Status and recent results

Julien, Emille, Anais, on behalf of the Fink team

16/05/2022

Rubin time-domain challenges

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

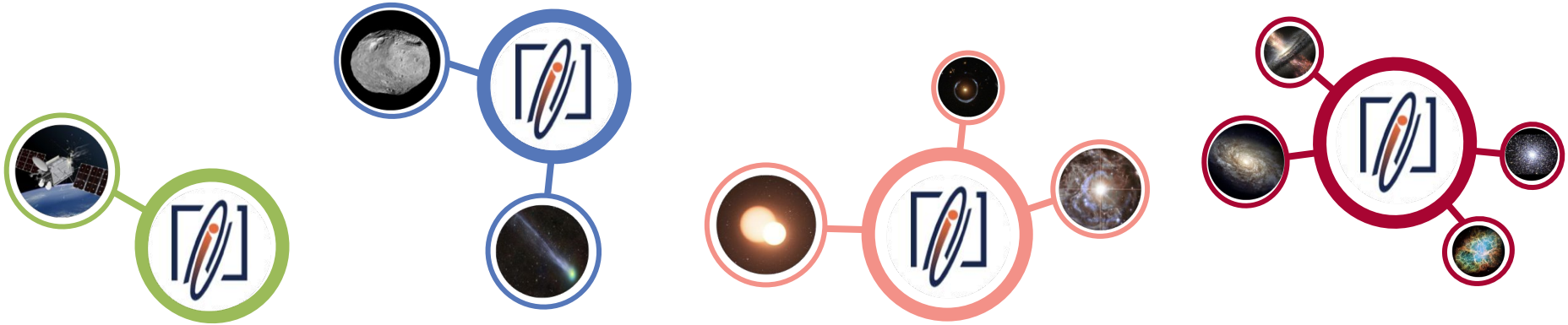
- Several orders of magnitude above current streams
- Current tools do not scale (~1TB / night)

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.

Rubin will be the main driver.

White paper: https://dx.doi.org/10.1093/mnras/staa3602

Looking back

2019: **Project started**

- Merging two independent R&D efforts: Active Learning & big data processing
- Letter of Intent submitted & project pre-selected

2020: **First data processed**

- Partnership signed with ZTF
- White paper published

2021: **Confirmation of the project**

- Project selected by Rubin (7 laureates: 1 Chile, 3 Europe, 3 US), and officialised at IN2P3 (LSST Master Project)
- First science papers submitted (Active Learning, KN follow-up, Satellite glints)
- Partnerships with other projects: GRANDMA, SVOM

2022 – Towards Rubin

Science portfolio is growing fast!

- 15 projects as of May 2022: AGN, SN, KN, SSO, GRB, neutrinos, satellites, microlensing, anomaly detection, …

LSST-DESC ELAsTICC

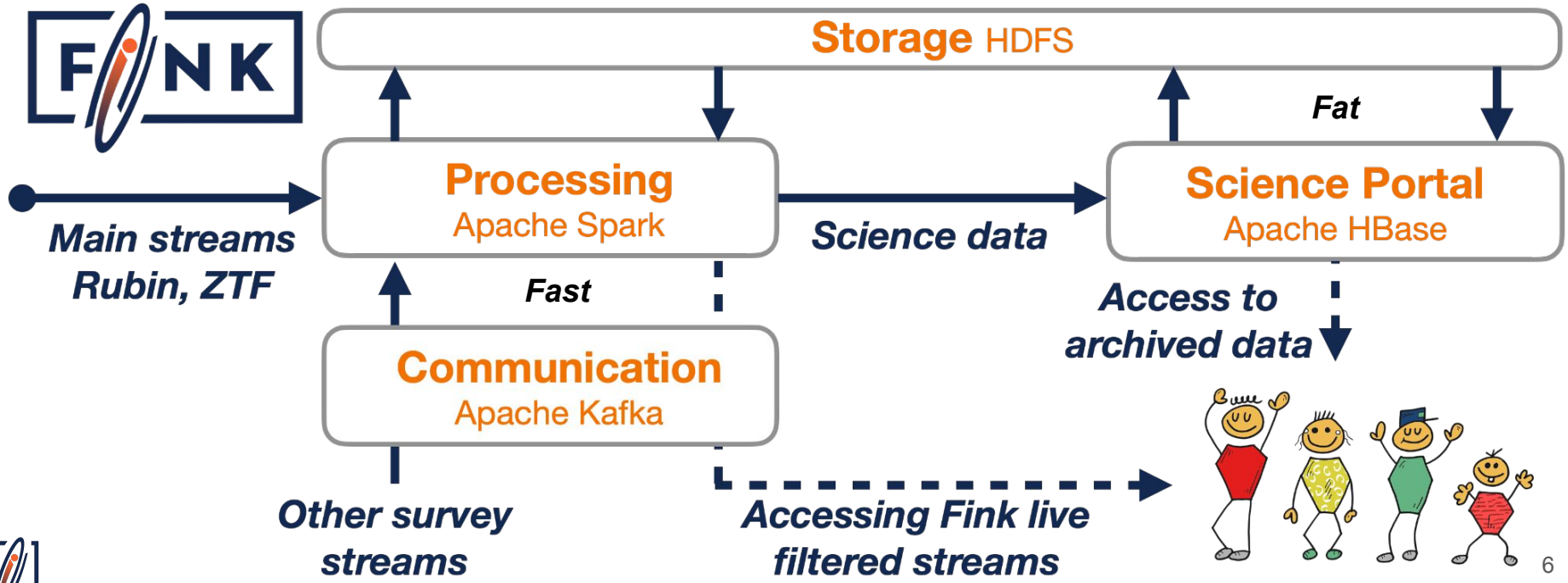
- Realistic set of LSST-like simulations for some classes of transients
- Include: SN, KN, TDE, AGN, microlensing, periodic stars, …
- Broker challenge, but also opportunity to deal with LSST-like data

Recent grants: Mission for Transversal and Interdisciplinary Initiatives

- Pair-Instability SuperNovae (PI: Emille Ishida)
- LSST-Euclid: Solar System Objects (PI: Benoit Carry)

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).

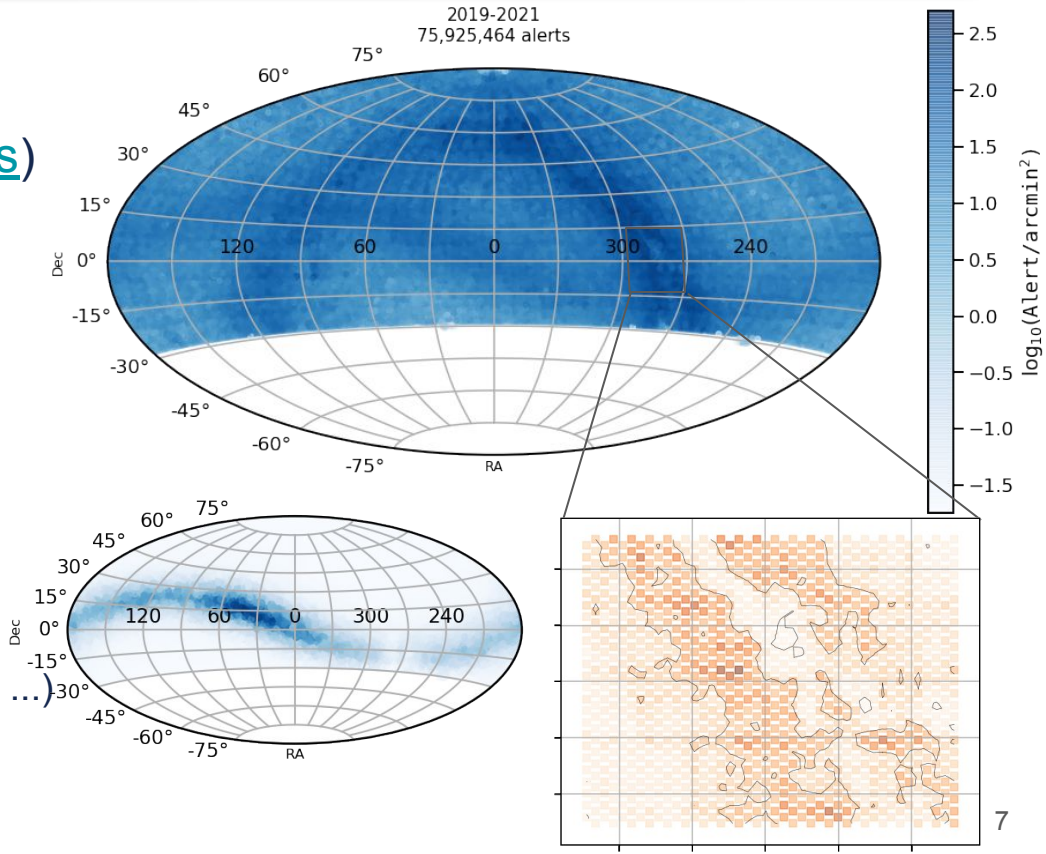


ZTF/Fink statistics

125 million alerts received, 84 million processed (https://fink-portal.org/stats)

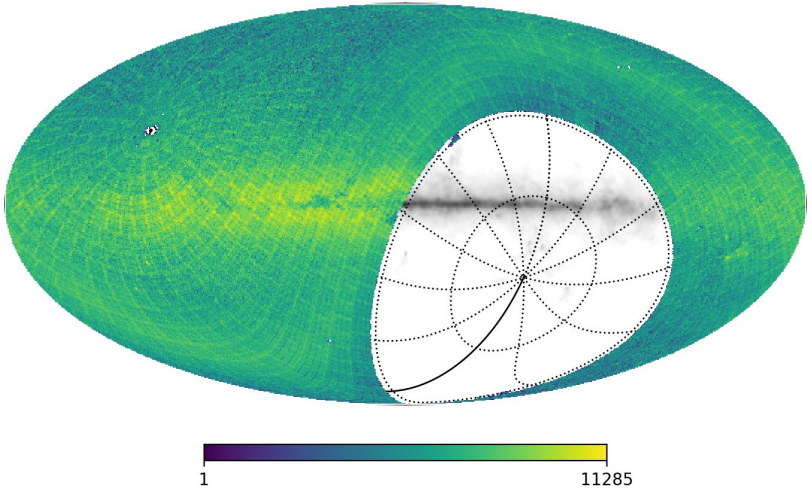
Typical nightly rates (200,000 alerts):

- ~75,000 known variable stars
- ~25,000 known SSO
- ~100 new SSO candidates
- ~100 new supernovae & core-collapse candidates
- ~10 (un)identified satellite glints
- ~5 new SN Ia candidates
- ~1 fast transient candidate (KN, GRB, CV …)
- ~1 new microlensing candidate

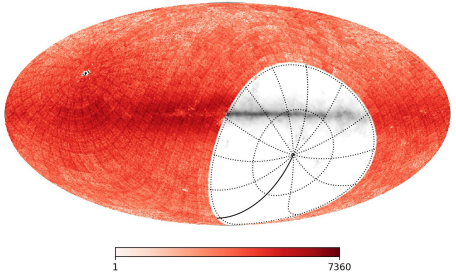


Sky maps (2019-2021)

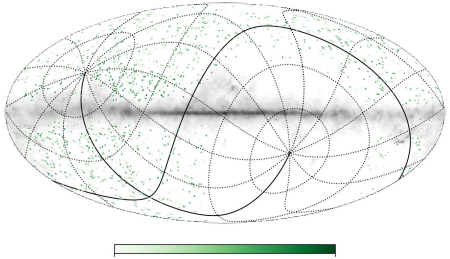
All processed alerts: 75,925,464 alerts



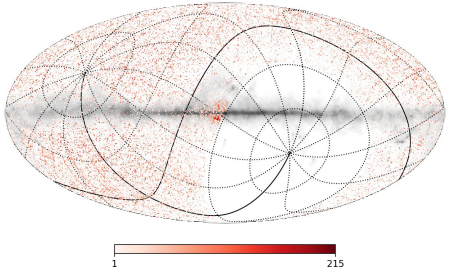
Unknown: 38,016,269 alerts



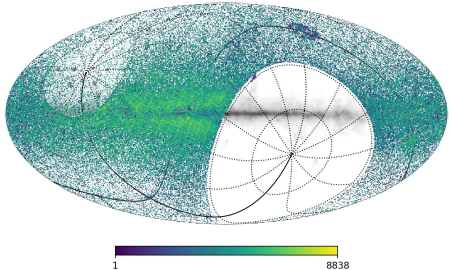
Early SN Ia (candidates): 7,654 alerts



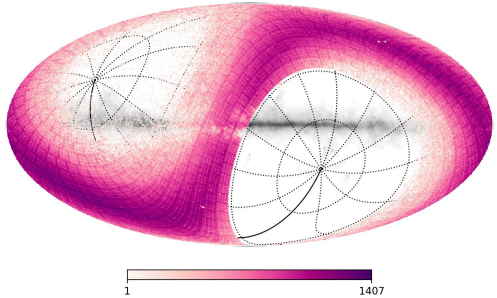
SNe candidates: 185,128 alerts



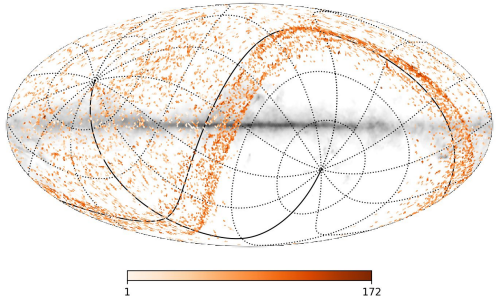
Variable Stars (Simbad): 14,626,103 alerts



Solar System Objects (MPC): 10,901,719 alerts



Fast moving objects: 73,365 alerts



Contents of alerts: ZTF

Original schema alerts from ZTF can be found at

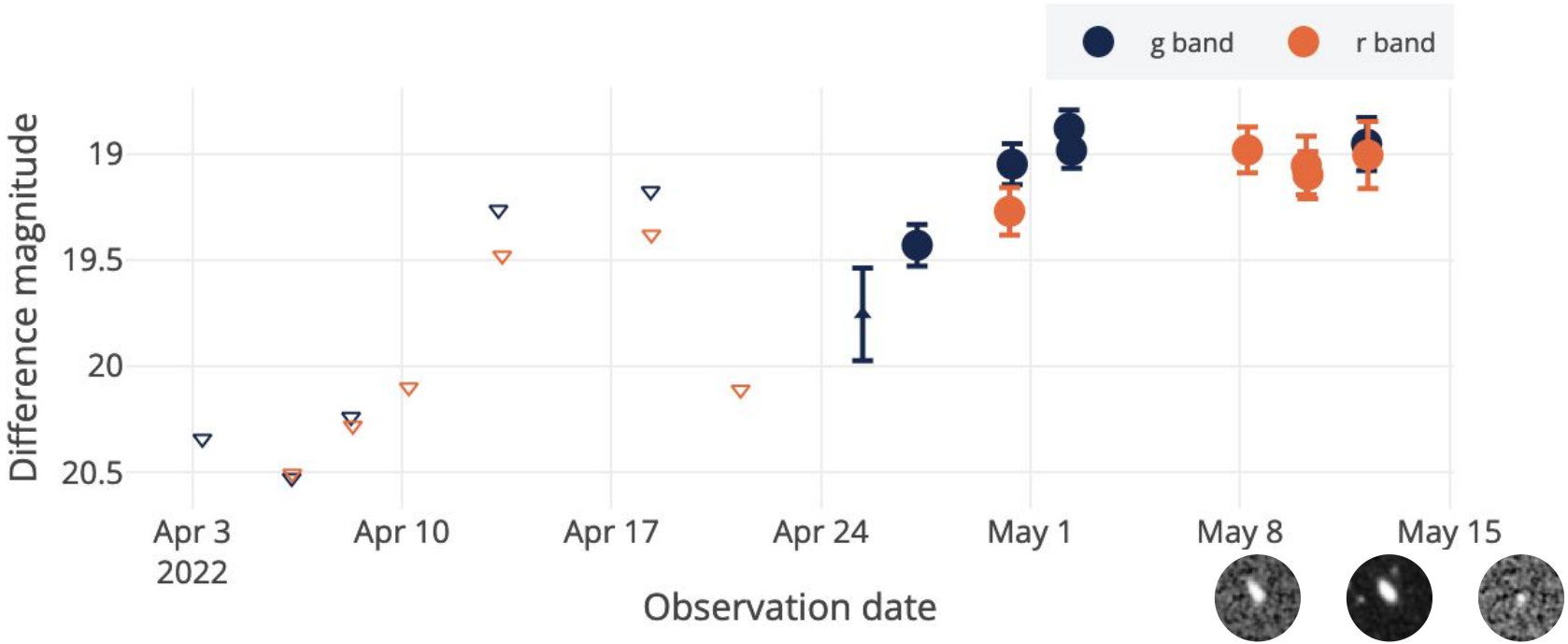
- https://zwickytransientfacility.github.io/ztf-avro-alert/schema.html

2 filter bands: g & r (differential magnitude – see tutorials on magnitudes)

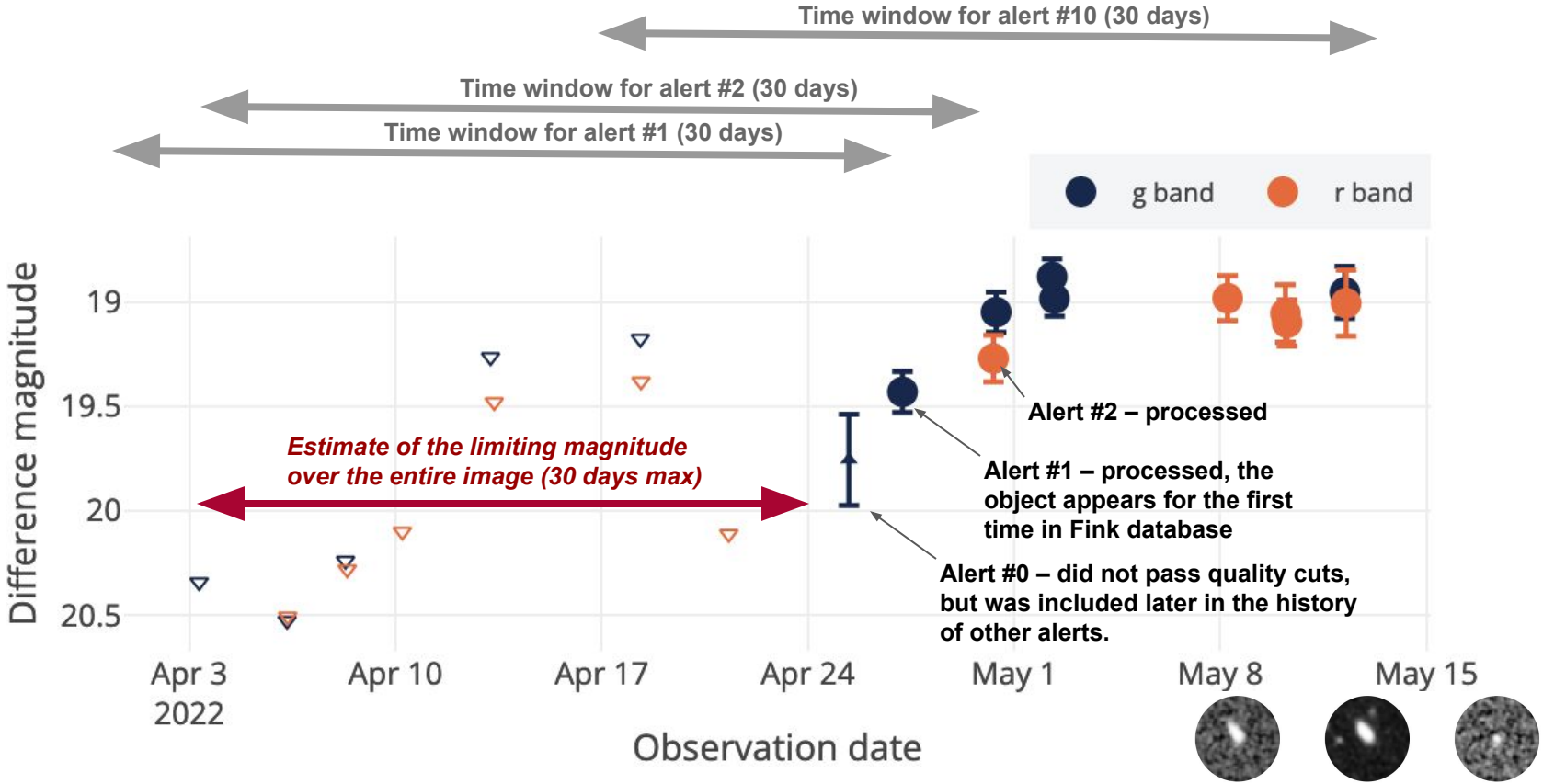
The alert packet contains (about 50 KB):

- IDs, coordinates, photometry estimates, calibration data, quality metrics, crossmatch information
- 3 cutouts (observation, template, difference)
- The previous measurements at this position (within a radius of 1.5”), up to 30 days in the past - aka *the history*.

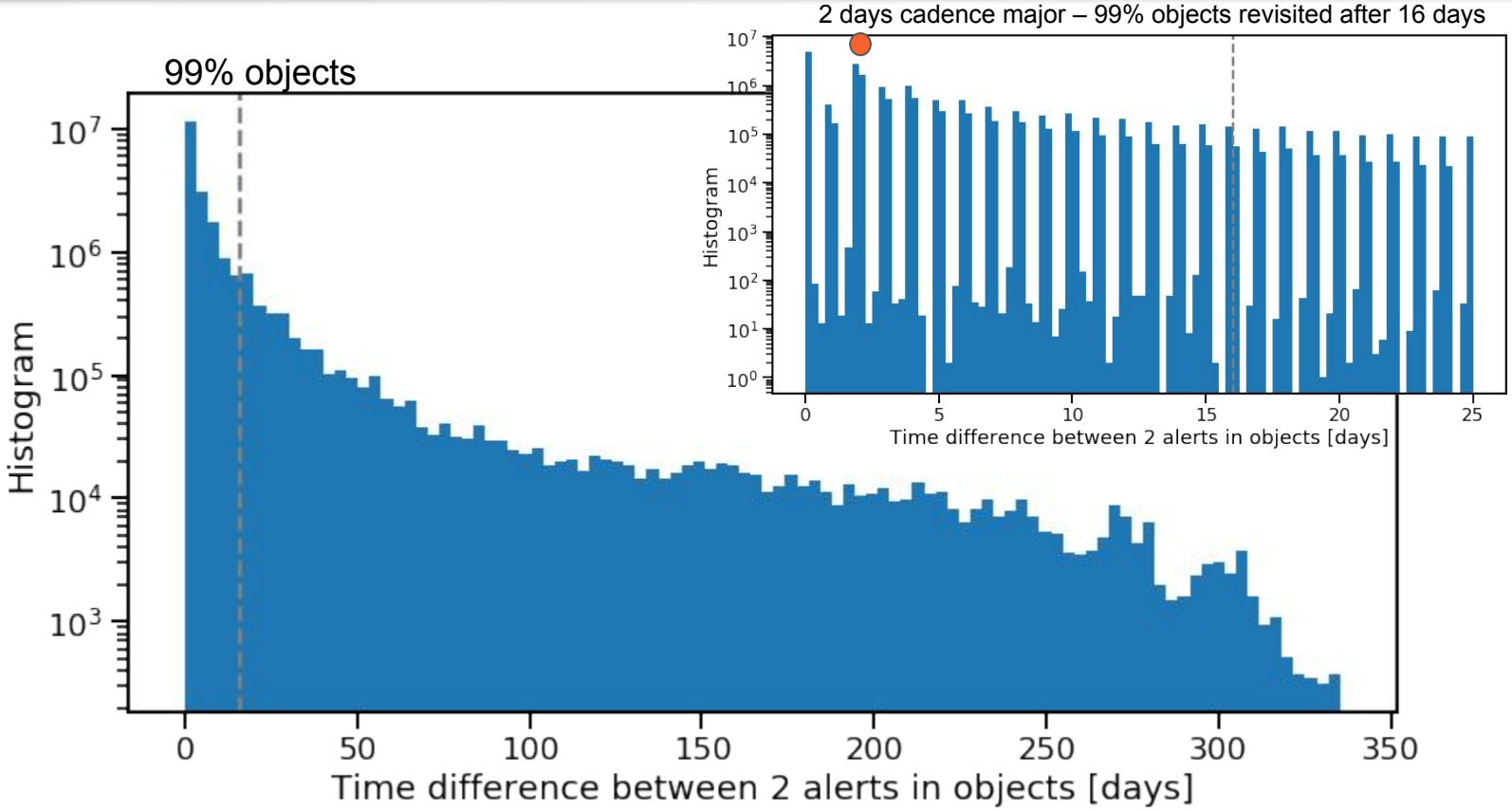
Alert vs object



Alert vs object

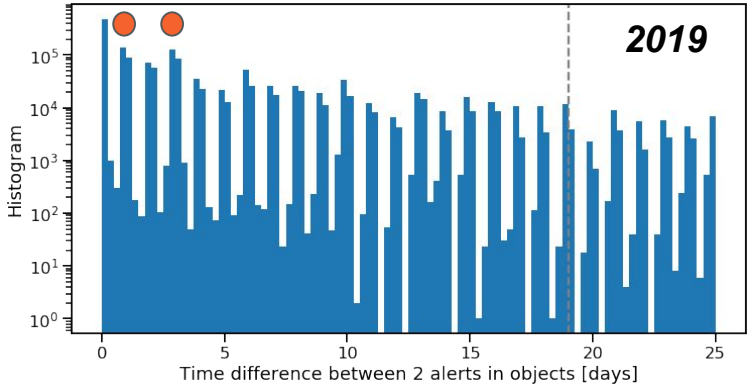


Cadence for ZTF (2021)

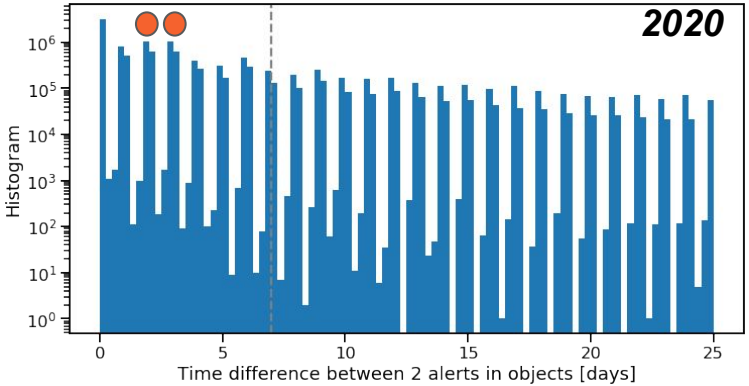


Cadence evolution

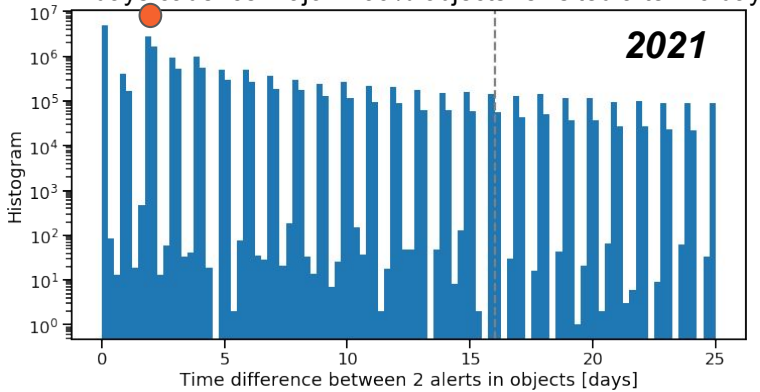
1-3 days cadence major – 99% objects revisited after 19 days



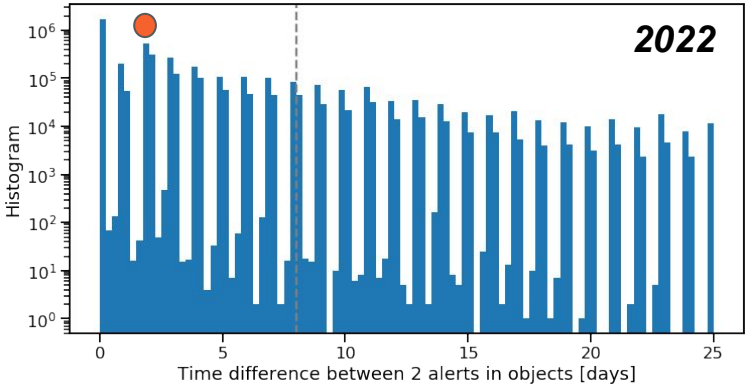
2-3 days cadence major – 99% objects revisited after 7 days



2 days cadence major – 99% objects revisited after 16 days



2 days cadence major – 99% objects revisited after 8 days



What adds Fink (online)?

Field name	Type	Contents
cdsxmatch	string	Counterpart (cross-match) in the Simbad database
rf_snia_vs_nonia	float	Probability to be a SNe Ia based on Random Forest classifier (1 is SN Ia). Based on https://arxiv.org/abs/2111.11438
snn_snia_vs_nonia	float	Probability to be a SNe Ia based on SuperNNova classifier (1 is SN Ia). Based on https://arxiv.org/abs/1901.06384
snn_sn_vs_all	float	Probability to be a SNe based on SuperNNova classifier (1 is SNe). Based on https://arxiv.org/abs/1901.06384
mulens	float	Probability score to be a microlensing event by LIA. Based on https://arxiv.org/abs/2004.14347
roid	int	Determine if the alert is a Solar System object
rf_kn_vs_nonkn	float	probability of an alert to be a kilonova based on kndetect using a Random Forest Classifier (binary classification).

Under integration: T2, AGN classifier, feature extraction + anomaly detection, crossmatch with Gaia, USNO, GCVS, VSX, …

Selected results

Since last LSST-France…

1. Active Learning for supernova Ia detection *arxiv:2111.11438*
2. Project: Fast transient detection
3. Follow-up of kilonova candidate by GRANDMA *arxiv:2202.09766*
4. Satellite glints impact for transient science *arxiv:2202.05719*
5. Project: DESC ELAsTICC challenge

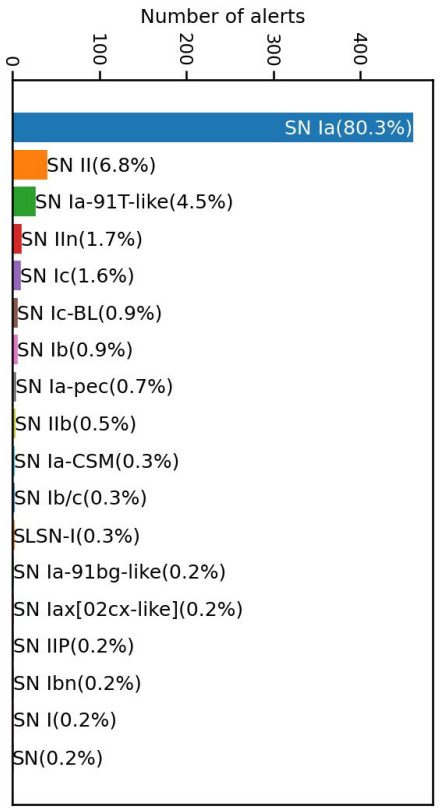
Check also the program of the Fink collaboration meeting 2022

Active Learning & SN Ia

Problem 1: labels are expensive, resources are limited
Problem 2: training (spectroscopically classified light curves) is not representative from test (purely photometric light curves)

Strategy: optimize the construction of (small) training samples by using Active Learning.

Application: Early detection for SN Ia
Leoni et al., arxiv:2111.11438, in press A&A

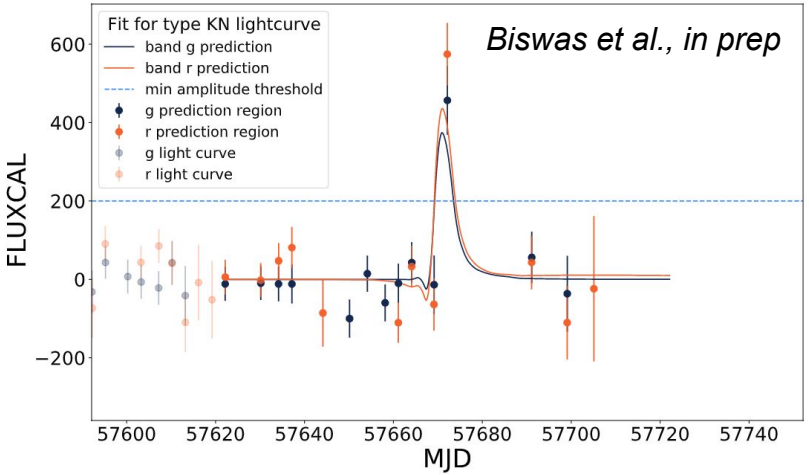


Fink Early SN Ia candidates reported to TNS from November/2020 - March/2022 and follow-up.

Case study: Kilonova

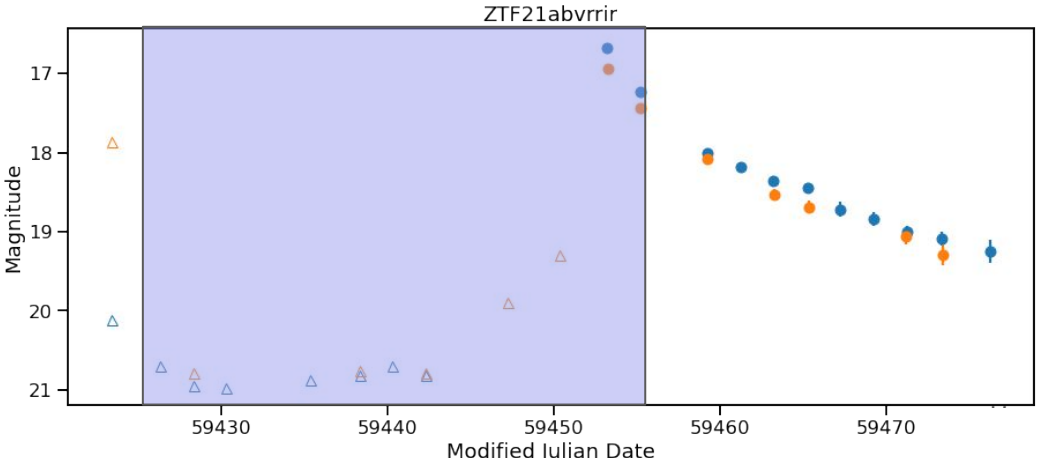
Problem 1: there are no labels, only 1 confirmed detection.

Problem 2: we need to find it fast.



(c) KN event, at $z \approx .04$

Data set: Simulated ZTF light curves
Feature extraction: Principal components from perfect sims
Classifier: Random Forest



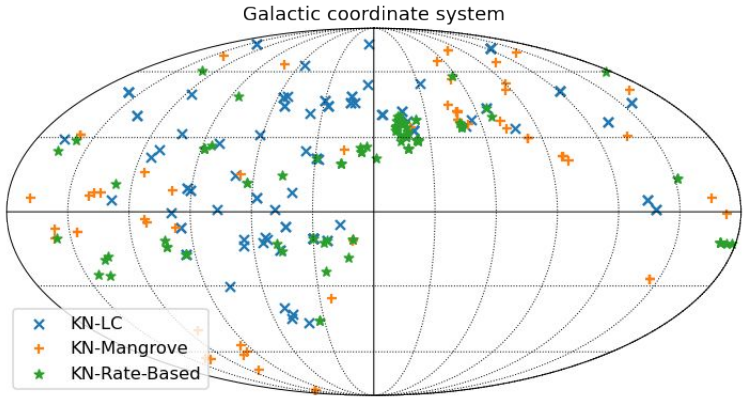
Follow-up of Kilonova alerts

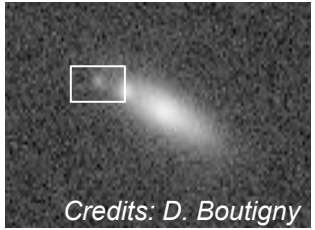
GRANDMA observation campaign (April-Sept 2021) for following up ZTF alerts classified & transmitted by Fink.

Focus on Kilonova candidates. Three methods:

- KN-LC (*Biswas et al., in prep*)
- KN-Mangrove (*Ducoin et al, 2020*)
- KN-Rate (*Andreoni et al, 2021*)

Active participation of amateurs – large coordination between different communities.





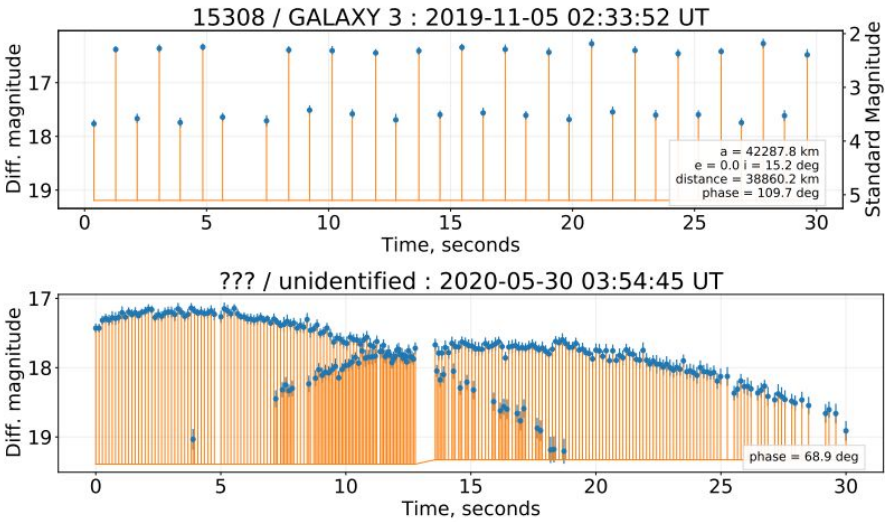
Aivazyan et al., 2021, arxiv:astro-ph/2202.09766

Bip, bip, bip…

Thousands of active artificial objects are orbiting around Earth along with much more non-operational ones.

Most satellites are masked prior alert generation (bright), but fainter signals remain such as satellite glints

- rapid flashes produced by reflections of a sunlight from flat surfaces of rotating satellites, and impacting transient science.



About 200 alerts per night, 4% all science image affected.

Karpov and Peloton, 2021, arXiv:astro-ph/2202.05719

DESC ELAsTICC challenge

- Using LSST-like alerts generated by LSST-DESC
  - Only some classes of interest simulated
- Focus on **SuperNNova** and **Active Learning** modules in Fink (more to come!).
- Selection criteria less important (synthetic data)
  - … but scores are currently dummies, as we need to retrain models.
- Many common entries in the alert content with ZTF, but some small differences (non crucial so far).

Output alert content


```
{
    "alertId": 1231321321,
    "brokerIngestTimestamp": 1651180866.509,
    "brokerName": "Fink",
    "brokerVersion": "2.1",
    "classifications": [
        {
            "classId": 10,
            "classifierName": "rf_snia_vs_nonia_1.1.1",
            "classifierParams": "coucou",
            "probability": 0.0
        },
        {
            "classId": 10,
            "classifierName": "snn_snia_vs_nonia_1.1.1",
            "classifierParams": "coucou",
            "probability": 0.49766847491264343
        },
        {
            "classId": 10,
            "classifierName": "snn_sn_vs_all_1.1.1",
            "classifierParams": "coucou",
            "probability": 0.4642139971256256
        }
    ],
    "diaSourceId": 1572028,
    "elasticcPublishTimestamp": 1726374824.64
}
```


Using the DESC brokerClassification schema 0.9

This example includes 2 SN classifiers:

- **Active Learning** (Leoni et al 2022) for the detection of Early SN Ia (*rf_snia_vs_nonia*)
- **SuperNNova** (Möller et al 2020), with two different models:
  - *snn_snia_vs_nonia* for the detection of SN Ia
  - *snn_sn_vs_all* for the detection of SN and core-collapse.

At the next episode…

Solar system objects

GRB projects

Pair-instability Supernovae

AGN

… and perhaps more!


FINK
https://fink-broker.org
https://fink-portal.org
LSST Project/NSF/AURA

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*

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!