The needle in a haystack

Low-latency alerts & Data analysis for Multi-messenger Astrophysics

Julien Peloton @ IJCLab

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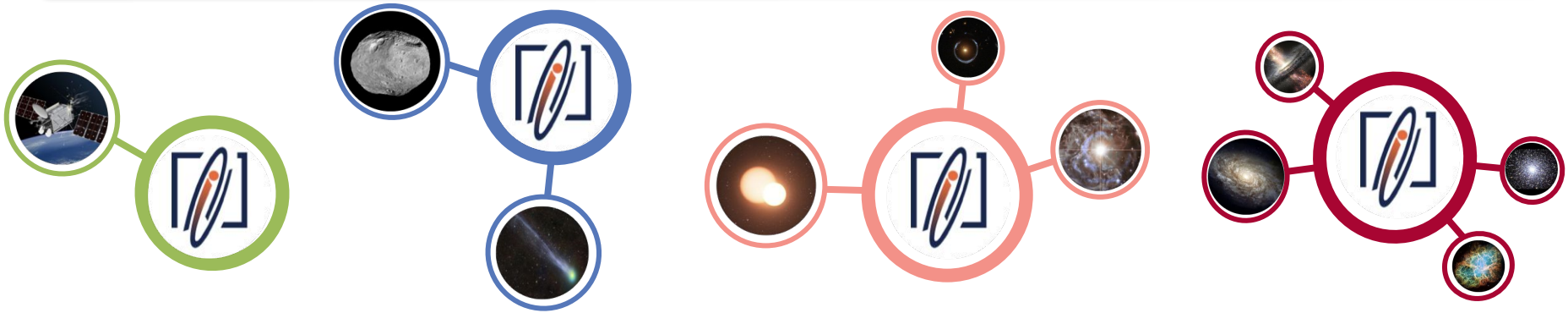
Rubin broker landscape

Do not be mistaken – a lot of collaborative work between us!

Fink scientific objectives



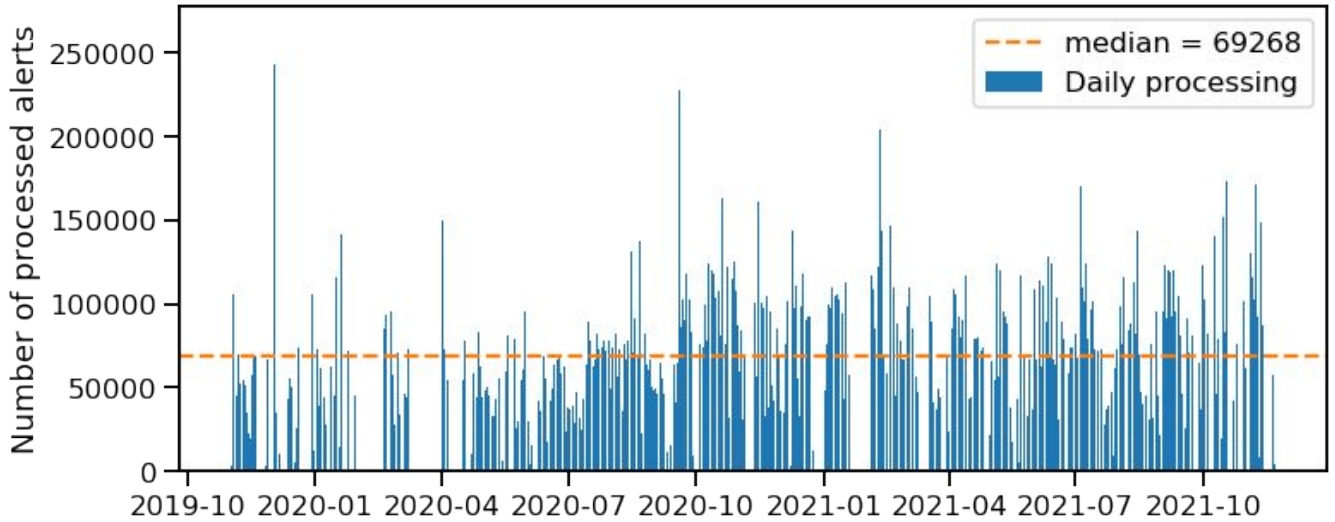
Objective: **studying transient sky as a whole**, from solar system objects to galactic and extragalactic science. https://dx.doi.org/10.1093/mnras/staa3602

Currently deployed at VirtualData (Paris-Saclay). Production services for Rubin under deployment at CC-IN2P3.

Processing ZTF data

Fink is already operating on real alert data

- Listening to Zwicky Transient Facility (ZTF) since end of 2019
- ~200,000 alerts received per night (~20GB/night) -- ⅓ survives our quality cuts

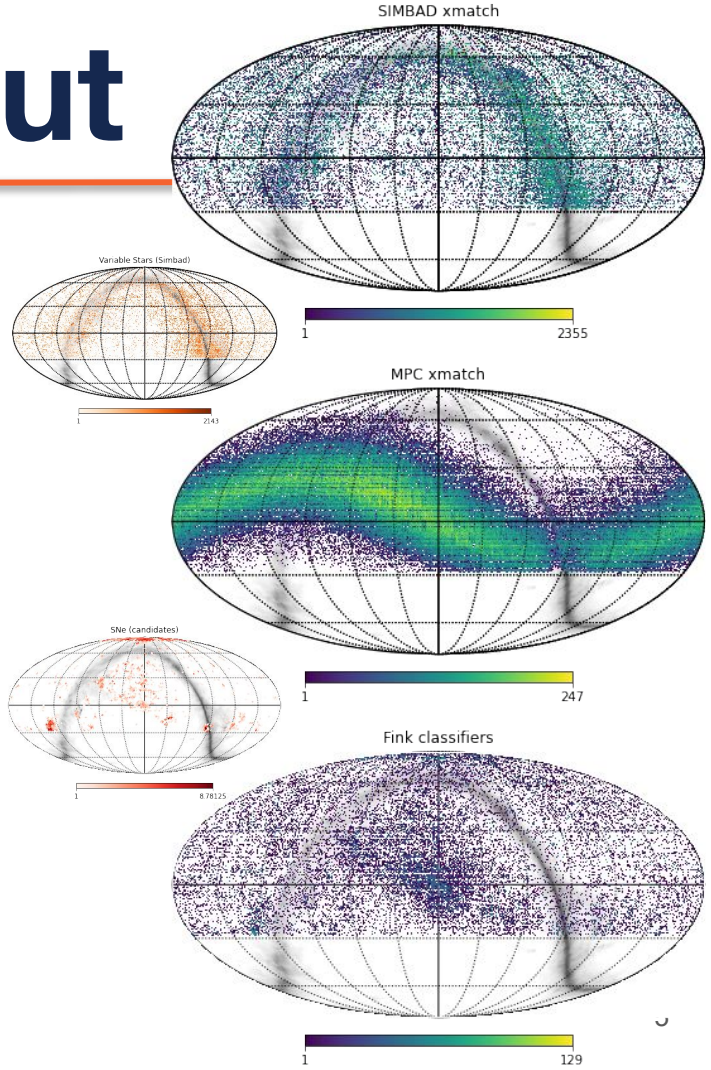


Fink science output

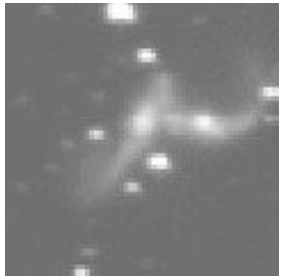
More than 120 million alerts collected since 2019.
Cross-matching (e.g. with CDS xmatch service) + **classification** (machine learning based algorithms)

Each night, we transmit to the community:

- ~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)
  - https://github.com/astrolabsoftware/fink-client
- Science Portal & REST API
  - All data will remain accessible for the full survey duration
  - https://fink-portal.org
- TOM module
  - https://github.com/TOMToolkit/tom_fink

If you are a user of the Lasair broker, see also Roy’s talk for accessing some part of Fink’s classification products through their system.

MMA projects in Fink

MMA effort started early, as there are many challenges: data models, interoperability of tools, diversity of backgrounds, large infrastructures to develop for low-latency operations…

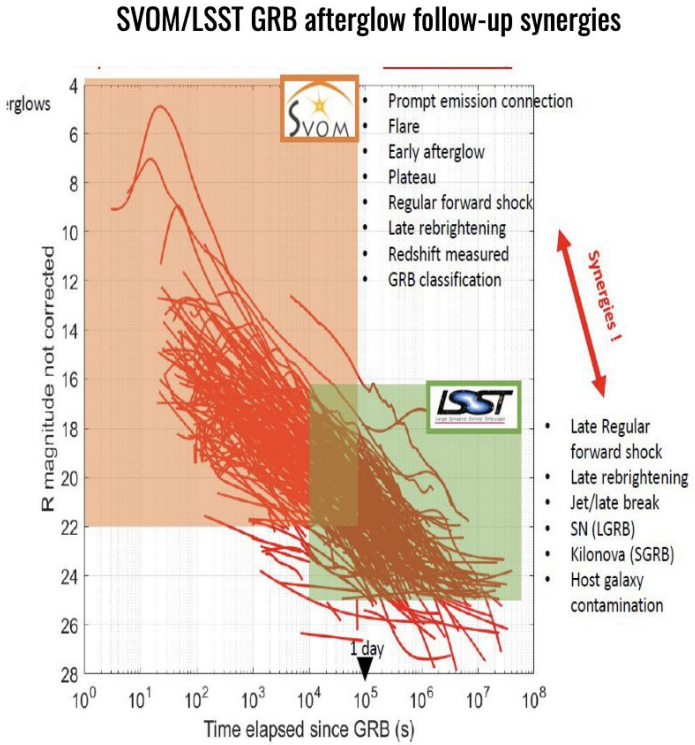
- Detection of fast fading on-axis GRB afterglows and slow-evolving off-axis GRB afterglows with the SVOM mission (See Cyril Lachaud's talk)
- Search for Kilonova with the network of telescopes GRANDMA (see Sarah Antier's talk)

GRB science with LSST & SVOM

SVOM & Rubin will probe different aspects of an event: prompt vs late emission.

Rubin thanks to its cadence and limiting magnitude (~24), it will be able to follow the signal over several days (several weeks for the brightest events).

Rubin can localise precisely an event, assuming we can find it in the deluge of alerts!



Credit: D. Turpin

GRB science with LSST & SVOM

Goal: detection of fast fading on-axis GRB afterglows and slow-evolving off-axis GRB afterglows

Fink should enable at minimum:

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

Three ongoing efforts

- Integration with SVOM – interoperability (lead D. Turpin)
- Orphan GRB afterglows detection in ZTF/Rubin (lead J. Bregeon)
- Modeling GRB (incl. orphans) & kilonova at Rubin scale (lead J.G. Ducoin)

Kilonova science

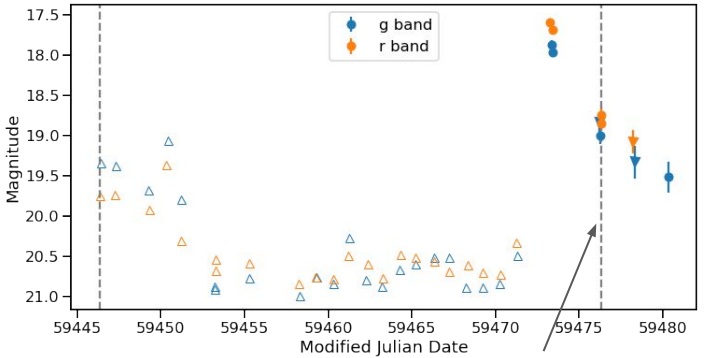
Difficulty: we have very little data to compare with…

Fink has several ways to select likely kilonova candidates from optical data:

- Simple arguments (e.g. slope of the lightcurve)
- Machine learning based light-curve classification
- Contextual information (criteria on host galaxy, distance, absolute magnitude, etc.)

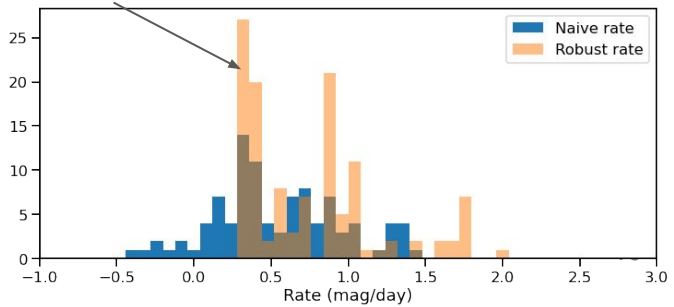
All selected candidates are sent real-time to GRANDMA for potential follow-up.

Example KN candidate



Alert was sent at this moment to GRANDMA

Objects with rate above 0.3 mag/day



Science with amateurs

Part of our mission is also to open astronomy to a larger community – larger than *the professional astronomers*.

Thanks to GRANDMA, we participate to the Kilonova Catcher that brings professional astronomers and amateurs together to search for kilonovae.

Each Friday, Fink sends its KN candidates to the amateur astronomy community so that follow-up observations can be performed over the week-end. Huge success so far*, but a lot of challenges! Coordination, photometry, interpretation…

Credits: D. Marchais, D. Boutigny, S. Leonini, A. Cailleau, and many others

*But obviously no kilonovae found ;-)

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

LSST Project/NSF/AURA

Fink team

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

30+ members all over EU

Fink members & collaborators

- **CEA/AIM, Université Paris-Saclay**: D. Turpin
- **Centre for Data Intensive Science/MSSL, University College London**: T. Allam Jr.
- **CEICO, Institute of Physics, Czech Academy of Sciences**: S. Karpov
- **CNRS/APC, Université de Paris**: A. Boucaud, A. Coleiro
- **CNRS/CC-IN2P3**: F. Hernandez
- **CNRS/CDS, Observatoire Astronomique de Strasbourg, Université de Strasbourg**: A. Nebot Gomez-Moran
- **CNRS/CPPM, Aix Marseille Université**: D. Dornic, D. Fouchez
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- **CNRS/IRAP, Université Paul Sabatier**: O. Godet, N. Webb
- **CNRS/LAPP, Université Grenoble-Alpes, Université Savoie Mont Blanc**: D. Boutigny
- **CNRS/LPC, Université Clermont Auvergne**: E. Gangler, P. Gris, E. Russeil
- **CNRS/LPSC, Université Grenoble-Alpes**: J. Bregeon
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- **Las Cumbres Observatory**: E. Bachelet
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Development Team

- Julien Peloton (Lead) - CNRS/IJCLab, IT department
- Chris Arnault (distributed computing) - CNRS/IJCLab, IT department
- Julius Hrivnac (database) - CNRS/IJCLab, IT department
- Marco Leoni (machine learning) - Université Paris-Saclay, IT department
- Sacha Pateyron (cloud management, deployment, monitoring) - CNRS/IJCLab, IT department

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.