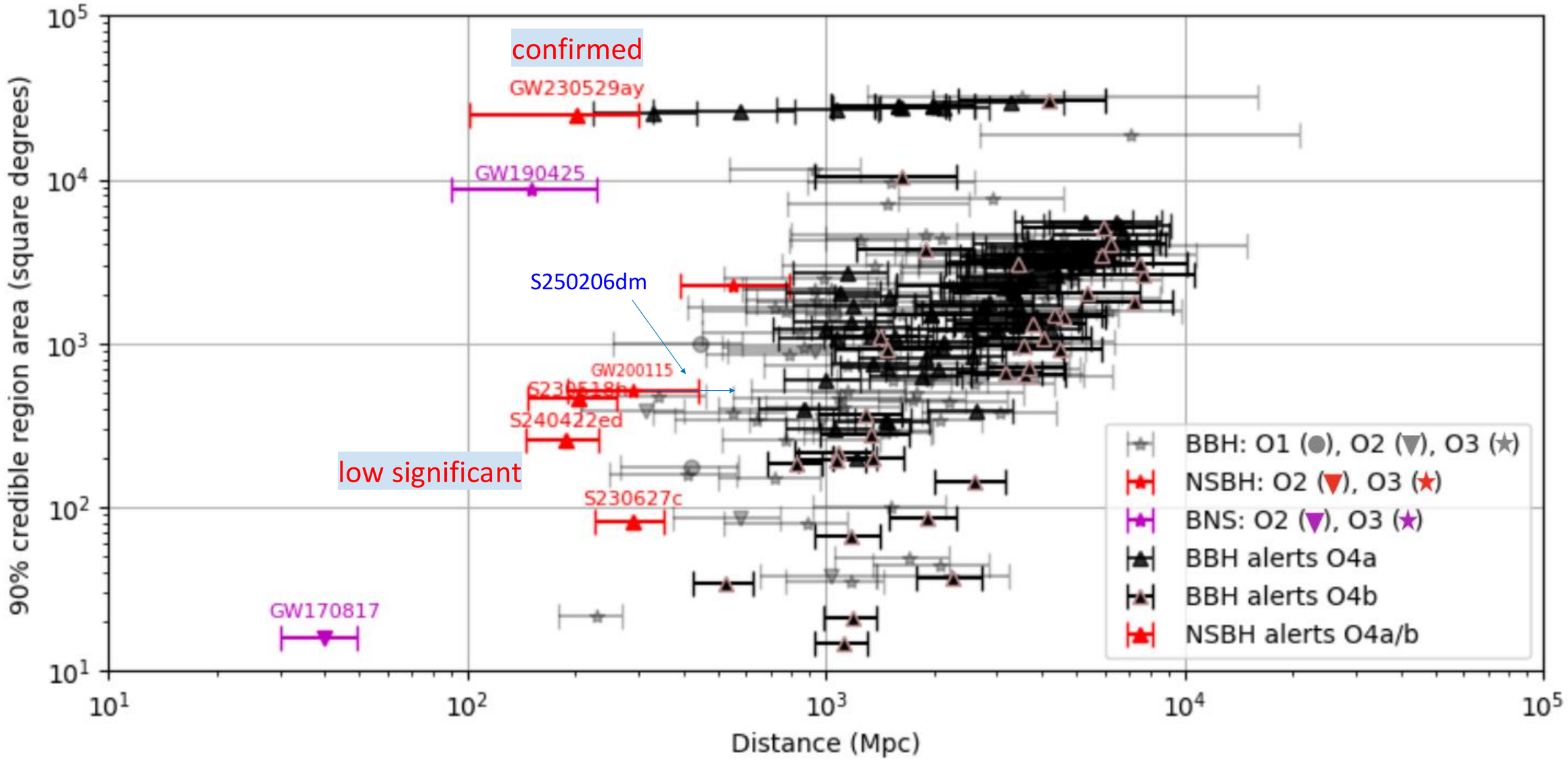
Skyportal

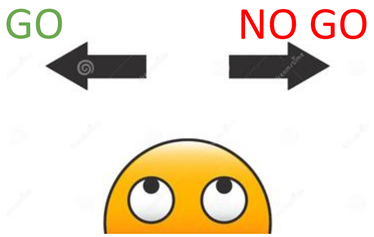
A data-science platform to enable time-domain astronomy

Sarah Antier, IJCLAB, OCA, France

BNS and NS-BH GW events for O4 a and b



How to manage observations in time domain ?



Follow-Up Decision Making

Multi-band Follow-up

Discovery

Online Characterization

….

event properties Extraction

Decision Making and Follow-up

When an alert comes

As an astronomer…

Wake up

Do you have shifters / a rota ?
Do you have automatic processing ?

FocuS

Is it Important ?
Is it Urgent ?
Can I solve it myself ? Do I need a team ?

Filter

Pass or reject based on automated criteria
Read manual to understand the Process
Similar situation as before, can solve
Don't know !

GO / NO GO / ?

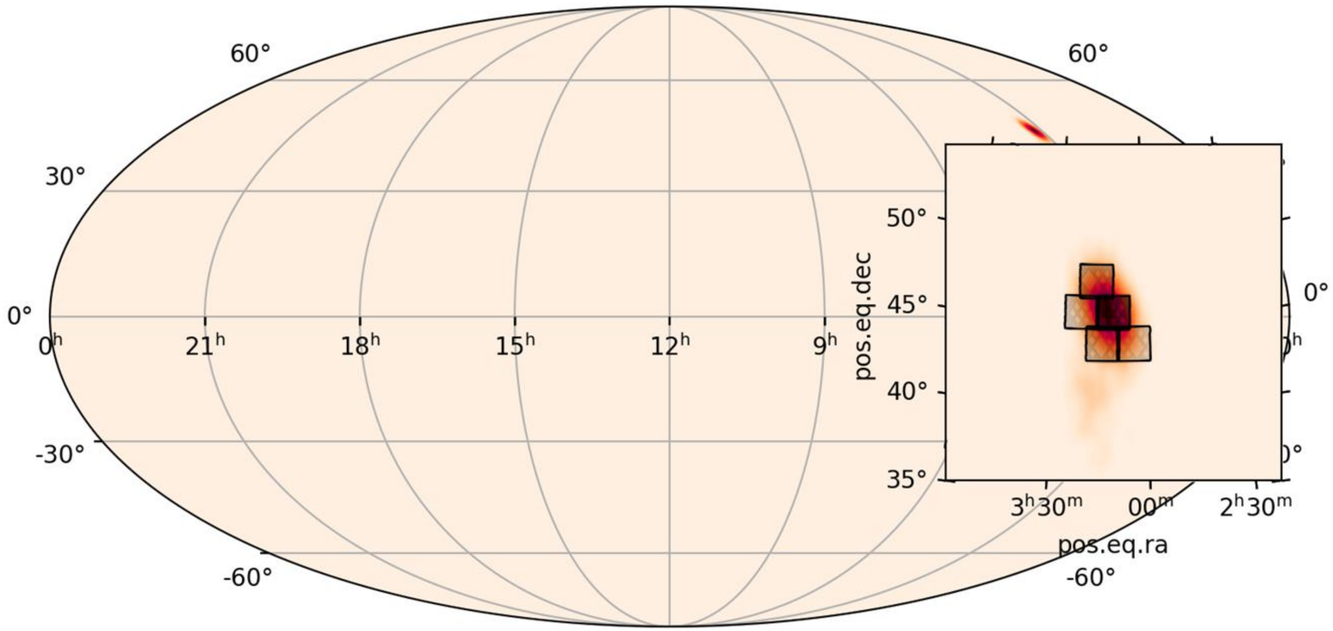
Is it worth it for the experts !!! Argg

Finding Counterparts of MM events: Where ? and When ? to Observe

Tools / Services

TOM : BH TOM, Skyportal, LCOGT
Brokers: AMPEL, Fink, ALICE, Boom

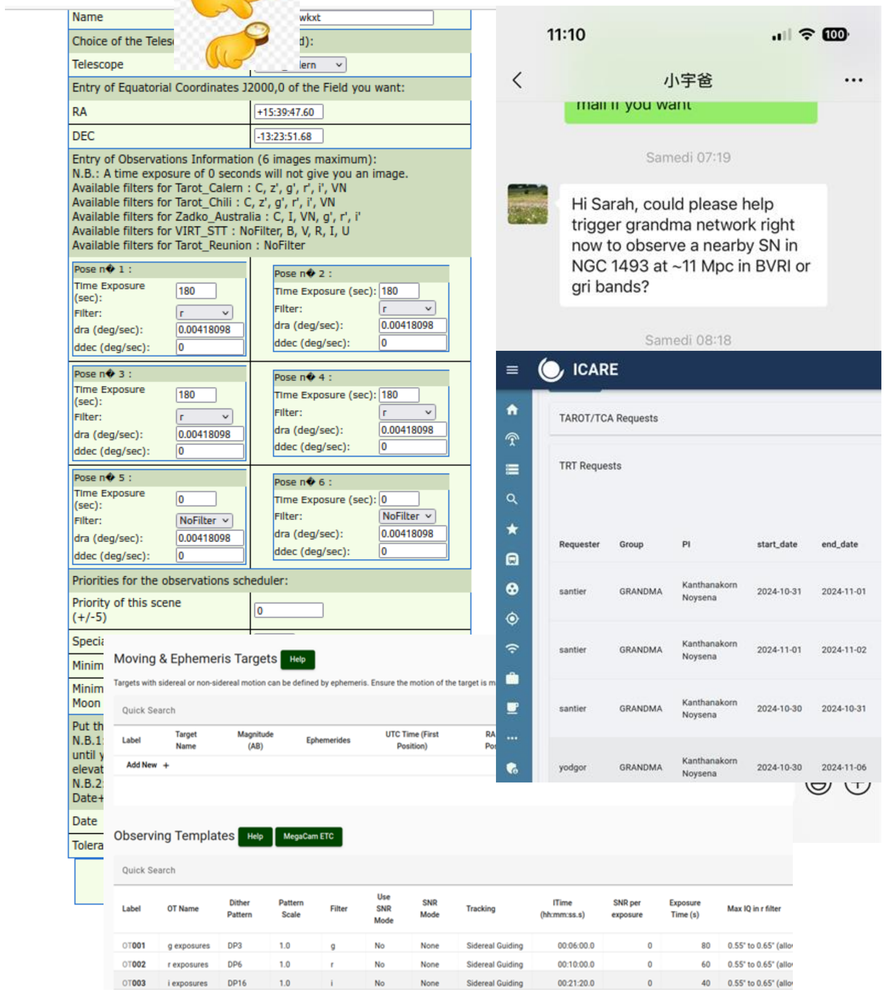
Follow-up results: Treasure Map, GCN



S240621dy Tiling strategy with TAROT/TCA GWEMOPT Package Coughlin

Most telescopes are not AUTOMATIC
It can be cloudy sometimes
PI Telescopes ⇒

tional Telescopes



[Windows on the Universe: Establishing the Infrastructure for a Collaborative Multi-messenger Ecosystem](), Ahumada, 2024

How to solve it ?

Lots of data to look at, lots of people doing it at the same time

- Many surveys, with too much data to look through manually
- Lots of data for each seen by many people at simulatenous time
- Many instruments to coordinate

More in the race over time …

- But not everyone sees the same data, complex data access rules
- Combine ToO with “regular” observations
- Report results quickely

We need

Automatization

Adequate tools for time domain

Alert Brokers → Science portals

Astrophysics > Instrumentation and Methods for Astrophysics

[Submitted on 28 Apr 2023 (v1), last revised 14 Jun 2023 (this version, v2)]

A data science platform to enable time-domain astronomy

Michael W. Coughlin, Joshua S. Bloom, Guy Nir, Sarah Antier, Theophile Jegou du Laz, Stéfan van der Walt, Arien Crellin-Quick, Thomas Culino, Dmitry A. Duev, Daniel A. Goldstein, Brian F. Healy, Viraj Karambelkar, Jada Lilleboe, Kyung Min Shin, Leo P. Singer, Tomas Ahumada, Shreya Anand, Eric C. Bellm, Richard Dekany, Matthew J. Graham, Mansi M. Kasliwal, Ivona Kostadinova, R. Weizmann Kiendrebeogo, Shrinivas R. Kulkarni, Sydney Jenkins, Natalie LeBaron, Ashish A. Mahabal, James D. Neill, B. Parazin, Julien Peloton, Daniel A. Perley, Reed Riddle, Ben Rusholme, Jakob van Santen, Jesper Sollerman, Robert Stein, Damien Turpin, Avery Wold, Carla Amat, Adrien Bonnefon, Adrien Bonnefoy, Manon Flament, Frank Kerkow, Sulekha Kishore, Shloke Jani, Stephen K. Mahanty, Céline Liu, Laura Llinares, Jolyane Makarison, Alix Olliéric, Inès Perez, Lydie Pont, Vyom Sharma

SkyPortal is an open-source software package designed to efficiently discover interesting transients, manage follow-up, perform characterization, and visualize the results. By enabling fast access to archival and catalog data, cross-matching heterogeneous data streams, and the triggering and monitoring of on-demand observations for further characterization, a SkyPortal-based platform has been operating at scale for 2 yr for the Zwicky Transient Facility Phase II community, with hundreds of users, containing tens of

A solution: SkyPortal

An all-in-one astronomical tool

- Receive large amounts of data concurrently -> **API-based system + Web client**
- Scan through incoming data streams -> **Candidates page & API**
- Visualize transients and trigger follow-up -> **Source(s) pages & API**

Skyportal ICARE for ACME

- Visualize multi-messenger events and plan observations -> **GCN(s) pages & API**
- Classify and report to the community -> **Integration with TNS**
- Work as a team, collaborate -> **Comment on important data products**
- Stay up to date -> **Real time & customizable notification system**

Skyportal ICARE for ACME (open source project)

Who ?

J. Bloom (founder, Berkeley)

M. Coughlin (manager, UMN)

T. Du Laz (Dvp, Caltech)

A. Le Calloch (Dvp)

S. Antier (ICARE scientist lead)

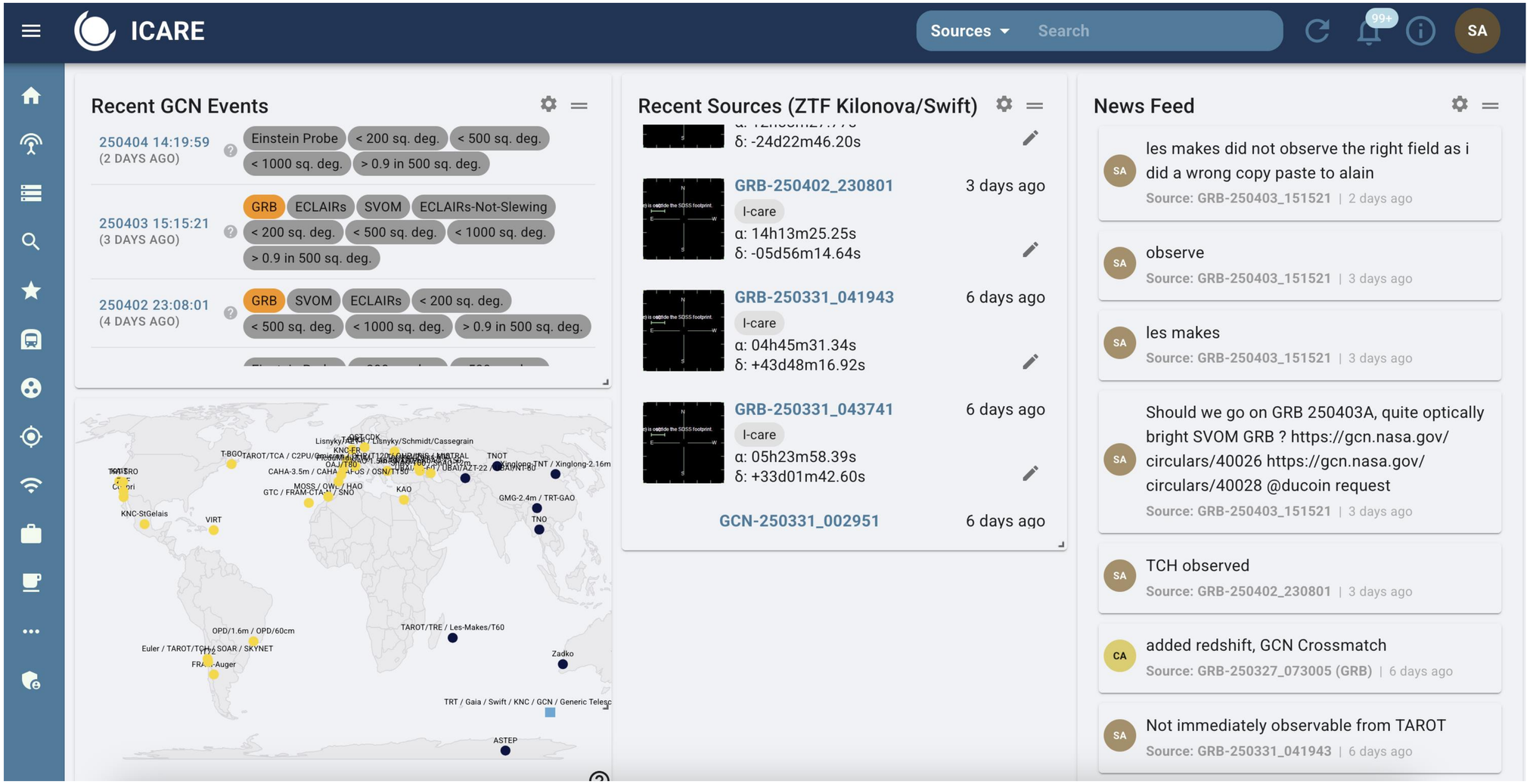
P. Hello (Host manager)

J. Peloton (Devp and security manager)

C. Douzet (ACME, dvp)

Joint supervision of students
2022 - 2023 : 10x2 ESILV students
2022/2024: T. Cullino, S. Clenet, T. Du Laz (6 months)
2024: A. Le Calloch, T. Bonzi, J. Di Basso (6 months)

Let’s take a quick look : Overview



Scientific results with the use of Skyportal Gravitational waves with NSBH DECAM, ZTF, GRANDMA

Limits on the Ejecta Mass and Binary Properties During the Search for Kilonovae Associated with Neutron Star-Black Hole Mergers: A case study of S230518h, GW230529, S230627c and the Low-Significance Candidate S240422ed

M. Pillas,[1,2] S. Antier,[1,3] K. Ackley,[4] T. Ahumada,[5] D. Akl,[6] L. de Almeida,[7] S. Anand,[5] C. Andrade,[8] I. Andreoni,[9] K. A. Bostroem,[10] M. Bulla,[11,12,13] E. Burns,[14] T. Cabrera,[15] S. Chang,[16] H. Choi,[16] B. O'Connor,[15] M. W. Coughlin,[8] W. Corradi,[7] A. R. Gibbs,[17] T. Dietrich,[18,19] D. Dornic,[20] J.-G. Ducoin,[20] P.-A. Duverne,[21] M. Dyer,[22] M. Fausnaugh,[23] Wen-fai Fong,[24] F. Foucart,[25] D. Frostig,[26] N. Guessoum,[6] Vaidehi Gupta,[8] P. Hello,[3] G. Hosseinzadeh,[10,27] L. Hu,[15] T. Hussenot-Desenonges,[3] M. Im,[16] R. Jayaraman,[23] M. Jeong,[16] V. Karambelkar,[28] M. Kasliwal,[28] S. Kim,[16] C. D. Kilpatrick,[29] N. Kochiashvili,[30] S. Karpov,[31] K. Kunnumkai,[15] M. Lamoureux,[32] C. U. Lee,[33] N. Lourie,[23] J. Lyman,[4] M. Mašek,[31] F. Magnani,[20] G. Mo,[23,34] M. Molham,[35] M. Nicholl,[36] A. H. Nitz,[37] F. Navarete,[38] K. Noysena,[39] D. O'Neill,[4] G. S.H. Paek,[16,40] A. Palmese,[15] R. Poggiani,[41] T. Pradier,[42] O. Pyshna,[43] Y. Rajabov,[44] J. C. Rastinejad,[24] D. J. Sand,[10] P. Shawhan,[45] M. Shrestha,[10] R. Simcoe,[23] S. J. Smartt,[16,36] D. Steeghs,[4] R. Stein,[47,48,49] H. F. Stevance,[46] M. Sun,[39] A. Takey,[35] A. Toivonen,[8] D. Turpin,[50] K. Ulaczyk,[4] A. Wold,[51] and T. Wouters[52,53]

Filter	0 - 1 day		1 - 2 day		2 - 6 day		Instruments
	% c.r	upper	% c.r	upper	% c.r	upper	
S230518h							
600 - 1000 nm	25%	16	25%	16	25%	16	TESS
R	21%	21.6	18%	21.6	-	-	GECKO
o-band	44%	17.9	-	-	25%	18.8	ATLAS
c-band	-	-	25%	19.5	47%	19.5	ATLAS
GW230529							
L-band	10%	19.7	2%	19.4	2%	19.2	GOTO
g-band	16%	20.6	-	-	-	-	ZTF
r-band	12%	20.6	-	-	-	-	ZTF
i-band	5%	20.1	-	-	-	-	ZTF
o-band	2%	17.8	4%	18.9	23%	17.6	ATLAS
S230627c							
L-band	45%	19.1	84%	19.0	23%	19.1	GOTO
g-band	88%	21	-	-	-	-	ZTF
R-band	4%	18.5	2%	20.7	2%	20.7	GRANDMA - GECKO
r-band	88%	21	-	-	-	-	ZTF
o-band	-	-	18%	18.6	17%	18.0	ATLAS
S240422ed							
g-band	53%	19.5	83%	19.7	<1%	22.5	GRANDMA, ZTF
L-band	96% %	19.1	96%	19.6	94%	20.1	GOTO
G-band	19% %	19.5	-	-	-	-	CSS/SAGUARO
R-band	69 %	16.7	67%	21.6	22%	21.3	GRANDMA - GECKO
r-band	86 %	23.15	90%	22.9	71 %	23.3	DECam, GRANDMA, ZTF
o-band	99%	18.9	7%	18.7	99 %	18.6	ATLAS
z-band	75%	22.6	81%	22.4	71%	23.0	DECam
J-band	16%	16.5	-	-	-	-	WINTER

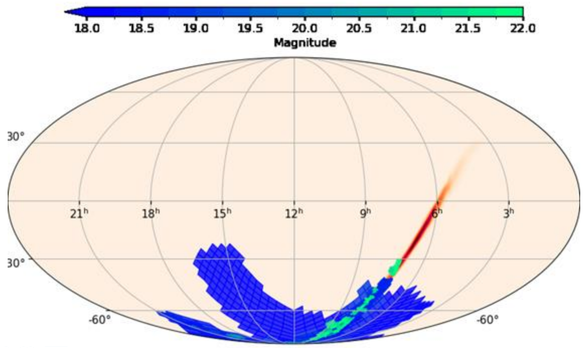
Meerlich, BlackGEM, Magellan

Summary of the coverage from 0 to 6 days post T0

S230518h

81% cr. coverage

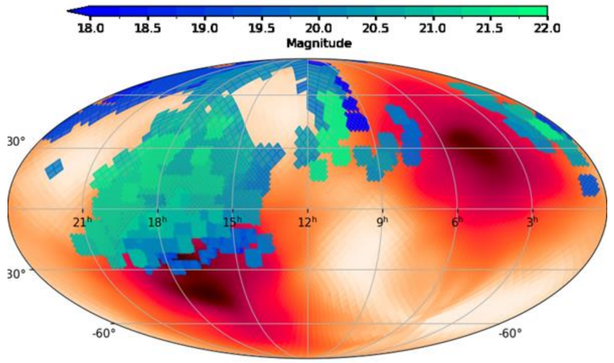
from 14.5 to 23.3 mag upper limit



GW230529

37% cr. coverage

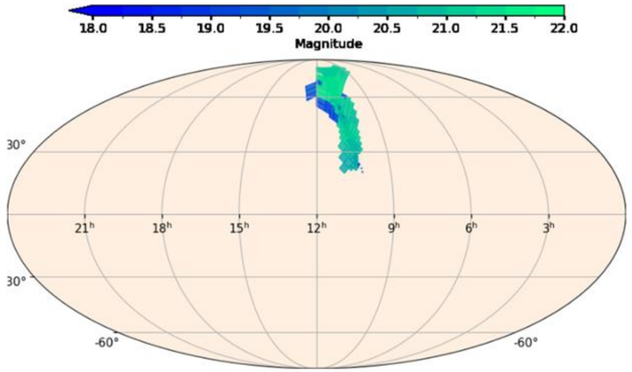
from 13.2 to 21.7 mag upper limit



S230627c

96% cr. coverage

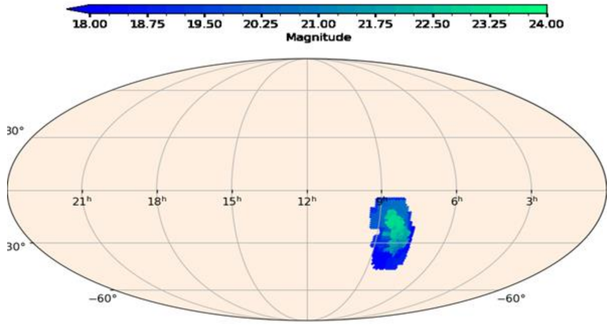
from 16.3 to 21.3 mag upper limit



S240422ed

> 99% cr. coverage

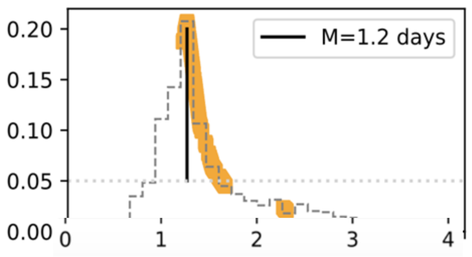
from 14.1 to 23.5 mag upper limit



Scientific results with the use of Skyportal Gravitational waves with NSBH
ZTF, GROWTH, GRANDMA, DECAM

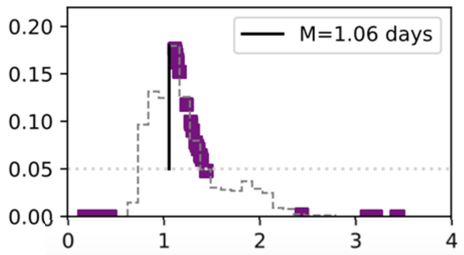
Fraction of the KNe from AnBulla2021 that peak at this time

i-band



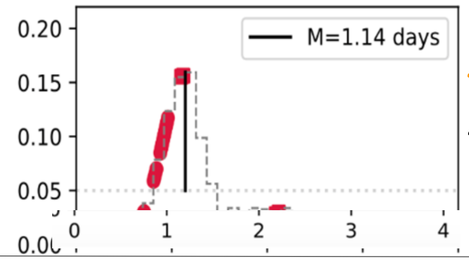
S230518h, 204 ± 57 Mpc, 460 deg2
44% of KN peaks cover in i-band

L-band



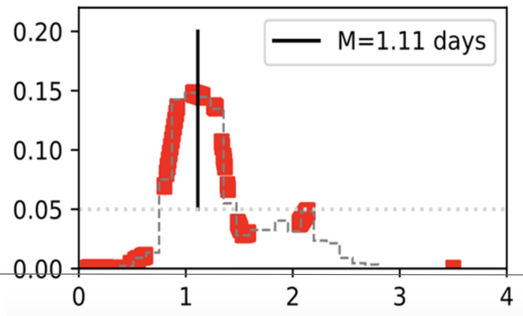
GW230529, 200 ± 100 Mpc, 24,100 deg2
44% of KN peaks cover in L-band

R-band



S230627c, 291 ± 64 Mpc, 82 deg2
26% of KN peaks cover in R-band

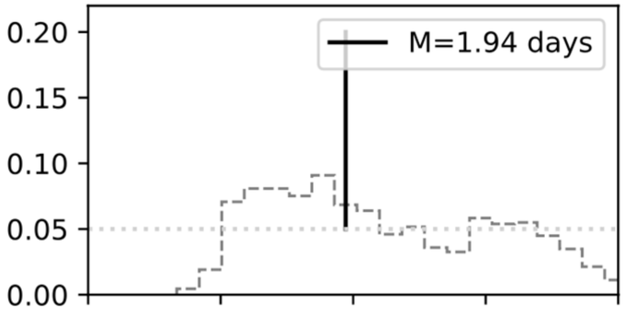
r-band



S240422ed, 190 ± 40 Mpc, 300 deg2
Astrophysical origin ?
82% KN peaks time cover in r-band

Time from merger [days]

J-band

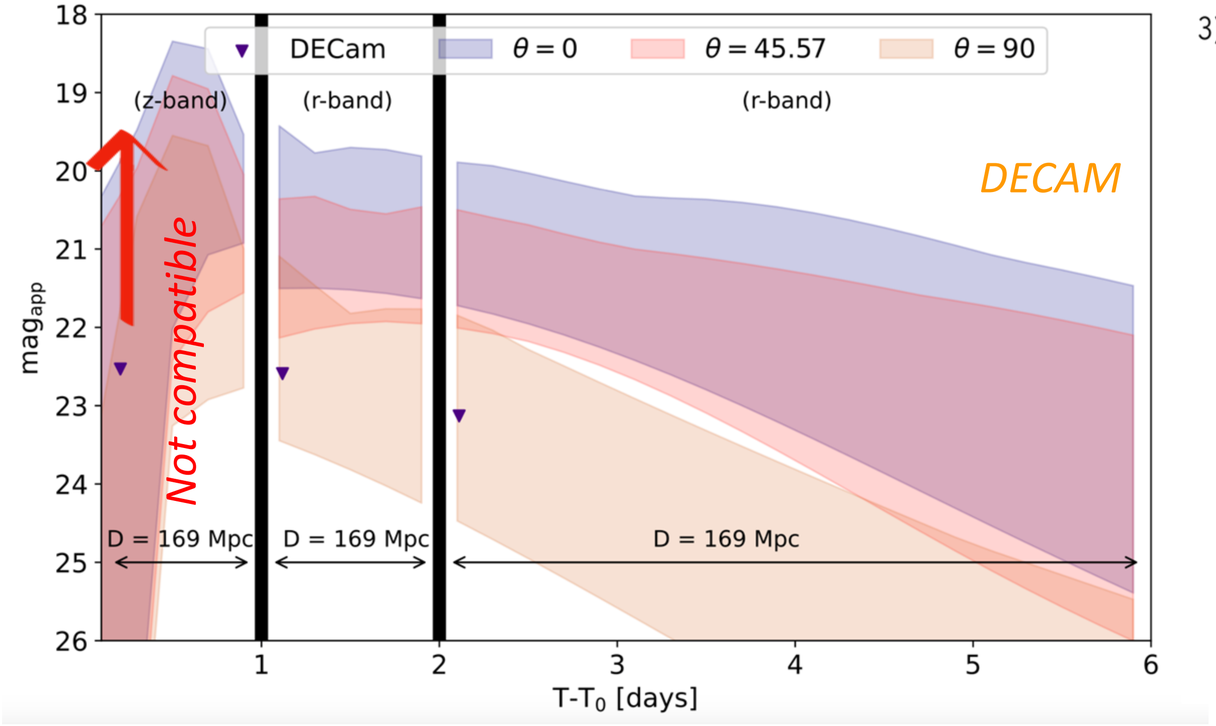


« Later time » strategy not always realized

We need image the first moment but **also the importance of imaging 1 day post-merger for NSBH**

Optical Follow-up of NSBH events : S240422ed : optimized Example

One mocked KN (ArnandBulla) projected at distance and T0 from S240422ed



Compare the magnitude of the LC with one optical obs

3) Compare the magnitude of the light curve (M_{KN}) with the one of optical observations (M_{obs})

- Compute the M_{app} of the kilonova light curves models for each pixel and at the corresponding distance
- Compare the brightness of the simulated kilonova with the upper limits of the fields that contains the pixel at the epoch of the field
- Compute a score representing the probability of the « presence » of a KN:

Time range of the observations that occurred at time $t \in \Delta t$ = [0,1[, [1,2[or [2,6[days

Synthetic KN from Bulla-Anand

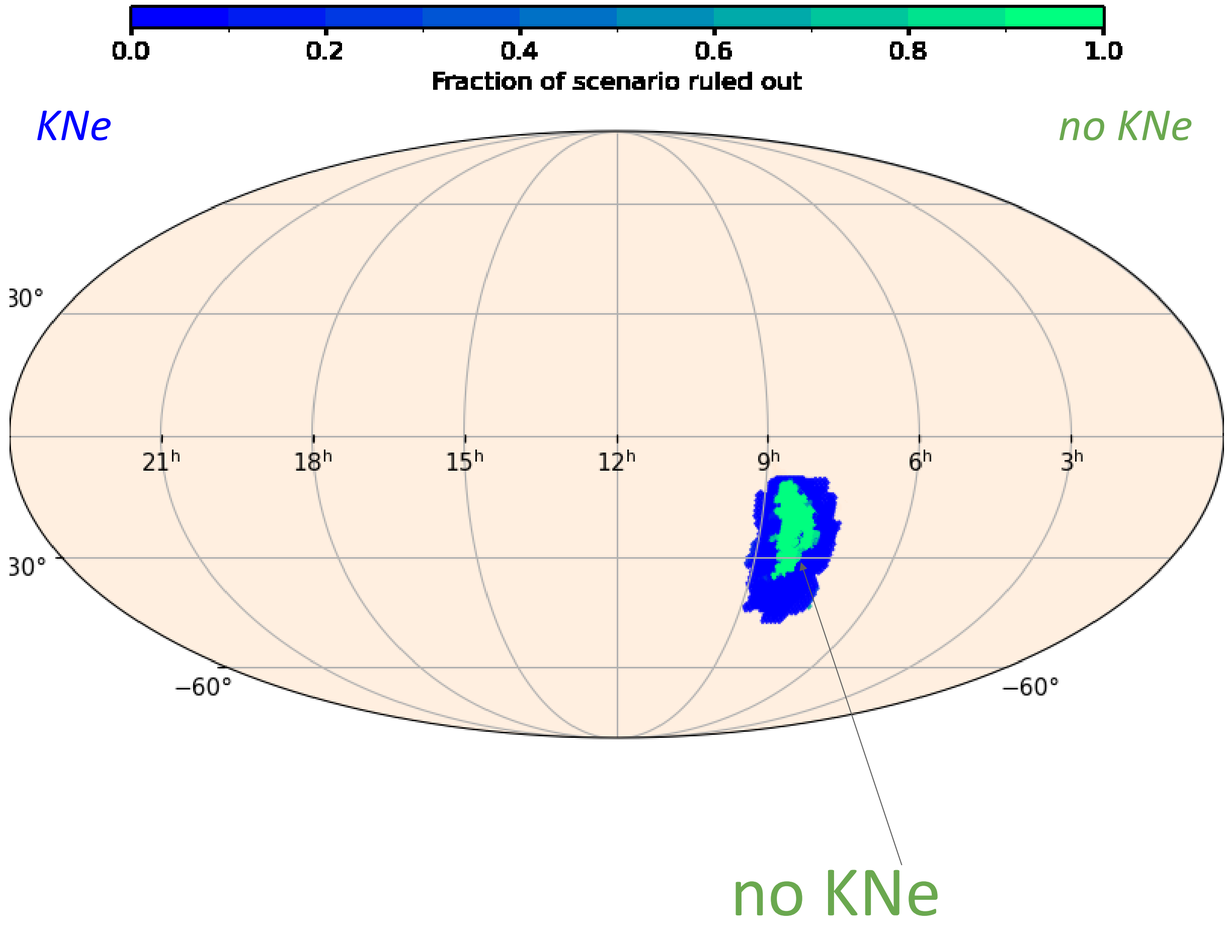
Filter

$$S_{KN,\Delta t,ipix} = \frac{1}{n_{tot,KN}} \times \sum_{k=1}^{n_{tot,KN}} \begin{cases} 1 & \text{if } M(fil, \theta, m_{dyn}, m_{wind}, t) > \text{mObs}(fil, t, ipix) \\ 0 & \text{otherwise} \end{cases}$$

Total number of synthetic kilonovae from the grid considered for each event

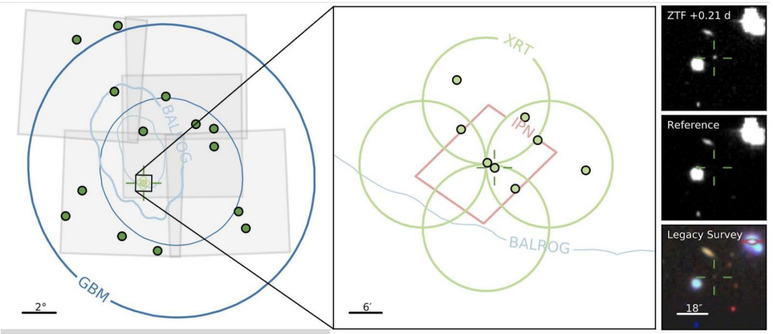
Telescope observation

Optical Follow-up of NSBH events : S240422ed : optimized Example



Observations taken one day after S240422ed ruled out Totally Kne Signal in sky coverage of 180 deg2 from NS-BH mergers

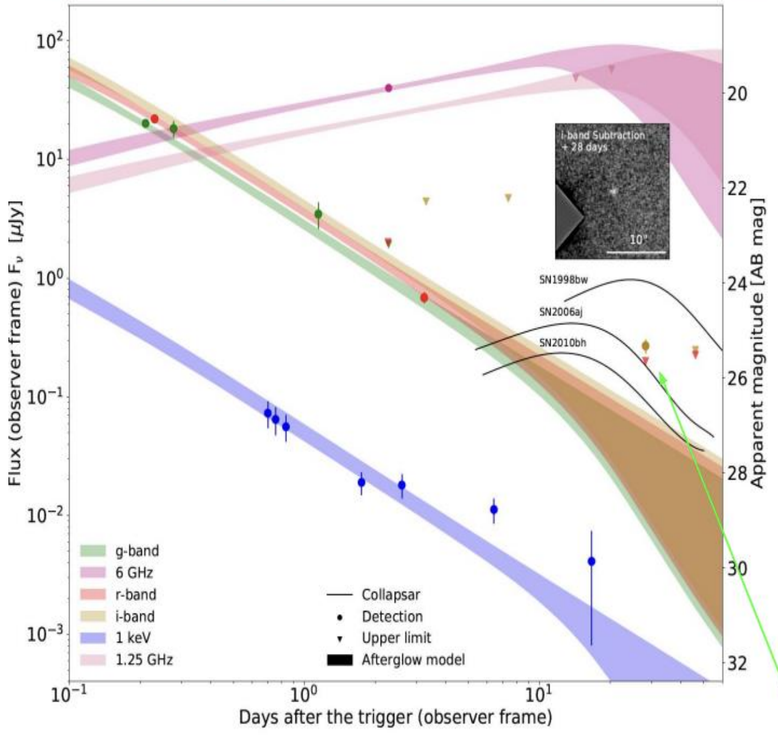
GRB Optical Counterpart discovery



GRB200826A 90% ~250 sq. degrees

Ahumada et al. 2021

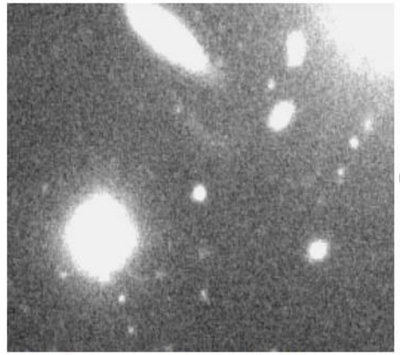
Discovery paper Ahumada et al. 2021, arxiv:2105.05067



afterglowpy Ryan et al. 2021
Inference pipeline Dietrich et al. 2020

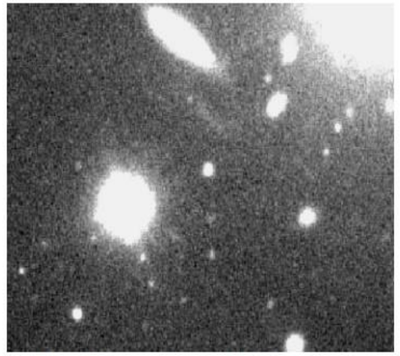
The 'shortest' collapsar ~ 0.6s T90 rest-frame

Science Sept. 23



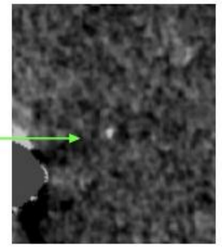
~28 days after GRB

Reference Oct. 10

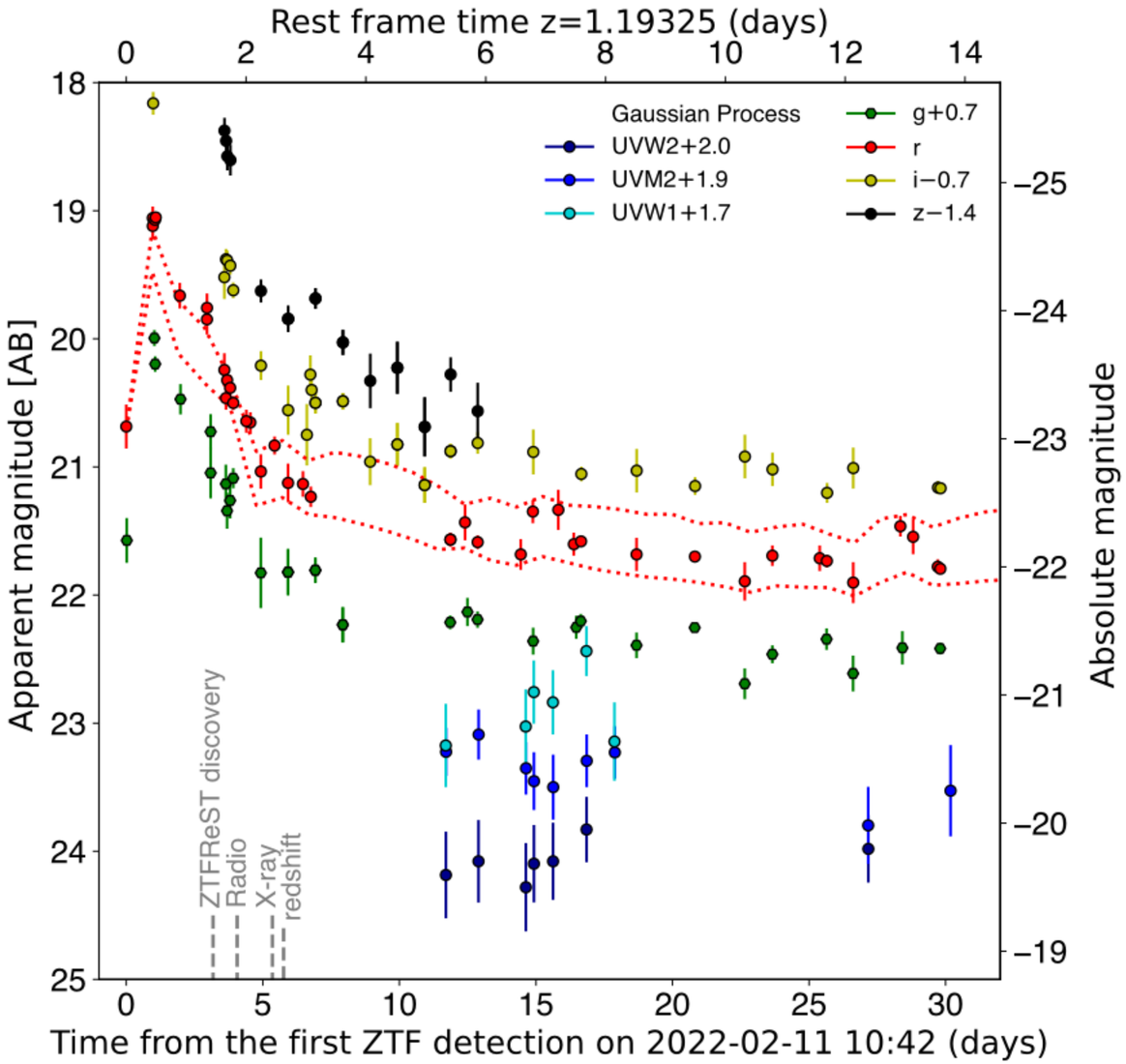


~45 days after GRB

i-band = 25.45 mag



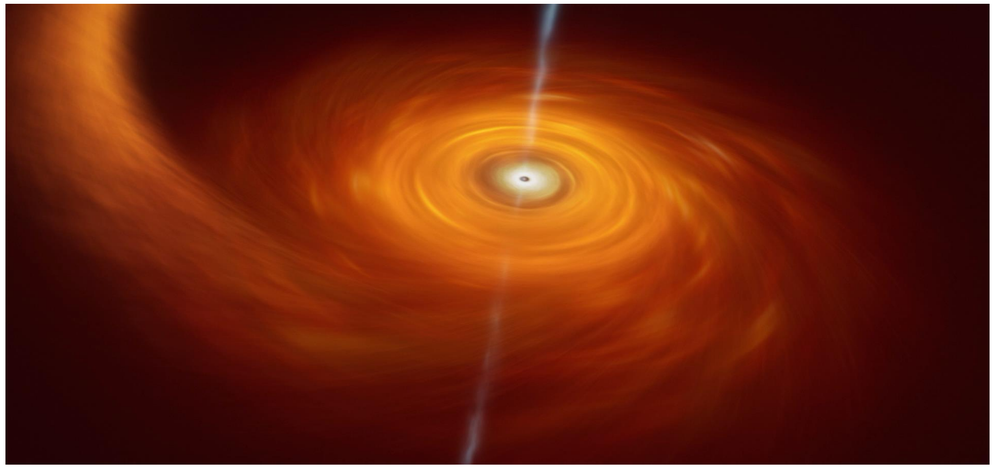
(jetted) TDE discovery



A couple of fun facts:

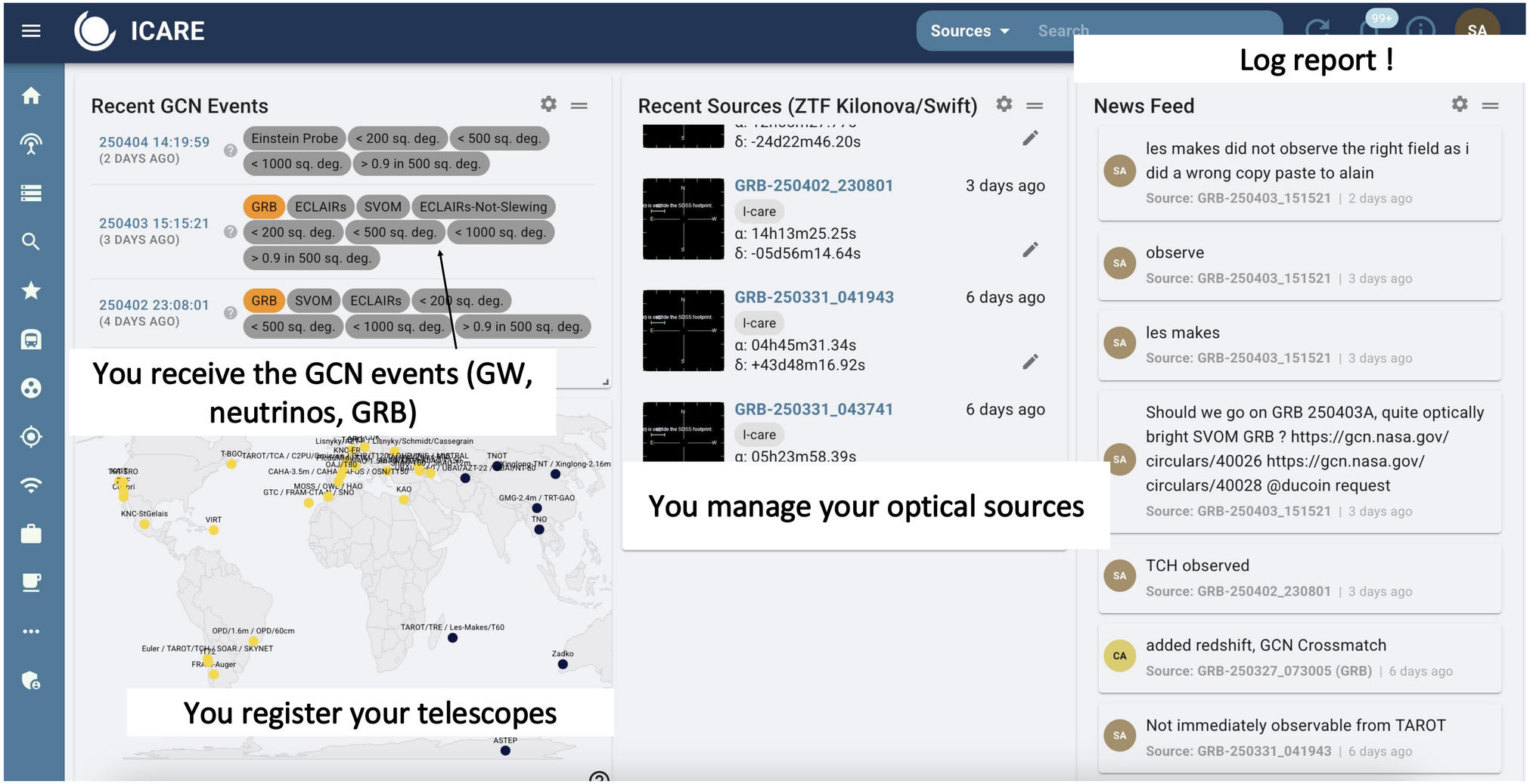
❖***First*** relativistic TDE identified in near real time by an optical survey

❖***Furthest*** TDE ever found



Andreoni & Coughlin et al. (2022), Nature, 612, 7940

Let’s take a quick look

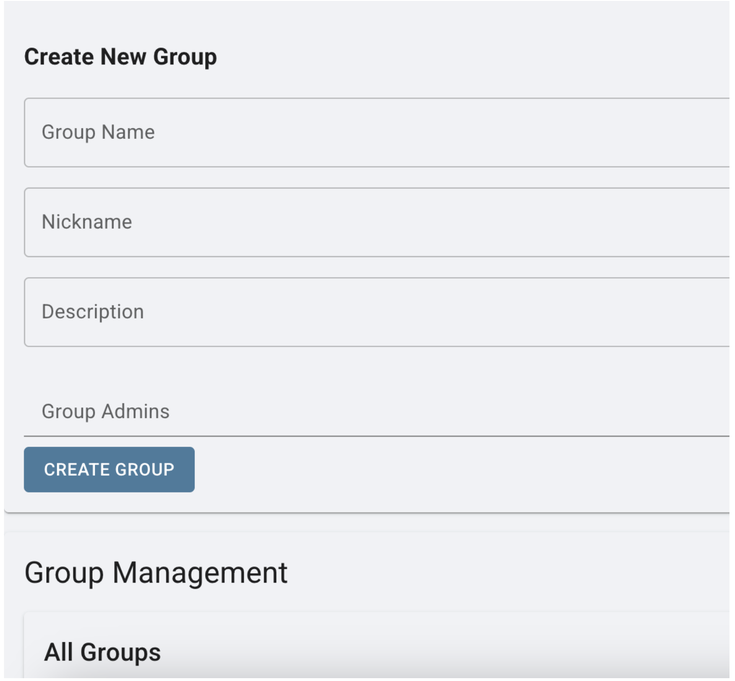


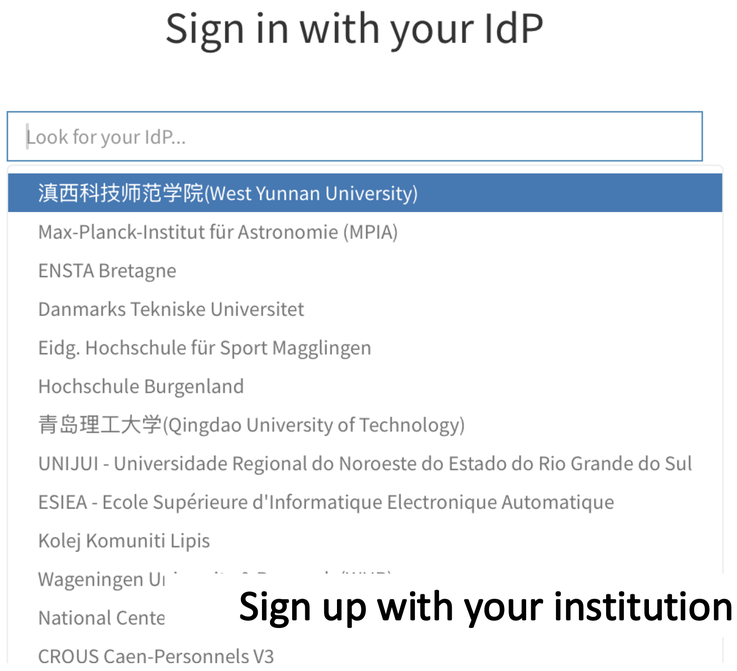
Skyportal for ACME

We will provide access to ICARE to all ACME proposants

It will guarantee privacy and but also sharing among groups and individuals

Part of the grant is devoted to profile and customization for ACME





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ICARE

Sources Search

Today | Back | Next

April 06 – 12

Month | Week | Work Week | Day | Agenda

	06 Sun	07 Mon	08 Tue	09 Wed	10 Thu	11 Fri	12 Sat
12:00 AM	– 3:59 AM kilonova 3/7 GRANDMA	– 3:59 AM kilonova 4/7 GRANDMA	– 3:59 AM kilonova 5/7 GRANDMA	– 3:59 AM kilonova 6/7 GRANDMA	– 3:59 AM kilonova 7/7 GRANDMA	– 3:59 AM supernova 1/6 GRANDMA	– 3:59 AM supernova 2/6 GRANDMA
2:00 AM							
4:00 AM	4:01 AM – 11:59 kilonova 3/7 GRANDMA	4:01 AM – 11:59 kilonova 4/7 GRANDMA	4:01 AM – 11:59 kilonova 5/7 GRANDMA	4:01 AM – 11:59 kilonova 6/7 GRANDMA	4:01 AM – 11:59 kilonova 7/7 GRANDMA	4:01 AM – 11:59 supernova 1/7 GRANDMA	4:01 AM – 11:59 supernova 2/7 GRANDMA
6:00 AM							
8:00 AM							
10:00 AM							
12:00 PM	12:01 PM – 7:59 kilonova 4/7 GRANDMA	12:01 PM – 7:59 kilonova 5/7 GRANDMA	12:01 PM – 7:59 kilonova 6/7 GRANDMA	12:01 PM – 7:59 kilonova 7/7 GRANDMA	12:01 PM – 7:59 supernova 1/7 GRANDMA	12:01 PM – 7:59 supernova 2/7 GRANDMA	12:01 PM – 7:59 supernova 3/7 GRANDMA
2:00 PM							
4:00 PM							
6:00 PM							
8:00 PM	8:01 PM – kilonova 4/7 GRANDMA	8:01 PM – kilonova 5/7 GRANDMA	8:01 PM – kilonova 6/7 GRANDMA	8:01 PM – kilonova 7/7 GRANDMA	8:01 PM – supernova 1/6 GRANDMA	8:01 PM – supernova 2/6 GRANDMA	8:01 PM – supernova 3/6 GRANDMA
10:00 PM							

Show All Shifts

Sort By Group(s)

shifts

AD

Grou

AM

Shi

Nu

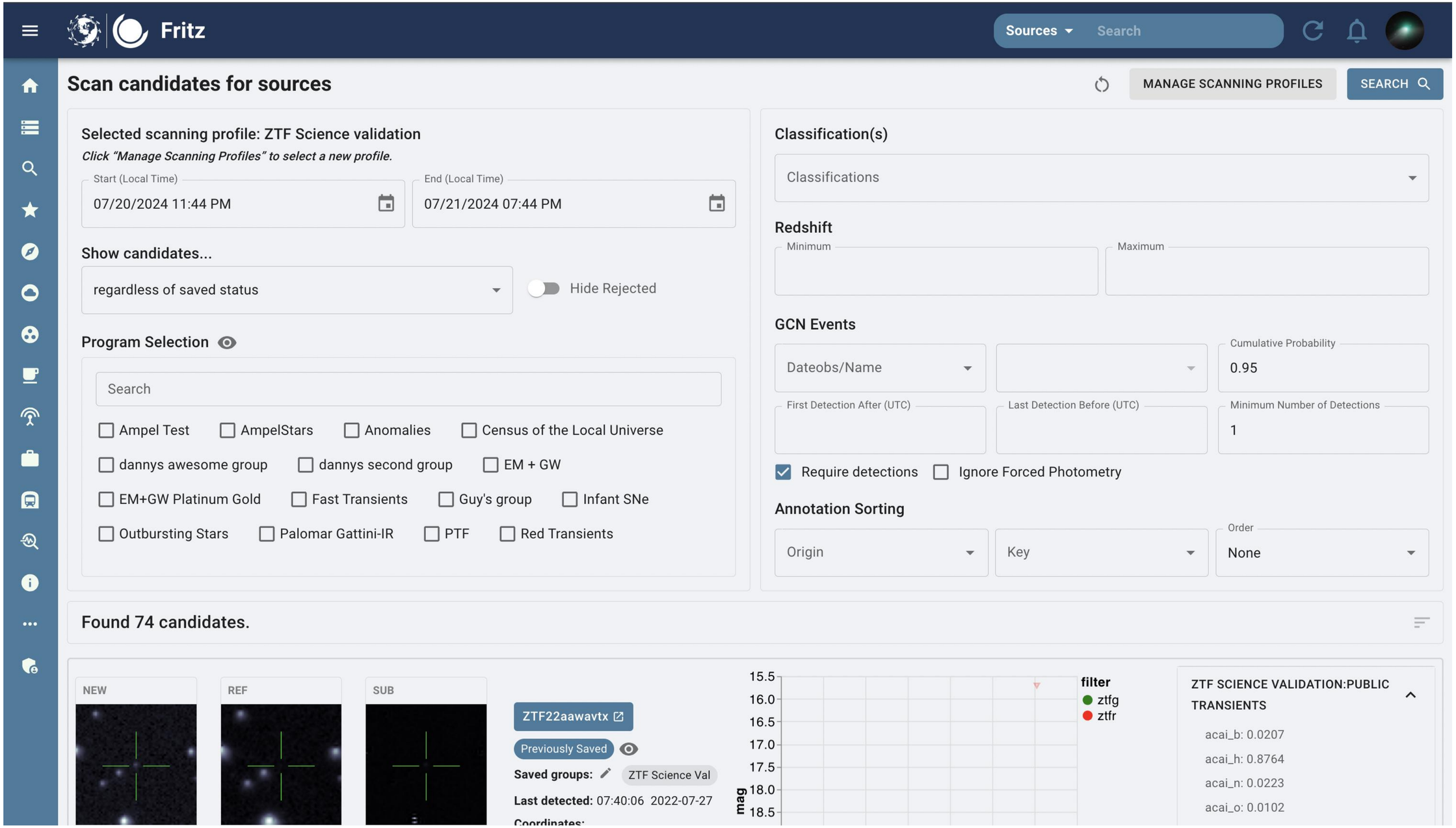
Shi

Do yo daily

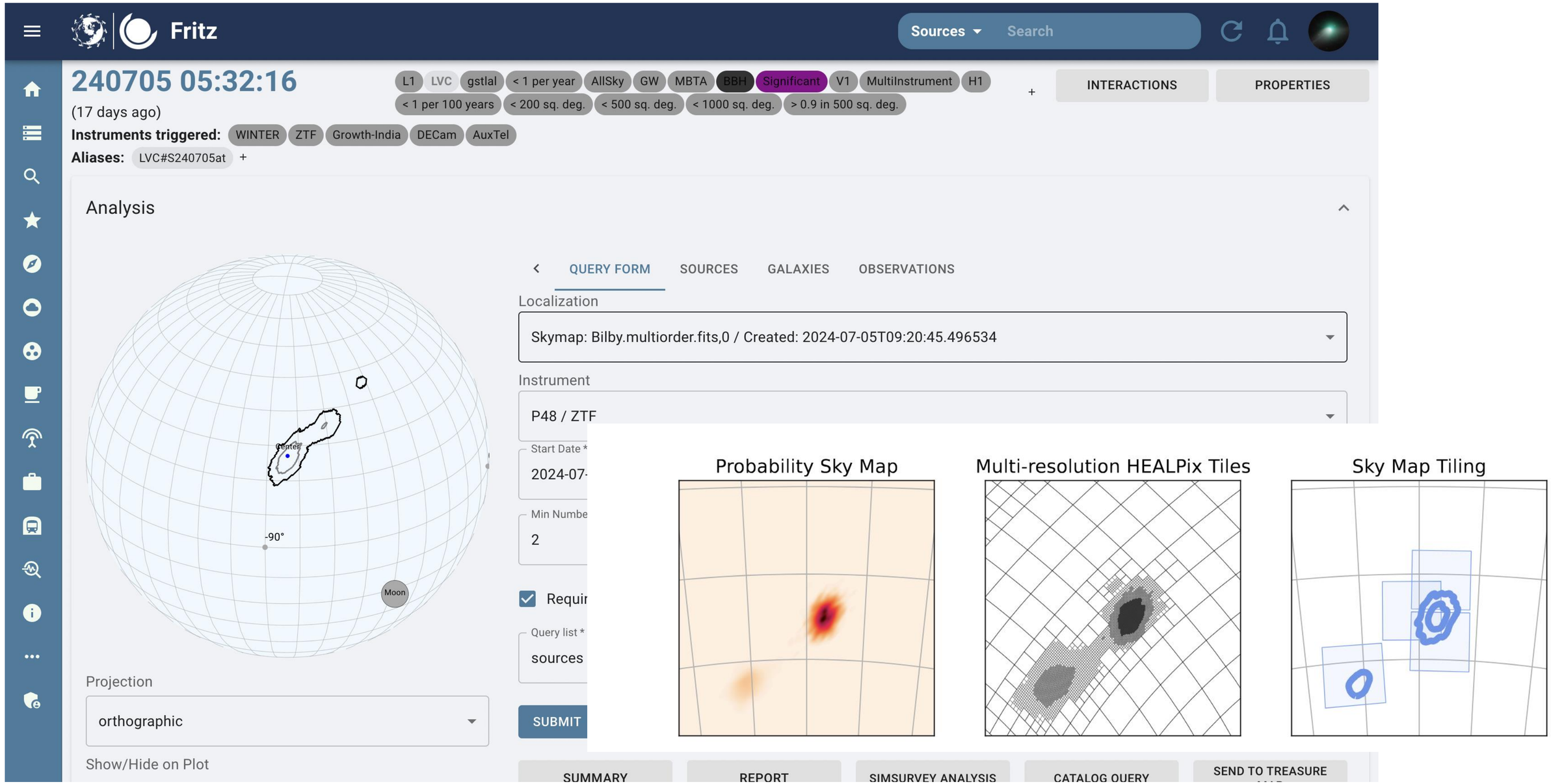
Use

Loc

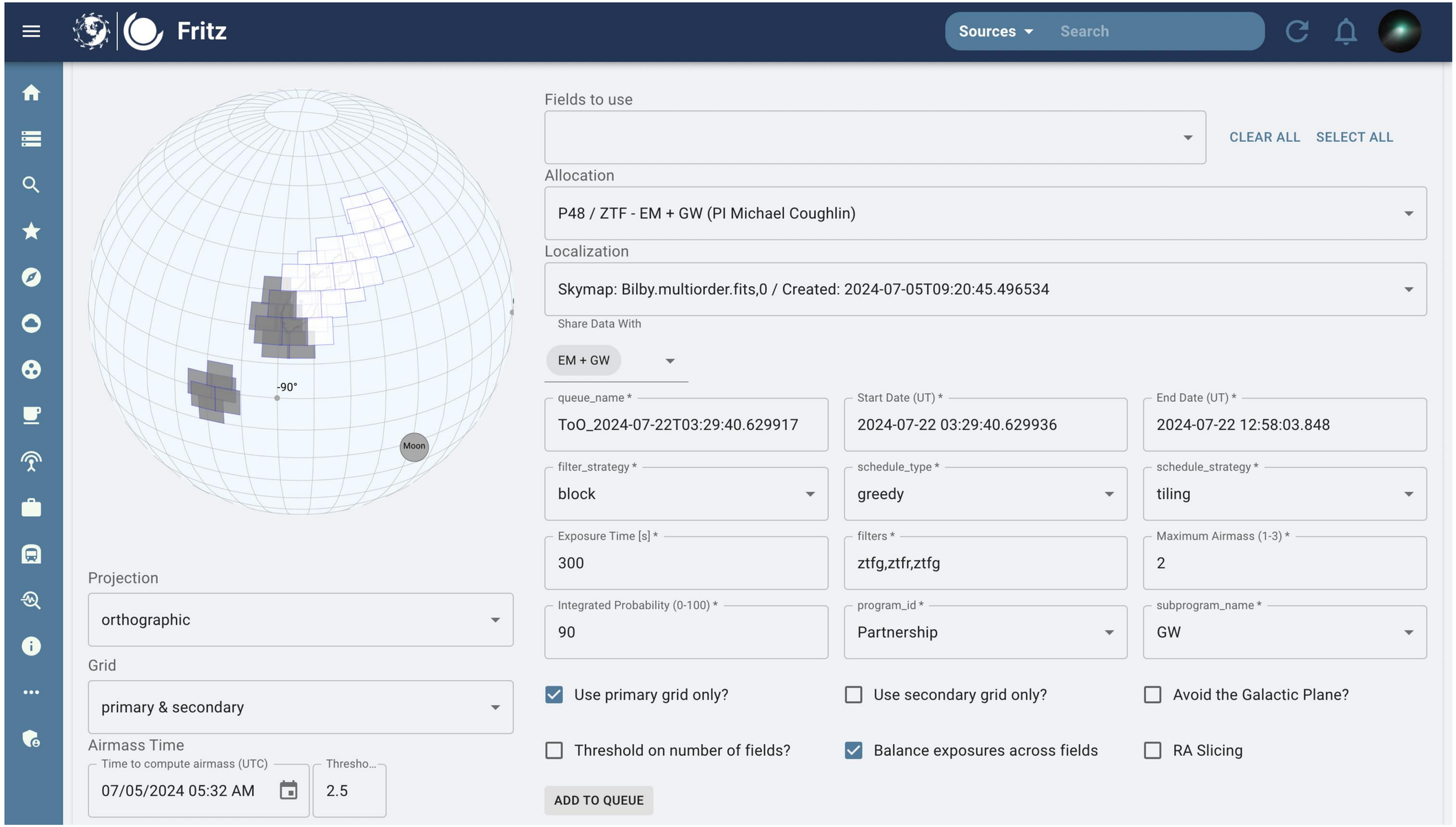
Microsoft Au



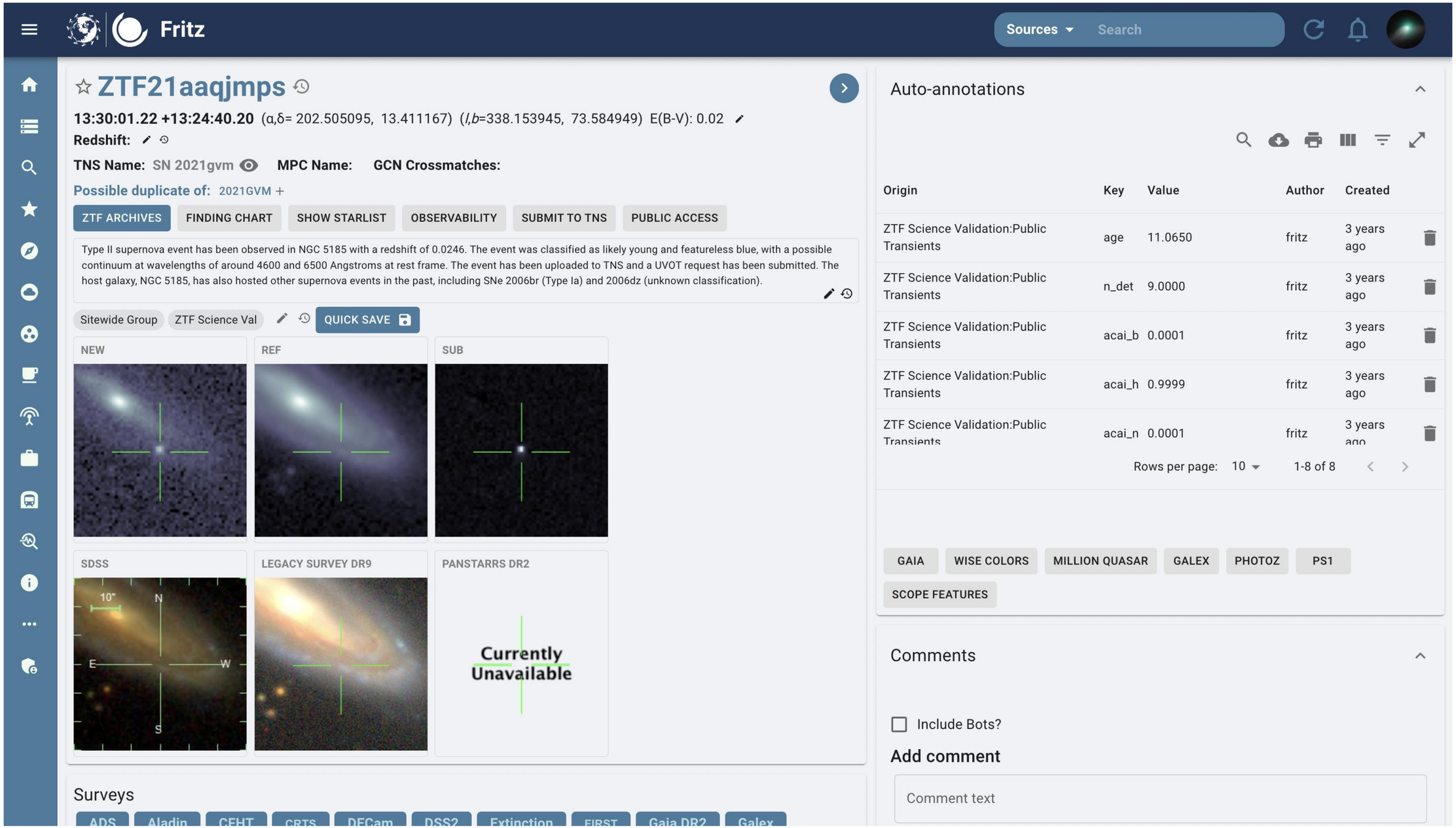
Candidates scanning page



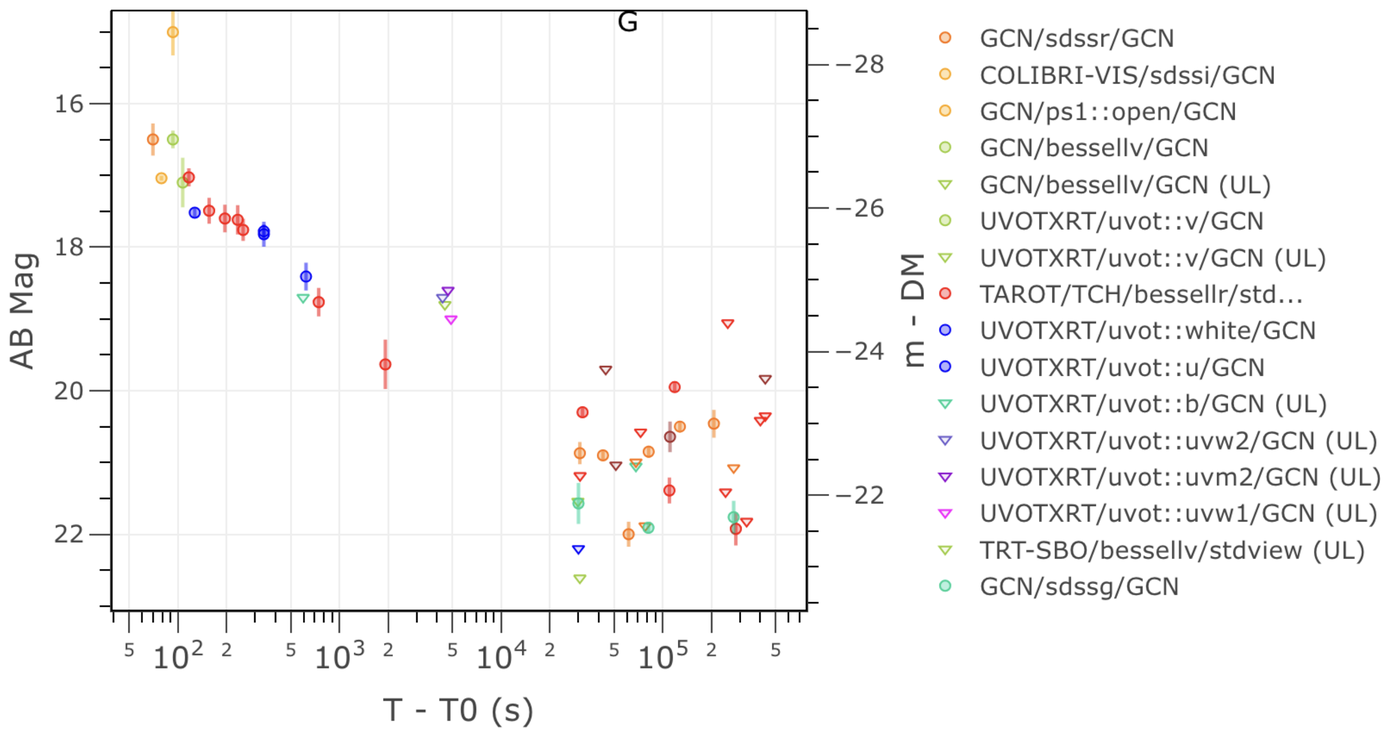
GCN page: overview



GCN page: Observation plan



Manage the source(s) **pages**



Non-Detections

Forced Photometry

X axis since T0

T - T0 in log

Marker Size

6

Centroid Plot

Offsets from nearest sources in reference catalogs:

TNS: 0.06"

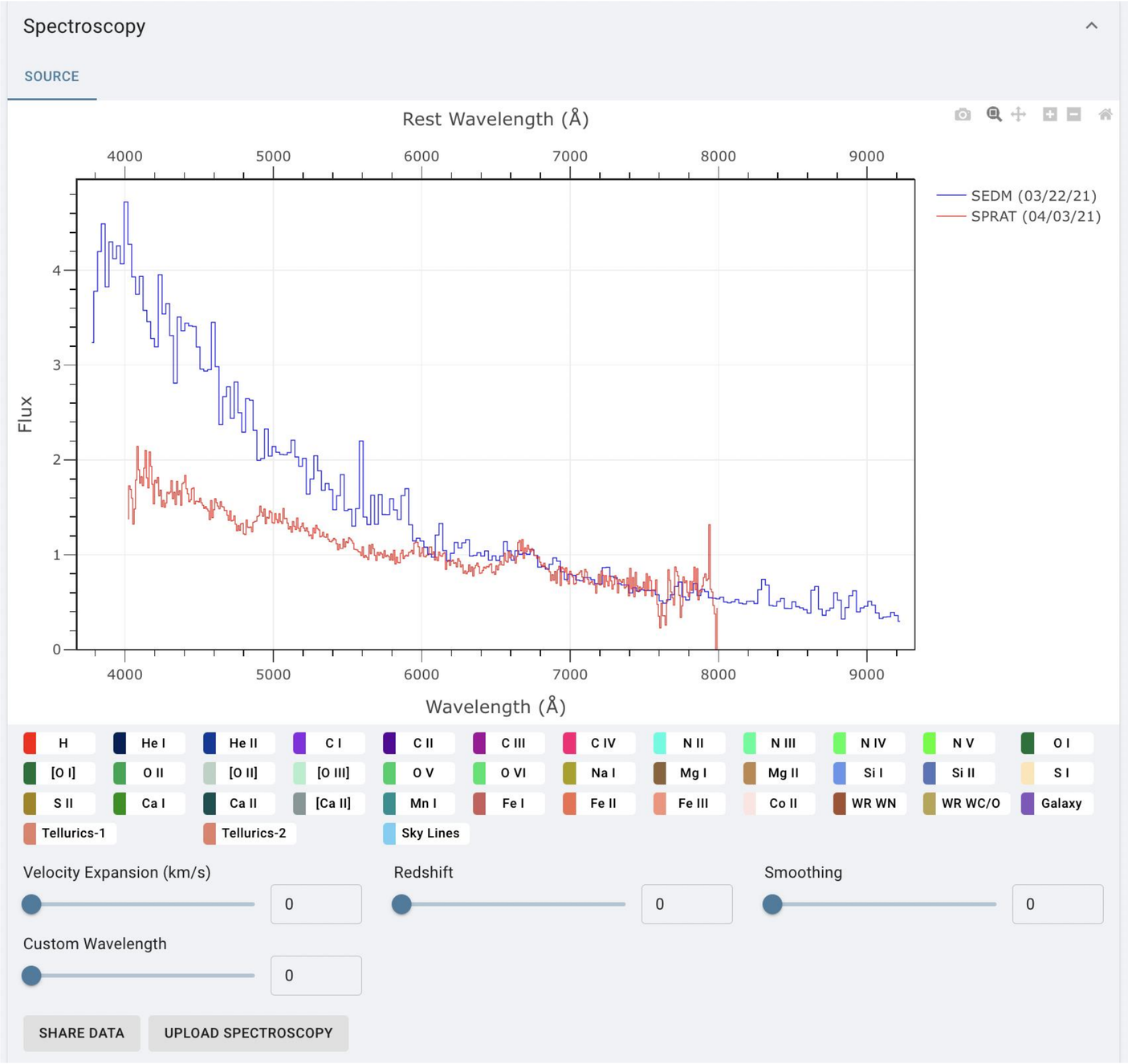
PS1_DR1: 7.48"

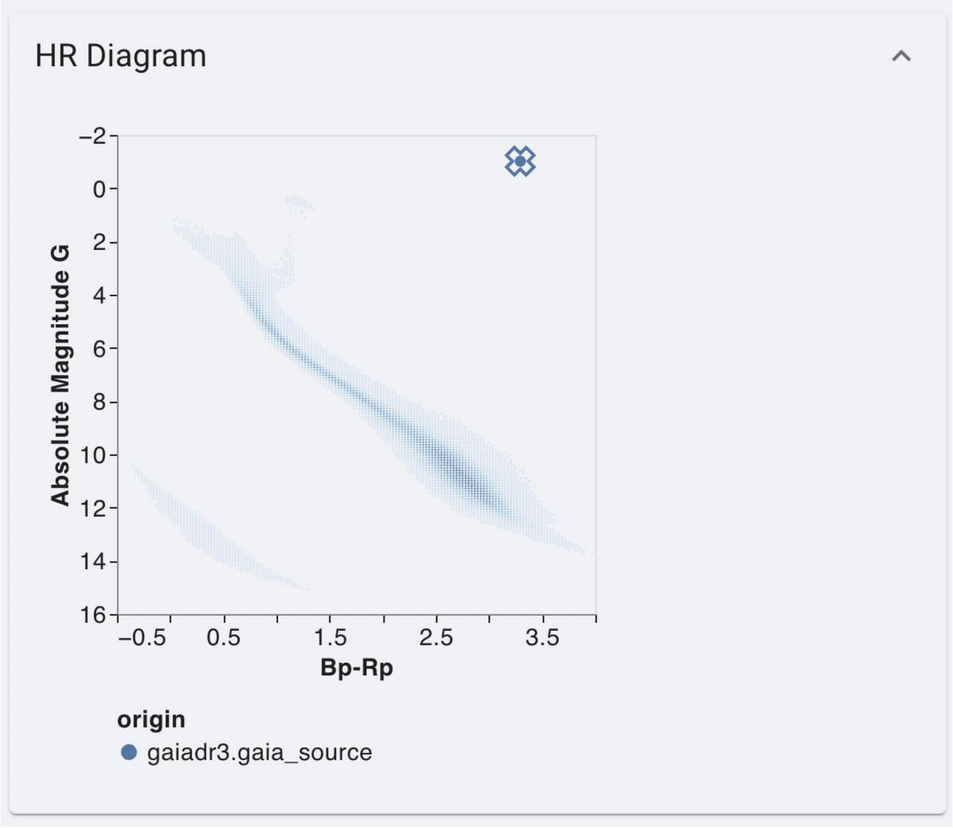
ADD LOG VIEW !
Possibility to share results outside with public pages !

Manage the source(s) pages

Trigger automatically
Telescopes

Manage the source(s) pages





Source(s) pages
Spectroscopy

Candidates scanning page

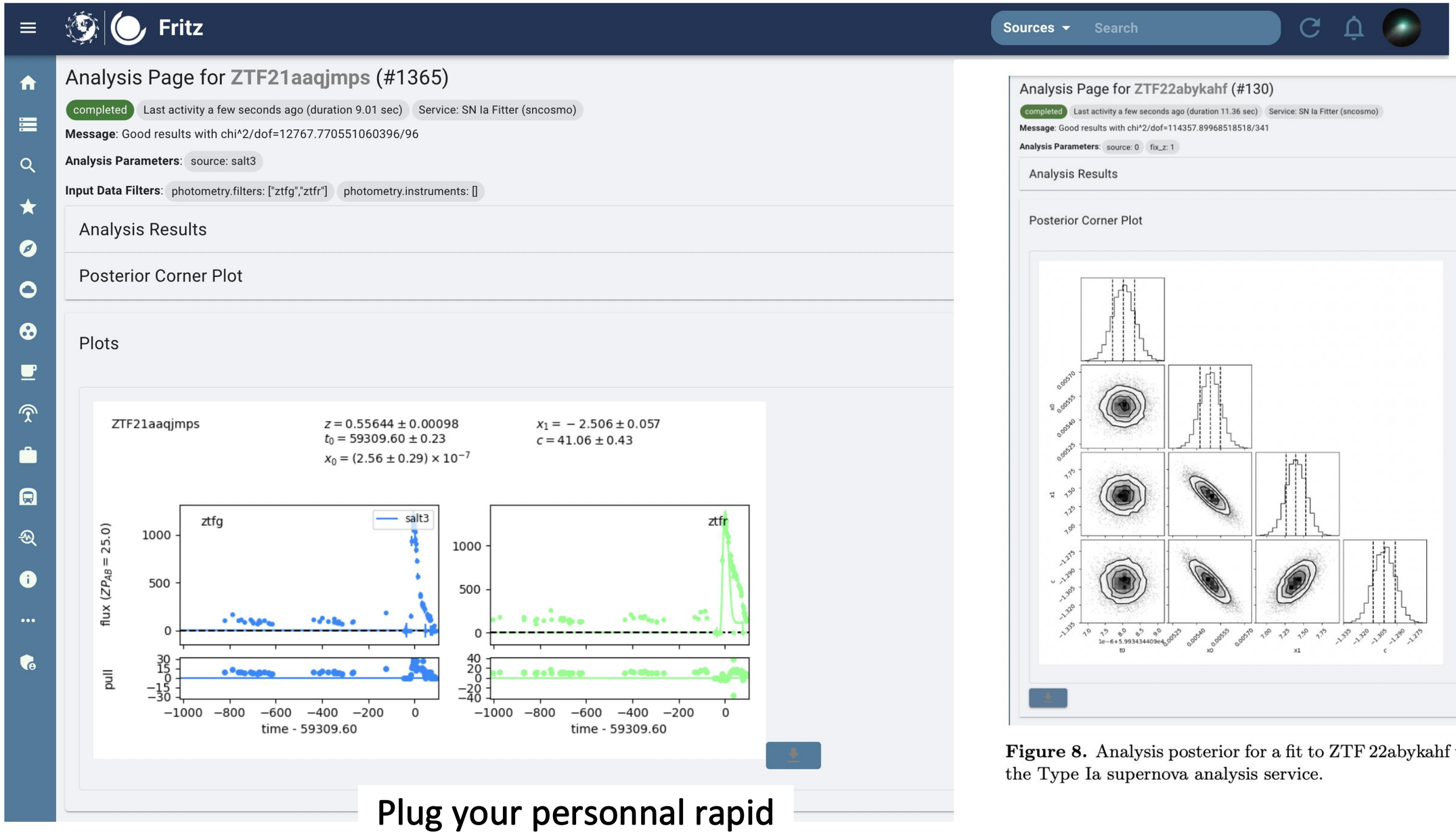
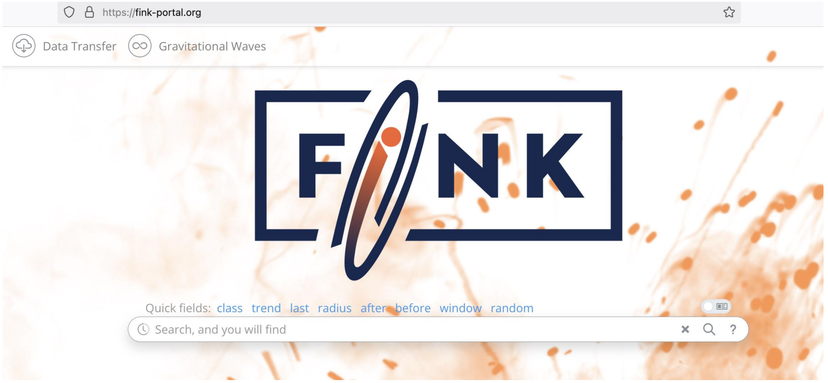


Figure 8. Analysis posterior for a fit to ZTF 22abykahf with the Type Ia supernova analysis service.

Plug your personnal rapid analysis

Source Analysis page

Integration and preparation of LSST / KM3NET



+

GRANDMA

And other partners

+

Skyportal

Who would like to collaborate with us in this new Time domain Poésie ?