

Introduction to

From alerts to science

*Enabling Astronomical Transient discoveries in the Rubin era: the Fink-Brazil Workshop
6 May 2024, CBPF - Rio de Janeiro, Brazil*



Emille Ishida, Julien Peloton and Anais Möller

The astronomical context:

- Astronomy has traditionally been an experience of solitude
- Old telescopes provided detailed information about a small number of objects

In the last few decades this changed drastically ...



The old astronomer, poem by Sarah Williams, 2
illustration by Charlie Bowater

How did we get here?

Big data happened



SDSS

2000 - now

120 TB

Primary mirror: 2.5 m



ZTF

2018 - now

1.4 TB/night

Primary mirror: 1.2 m



**VERA C. RUBIN
OBSERVATORY**

15 TB/night

From 2025

Primary mirror: 8.4 m

The Vera Rubin Observatory Large Survey of Space and Time (LSST)

In a nutshell:

- telescope: 8.4m primary mirror
- world's largest CCD camera:
3.2 Gpixels

In numbers:

- 10-year survey, starting 2025+
- 1,000 images/night = 15TB/night
- 10 million transient candidates per night
 - Publicly available...
 - ... but huge!



Summit on January, 2023



Rubin Observatory/NOIRLab/NSF/AURA/Y. AlSayyad

Rubin science goals

Four main science themes

- Probing dark energy and dark matter.
- Taking an inventory of the solar system.
- Exploring the transient optical sky.
- Mapping the Milky Way.

Eight science collaborations (about 1,500 scientists) - several dozens roadmaps

LSST
AGN Science Collaboration
Roadmap

1. AGN Selection, Classification, and Characterization
2. AGN Redshift Estimates
3. AGN Variability Science
4. Ancillary Data & Follow-up

Active Galaxy Science in the LSST Deep-Drilling
Fields: Footprints, Cadence Requirements, and
Total-Depth Requirements

W.N. Brandt (Penn State), Q. Ni (Penn State), G. Yang (Penn State),
S.F. Anderson (Univ Washington), R.J. Assef (Univ Diego Portales), A.J. Barth (UC Irvine),
F.F. Bauer (Catalina) A. Bongiorno (Oss Ast Roma) C.T. Chen (MSEF)

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<https://doi.org/10.1086/1558.2013.23131a>

Rubin Observatory LSST Transients and Variable Stars Roadmap

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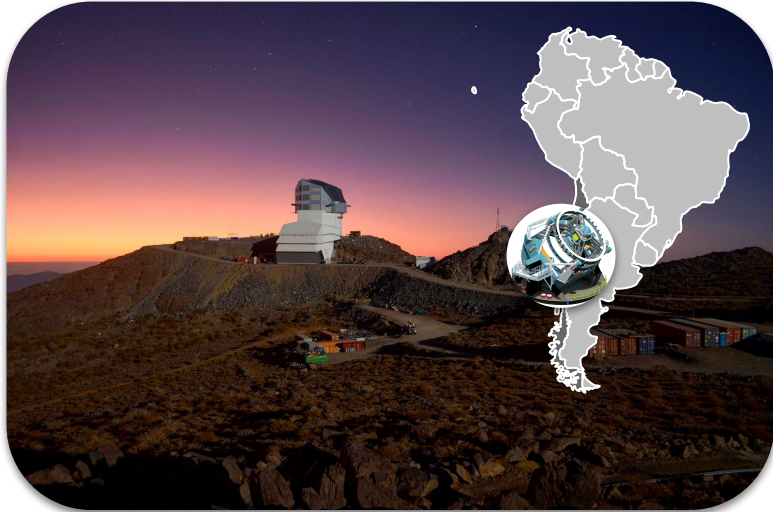
zars and Fast Radio Bursts with LSST

, M.I. Carrerero, B. Balmaverde, F. D'Ammando, C. Righi et al.

November 30, 2018



Rubin/LSST data products



Now

Raw Data

Sequential 30s image, 20TB/night

60s

Prompt Data Product

Difference Image Analysis
Alerts: up to 10 million per night

24h

Prompt Products DataBase

Images, Object and Source catalogs from DIA
Orbit catalog for ~6 million Solar System bodies

Year

Annual Data Release

Accessible via the LSST Science Platform &
LSST Data Access Centers.

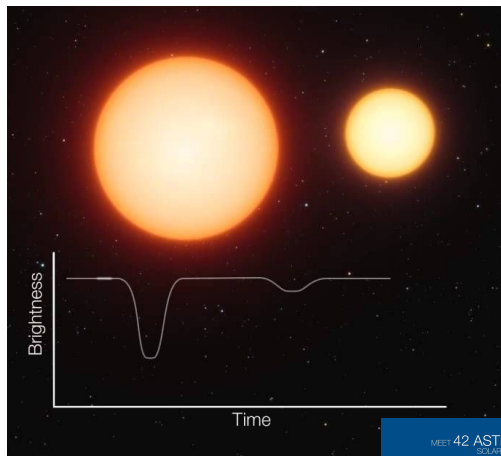
End

Final 10yr Data Release

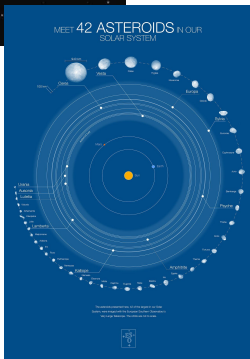
Images: 5.5 million x 3.2 Gpx
Catalog: 15PB, 37 billion objects

The transient sky

Eclipsing binaries



Credit: ESO/L. Calçada



ESO/M. Kornmesser/Vernazza et al./MISTRAL algorithm (ONERA/CNRS)



Credit: ESO/L. Calçada

Supernovae



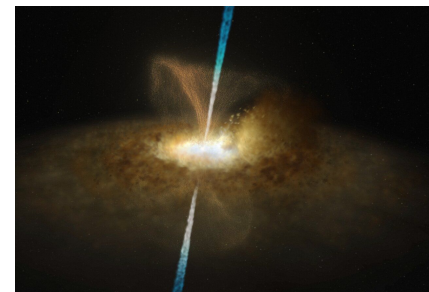
Credit: ESO

Tidal Disruption Event



Credit: ESO/M. Kornmesser

Active Galactic Nucleus

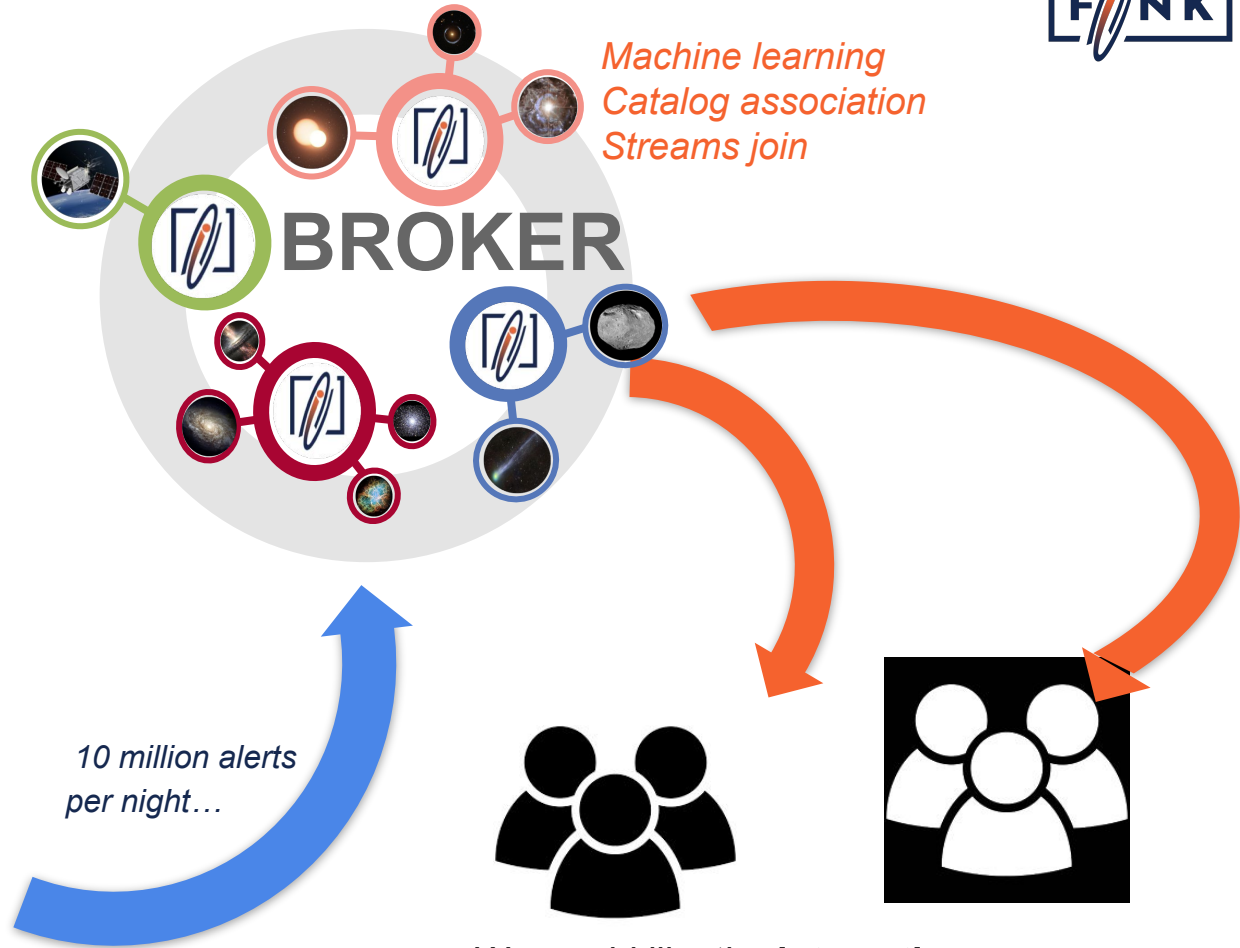
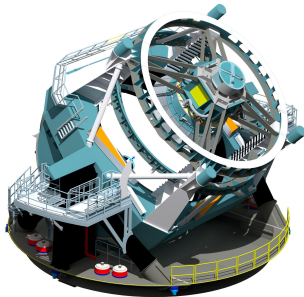


Credit: ESO/M. Kornmesser and L. Calçada

The data path



every ~30 seconds down to
mag ~24



Machine learning
Catalog association
Streams join

BROKER

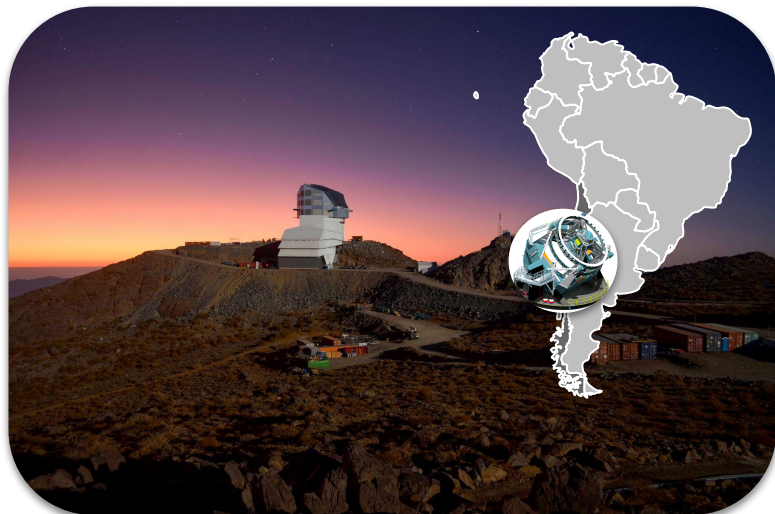
10 million alerts
per night...



We would like the *interesting* ones ...



Rubin/LSST data products



Rubin Observatory (2025+)

- **20TB of images / night**
- **1TB of alerts / night:** x100-x1000 above current streams
- *Everything matters a priori*

Now

Raw Data

Sequential 30s image, 20TB/night

60s

Prompt Data Product

Difference Image Analysis
Alerts: up to 10 million per night

24h

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Alert content

Alerts based on **Difference Image Analysis**

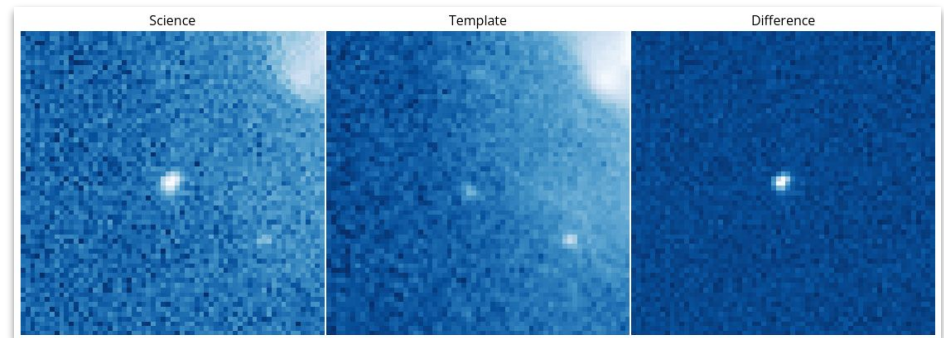
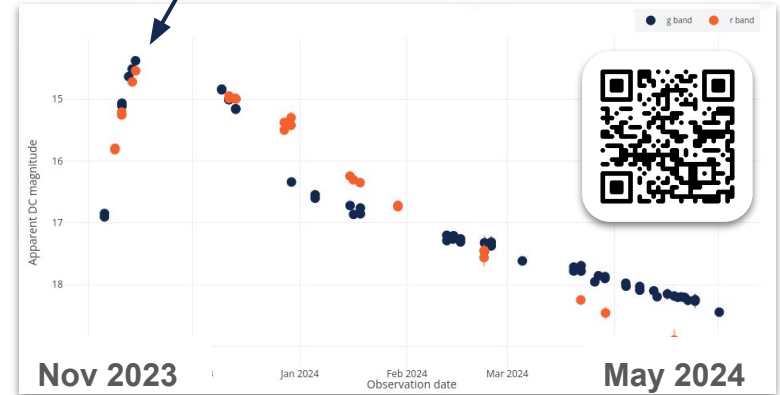
Alert contains typically (based on ZTF)

- 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:

https://github.com/lstt/alert_packet

Each measurement is from an alert



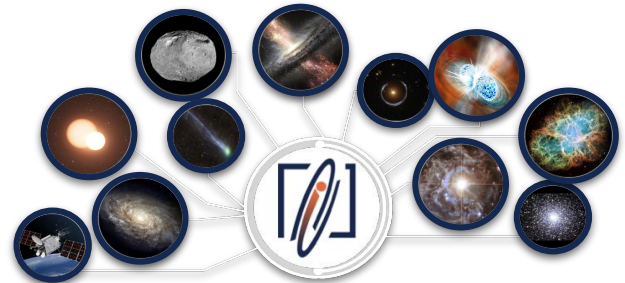
Rubin alert brokers

Rubin will send the full alert stream to **seven brokers**: they are the public interface to the LSST alert stream

- ALERCE, AMPEL, ANTARES, Babamul, [Fink](#), Lasair, Pitt-Google

Serve a large scientific community by **ingesting, classifying, filtering, and redistributing** alerts. Classification is a community-driven effort.

All prototyping on ZTF (300k alerts/night), and test deployment of the Rubin Alert Distribution system.



Fink (2019 –)

Operating 24/7 since 2019, serving 100+ unique users per day (**scientists & follow-up facilities**).

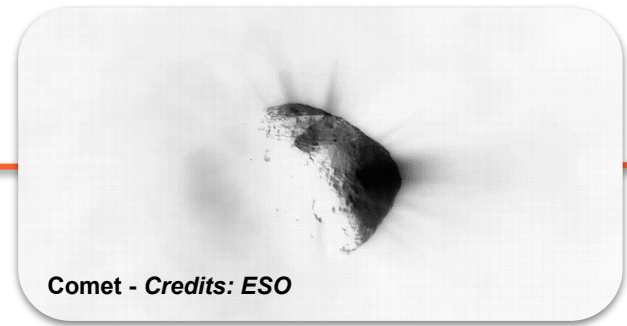
- Real-time components (million+ event/night)
- Event database (~1B entries)

Processing the **ZTF alert stream** since 2019

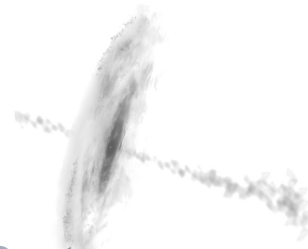
- 225 million ZTF alerts received
- $\frac{2}{3}$ is classified: 40% galactic, 15% Solar System, few% extra-galactic
- Coupled to **GCN**: Fermi, Swift, Icecube, LVK, ...

Community-driven: scientists bring building bricks

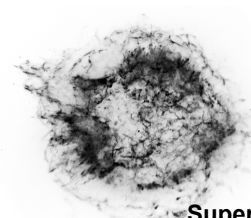
- 60+ members, 15+ scientific topics covered



Comet - Credits: ESO



Active Galactic nucleus



Supernova



Tidal disruptive event

Turning information into science



Alert information solely is not enough – we need **communication protocols** with experts and follow-up facilities

- More than 60 scientists worldwide contribute to the project.
- Focus on building models according to community requirements
- Open & collaborative process: “One man's trash is another man's treasure”



What does that mean in practice?

Selected examples of community engagements in Fink:

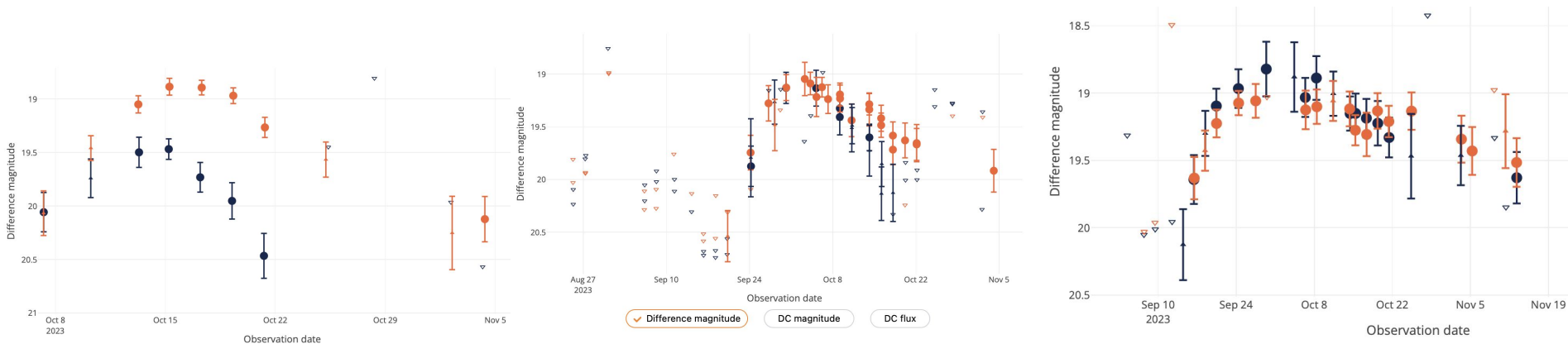
1. On-the-fly adaptive learning: Early SN Ia
2. Follow-up for new solar system objects
3. Search for fast transients
4. The anomaly detection ecosystem



1. On-the-fly AL: Early SN Ia

Goal: optimize follow-up + build informative training samples
The dream: automatic processing + ML training

2 CV, 16 SN Ia, 1 SN Ib, 2 SN Ibn, 1 SN Ic, 5 SN II, and others low SNR



ANU 2.3m IFU for spectroscopic follow-up + extra spectra by DEBASS and ePESSTO+

Check Emille's talk on Wednesday!



2. New Solar System objects

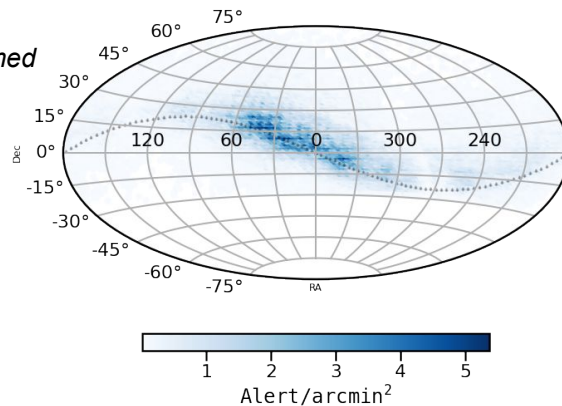
Originally started with search for GRB...
ended up doing SSO!

Fink-FAT: return trajectories from new
candidate moving objects with orbit
estimates (nightly)

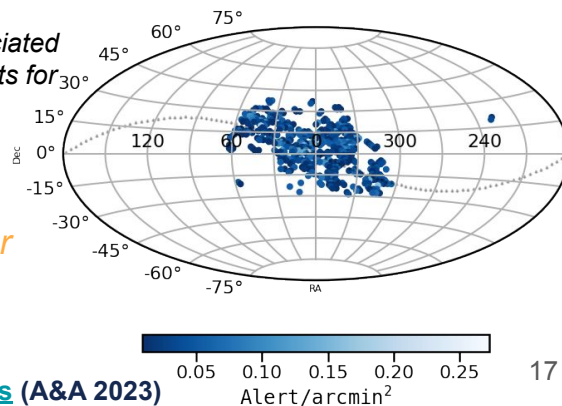
Two (late!) follow-up campaigns in 2022
with Las Cumbres Observatory (1 meter) &
Observatoire Haute Provence (1.2 meter)

- 3 irregular Jupiter satellites (Pasiphae & Sinope),
1 known asteroid, 2 unclear

15,381,246 ZTF alerts
associated with confirmed
Solar System objects



2,205 ZTF alerts associated
with reconstructed orbits for
new SSO candidates



*Talk to Roman for
more details!*



3. Search for fast transients

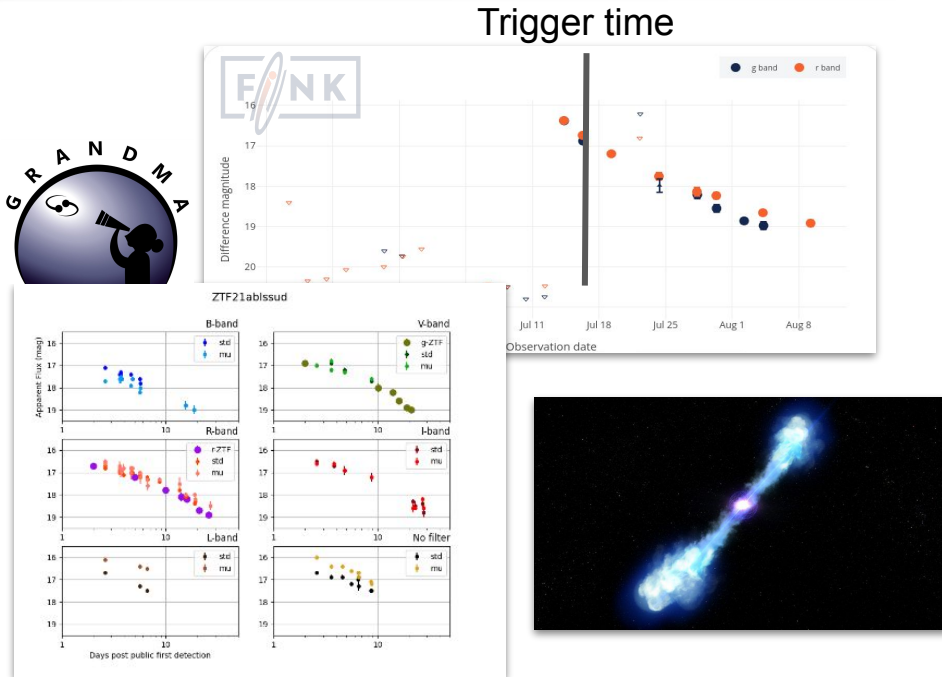
Fink classifies in real-time ZTF alerts from the public stream: ~200k/night

Selected fast transients (~1/night) are sent to the GRANDMA network in real-time for potential follow-up. Three automatic channels & human veto:

- ML techniques
- Rate-based consideration
- Contextual consideration

Citizen science program in parallel:

[Kilonova Catcher](#)



- GRANDMA Collaboration 2022 MNRAS 515 4, 6007-6022
- B. Biswas et al 2023 A&A 677, A77
- M. W. Coughlin et al 2023 ApJS 267 31

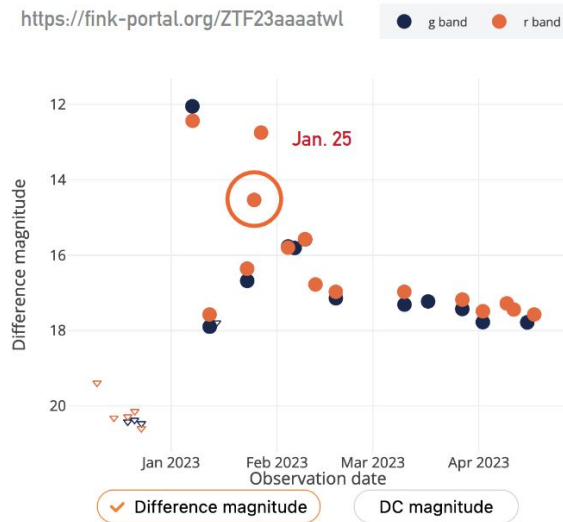


4. Anomaly Detection ecosystem

- Started with extragalactic experts, now Fink-wide engagement
- Random forest model
- Quick reaction from the follow-up community:
 - 9.2m SALT (South Africa)
 - 0.6m and 2.5m KGO (Russia)
 - 0.25m FRAM-ORM (Spain)
 - 0.2M FOSC-ES32 (Italy)

FIRST NIGHT – FIRST ANOMALY

<https://fink-portal.org/ZTF23aaaatwl>



▶ ASASSN-23ac/PNV
J06245297+0208207

▶ Simbad: WD candidate



REPORTED IN TNS AS AT 2023AWT

Check Maria's talk on Wednesday!



The best of Fink

Fink Collaboration meeting 2024



ozFink meeting 2023



Fink hackathon 2022



Fink collaboration meeting 2022

FinkBR 2024

FINK BRAZIL

SPEAKERS:
Anais Möller
Swinburne University, Australia
Antonello Palmese
CNR, USA
Claudia Mendes de Oliveira
Universidade de São Paulo, Brazil
Clecio R. Bom
CBPF, Brazil
Charlie Kilpatrick
Northumbria University, UK
Emile E. O. Ishida
CEBRASUR, France
Julien Peloton
CNRS/CNRS, France
Mariano Penna-Lima
Universidade de Araraquá, Brazil
Maria Pruzhinskaya
CEBRASUR, France
Martín Mosler
UNSW, Argentina and CBPF, Brazil

ENABLING ASTRONOMICAL
TRANSIENT DISCOVERIES
IN THE RUBIN ERA
6 - 10 May 2024
CBPF, Rio de Janeiro

Logos for FINK, CBPF, IANIGLA, FRON, CCINAPS, and IANIGLA are visible.

www.cbpf.br/fink2024

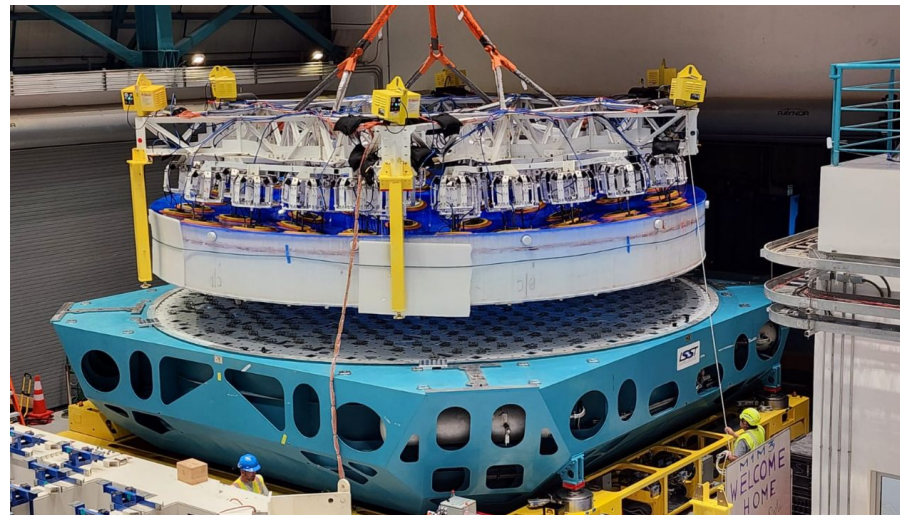
LSST alert system status

LSST commissioning in Chile will start shortly.

- Do not expect to get alerts from ComCam observing.

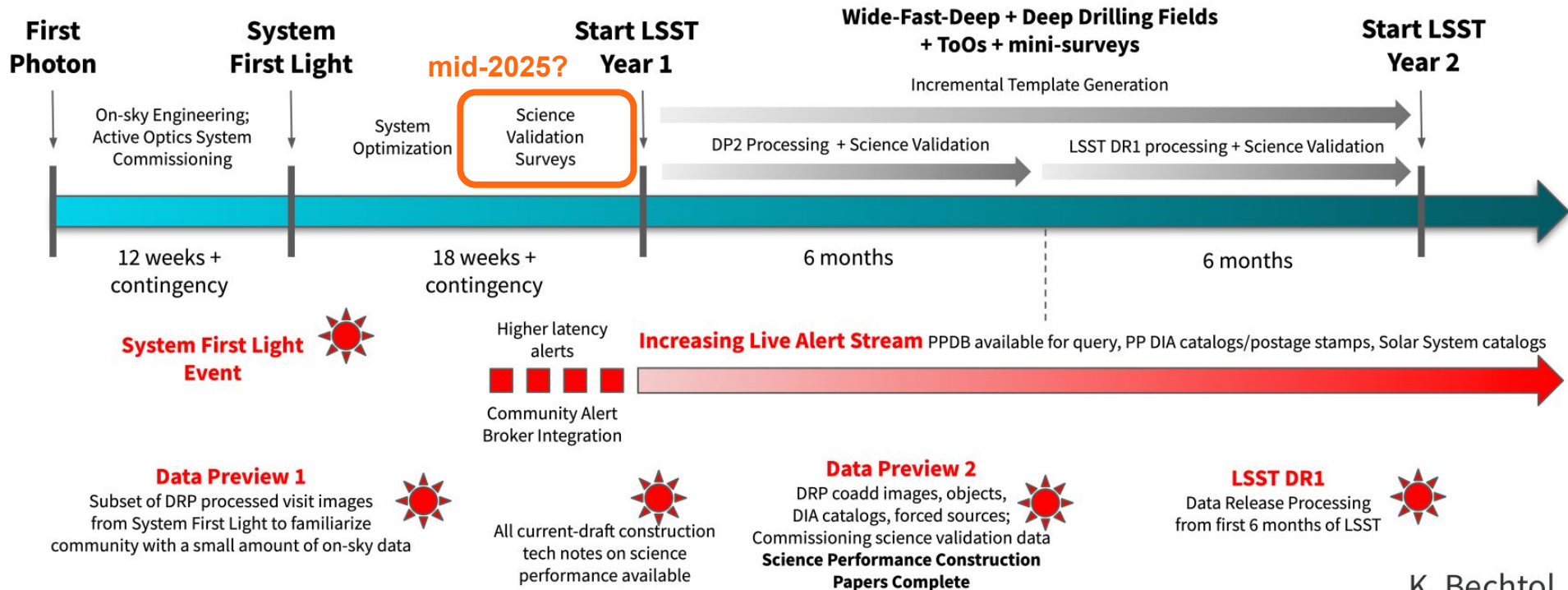
Rubin project aims to release alerts as soon as they are able.

- The most likely timescale for first alerts is around the start of the science validation surveys.



But it will take some time to build the **templates!**

Alert Production will ramp up as templates become available.



Goal(s) of the workshop

An opportunity to bridge communities beyond LSST

- *For us* to understand your expectations and needs
- *For you* to personalize your experience with LSST



All brokers provide basic interfaces, but complex scientific cases require **dedicated time and resources**.

All over the week, we will try to answer questions such as:

- How to access data with Fink?
- How to test & implement your ideas with Fink?
- How to get help, give feedback and provide suggestions?

