The needle in a haystack
SVOM & Fink

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Rubin time-domain challenges

The Rubin Observatory will send about **10 million alerts per night over 10 years**

- Several orders of magnitude above current streams
- Current tools do not scale (~1TB / night)

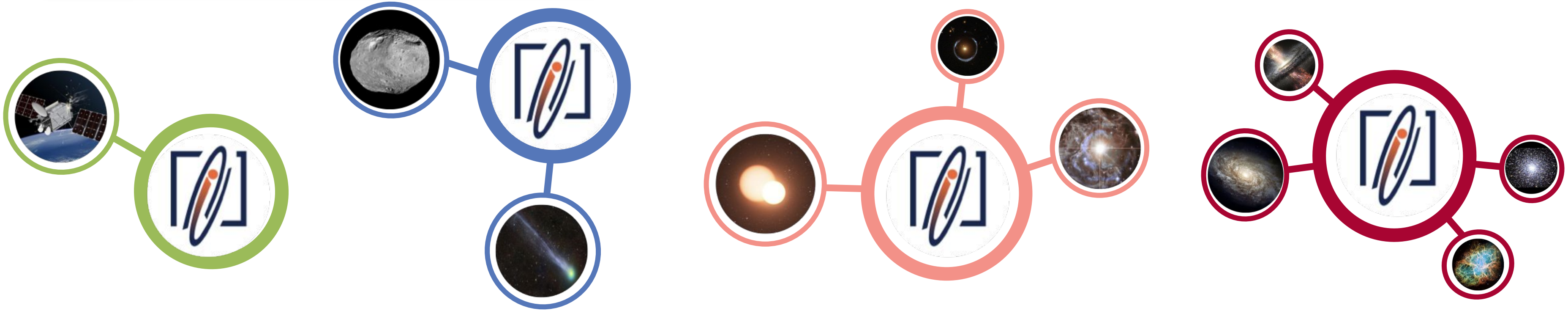
Individually, each observatory of the next decade will not characterise all of its events

- Additional observations will be necessary, and often within a short time delay after initial discovery
- The need for **multi-messenger astronomy** is rising fast

Follow-up resources will be crucial but limited!

Rubin broker landscape

Fink scientific objectives



Objective: **studying transient sky as a whole**, from solar system objects to galactic and extragalactic science.

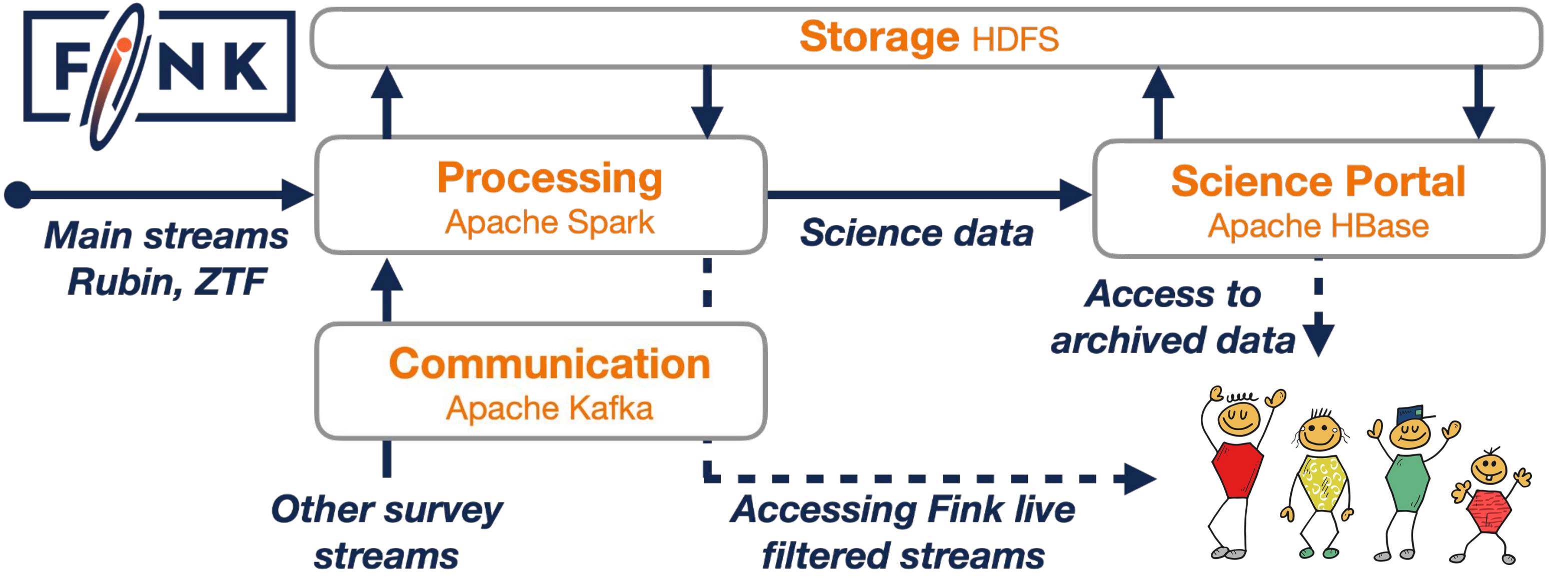
The survey cadence will generate image from the same field every ~3 days:

- A non-zero difference at 5 sigma between previous (aggregated) and the new observation produces an alert. Combination of *ugrizy* filters.

Fink white paper: https://dx.doi.org/10.1093/mnras/staa3602

Technical aspects

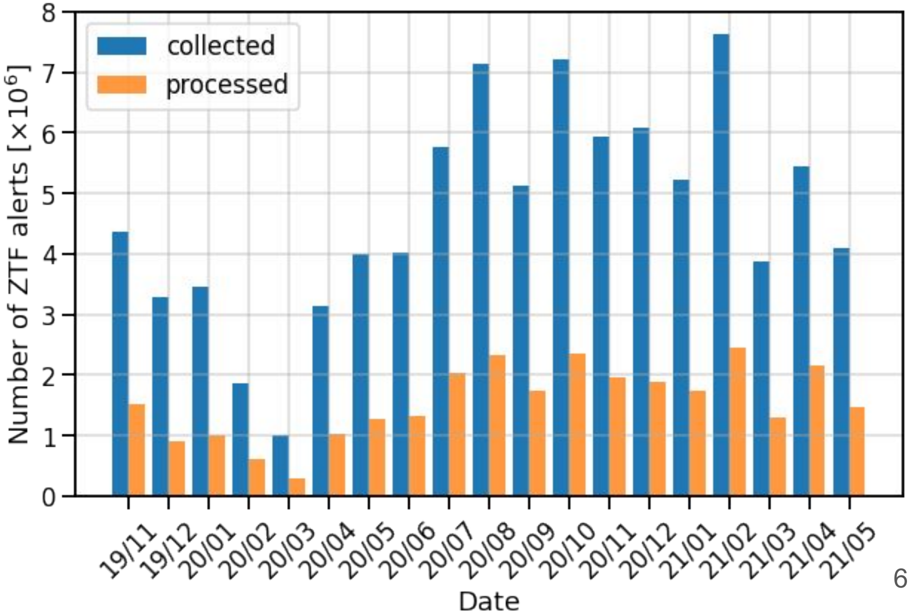
New technological approach based on big data and machine learning tools, and operating in real time on large cloud computing infrastructures. Deployed at VirtualData since 2019, and migrating at CC-IN2P3 in 2022.



Processing ZTF data

We can already test Fink on real alert data

- MoU with Zwicky Transient Facility (ZTF), preparation for LSST.
- ~200,000 alerts per night (~20GB/night)



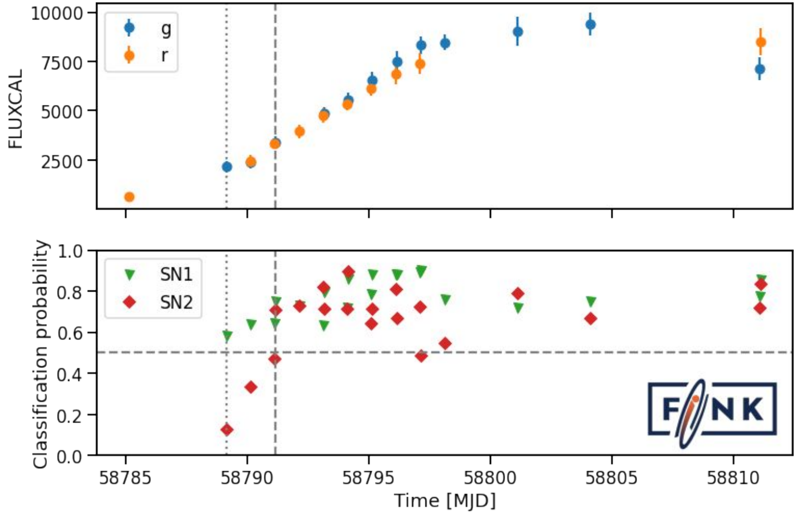
Alert content

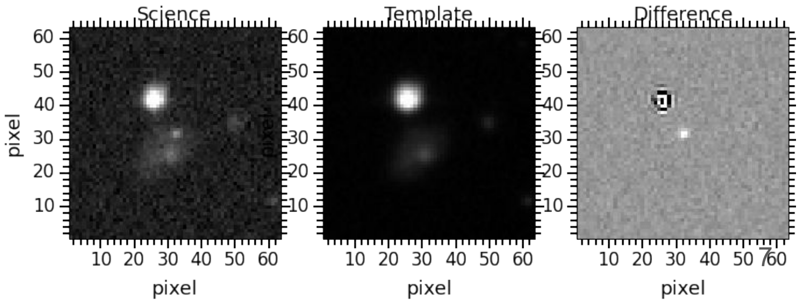
Alerts based on Difference Image Analysis

Each ZTF alert contains

- Information about the new detection (magnitude, position, ...)
- Neighbours information (Gaia, Panstarrs)
- Historical information if the object has been seen previously
- Small images around the detection (60x60 pixels)

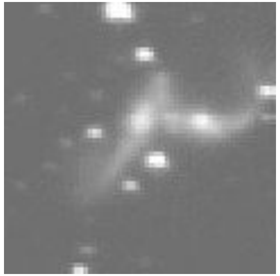
LSST alert content will be similar.

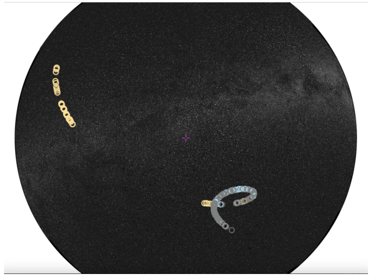




Fink science output

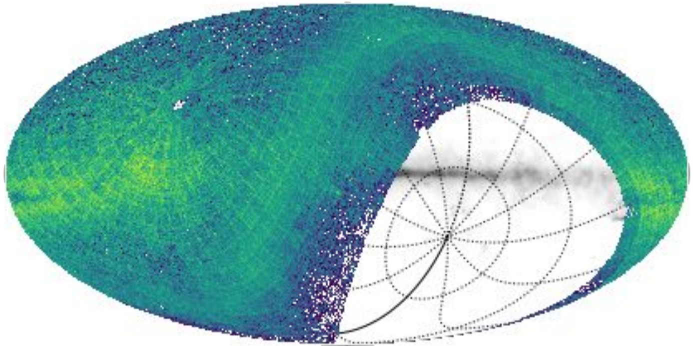
More than 100 million alerts collected since 2019.
Cross-matching (e.g. with CDS xmatch service) +
classification (machine learning based algorithms)





Each night, we transmit:

- ~10,000 known variable stars
- ~10,000 known SSO
- ~10 (un)identified satellite glints or space debris (!)
- ~100 new SSO candidates
- ~100 new supernovae & core-collapse candidates
- ~10 new SN Ia candidates
- ~1 new fast transient candidate (KN, GRB, CV ...)
- ~1 new microlensing candidate



Accessing Fink data

Two entry points for users:

- Live streams (Kafka streams)
  - Personalisable filters to select objects/parameters of interest
  - Data received “live” (+processing delays)
- Science Portal & REST API
  - All data will remain accessible for the full survey duration
  - https://fink-portal.org

GRB science with Fink

Goal: detection of fast fading on-axis GRB afterglows and slow-evolving off-axis GRB afterglows (lead: D. Turpin)

Fink should enable at minimum:

- Online response to a query and ToO program
- Complementary observations (with the ground segment)
- Subthreshold analysis and post-processing

Concretely?

On-line & ToO program

Two main modes of operation:

1. Fink listening to SVOM alerts, and forwarding back interesting counterparts.
2. GRB module in Fink flagging an interesting alert in LSST, and forwarding to SVOM

Concretely we would need selection criteria to select interesting alerts from the crossmatch

- LSST alert density could be quite high in some regions…

On-line & ToO program

We have at our disposal (Turpin, Karpov, Möller):

- All the other modules in Fink (to reject many of the false needles in the haystack)
- A large sample of real afterglow data.
- ML code (SuperNNOva) to classify transient lightcurves.
- Some analytical models of GRB afterglows (on and off axis) + a bank of non-GRB transient lightcurves (from PLASTICC) sampled at the ZTF cadency, and soon the same for LSST (ELASTICC).

Difficulty: Modeling GRB emission is crucial, as we will have very sparse data. Time window for the search is not trivial & reliable classification of other objects is questionable.

On-line & ToO program

In addition, we need to design metrics to rank candidates

- Globally: the chance probability of finding an optical transient in the error box of a detected GRB
- Individually: what makes alert X a better candidate than alert Y?

Finally, we should put in place communication tools

  - Shall we use VTP? Kafka?
  - Do we need a specific content, beyond what exists?

What about the ground segment?

In practice, not all interesting candidates in Fink can be a ToO, or at least the amount of information at hands will be not be enough to take immediate action with the satellite.

The ground could help filling the gap for some interesting candidates for which additional observations would help the decision. All studies described earlier apply here.

Question: what makes a candidate interesting for ground follow-up? Can we play the same game than SWIFT and Colibri?

Offline analysis

We want a tool to quickly explore individual alerts, and assess credibility, outside the online analysis. Example for GRB210204270 (dev server only!)

Measurements relative to a trigger time

GRB lightcurves collected and curated by Damien Turpin

Other ideas?

Please join the effort :-)

FINK

https://fink-broker.org
https://fink-portal.org

Fink team

PI: E. Ishida (LPC), A. Möller (Swinburne Uni.), J. Peloton (IJCLab)

30+ members all over EU

Fink members & collaborators

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