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

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on behalf of the TROVE team

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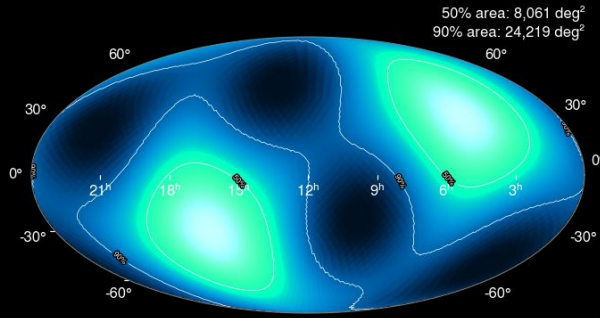
Northwestern | CIERA

Multi-messenger is hard

- Multi-messenger observations yield more than the sum of their parts: cosmology, neutron star EoS, origin of the heavy elements, and more!
- Gravitational waves produce large localization regions with confidence regions ~ 10^2 - 10^3 deg



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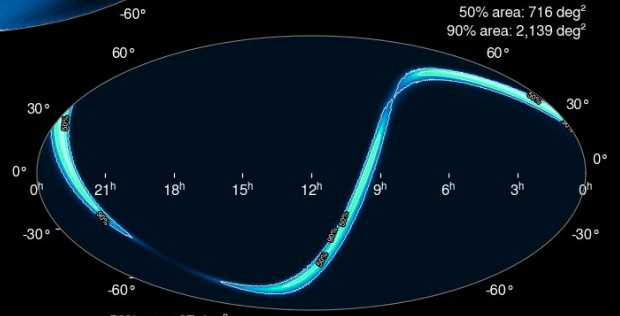

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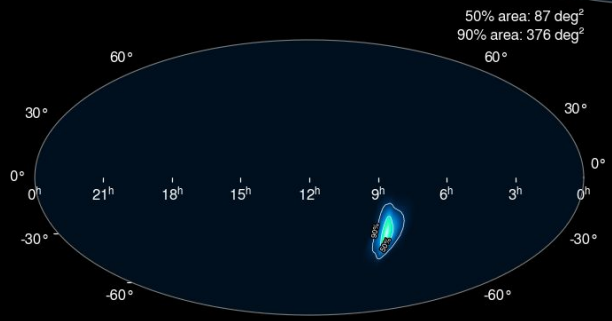

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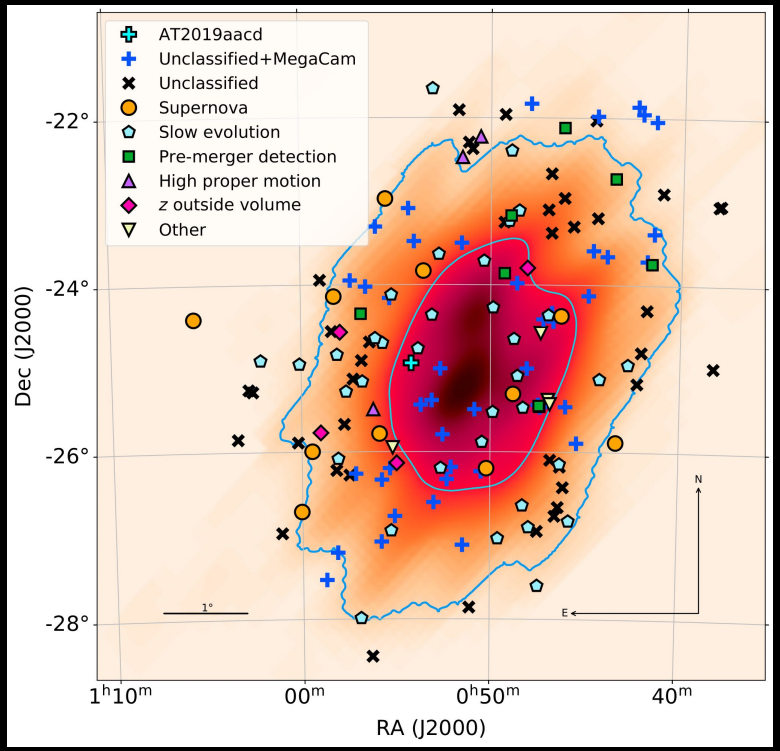
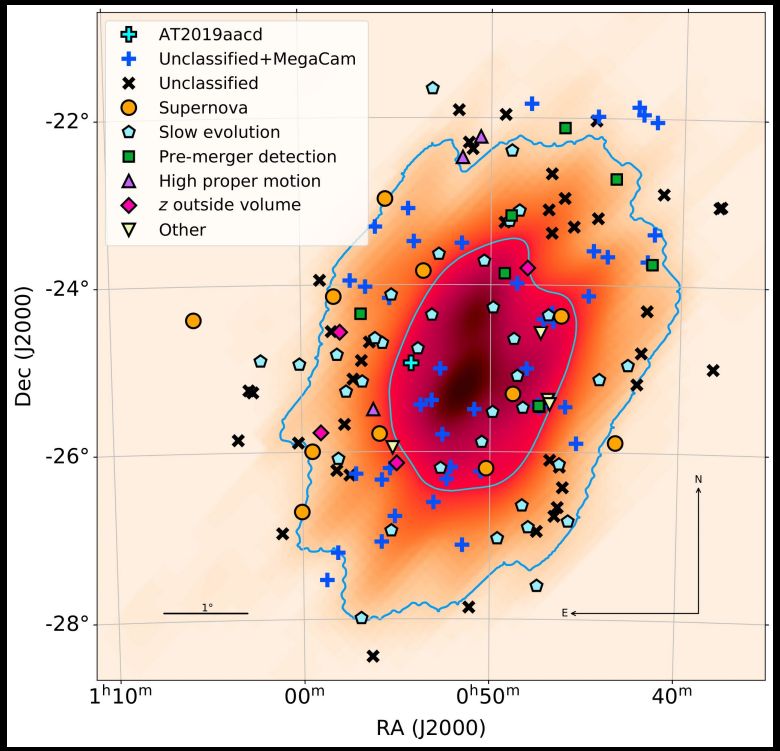
Multi-messenger is hard



Vieira+20

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

Multi-messenger is hard



Vieira+20

- Even exceptionally well-localized events like GW190814 will have dozens of candidate counterparts in their localization region—many never classified!
- **How do we efficiently spend finite resources to find electromagnetic counterparts to these events?**

TROVE!

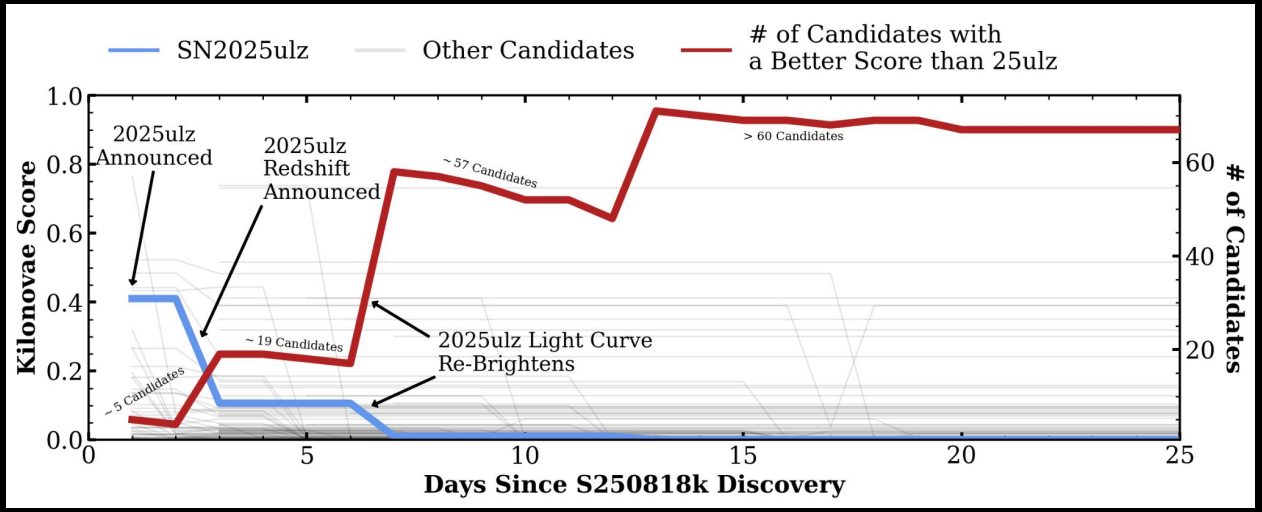
ingest:

- gravitational waves
- candidate counterparts
- galaxy, point source, and variability catalogs
- AGN catalogs
- candidates' photometry

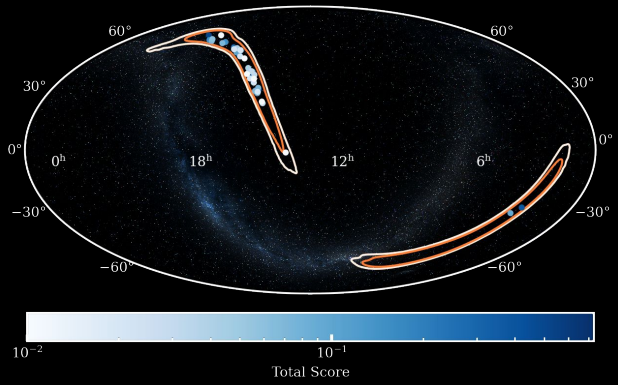
score based on:

- position in 2D localization
- distance to host
- association with point sources / asteroids
- association with AGN
- photometry

TROVE on S250818k and AT 2025ulz



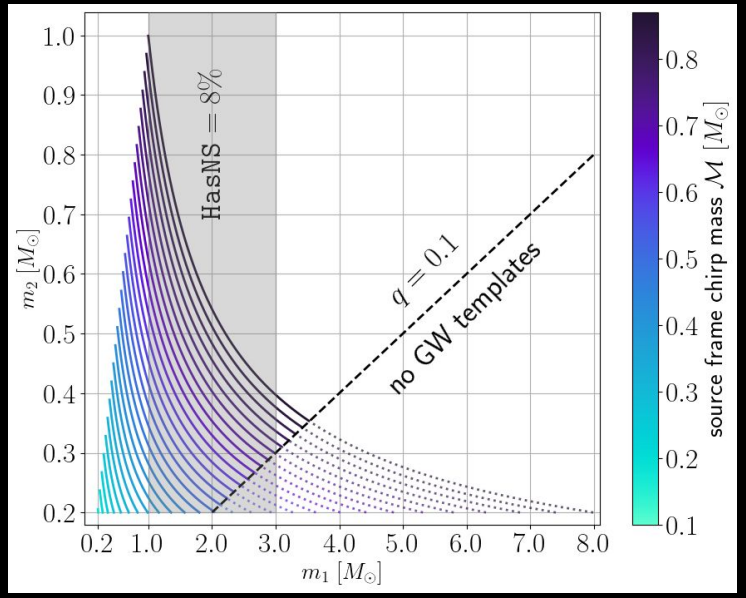
Franz+25 (ApJL, 994, 2, L45)



Led by Noah Franz, UofArizona grad student

TROVE on S251112cm

Vieira et al, in prep

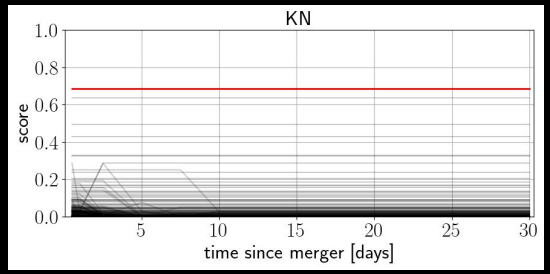


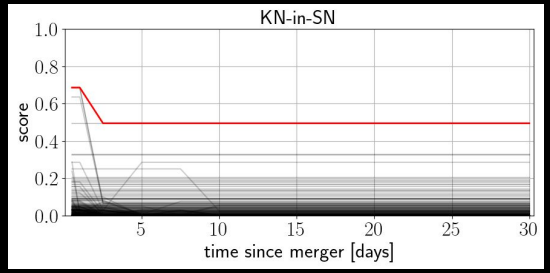
Merger of 1-2 subsolar mass object(s), unlikely to contain an object of 1-3 $M_\odot$

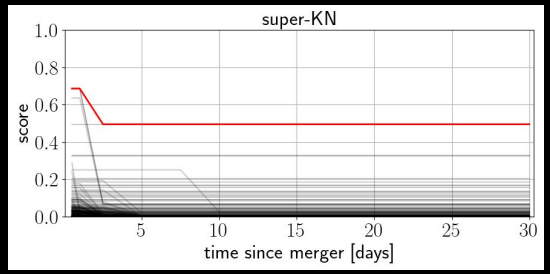
Vet candidates considering multitude of viable transients:

- **kilonovae**
- **KNe-in-SNe**
- **super-KNe**

Also searched for BBH-induced AGN flaring







We're using Rubin data!

Recently-released Rubin photometry brought our total number of candidates for S251112cm from 166 to **231**.

Optimizing follow-up with tools like TROVE will be critical in the Rubin era.

What we've learned:

- We can effectively score candidates as kilonovae to optimize follow-up
- The candidate counterpart to S250818k which received the most attention wasn't the highest scoring!

Read Franz+25

ApJL, 994, 2, L45

What to expect from us:

- Application to subsolar mass event S251112cm, expansion to new classes of transients
- TROVE 1.0 (web app and API)
- TROVE 1.0 applied to O3 and O4
- Documentation & tutorials; workshops at conferences
- Slack space for TROVE users

Interested in the TROVE? Want to beta test? Get in touch!

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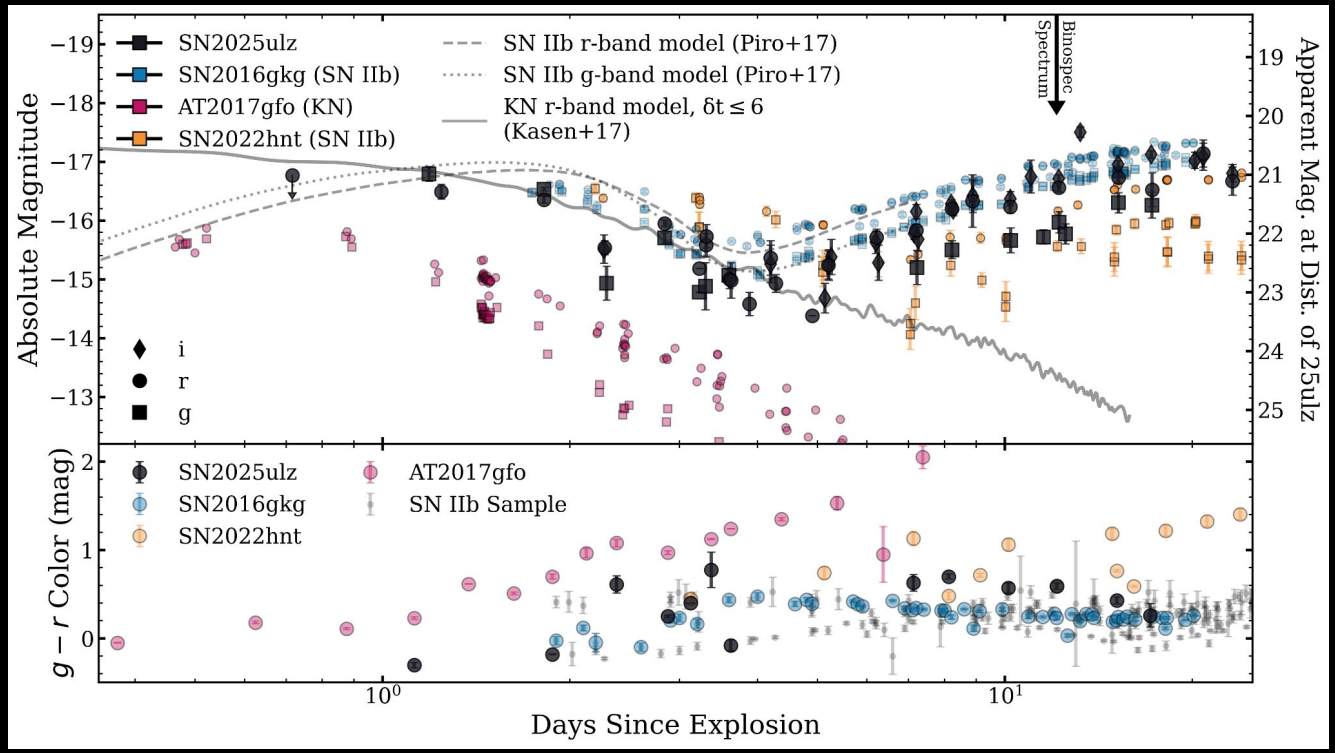
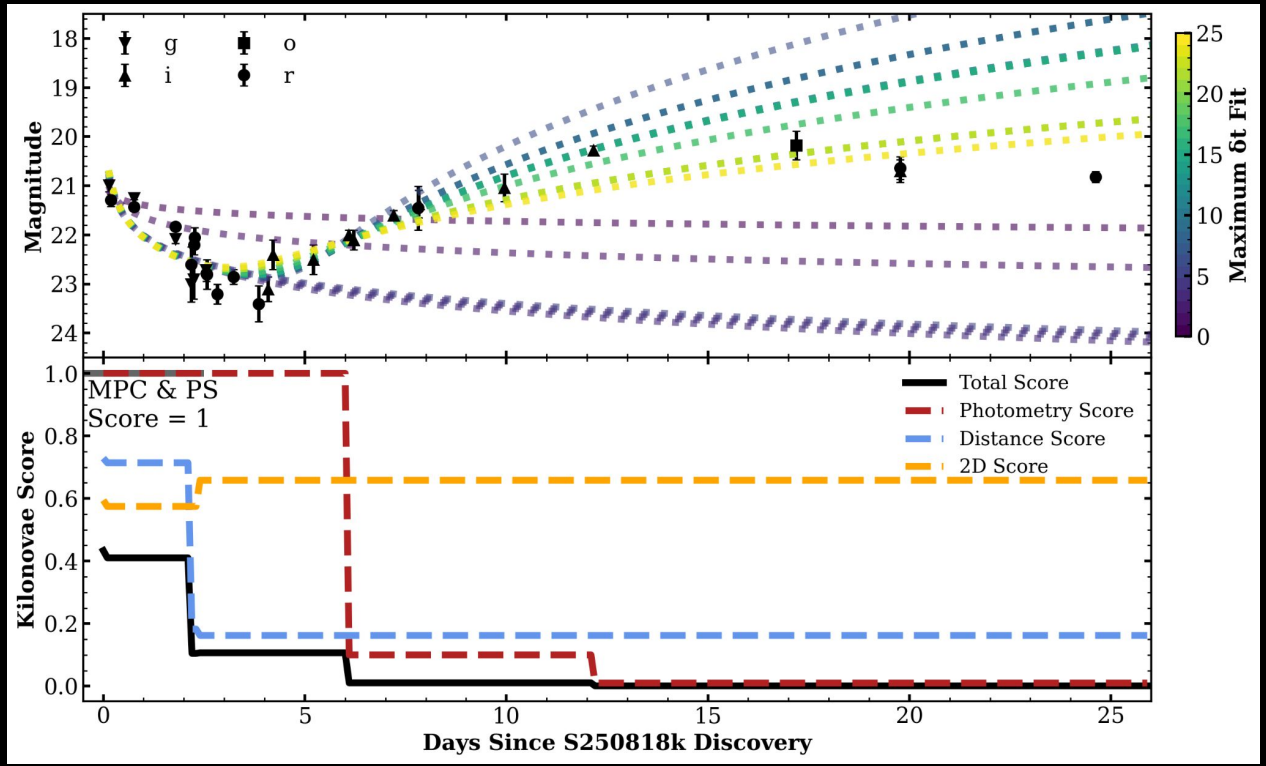
EXTRA SLIDES

SN2025ulz's photometry



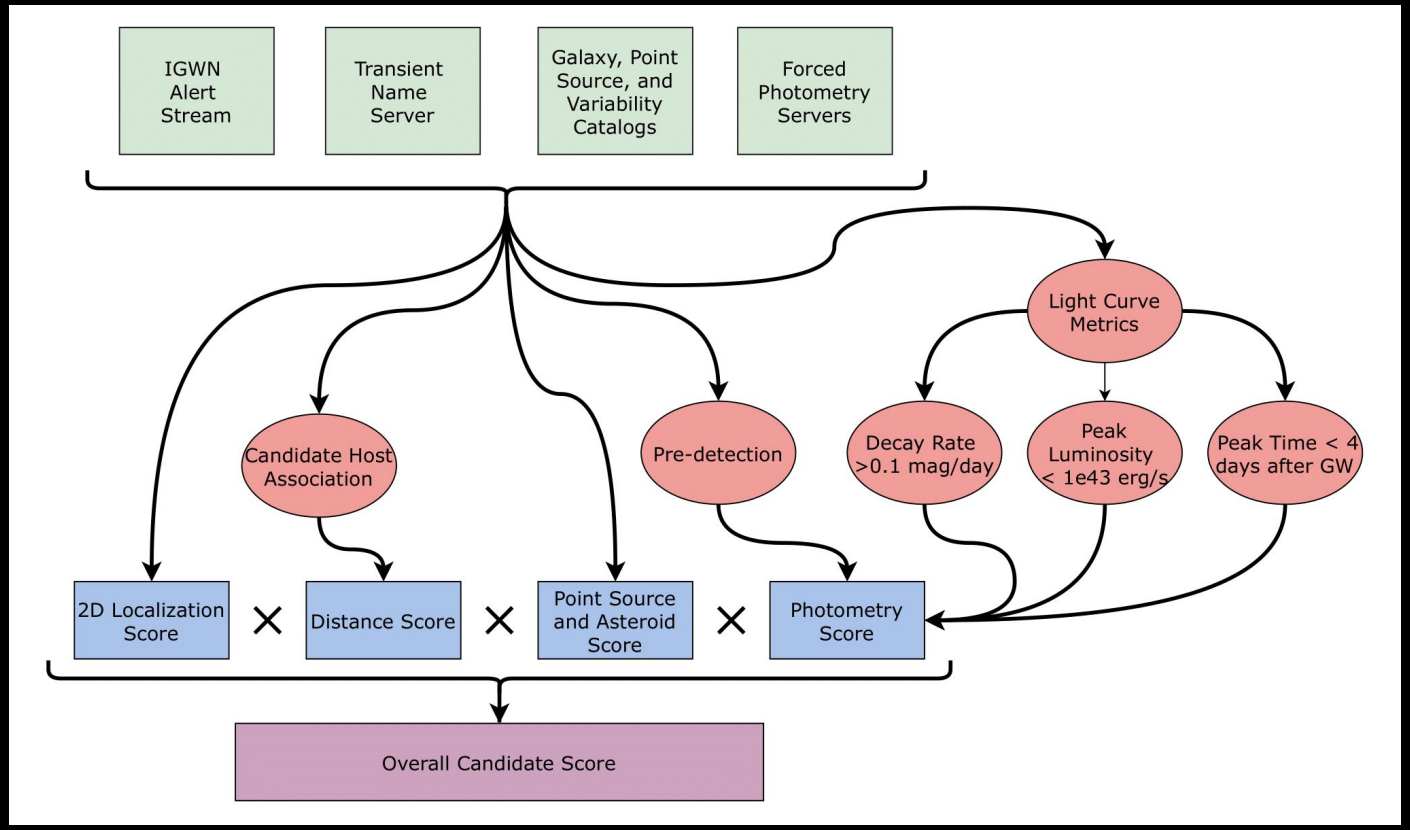
Franz+25
(ApJL, 994, 2, L45)

SN2025ulz's score with time



Franz+25
(ApJL, 994, 2, L45)

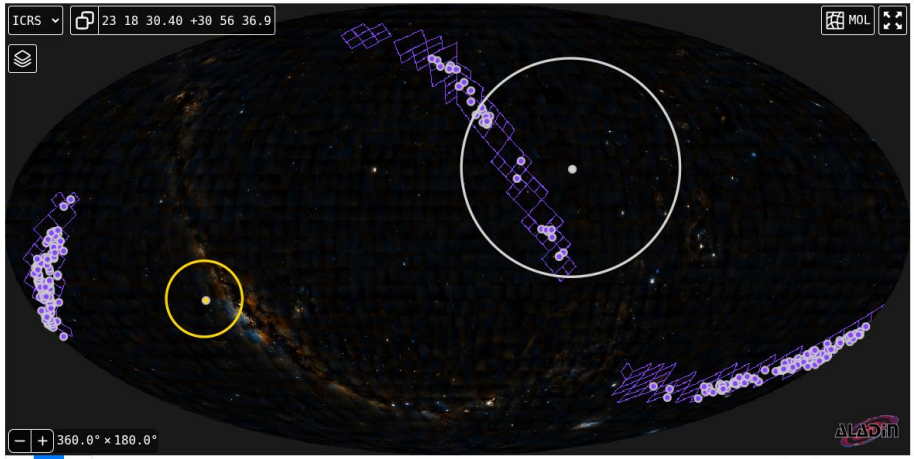
TROVE in Franz+25



Web interface

Candidates for S251112cm

Event Type	GW CBC	**1/FAR**	6.2 yr
Instrument	H1+L1+V1	**Distance**	96 ± 29 Mpc
50% Area	369 deg²	**HasNS**	8%
90% Area	1220 deg²	**HasSSM**	100%
		HasMassGap	0%



« 1 » (1-231 of 231)

Target

Rank	Target	Event	Score

AT2025adht

Classify Edit Share Delete Vet

Names	AT2025adht	
	S251112cm	
Coords.	12:00:24.350	+49:02:51.95
	180.101460	49.047765
Galactic	143.749477	65.966534
Ecliptic	155.448182	43.899524

Permissions	Public
Redshift	nan
Milky Way E(B-V)	0.0213
Classification	
Redshift	
MW E(B-V)	0.0216

Scores:

S251112cm	23

Photometry:

Recent Photometry

Time	Mag.	Abs. Mag.
2025-11-22 20:16:48	21.86	
2025-11-21 20:31:12	21.83	
2025-11-15 00:13:15	21.64	

Survey View

Score Details

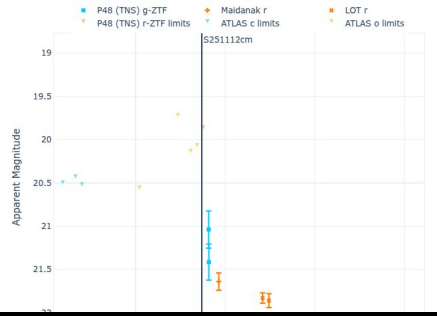
S251112cm

Point Source Score (1 or 0): 1
3D Association Score: 0.29
2D Localization Score: 0.83
Maximum Luminosity: 4.47 x 10^{42} erg/s
Time of Maximum Light Curve: 0.79 days
Light Curve Slope (positive is brightening): -0.57 mag/day
AGN Score (1 or 0): 1
Minor Planet Center Score (1 or 0): 1

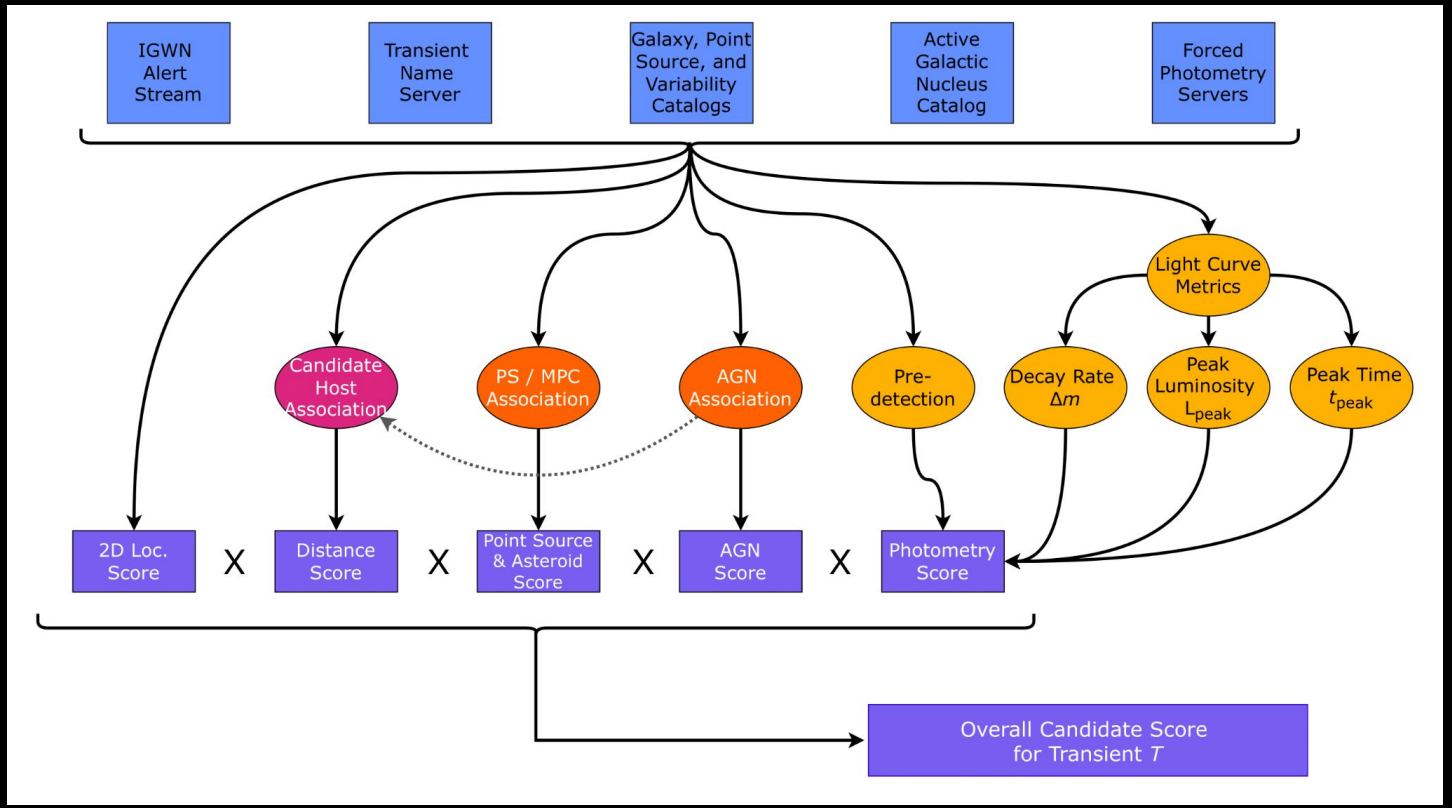
Host Galaxies

ID	Name	P_{cc}	Off. (")	Dist. (Mpc)	Redshift	Distance Type	Mag. (AB)	Source
1	PSO J180.1022+49.0484	0.000	2.92	508.6 ± 311.0	0.11 ± 0.07	photo-z	= 20.5	Ps1Galaxy
2	2964-301-1-0300-0367	0.000	3.21	923.8 ± 281.5	0.19 ± 0.06	photo-z	= 19.4	Sdss12Photoz

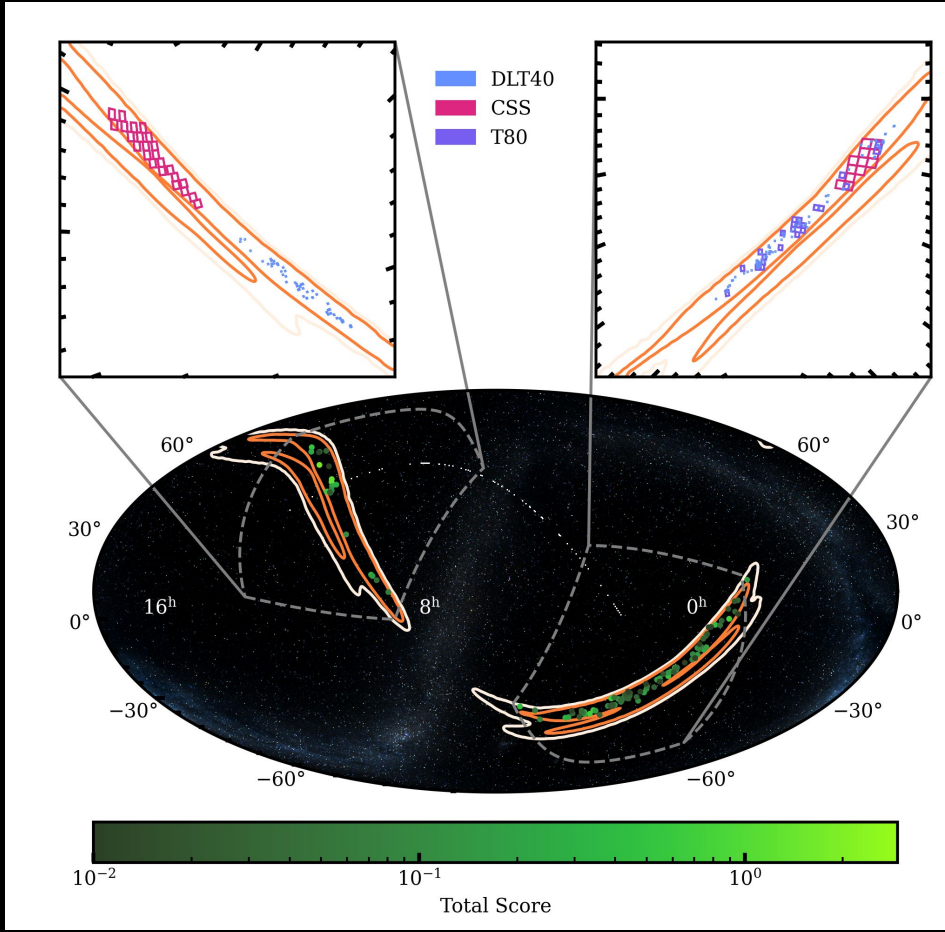
Photometry



TROVE in Vieira et al. (in prep)

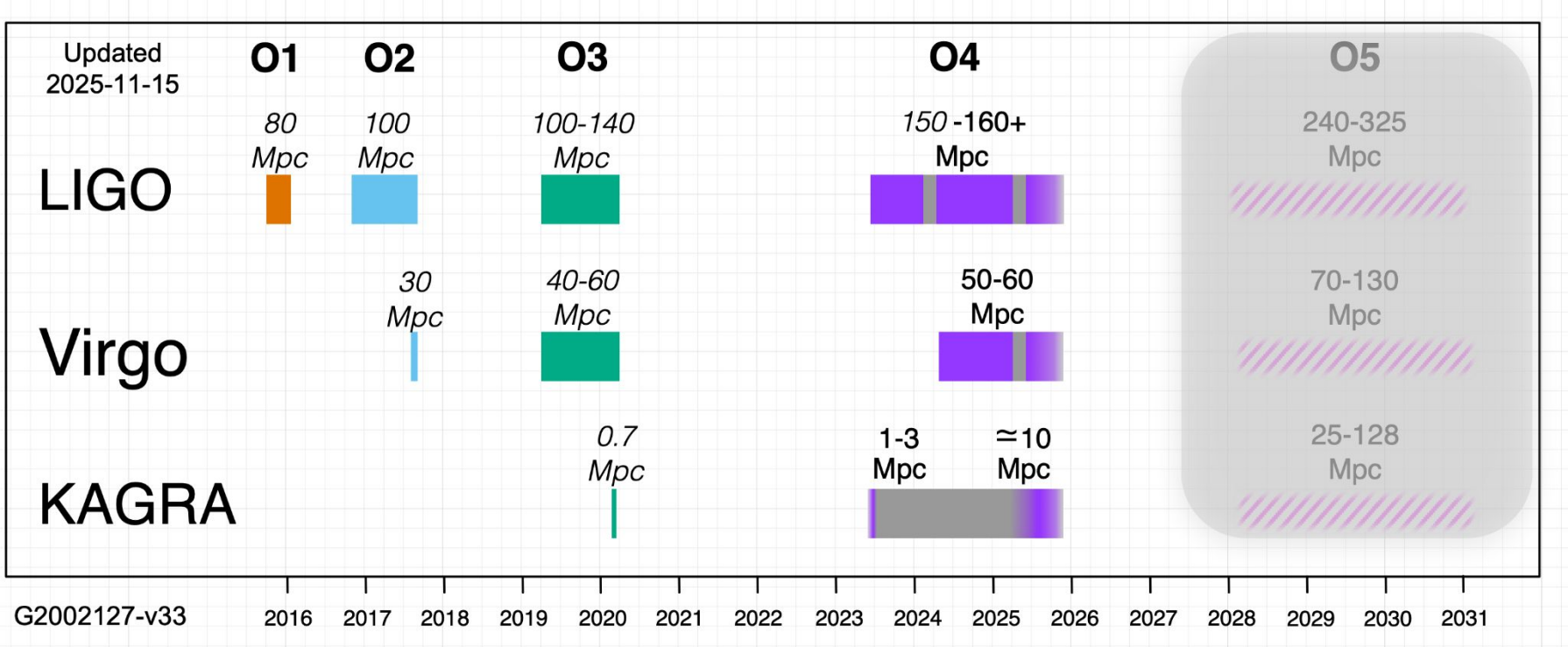


S251112cm skymap



Vieira et al. (in prep)

LVK observing plans



Masses in the Stellar Graveyard