The needle in a haystack
Colibri & Fink

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Rubin time-domain challenges

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

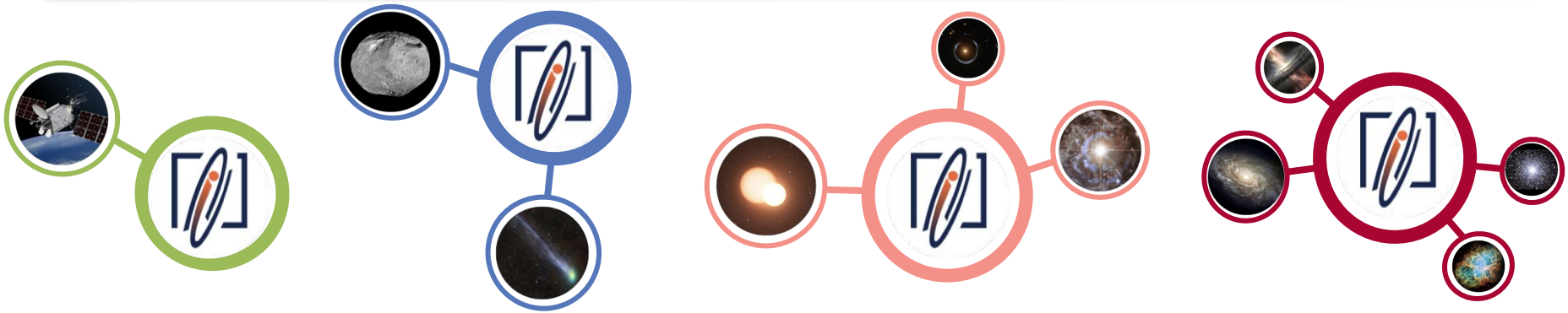
- Several orders of magnitude above current streams
- Current tools do not scale (~1TB / night)

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!

Fink scientific objectives



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

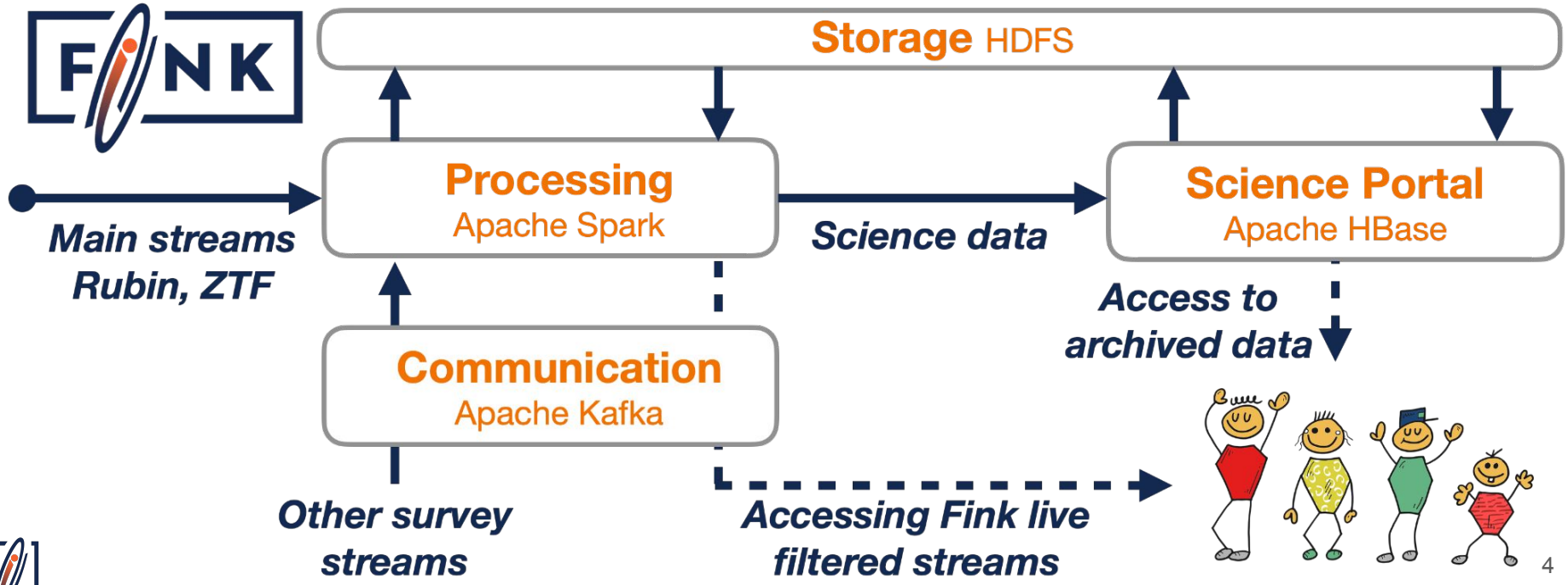
The survey cadence will generate image from the same field every ~3 days:

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

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

How Fink works?

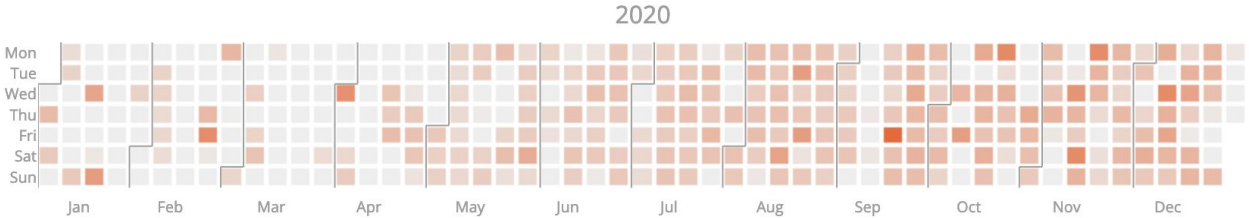
Operating in real time on large cloud computing infrastructures. Deployed at VirtualData since 2019, and now migrating at CC-IN2P3 (IN2P3 LSST Master Project).

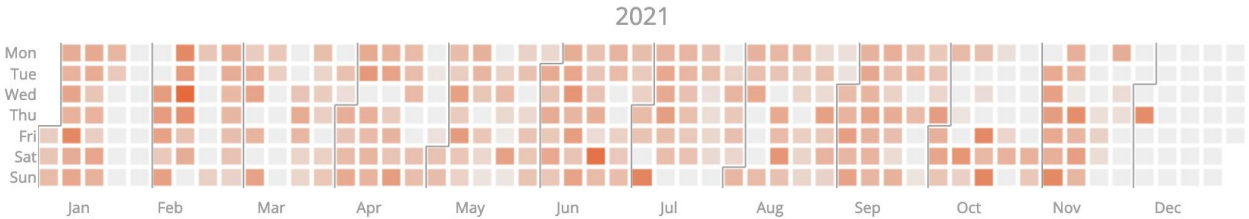


Processing ZTF data

We can already test Fink on real alert data

- MoU with Zwicky Transient Facility (ZTF), preparation for LSST.
- ~200,000 alerts received per night (~20GB/night) -- ½ survives quality cuts





DEMO

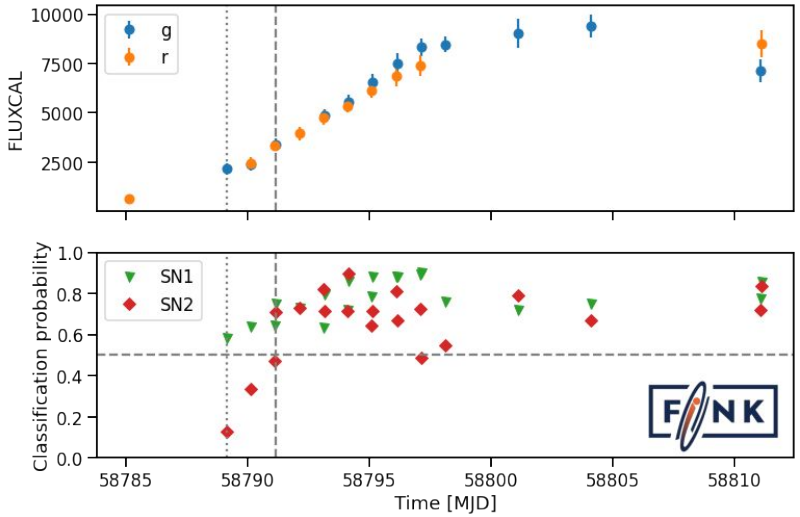
Alert content

Alerts based on Difference Image Analysis

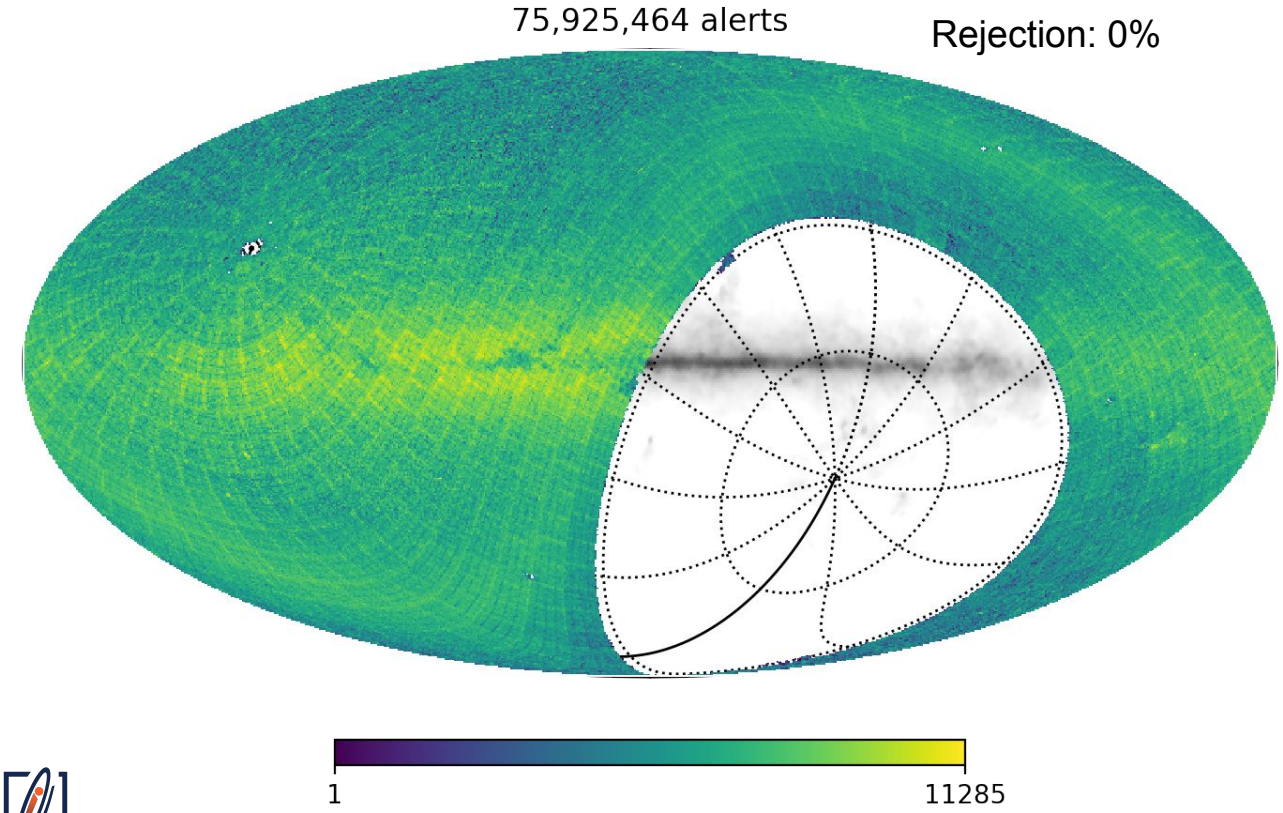
Each ZTF alert contains

- 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 (with even more information!): [sample]

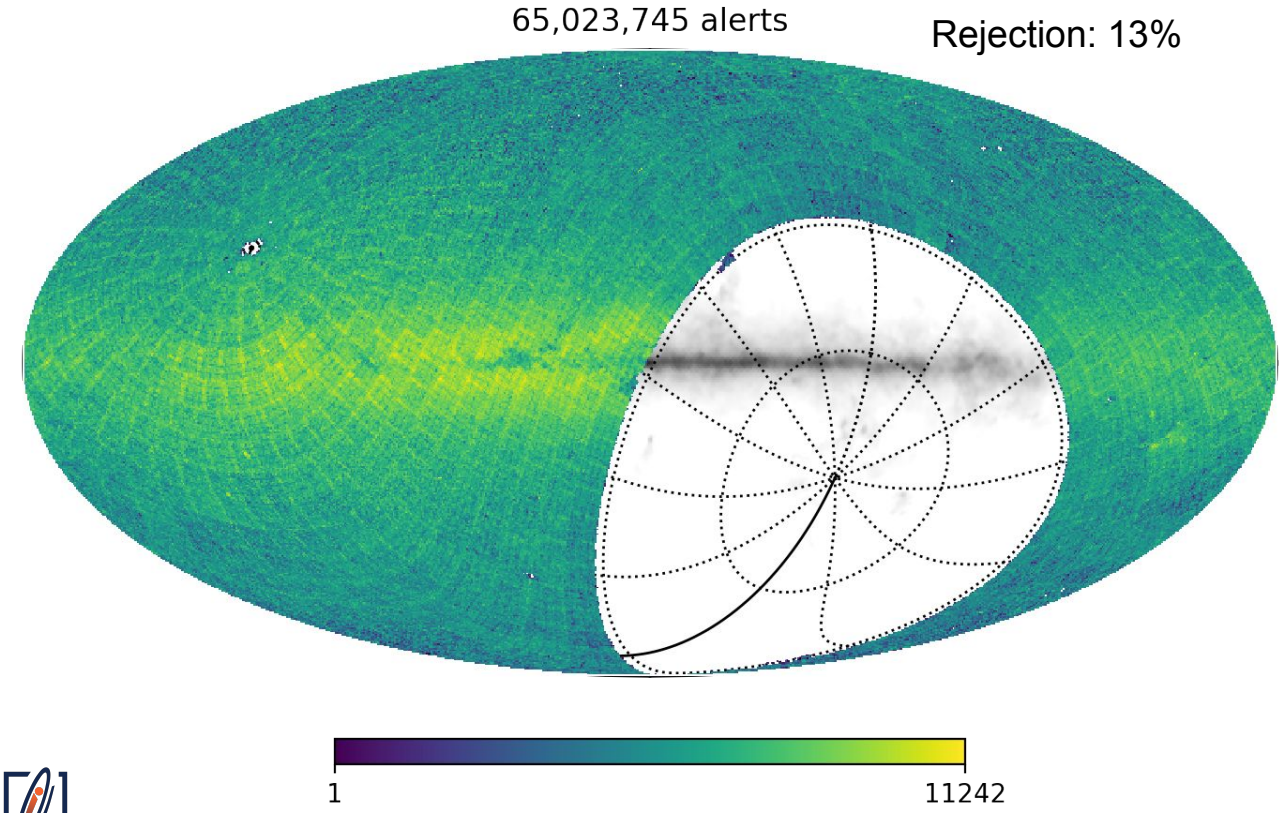


The needle in a haystack



All transients for 2 years of ZTF (about 10 days for LSST…)

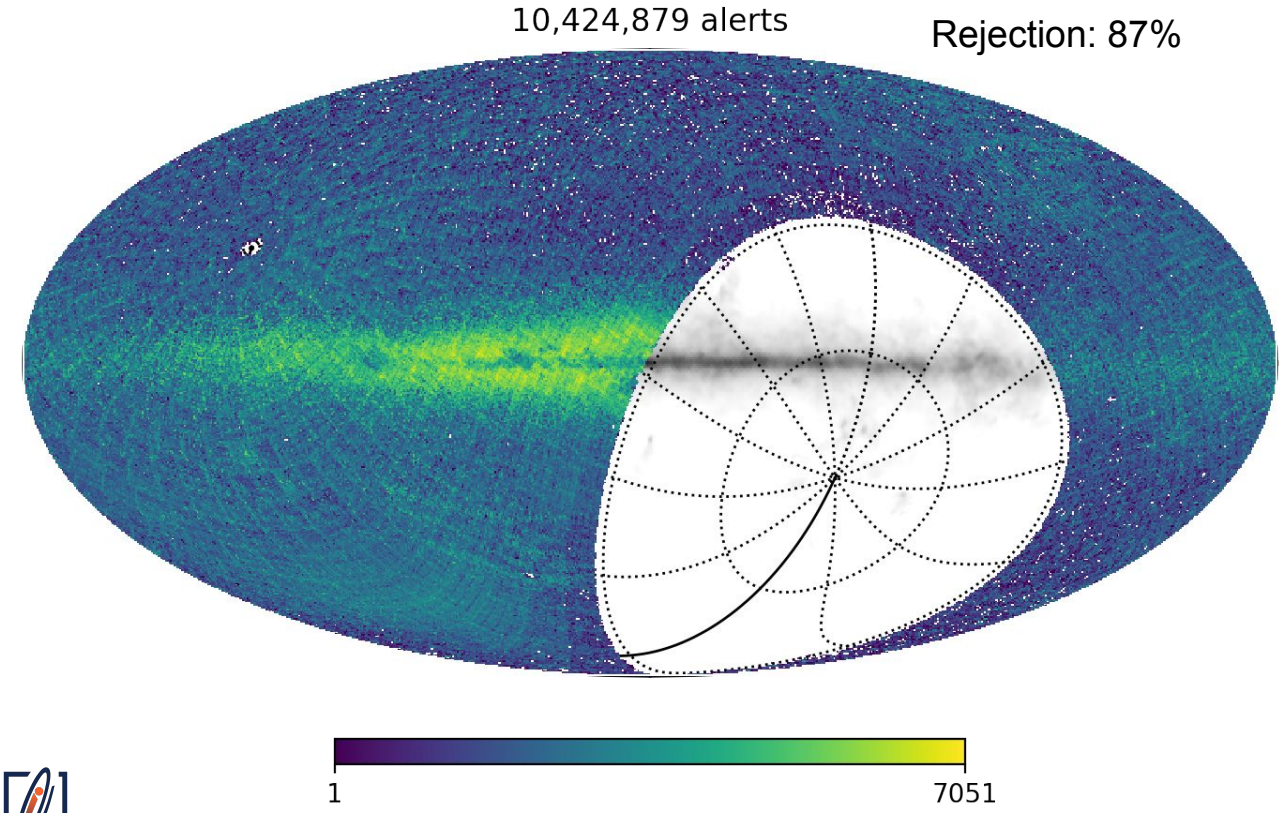
The needle in a haystack



All transients for 2 years of ZTF (about 10 days for LSST…)

- Known moving objects removed

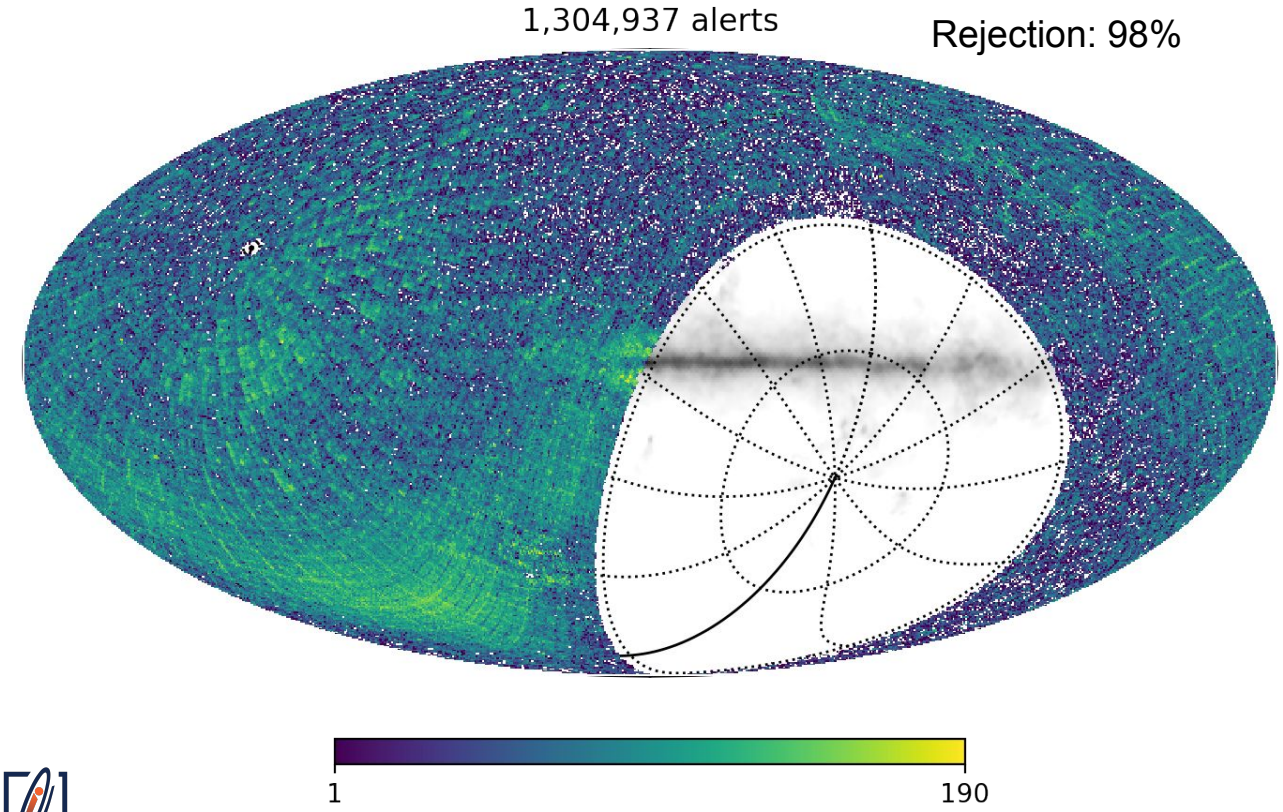
The needle in a haystack



All transients for 2 years of ZTF (about 10 days for LSST…)

- Known moving objects removed
- Known variable galactic sources removed

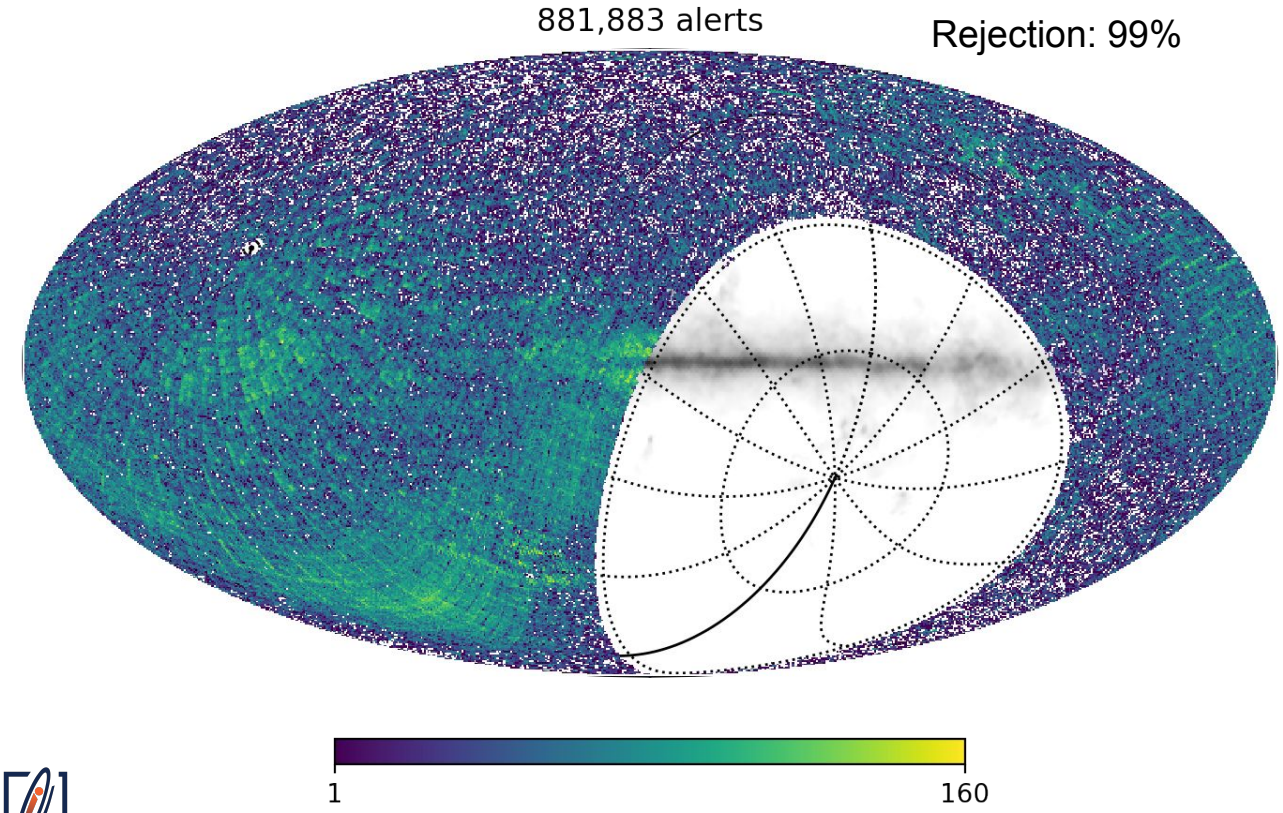
The needle in a haystack



All transients for 2 years of ZTF (about 10 days for LSST…)

- Known moving objects removed
- Known variable galactic sources removed
- Long trends removed

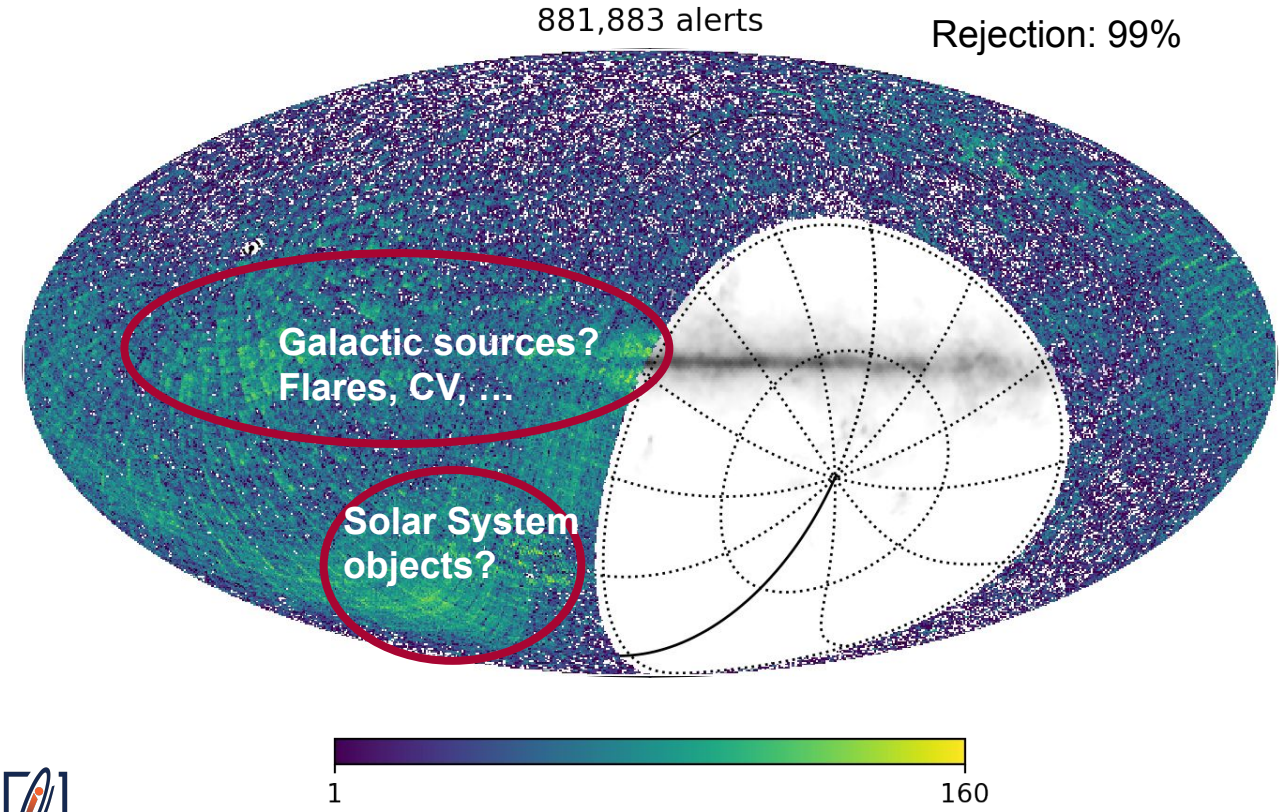
The needle in a haystack



All transients for 2 years of ZTF (about 10 days for LSST…)

- Known moving objects removed
- Known variable galactic sources removed
- Long trends removed
- Candidate sources removed

The needle in a haystack



If we want to find GRB more easily, we need to understand other classes of transients.

Targeting as many science cases as possible is crucial.

Fink strategy is to study the transient sky **as a whole**.

Ongoing projects

AGN: Etienne R, Roman

Anomaly detection: *Etienne R, Igor, Maria, Matwey*

Dark energy (incl. SN Ia): *Marco (https://arxiv.org/abs/2111.11438), Tarek*

Kilonova follow-up (w/ GRANDMA): *Juliette*, Damien (https://arxiv.org/abs/2202.09766)*

GRB (incl. orphans, on-axis/off-axis, integration with SVOM):

- *Damien T, Frederic, Jean-Gregoire, Johan, Manal, Marina, Nicolas, Roman, Sergey, Susanna*

GW (w/ LIGO/Virgo): *Didier*

Microlensing: *Etienne B, Marc, Petro*

Neutrino (w/ KM3NET): *Damien D, Godefroy, Vladimir*

Pair Instability SN: *Maria, Stéphane (MITI grant)*

Satellite glints: *Sergey (https://arxiv.org/abs/2202.05719)*

Solar System: *Benoit, Roman*

Rare Transient Finder: *Biswajit*

Real-time transient classification with contextual information (**GOTO**): *Justyn, Umar*

More to come? A new project? Let us know!

Lessons learned from ZTF

If we want to capitalise on the full scientific potential of Rubin, we must

- Deal efficiently with sources of contamination (*Le Montagner, Turpin*)
- Model targeted sources (*Bregeon, Ducoin, Daigne, Masson, Yassine, Vergani*)
- Define tools and protocols early to work together (*Turpin*)
- Perform efficient follow-up observations to palliate effects of the cadence (*Le Montagner*)

Event modeling efforts

Several groups working on modeling events, and defining the detectability of (on/off-axis) GRB events with Rubin. Current efforts focused on:

- (Orphan) GRB afterglows modeling
  - Simulating light curves of orphan gamma-ray burst afterglows
  - Studying the model parameters impact on the detection
  - Building template banks
- “Real-life” effects impact
  - Metric to study impact of observation strategy parameters → area, revisite rate, observation time, filter bands…

Goal: Designing and implementation in Fink new filters and modules for the study of GRB.

Follow-up with ground

Rubin's cadence is not yet fully known but **expect at least 1-2 days** between measurements at the same sky position.

- Sometimes difficult to assess the relevance of a new candidate using only Rubin's photometry.

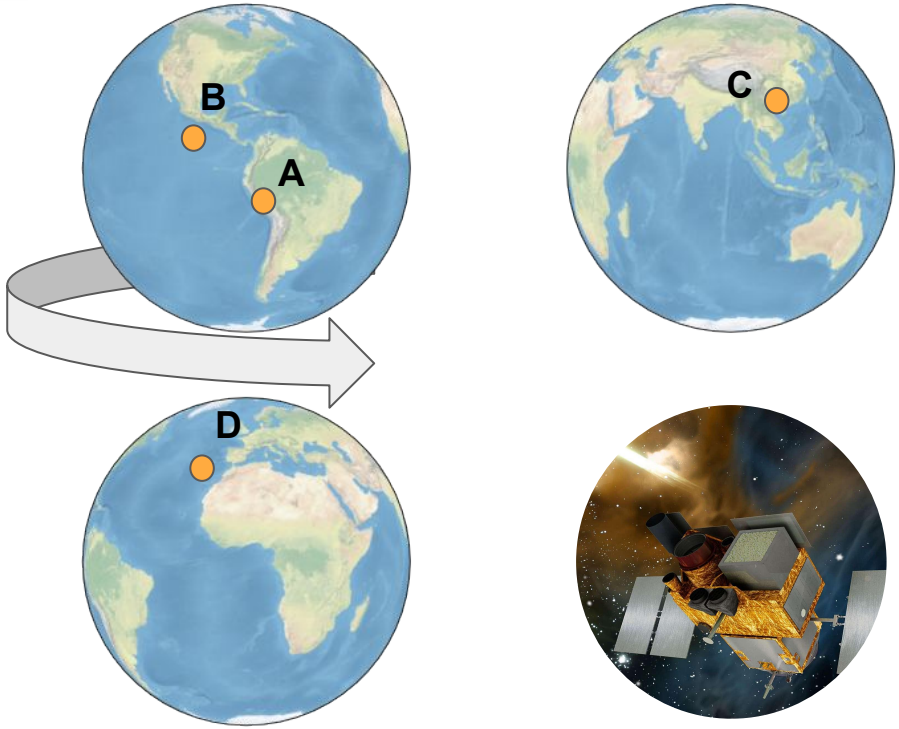
Quick follow-up will be crucial to complement the initial lightcurve, and motivate the decision for performing a ToO.

The **ground could help filling the gap** for some interesting Fink candidates.

Ground follow-up - a proposal

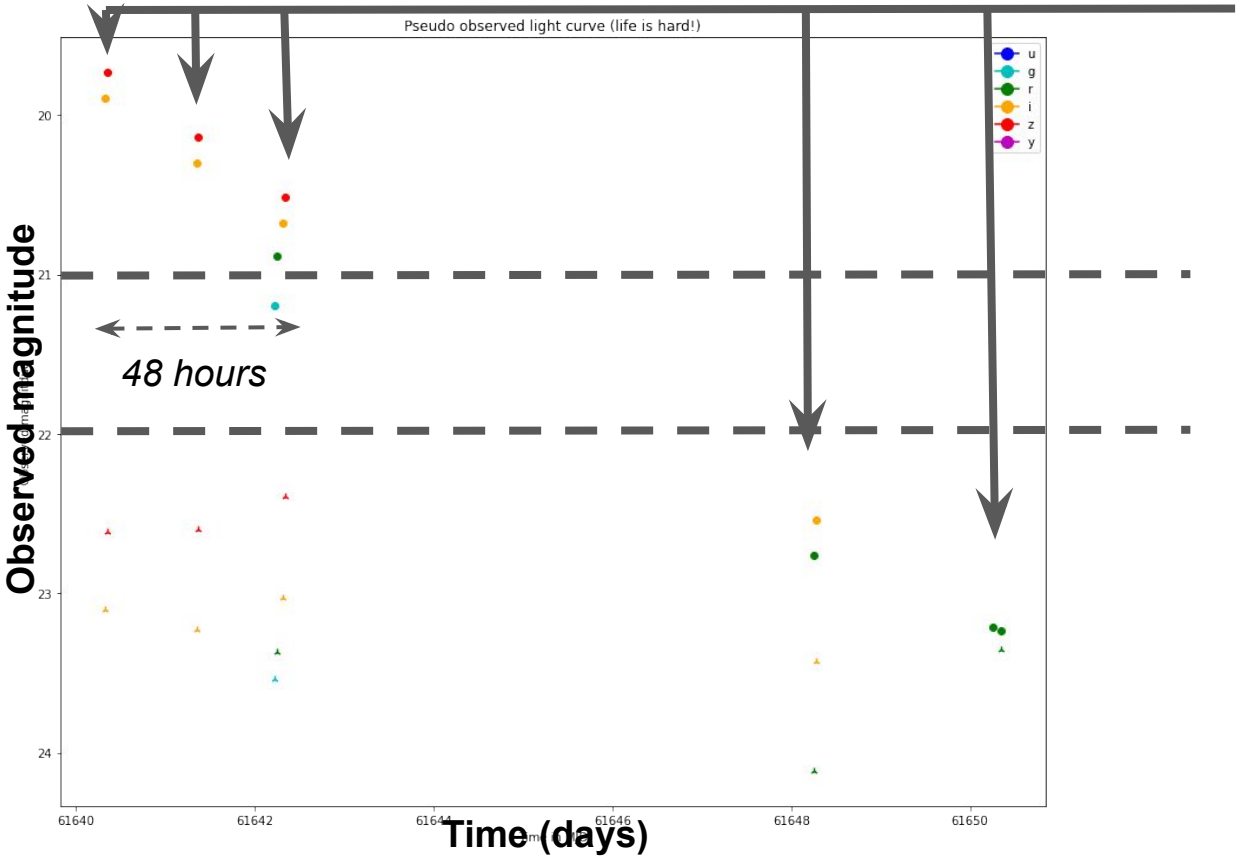
As Earth rotates:

- **A:** Fink/Rubin detects a new afterglow candidate
- **B:** Request follow-up photometry from Colibri. Lightcurve updated.
- **C:** If still candidate, request follow-up photometry from C-GFT. Lightcurve updated.
- **D:** If still candidate, request spectroscopy from the NOT (NTE)
- **Finally:** if still candidate, request ToO with the satellite.



Question: Can we already start some tests between Fink/ZTF & Colibri?

Example (bright event!)



Rubin measurements (sparse…)

21 mag

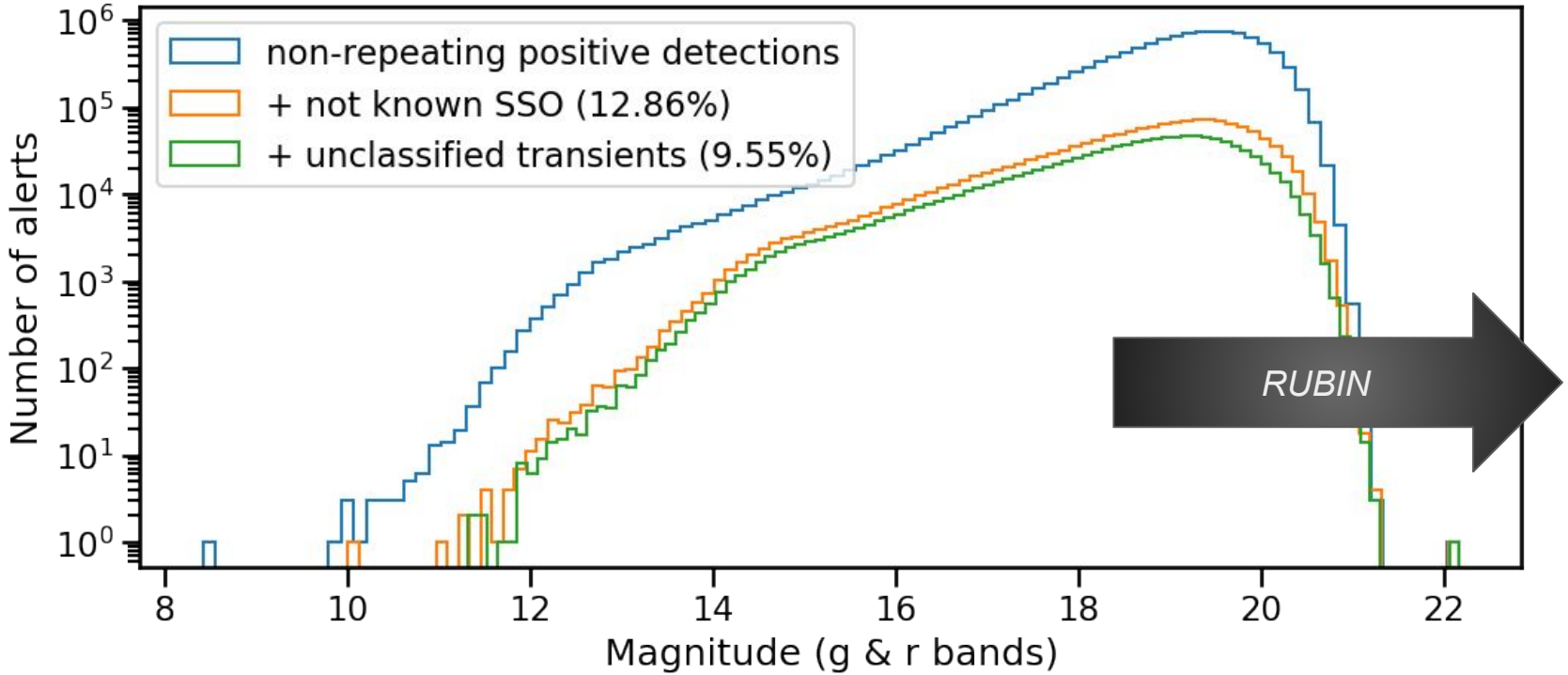
22 mag

Simulation from J. Bregreon

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

LSST Project/NSF/AURA

Magnitude


non-repeating positive detections
+ not known SSO (12.86%)
+ unclassified transients (9.55%)
Number of alerts
10^0
10^1
10^2
10^3
10^4
10^5
10^6
8
10
12
14
16
18
20
22
Magnitude (g & r bands)
RUBIN