The MM astronomy in the FINK era

The goal of the MM astronomy

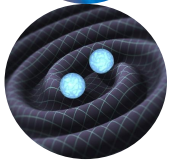
Each astro. messenger catches **unique** and/or **complementary information** about the physics of the most extreme phenomena in the Universe

Combining them is the key to have access to the “true picture” of such events:

- GW give us insights into the extreme properties of BH/NS objects and the pre-merger system
- the astroparticles (and especially the neutrinos) give us insights into the physics where the radiation is fully coupled and trapped by dense matter (early stages of explosion/acceleration mechanisms)
- the light tells us a lot about the transient environment, the nature of the radiating/absorbing chemical elements and the explosive mechanisms

The potential targets for the MM astronomy

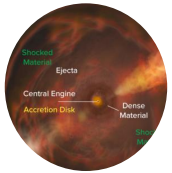
The high energy transient sky



CO merger & KN

SNe

GRB

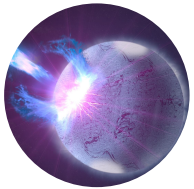


FBOT?

The high energy flaring sky

AGN/Blazars

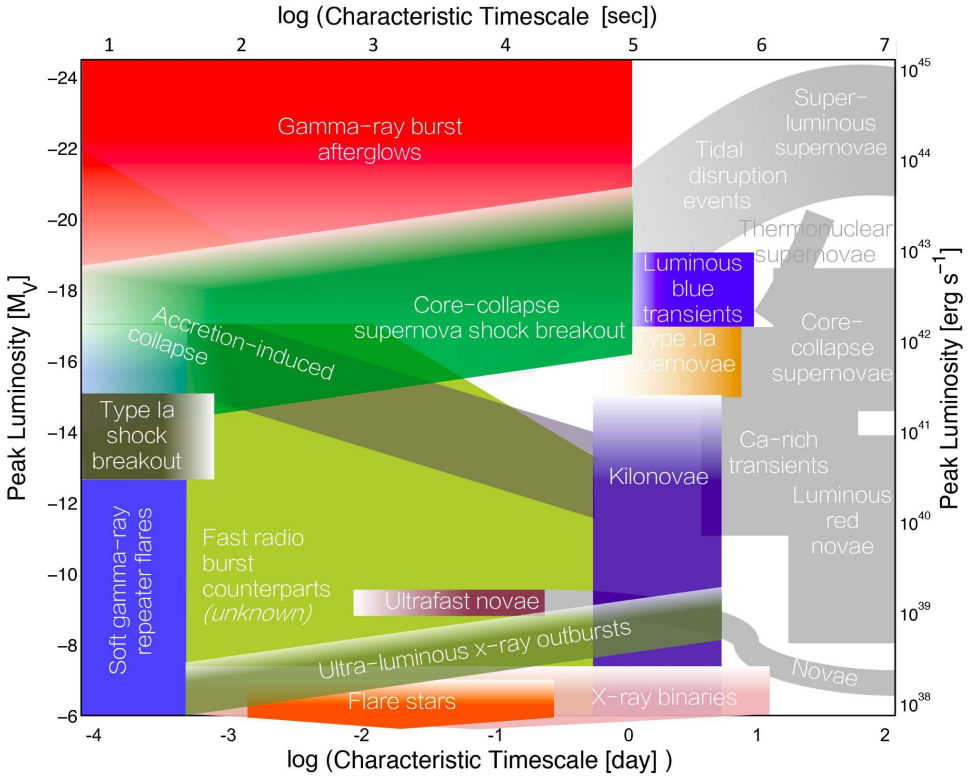
X-ray binaries



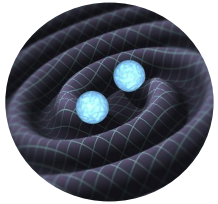
magnetars

The potential targets for the MM astronomy

Very different energy output and timescales!



The alert provider landscape of the next decade



LIGO / Virgo / KAGRA and upgrades for O5 and beyond

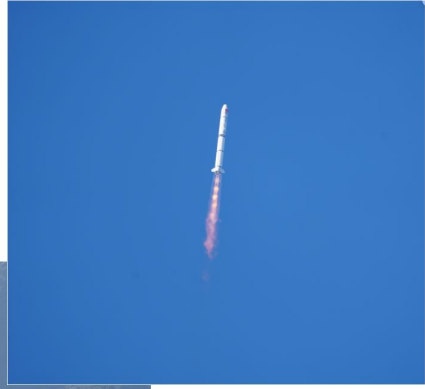
KM3NeT, IceCube (-gen2?), Super-Kamiokande

CTA?, LHASSO?, Hawk, Swift, **Fermi**, Gecam, Einstein Probe, SVOM, **VRO**, GOTO, **WFST?**, SKA?

Note that most of the alert providers are also a follow-up facility! This will make the number of published GCN notices/circulars to explode

Breaking news!

Yesterday at 8h20 (Beijing local time)
The Einstein Probe x-ray satellite was successfully launched!!!



CTA?, LHASSO?, Hawk, Swift, **Fermi**, Gecam, Einstein Probe, SVOM, **VRO**, GOTO, **WFST?**, SKA?

Breaking news!

There is a “new ZTF” in China

(science operations have started a month ago)

https://wfst.ustc.edu.cn/
https://arxiv.org/abs/2306.07590
https://gcn.nasa.gov/circulars/34979

CTA?, LHASSO?, Hawk, Swift, **Fermi**, Gecam, Einstein Probe, SVOM, **VRO**, GOTO, **WFST?**, SKA?

The MM astronomy challenges in a nutshell

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Transient source detection with 1 messenger

↓

Ex: 1 HE neutrino gold class from KM3NeT

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(live and archival detections)

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Follow-up campaign organization

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Ex: Generate an GCNC and ask for follow-up with instructions if needed. Keep in touch with other teams

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Joint publications

↓

Ex: Collect all data and start a MM analysis in collab. with external teams

Can FINK play a role in this game?

The answer is yes! What do we have? What more do we need?

1	2	3	4	5
Transient source detection with 1 messenger	**Crossmatch with other messengers** (live and archival detections)	**Classification and follow-up interest**	**Follow-up campaign organization**	**Joint publications**
	FINK	FINK	FINK	FINK
			TOM TOOLKIT	

What do we have? What more do we need?

Crossmatch with other messengers
(live and archival detections)

What we already have

- The *fink-MM* module: GCN notices (GW, Swift, Fermi, IC) crossmatched with the VRO stream (online and offline)
- The *fast transient* module (mag rate computation)
- The Simbad galaxy crossmatch
- The GW crossmatch service accessible in what we used to call the Fink science portal (RIP)

filter and sub-streams

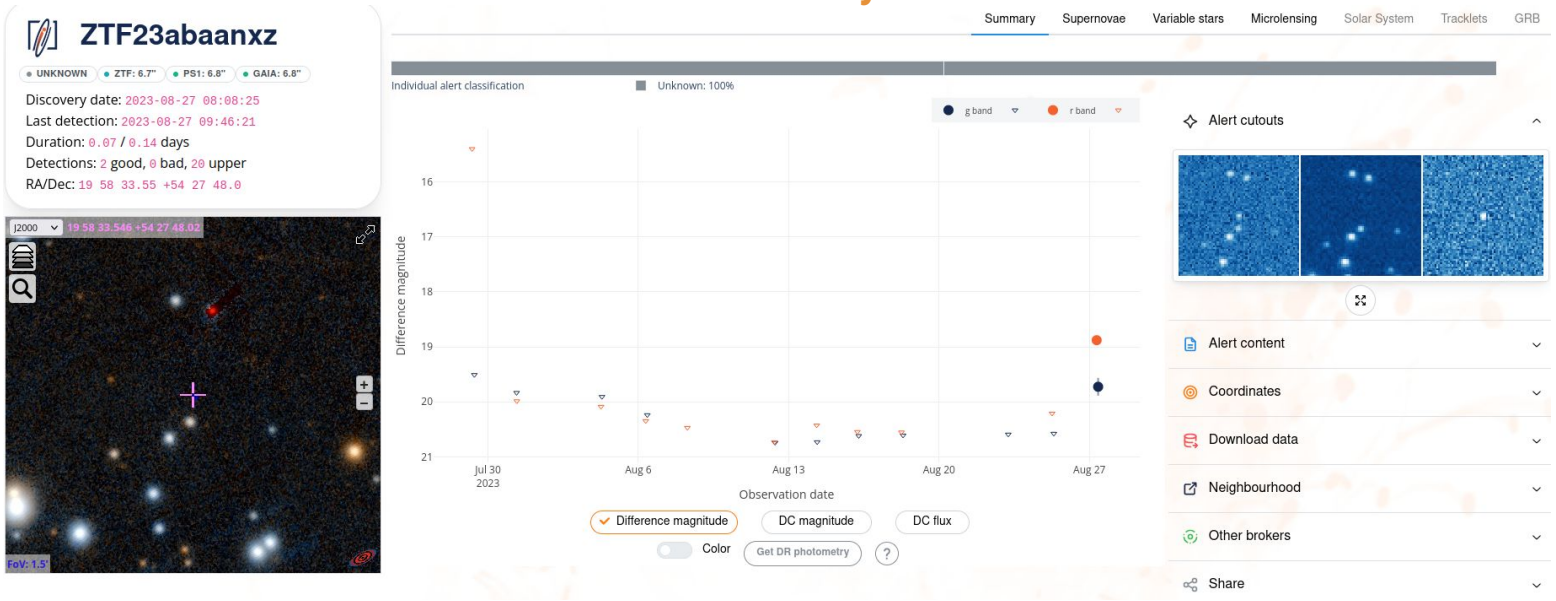
Topic Name	Description
--- GRB Filter ---	
fink_grb_bronze	Alerts with a real bogus (rb) >= 0.7, classified by Fink as an extra galactic events within the error location of a GRB event.
fink_grb_silver	Alerts satisfying the bronze filter with a grb_proba >= 5 sigma.
fink_grb_gold	Alerts satisfying the silver filter with a mag_rate > 0.3 mag/day and a rb >= 0.9.
--- GW Filter ---	
fink_gw_bronze	Alerts with a real bogus (rb) >= 0.7, classified by Fink as an extra galactic events within the error location of a GW event.

What do we have? What more do we need?

Crossmatch with other messengers

(live and archival detections)

Anomaly ?



What do we have? What more do we need?

Crossmatch with other messengers

(live and archival detections)

GRB 230728B detected ~2h prior to this ZTF/Fink candidate, fast rising (-0.7 mag/day), red color, z=0.88, we have a GRB afterglow here!

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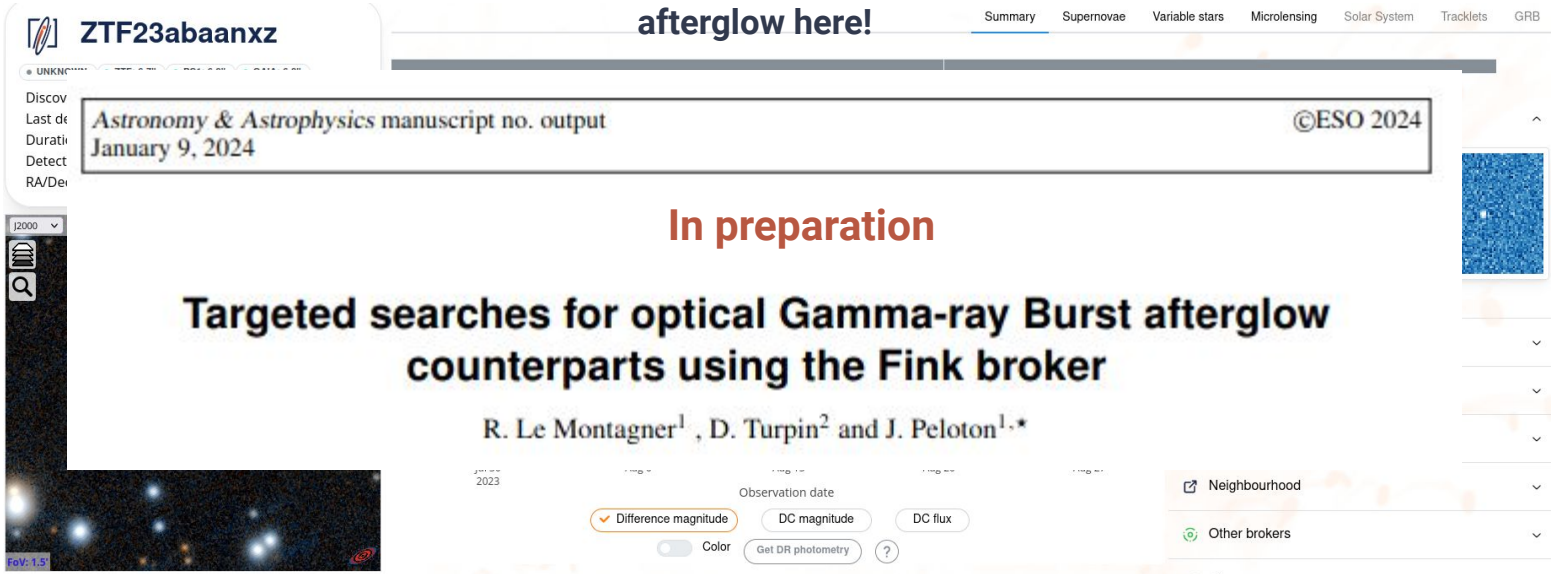


What do we have? What more do we need?

Crossmatch with other messengers

(live and archival detections)

What more do we need?

- Matches with more notices stream or make joint with more streams?
- Slack bot for MM associations with the VRO stream (a null result is also an information)
- Flag in the VRO alert that it is compatible in time and space with a (validated) MM source (science case dependent…)
- Matches with more catalogs for specific MM science cases? catalogs to be defined
- A SNIb/c classifier for long GRBs association
- other ideas….?

What do we have? What more do we need?

Classification and follow-up interest
(for VRO optical transient sources)

What we already have

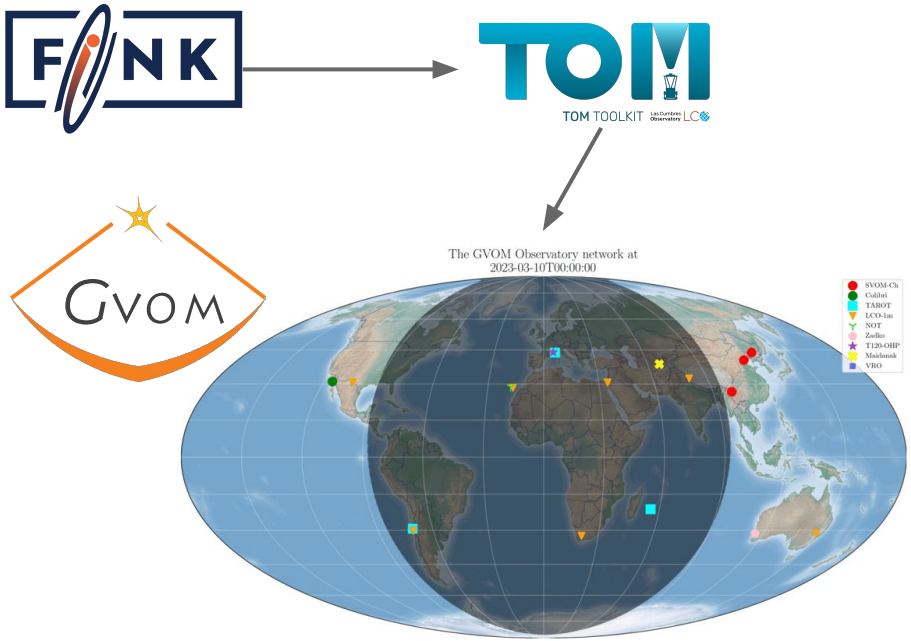
- All the FINK classifiers to filter out unrelated alerts

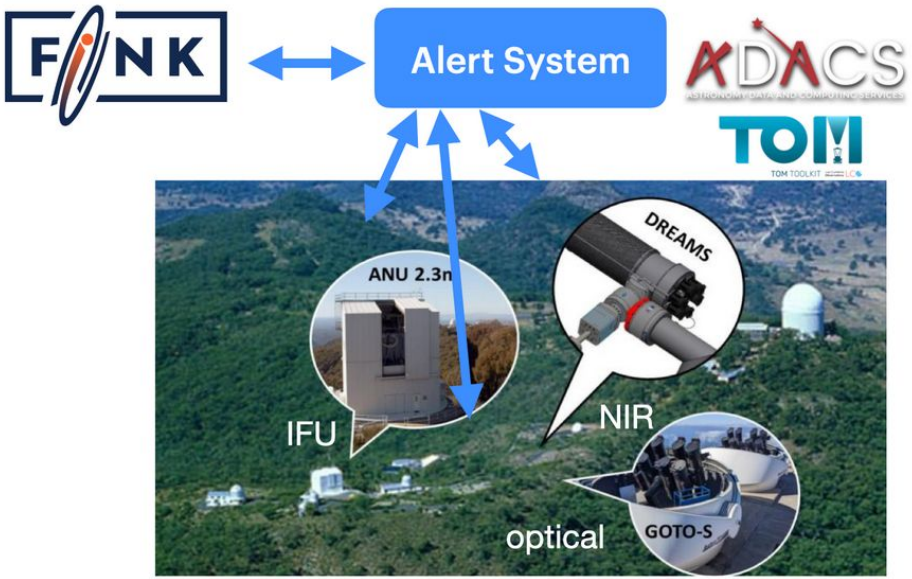
What more do we need?

- Probability of serendipitous association in the sky with a MM alert for each FINK source class that have a positive match?
- other dedicated classifiers to be implemented?
- A host or hostless? Look at template images if a galaxy is visible at the transient location or nearby (TBD)
- …. other ideas?

What do we have? What more do we need?

Follow-up campaign organization



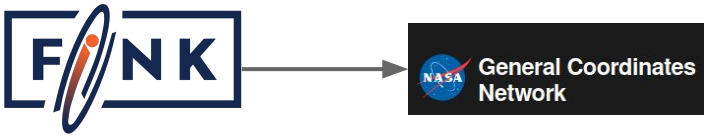


What do we have? What more do we need?

Follow-up campaign organization

What more do we need?

- If we are quick enough to identify robust identification via FINK, could we suggest follow-up to external teams via official FINK GCN Circulars? More visibility for the Broker and the FINK MM team but template and author list need to be defined
- …. other ideas?



What do we have? What more do we need?

Joint publications

What we already have

- A visibility in the MM community as being an official VRO broker that collects all the OT candidate data from LSST

What more do we need?

- Promote again and again our services to quickly extract data for transient source analysis.
- More interfaces (API, other?) with other MM Collaborations and services? Astro-Colibri To be listed…
- Other ideas…?

Any useful service for MMA that we don’t have yet?