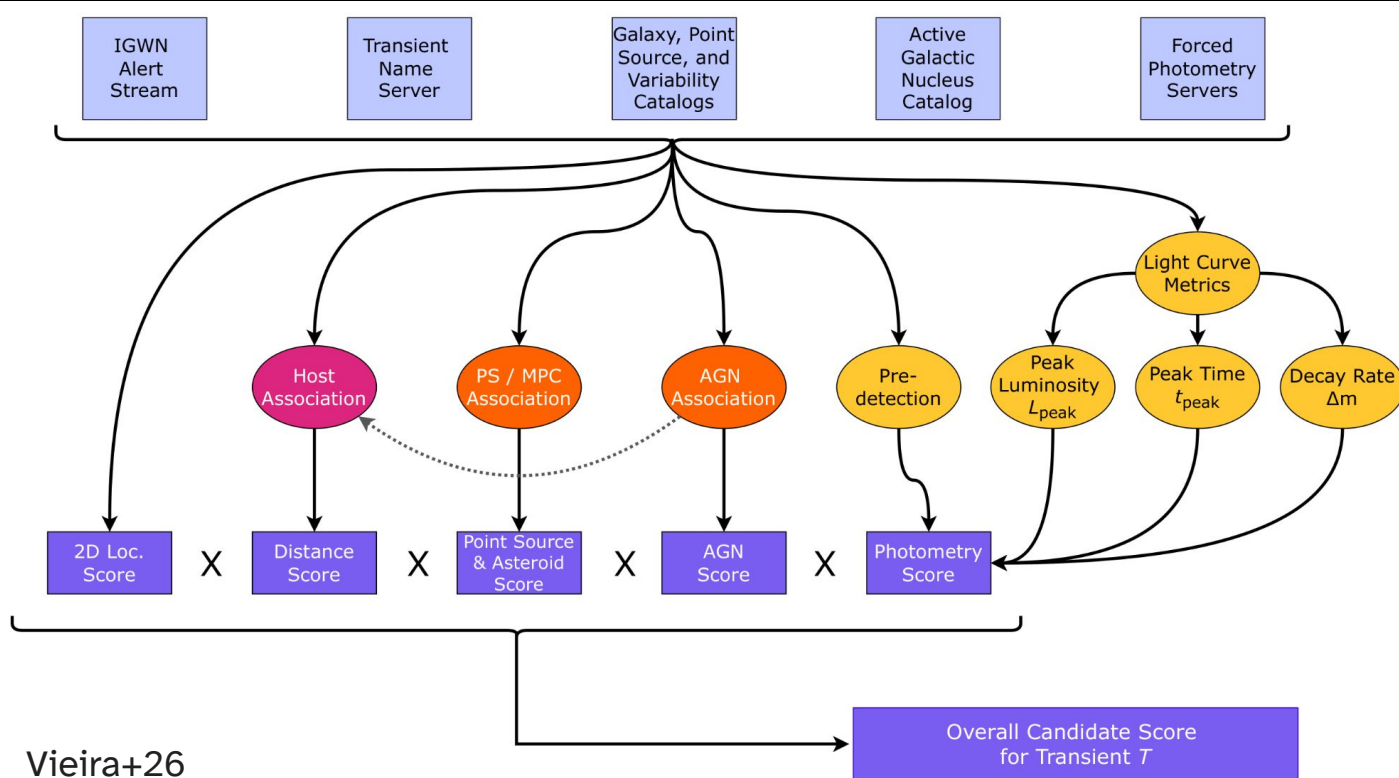
What this vetting approach can solve

We can do a better job saving valuable telescope time for candidates that are actually likely counterparts!

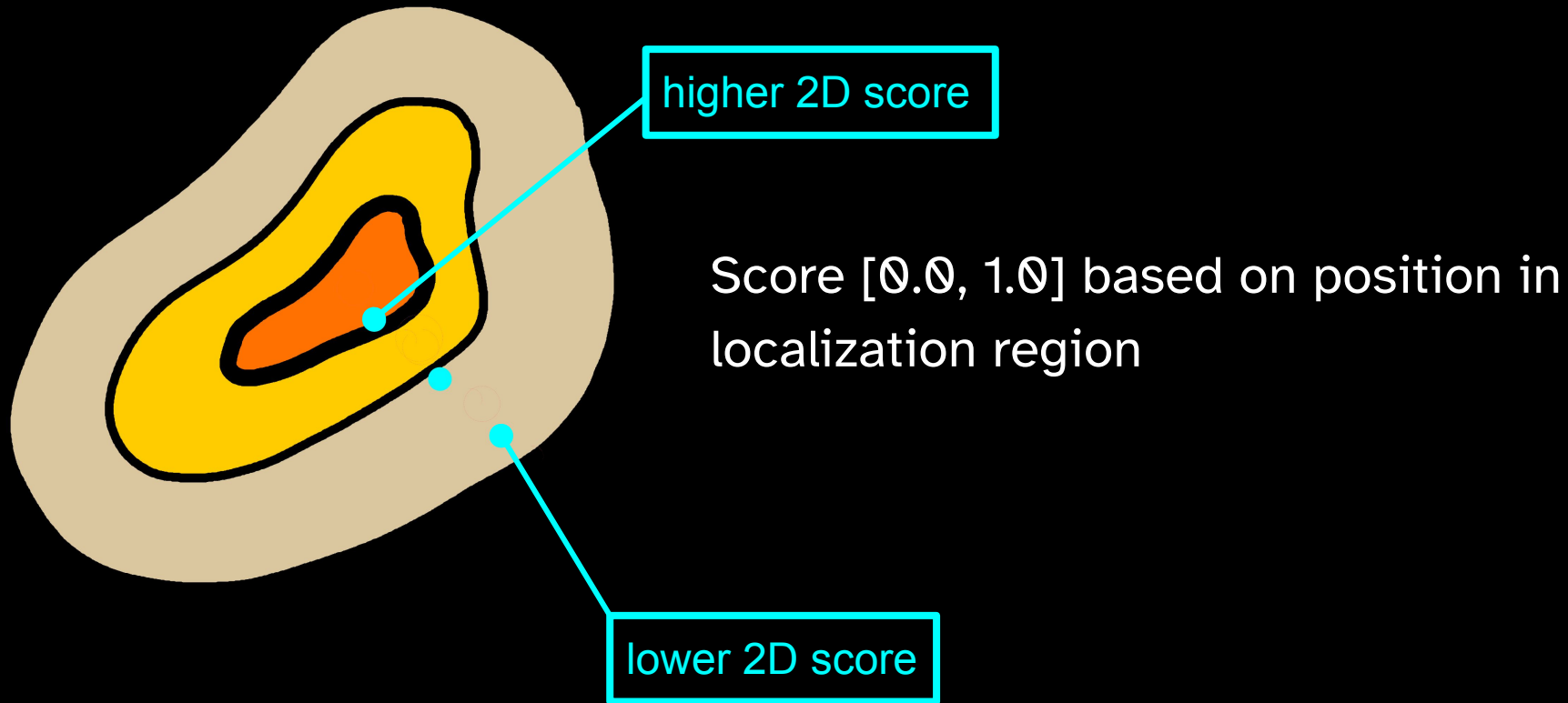


Rastinejad+22

TROVE: Tool for Rapid Object Vetting and Examination



2D (localization) scoring



3D (distance) scoring

Host has a **photo-z**, minimal overlap
→ low score

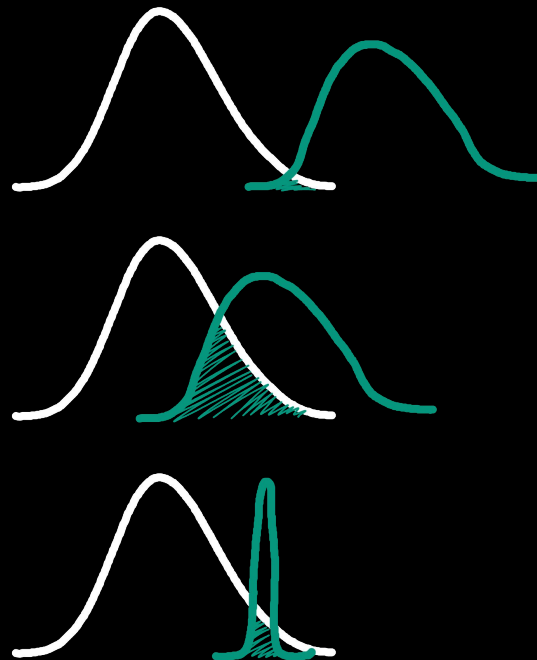
Host has a **photo-z**, some overlap
→ moderate score

Distance refined with **spec-z**, less overlap
→ lower score

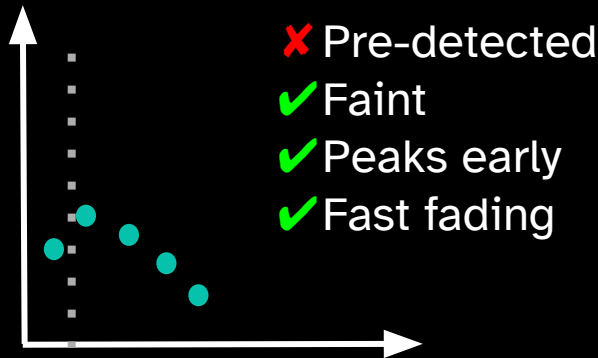
We're working on improving this framework
to not penalize spec-z's so heavily.

GW luminosity
distance PDF

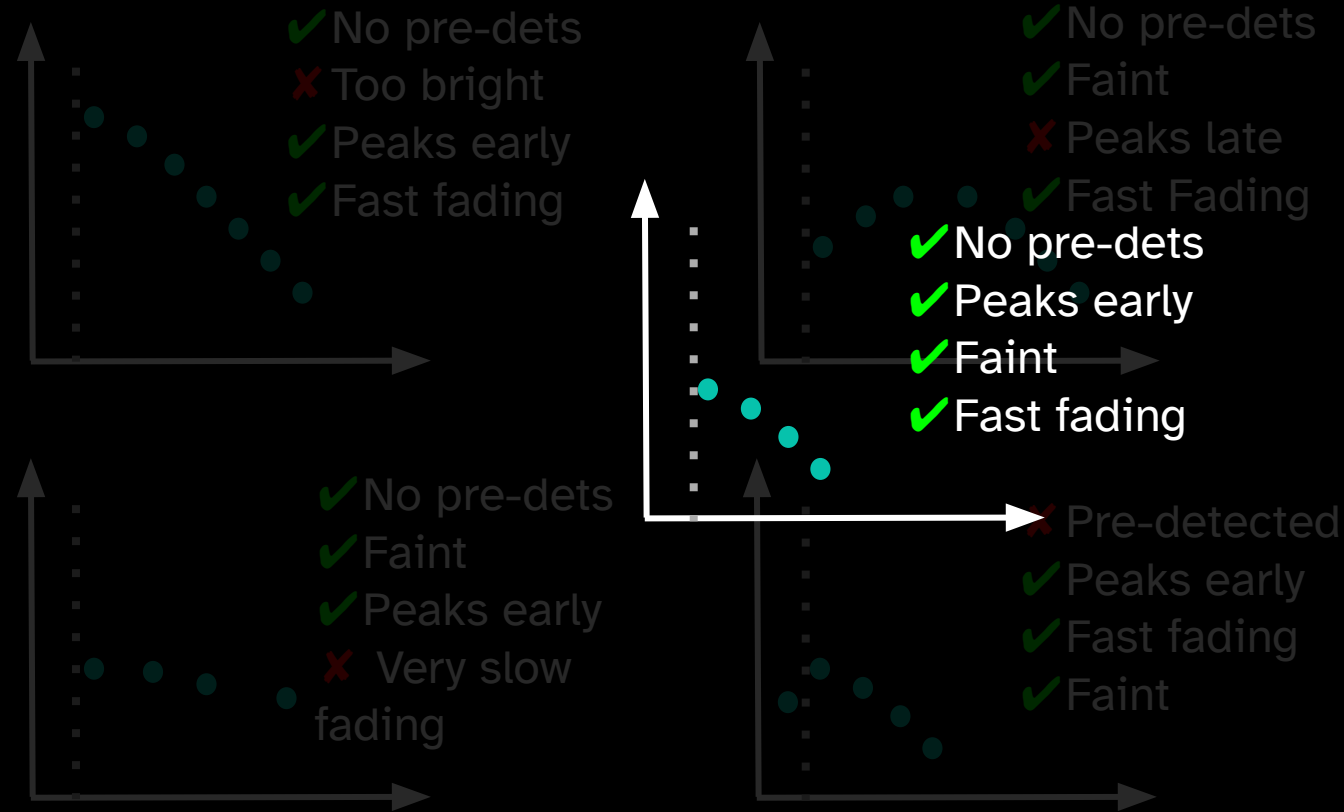
host galaxy
distance PDF



Photometry scoring



Photometry scoring

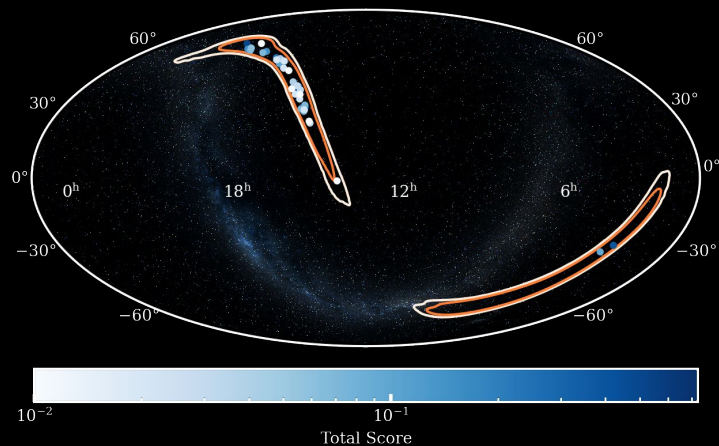


photometry
score drops by a
factor of 10x for
each criterion
not met

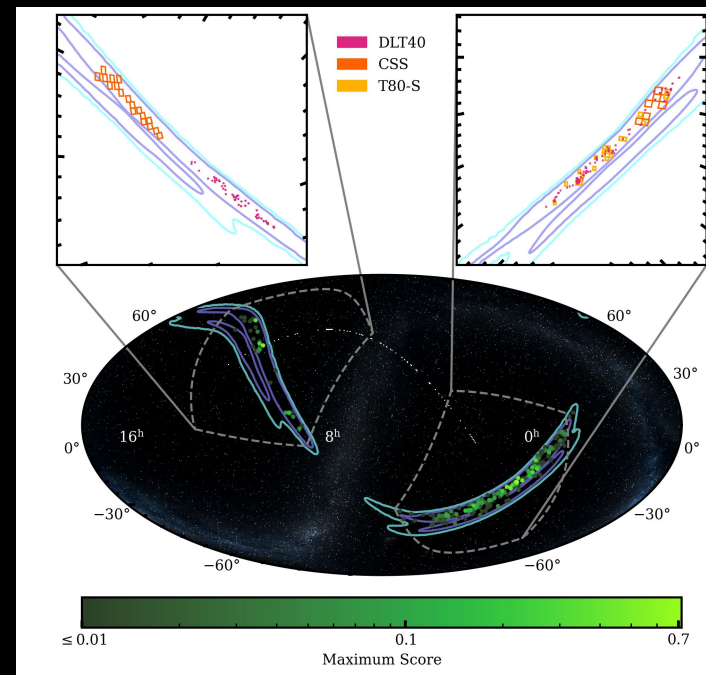
→ one of:

1.0,
0.1,
0.01,
0.001,
0.0001

TROVE has already been applied to two GW events!



Franz+25: TROVE on
S250818k, SN2025ulz



Vieira+26: TROVE on
S251112cm

Let's actually demo it!

What to expect from us:

- TROVE 1.0 infrastructure (Franz+in prep)
- TROVE 1.0 applied to O3/O4 events (Vieira+in prep)
- Documentation & tutorials; workshops at conferences
- Slack space for TROVE users
- Extensions to other poorly localized events

by IR1 start 🙏



Franz+25: TROVE on
S250818k, SN2025ulz



[ApJL, 994,
2, L45](#)

Vieira+26: TROVE on
S251112cm



[arXiv:
2603.17009](#)

**Interested in testing TROVE? Get
in touch:**

astrotrove@gmail.com

(Or find Noah or I during coffee!)

Now it's your turn!

Challenges:

1. Find a high-scoring candidate counterpart to GW190814 and explain to me *why* its score is high. Would you follow up on it?
2. Create a target within the localization region of GW190814. Associate it with GW190814. Vet it.
3. Add photometry to that target.* Vet it again.

datatrove.as.arizona.edu

* We envision users creating targets and adding to their photometry, spectroscopy, or adding a classification through the TNS, which TROVE ingests. But we'll circumvent that for the sake of this demo.