

# Transient alerts and brokers, a perspective from



Exploring the Transient Universe with the Nancy Grace Roman Space Telescope

**Anais Möller**  
February 10/11 2022



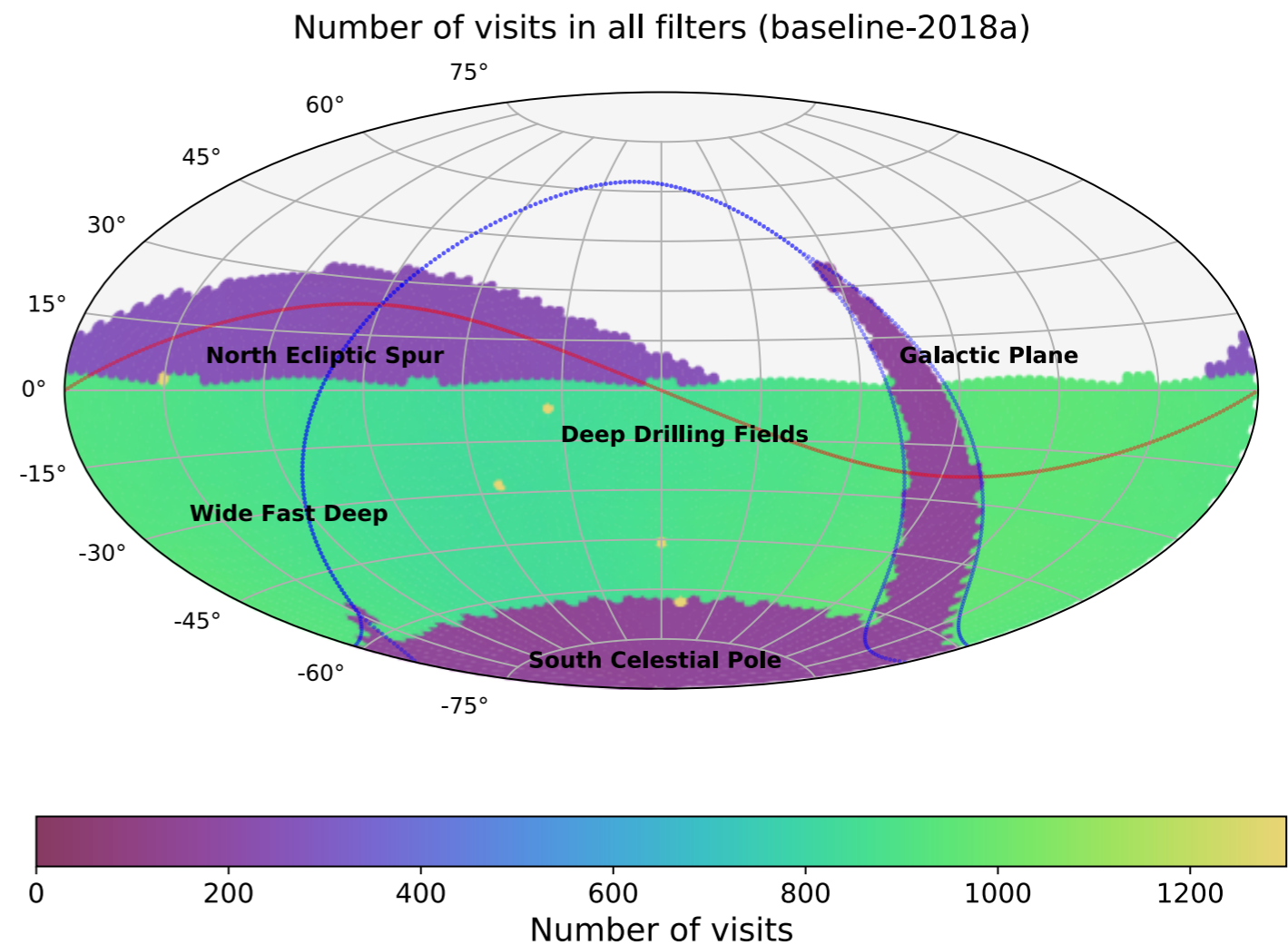
*Acknowledging the traditional owners of the  
land, Wurundjeri People of the Kulin Nation*

# LSST a deep “video” of the sky

- world’s largest CCD camera:  $3.2 * 10^9$  pixels
- 6 optical bands: *ugrizy* (320-1050nm)
- 1,000 images/night = 15 TB/night

## 5-sigma point source depth

Filter	Single
u	23.9
g	25.0
r	24.7
i	24.0
z	23.3
y	22.1



Call for White Papers on LSST Cadence Optimization  
Document-28382

# LSST data products

Now

## Raw Data

Sequential 30s image, 20TB/night

37s

## 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

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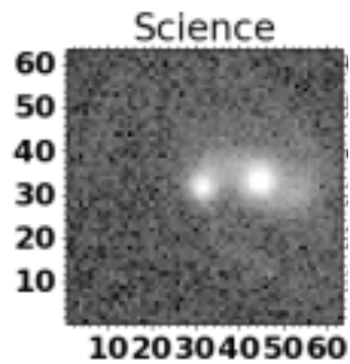
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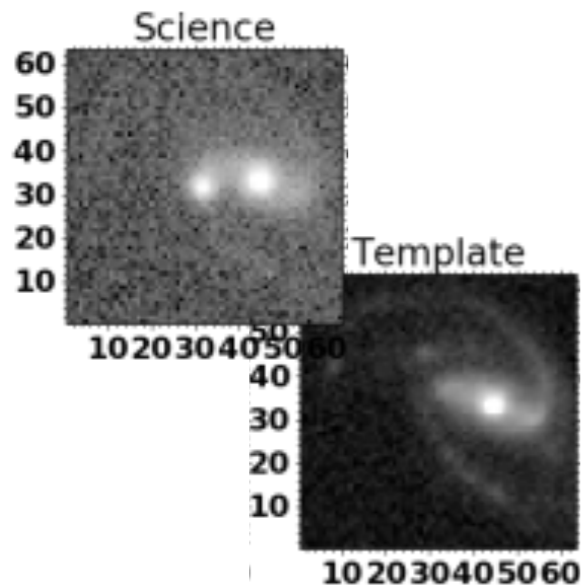
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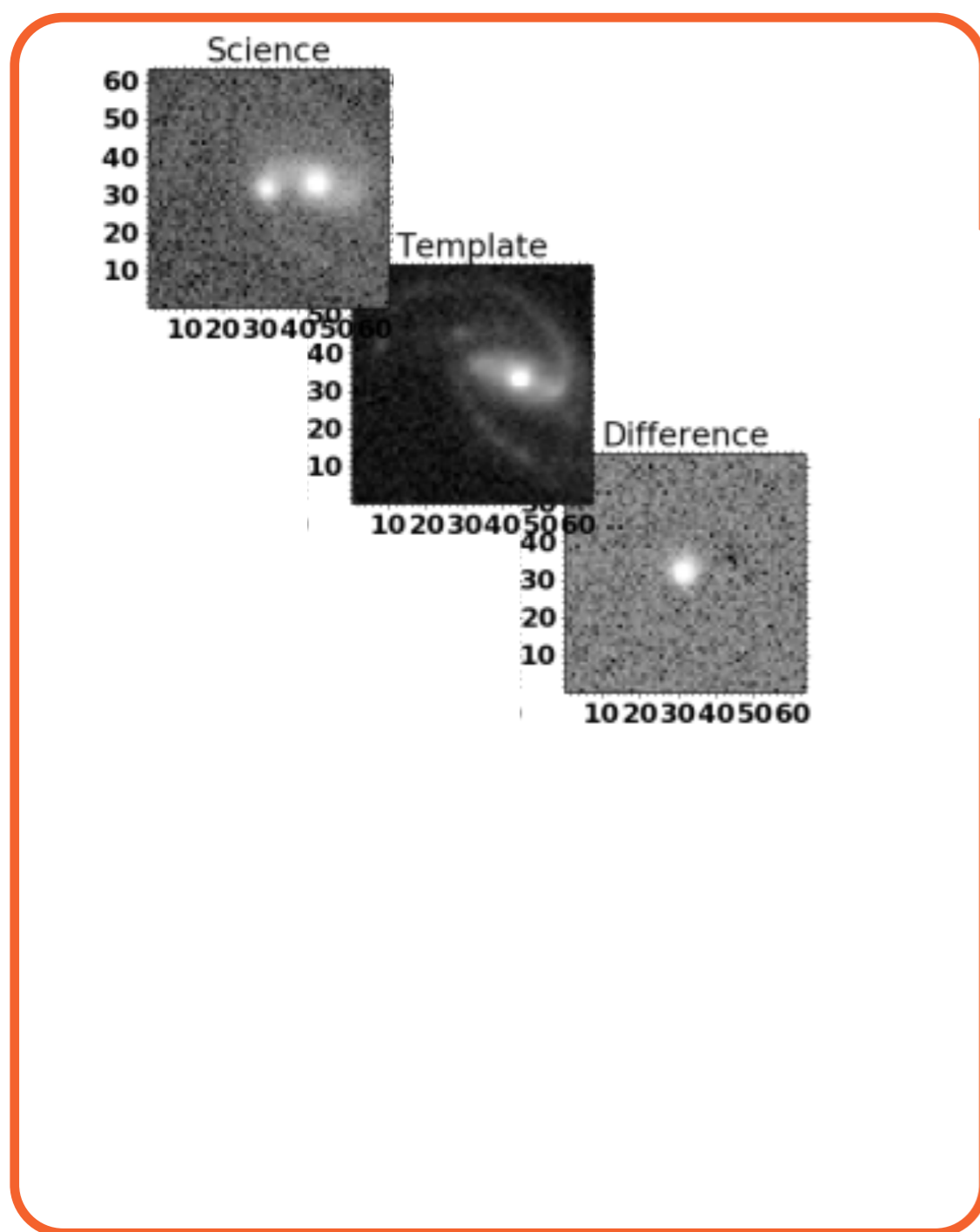
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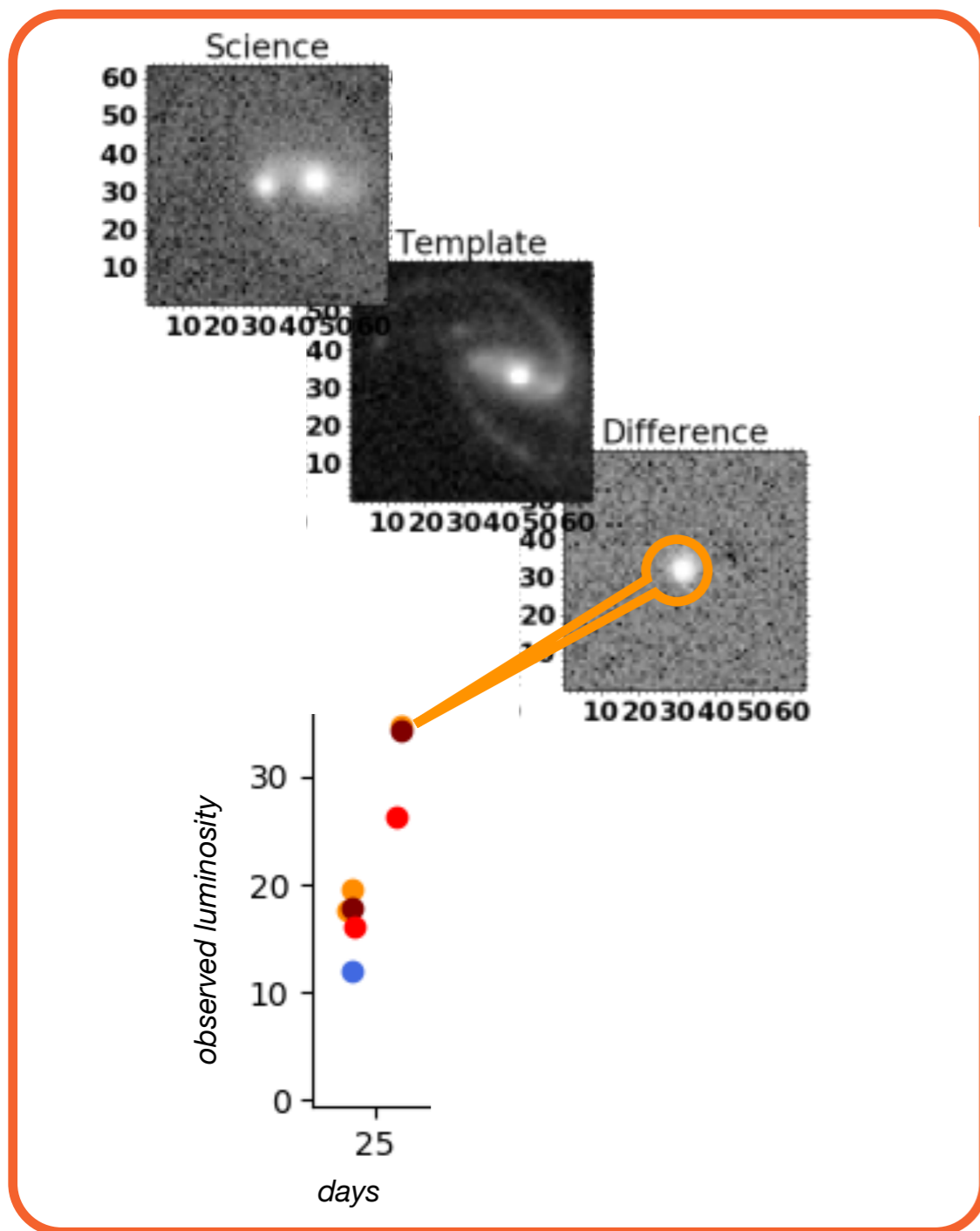
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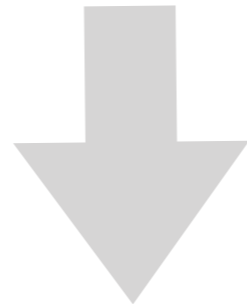
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**LSST ~ 10 million *transient alerts* per night**



***promising candidates for <X science>***

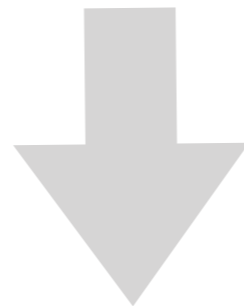
***+ connecting with other telescopes and data?***



**LSST ~ 10 million *transient alerts* per night**



# **Rubin community brokers**

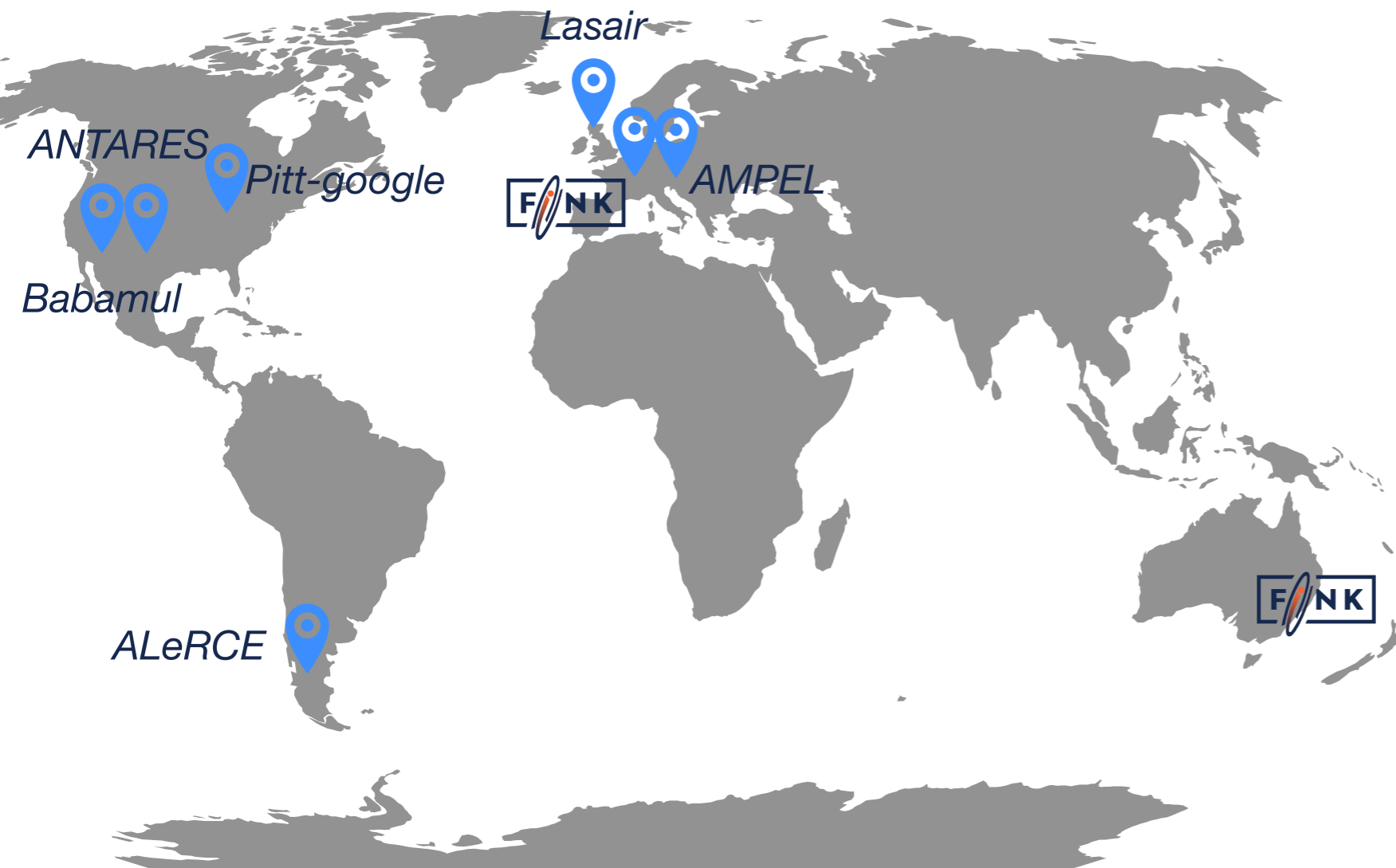


***promising candidates for <X science>***

***+ connecting with other telescopes and data?***



# Rubin community brokers



*In 2019....*

- 14 Letters of Intent
- A lot of work
- Decision on August 2021!

## **Full stream brokers**

- Will receive from Rubin ALL transient candidates within 37 seconds of detection
- Will do this for the 10 years of operations



***LSST ~ 10 million transient alerts per night***



***promising candidates for <X science>***

***+ connecting with other telescopes and data***





- A community driven effort, ***open to anyone***
- A community of >40 researchers and engineers >7 countries and growing!
- Open source data + source code





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- Designed for Rubin with ***big data technology*** (e.g. distributed computation)
- **Selected by Rubin** Operations to *receive the full alert stream* for 10-years





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- Now **processing ZTF II** public alert stream available at [fink-portal.org](https://fink-portal.org)





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- **First publication** *A. Möller, J. Peloton, E.E.O. Ishida et al. MNRAS 2020, [arXiv: 2009.10185](https://arxiv.org/abs/2009.10185)*
- Funding to deploy at CC-IN2P3 for LSST

French computing centre where half of the LSST data will be processed





# Fink in a nutshell



***LSST ~ 10 million transient alerts per night  
~10,000 every 37s***



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~10,000 every 37s***



***Cross-match***



***Catalogues***

***Survey  
streams***

- ***VOEvents / GCN***
- ***Dynamic catalogues***



**LSST ~ 10 million transient alerts per night  
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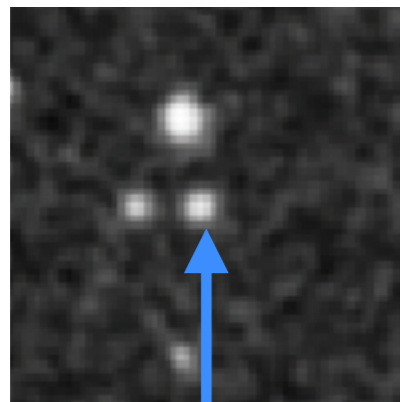
**Cross-match**



SIMBAD

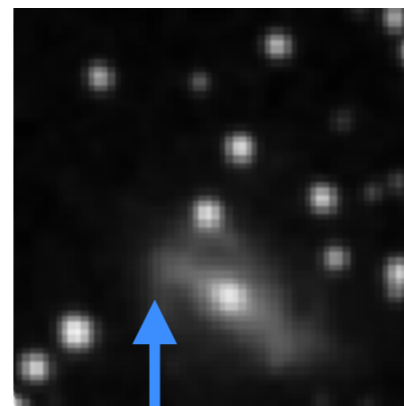


*A known variable star....*



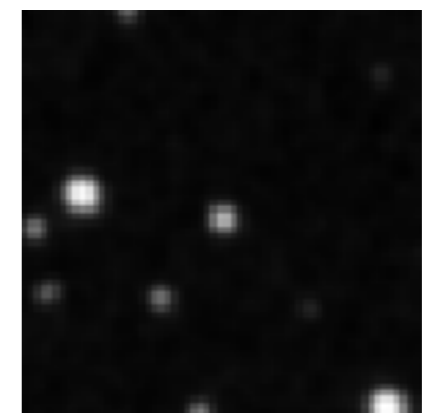
*Known Variable Star*

*Extra-galactic?*

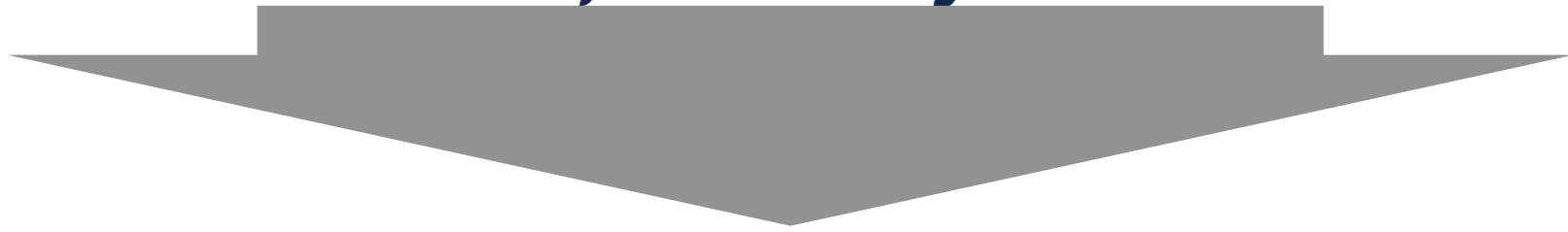


*Known galaxy close by*

*Or....*



**LSST ~ 10 million transient alerts per night**  
**~10,000 every 37s**



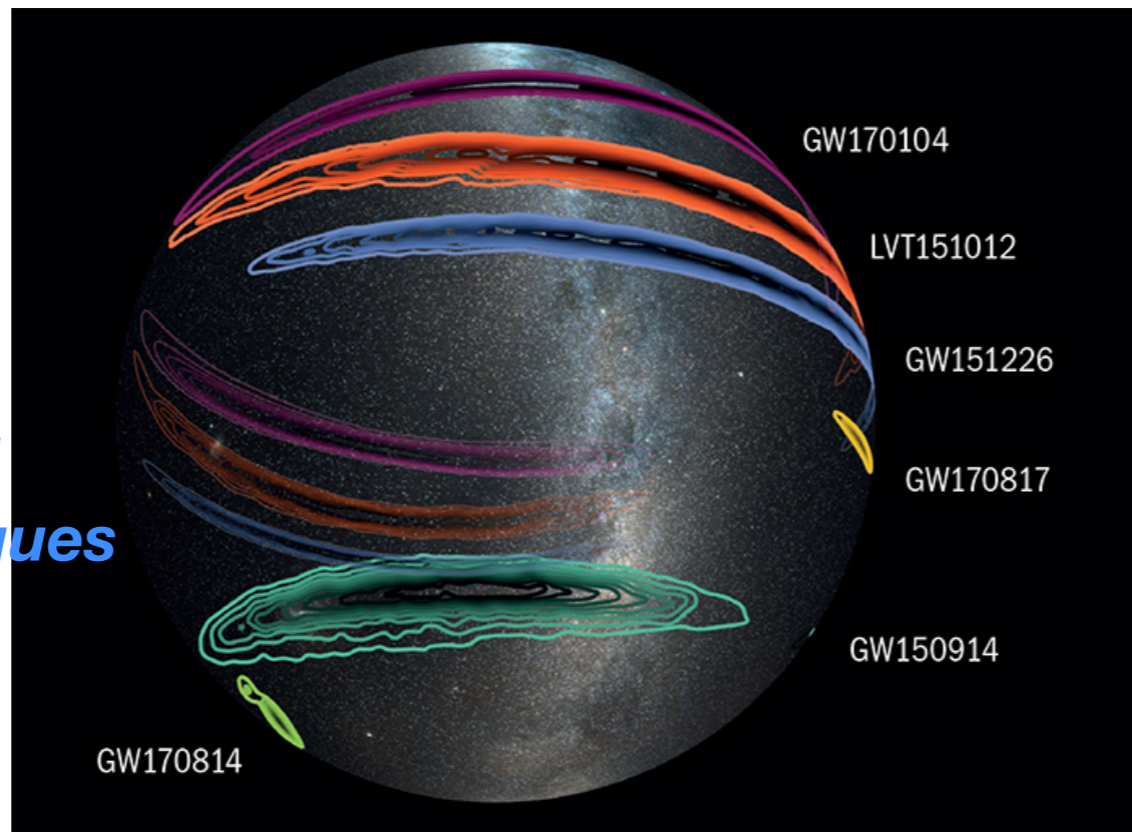
## Cross-match



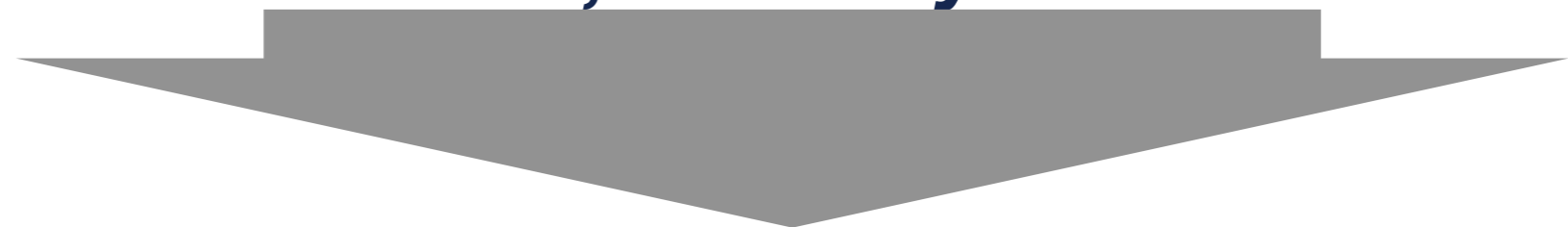
**Catalogues**

**Survey  
streams**

- **VOEvents / GCN**
- **Dynamic catalogues**



**LSST ~ 10 million transient alerts per night**  
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- *Probability of this object being X*
- *It looks like a blue object by 0.2 magnitudes*



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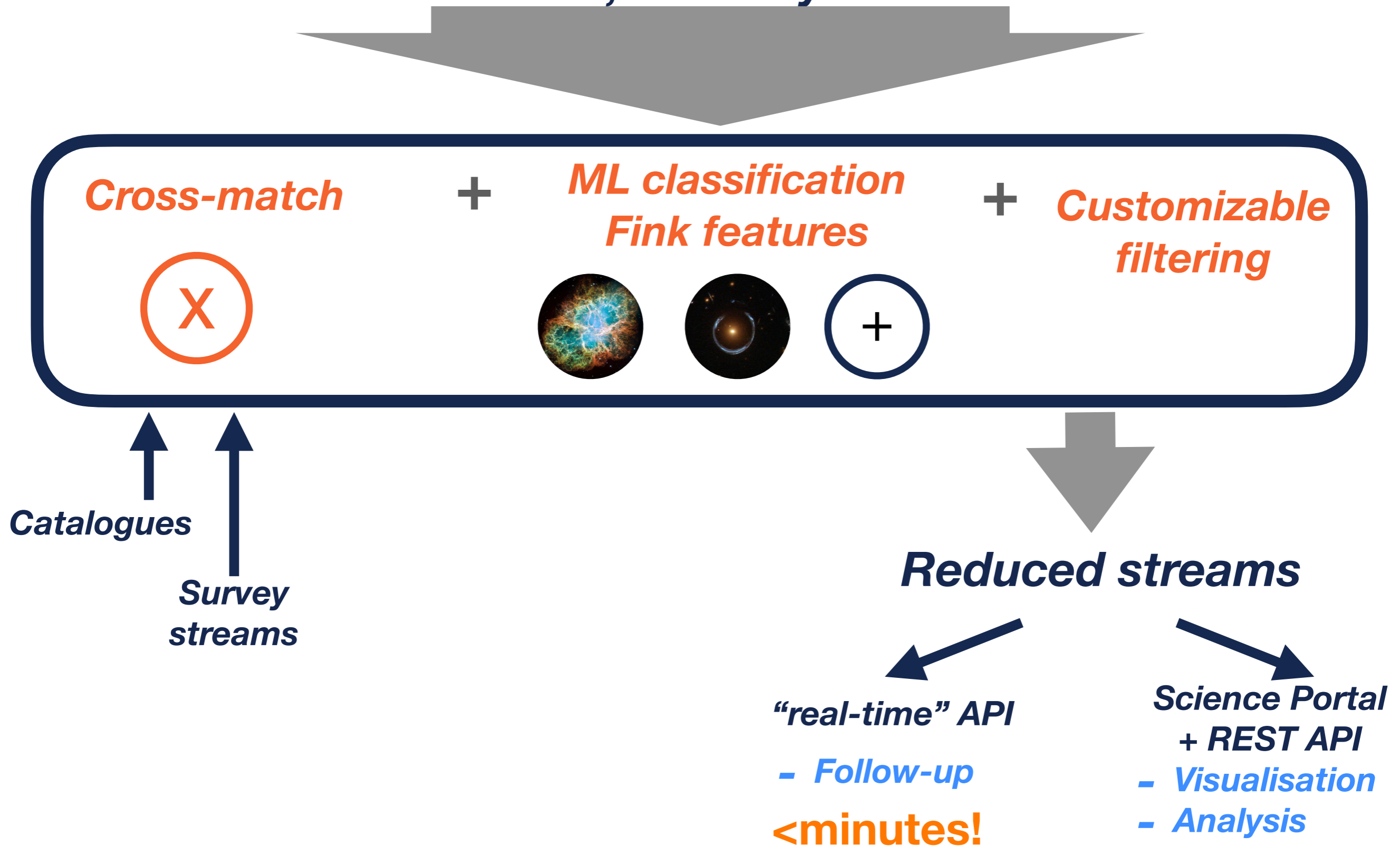
**Catalogues** ↑  
**Survey streams** ↑

- Probability of this object being X
- It looks like a blue object by 0.2 magnitudes

*I want transients that are close to a known galaxy and have large probability of being X*



**LSST ~ 10 million transient alerts per night**  
**~10,000 every 37s**



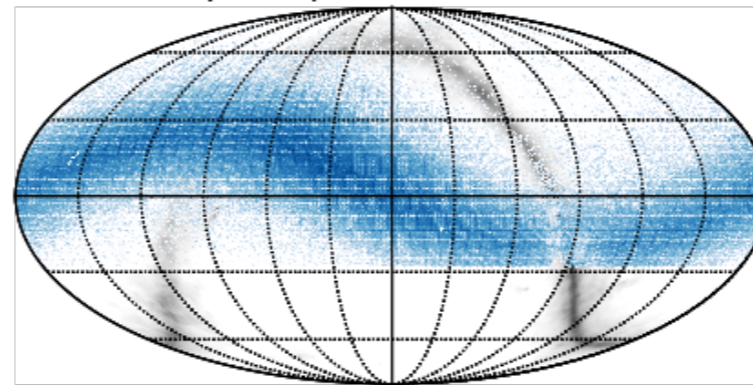


Since Nov 2019 > 120 million alerts collected & processed

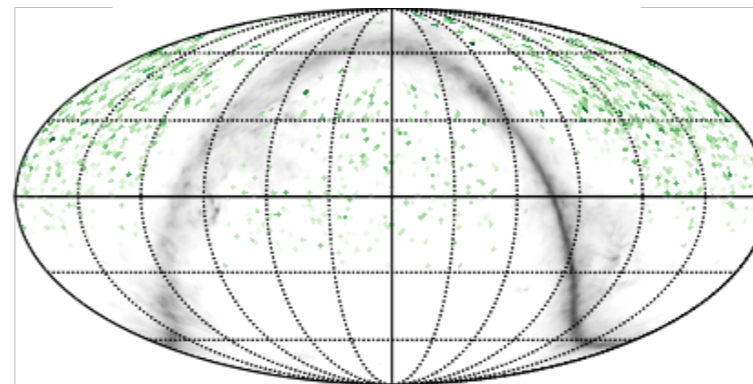
## Reduced streams:

- **Supernovae**
- Microlensing
- **Variable stars**
- **Solar System objects**
- GRB afterglows
- Kilonovae
- Early type Ia supernovae
- And more...

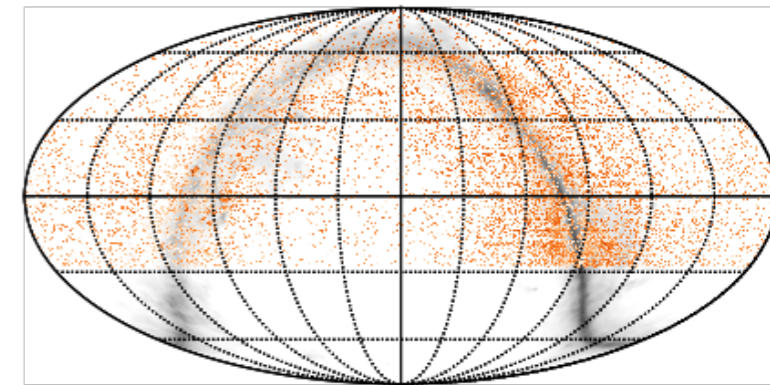
Solar System Objects  
(confirmed + candidates)



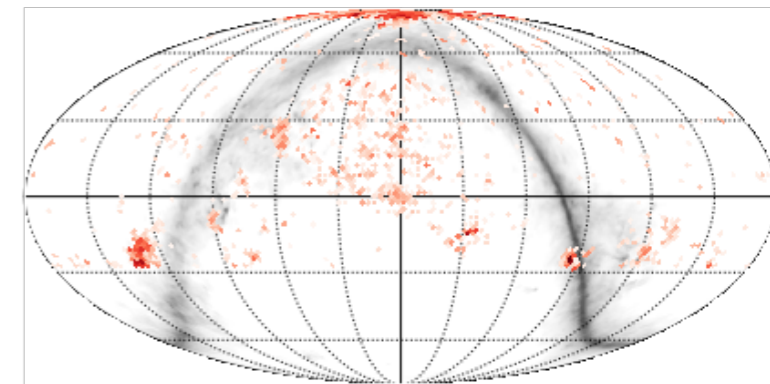
Transients with a close-by galaxy



Variable stars (SIMBAD)



SN candidates



# Rubin & Roman



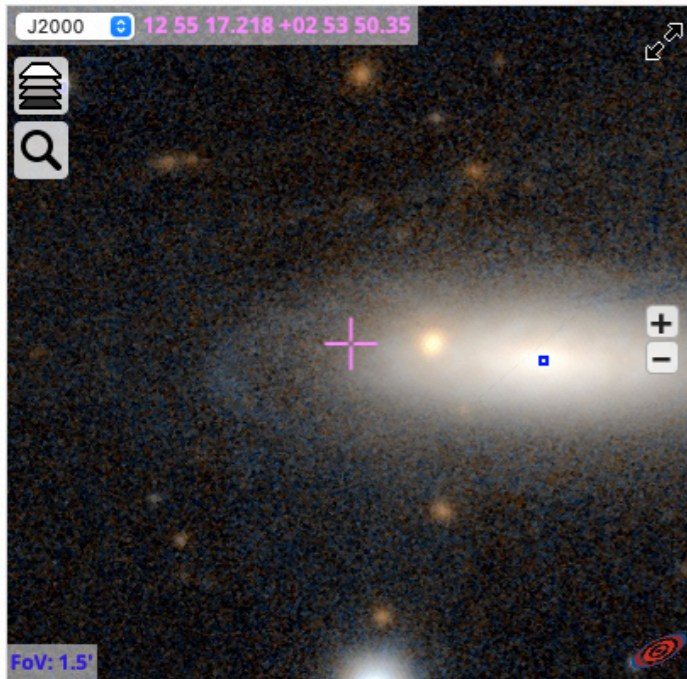
# Photometry

Rubin public optical photometry from Difference Imaging to complement Roman NIR data + contextual information + features

Fink Science portal 1.1

Search Statistics API Tutorials Info

## ZTF21abfmbix



Inspect alert data

Get object data

Summary

Supernovae

Variable stars

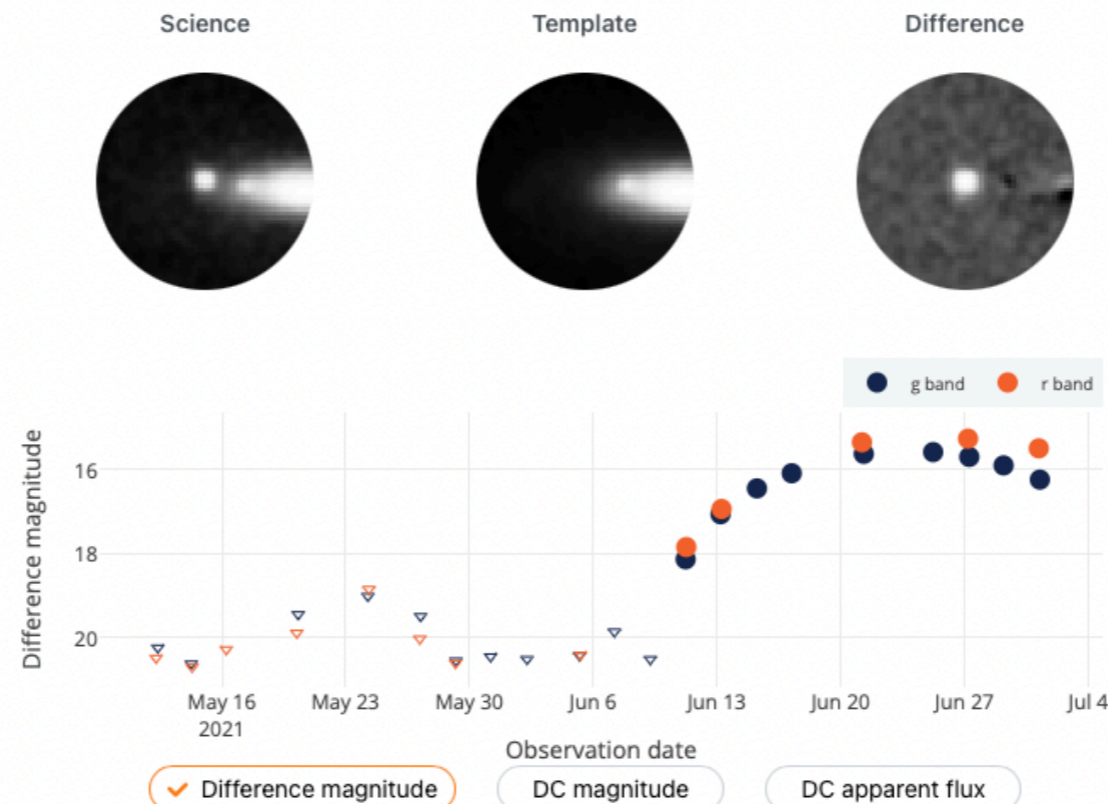
Microlensing

Solar System

Tracklets

GRB

Individual alert classification SN candidate: 86% Unknown: 14%



ObjectID: ZTF21abfmbix

Last class: SN candidate

# General properties  
Date: 2021-07-01 05:59:37.000  
RA: 193.8217409 deg  
Dec: 2.8973184 deg

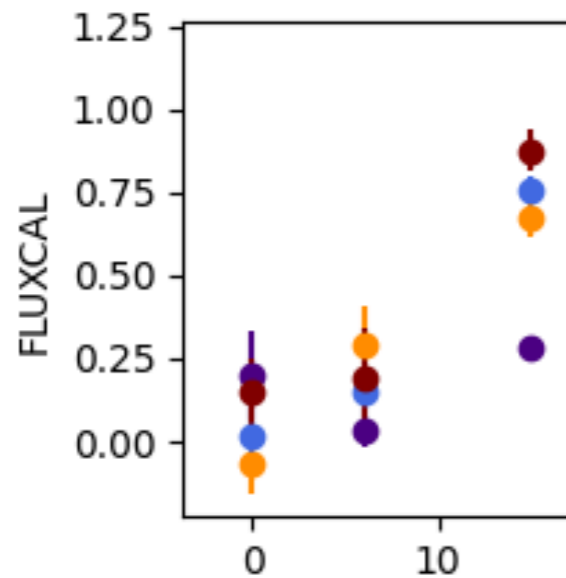
# Variability (DC magnitude)  
Rate g (last): 0.16 mag/day  
Rate r (last): 0.06 mag/day

# Neighbourhood  
Constellation: Virgo  
SIMBAD: Unknown  
MPC: null  
Distance (PS1): 10.79 arcsec  
Distance (Gaia): 10.75 arcsec  
Distance (ZTF): 2.36 arcsec



# Early transient candidates

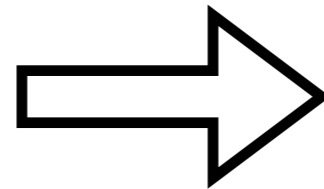
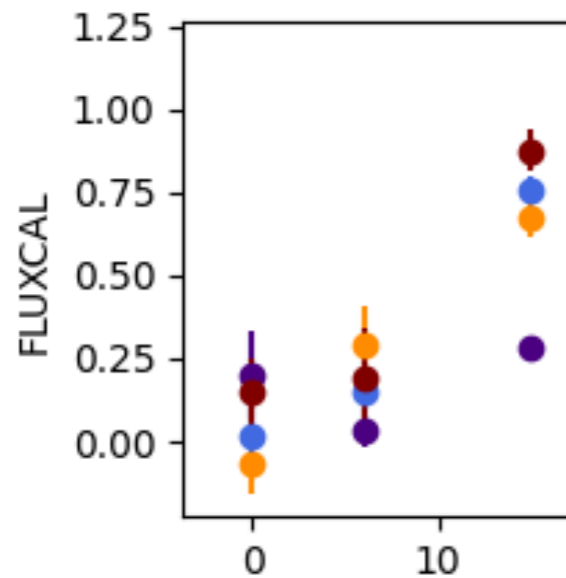
## Photometric detection @ Rubin



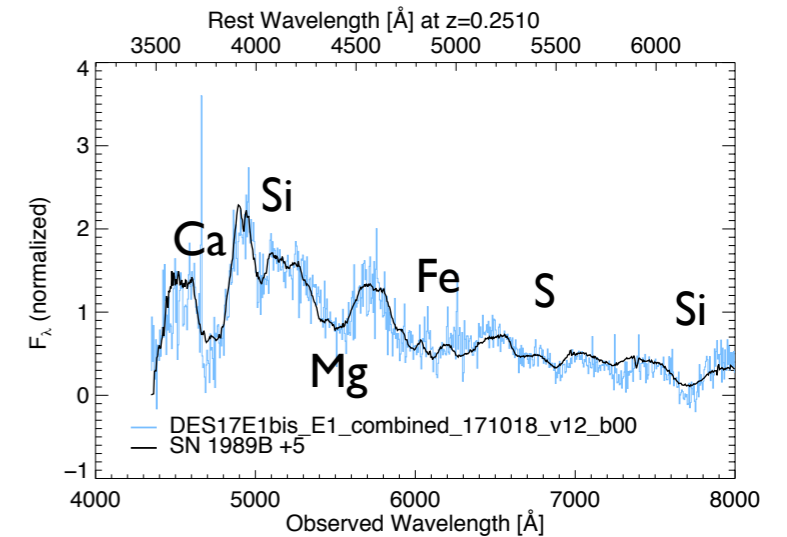
+ *shall we trigger follow-up?*  
+ *what could it be?*

# Early transient candidates

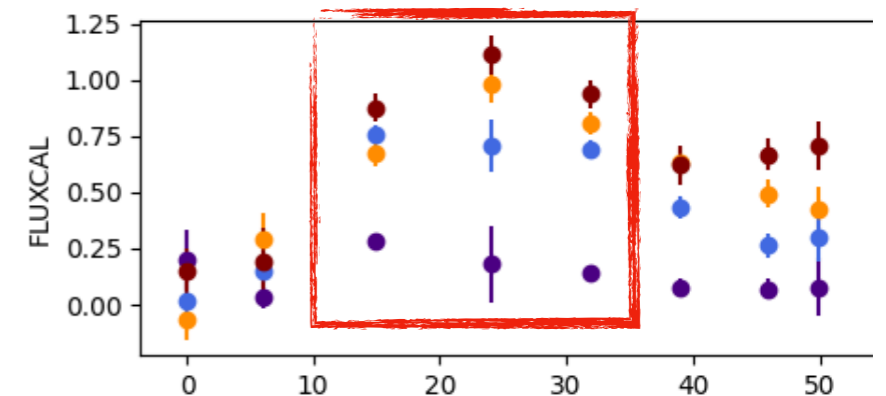
## Photometric detection @ Rubin



## Spectroscopic follow-up



Type Ia



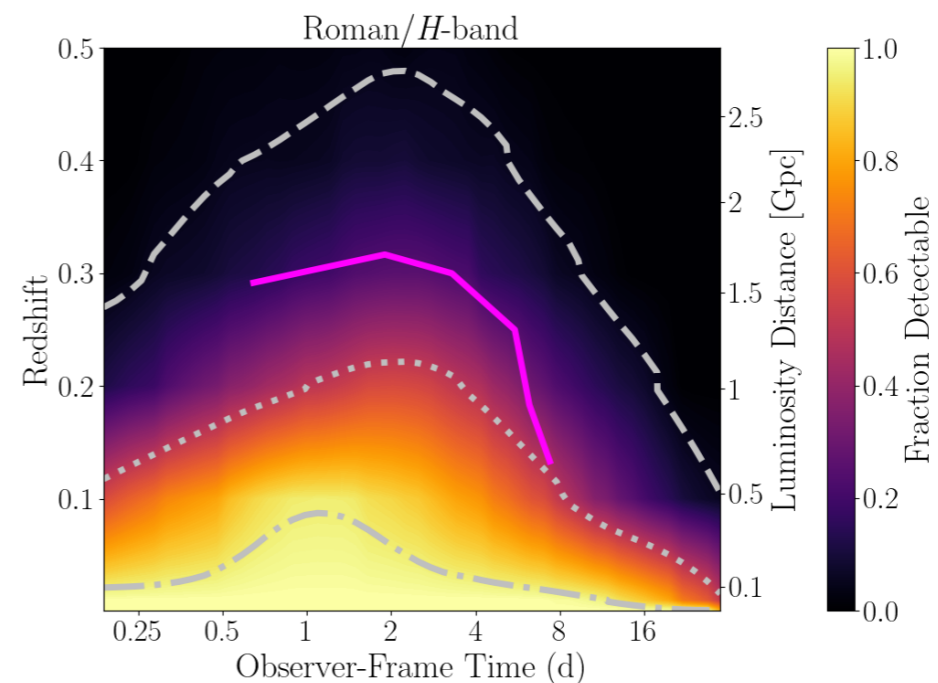
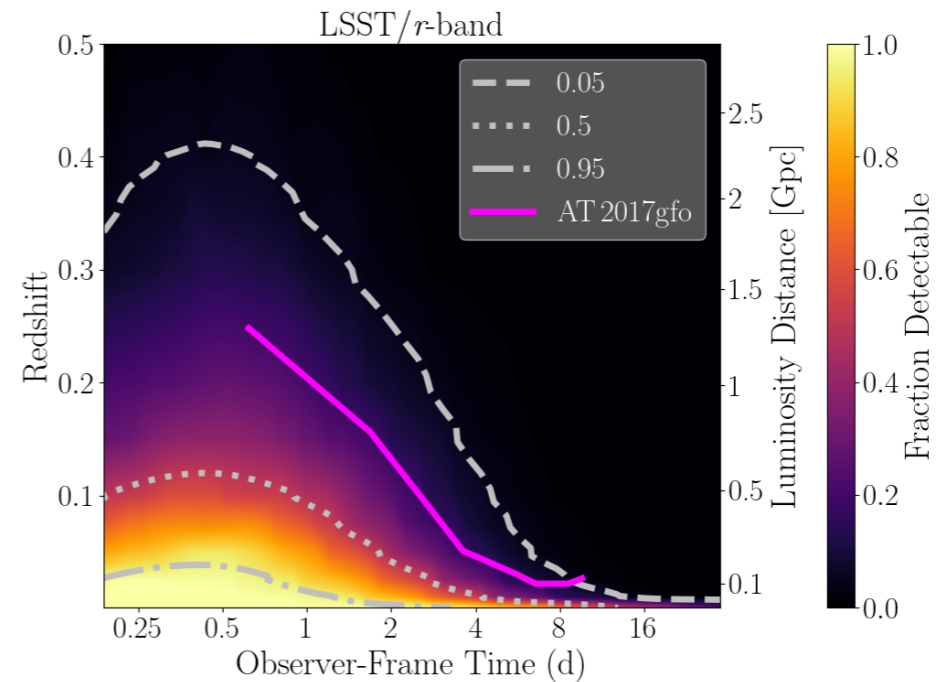
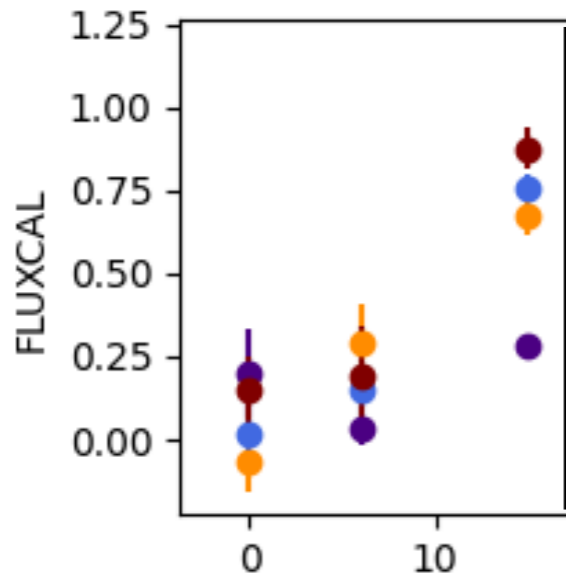
Spectroscopic resources are limited optimisation needed!

*We will not be able to follow-up all candidates in the Rubin era...*



# Early transient candidates

## Kilonovae candidates



Chase+21



- Machine learning scores: Biswas+ in prep.
- Magnitude rates
- Close-by galaxy catalogues (Mangrove Ducoin+20)



GRANDMA + Fink in prep.

+ Footprint cross-match

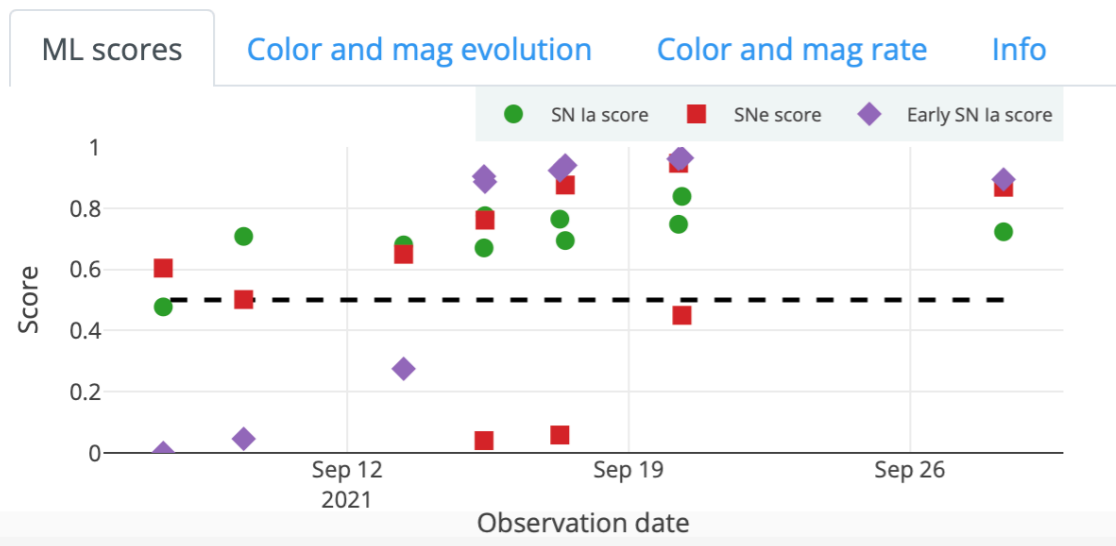
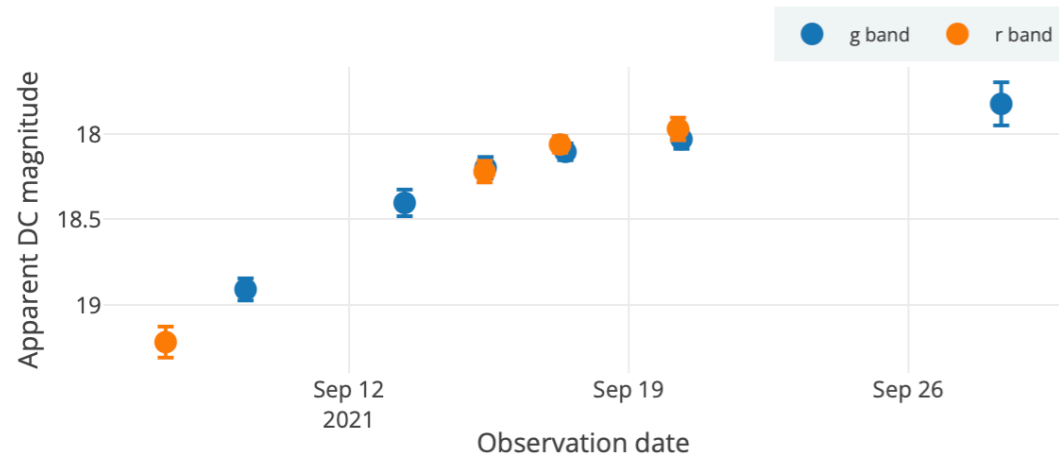


# Early transient candidates

## Early supernovae candidates

<https://fink-portal.org/ZTF21abyfxqr>

 ZTF21abyfxqr



Combining these scores and cross-matches with catalogues we obtain a filtered stream of SN candidates

*Early SN Ia Leoni et al. 2021*

*SN Ia SuperNNova (AM et al. 2020)*

*SN SuperNNova (AM et al. 2020)*



# Early transient candidates

## Early supernovae candidates

*Reported in average 7 days before max*

Reported by Fink 11/2020 to 11/2021	847
Spectroscopically confirmed SNe	552 from this 446 SNe Ia (>80%)
Spectroscopically confirmed non-SN	1

Combining these scores and cross-matches with catalogues we obtain a filtered stream of SN candidates

Publicly communicated



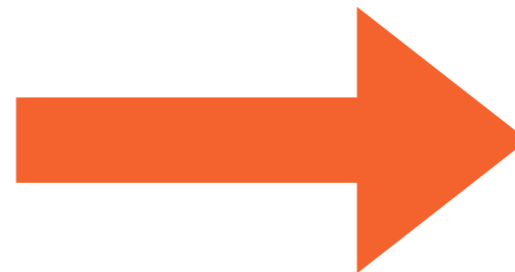


# Early transient candidates

*Other candidates in real-time to trigger follow-up*



- **Kilonovae**
- **GRB** (orphans, on-axis/off-axis)
- Neutrino
- **Fast transients**
- Anomalies
- Supernovae
  - SNe + contextual info
  - PISN
- ... more to come!



*Automatically  
reported in **real-time***



Kilonova Catcher

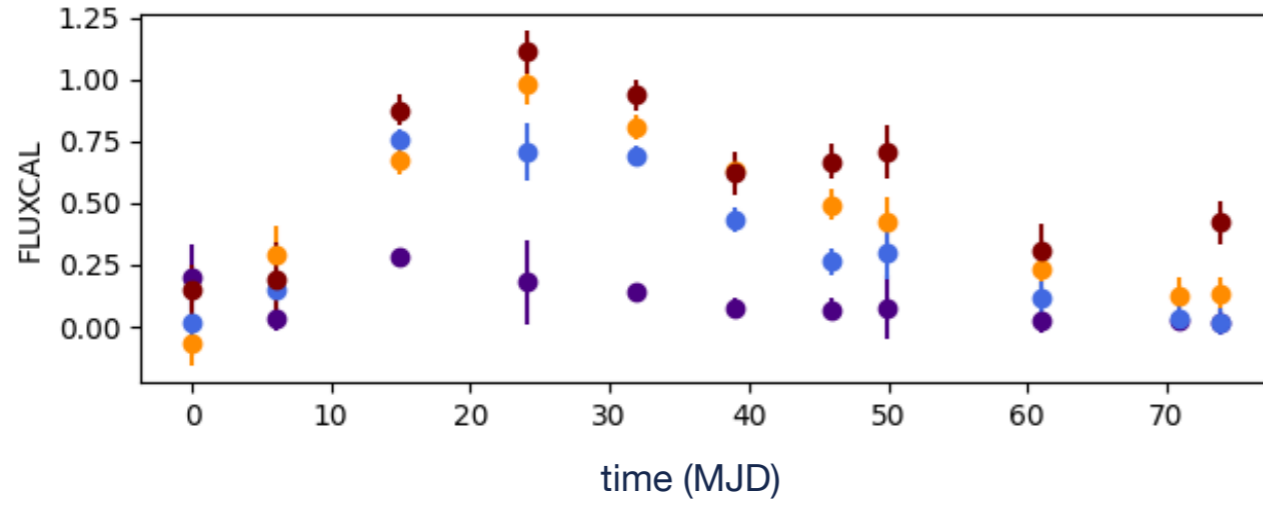


*Also Fink candidates are available for fup with integration*



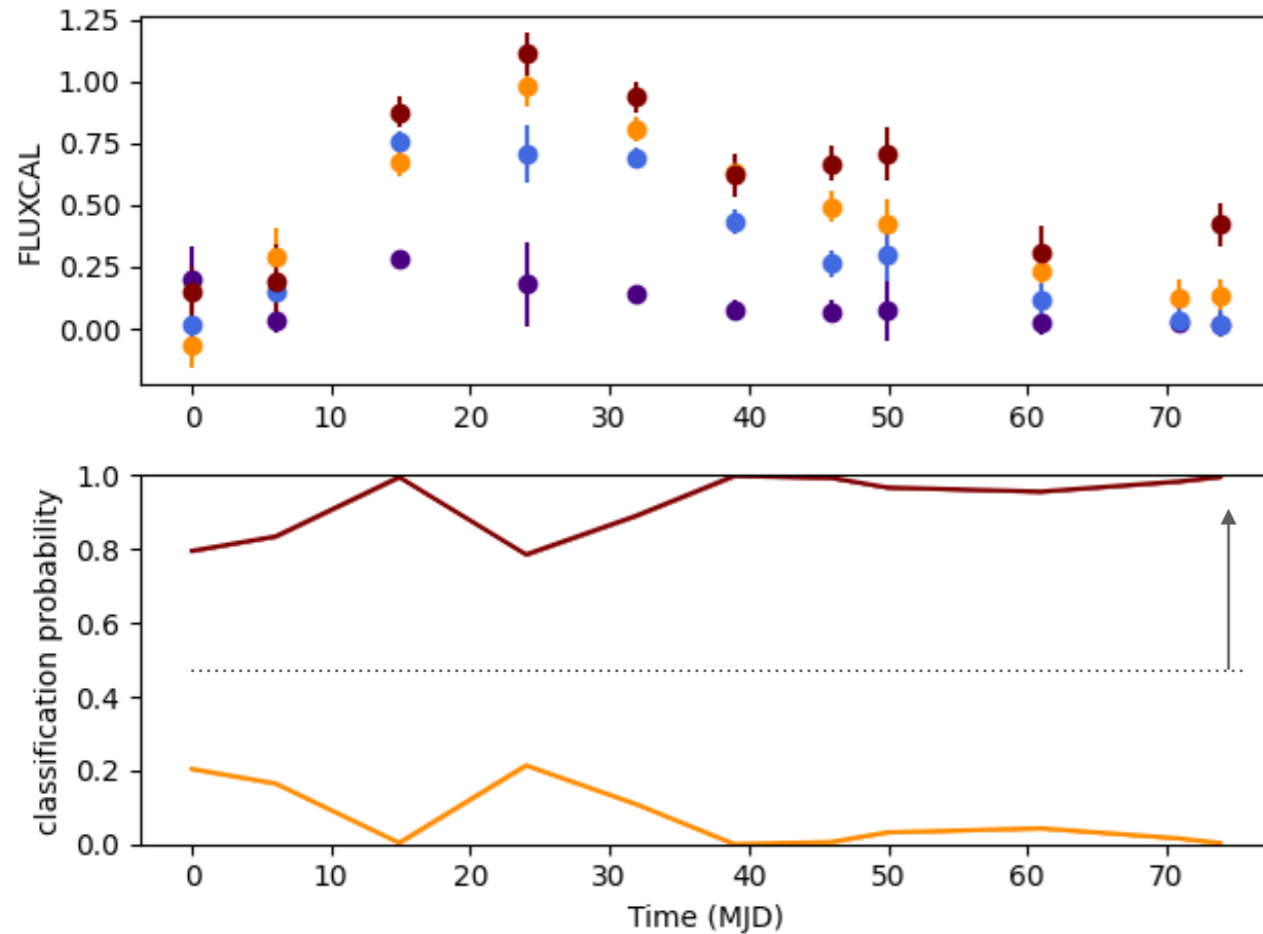
# Transient photometric classification

Obtaining large samples without spectroscopic follow-up



# Transient photometric classification

Obtaining large samples without spectroscopic follow-up: type Ia supernovae

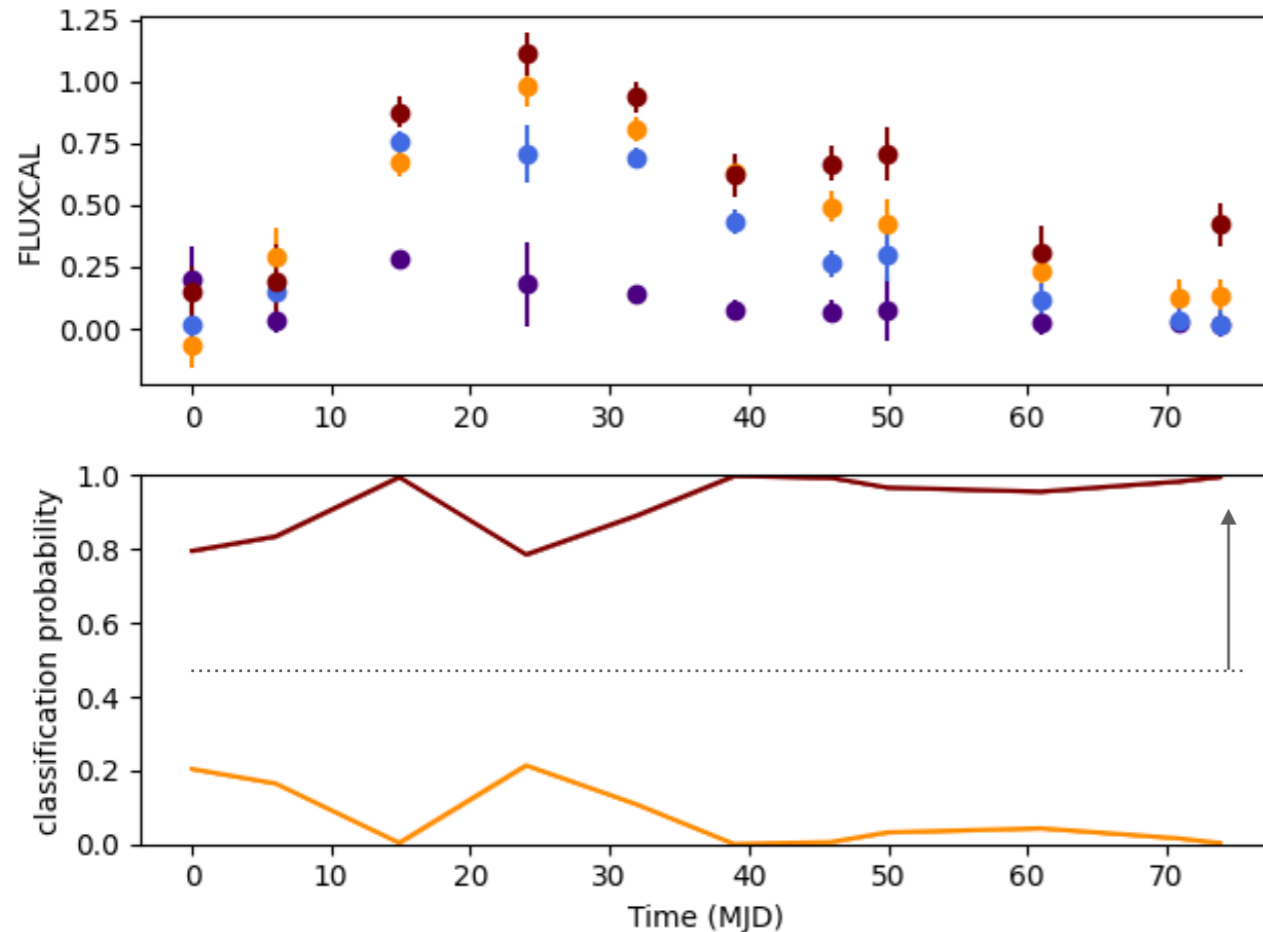


Select a sample using a probability threshold  
+ selection cuts



# Transient photometric classification

Obtaining large samples without spectroscopic follow-up: type Ia supernovae



Select a sample using a probability threshold  
+ selection cuts

**SN Ia vs non-Ia SNe classification in the Dark Energy Survey using light-curves & host-galaxy spectroscopic redshifts with SuperNNova**

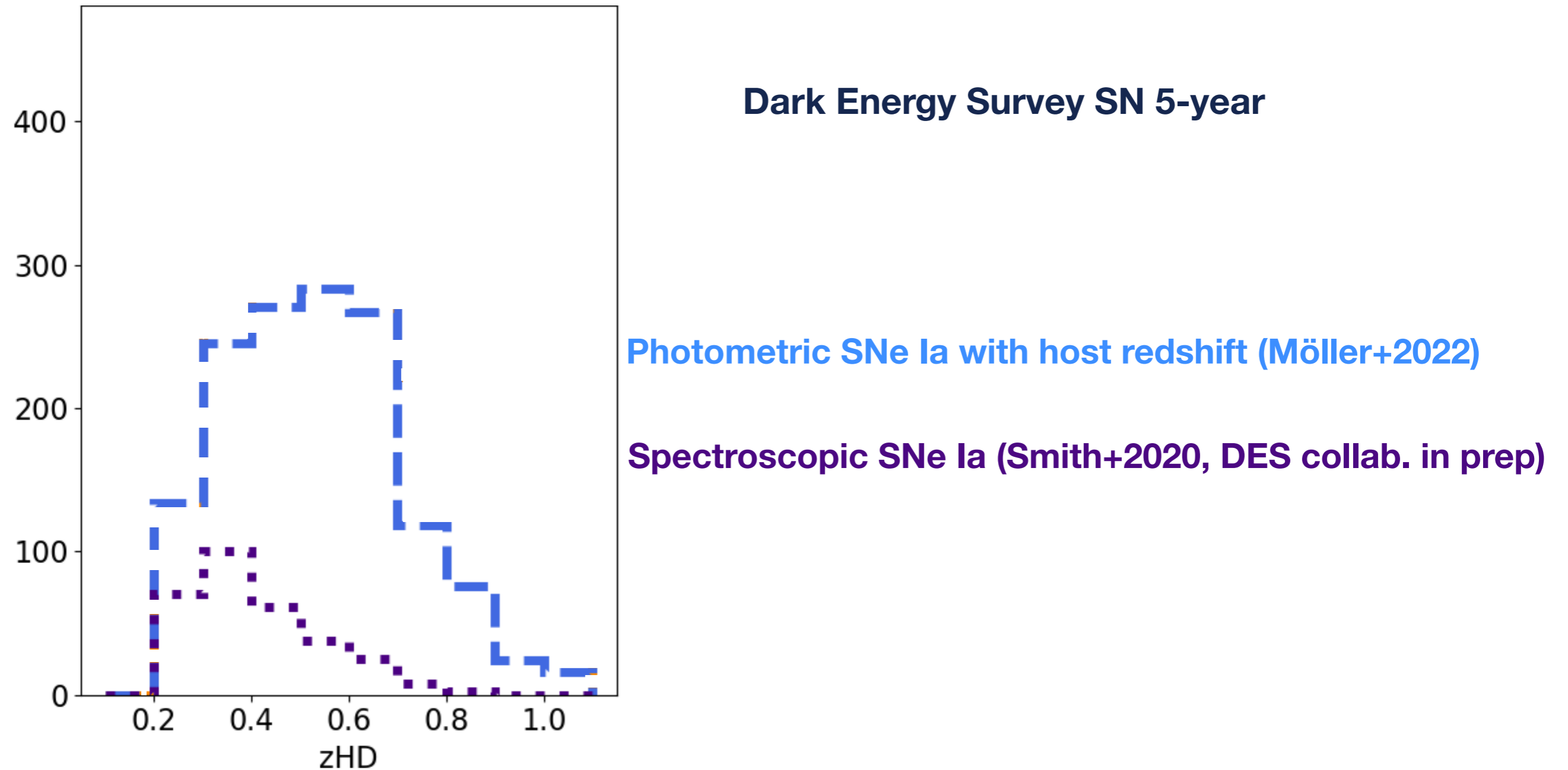
Accuracies >98% (Vincenzi+ 2021, AM+2022)

Contamination ~2% (Vincenzi+ 2021)



# Transient photometric classification

Obtaining large samples without spectroscopic follow-up: type Ia supernovae



*Spectroscopic samples of hundreds can become photometrically identified samples of thousands!*

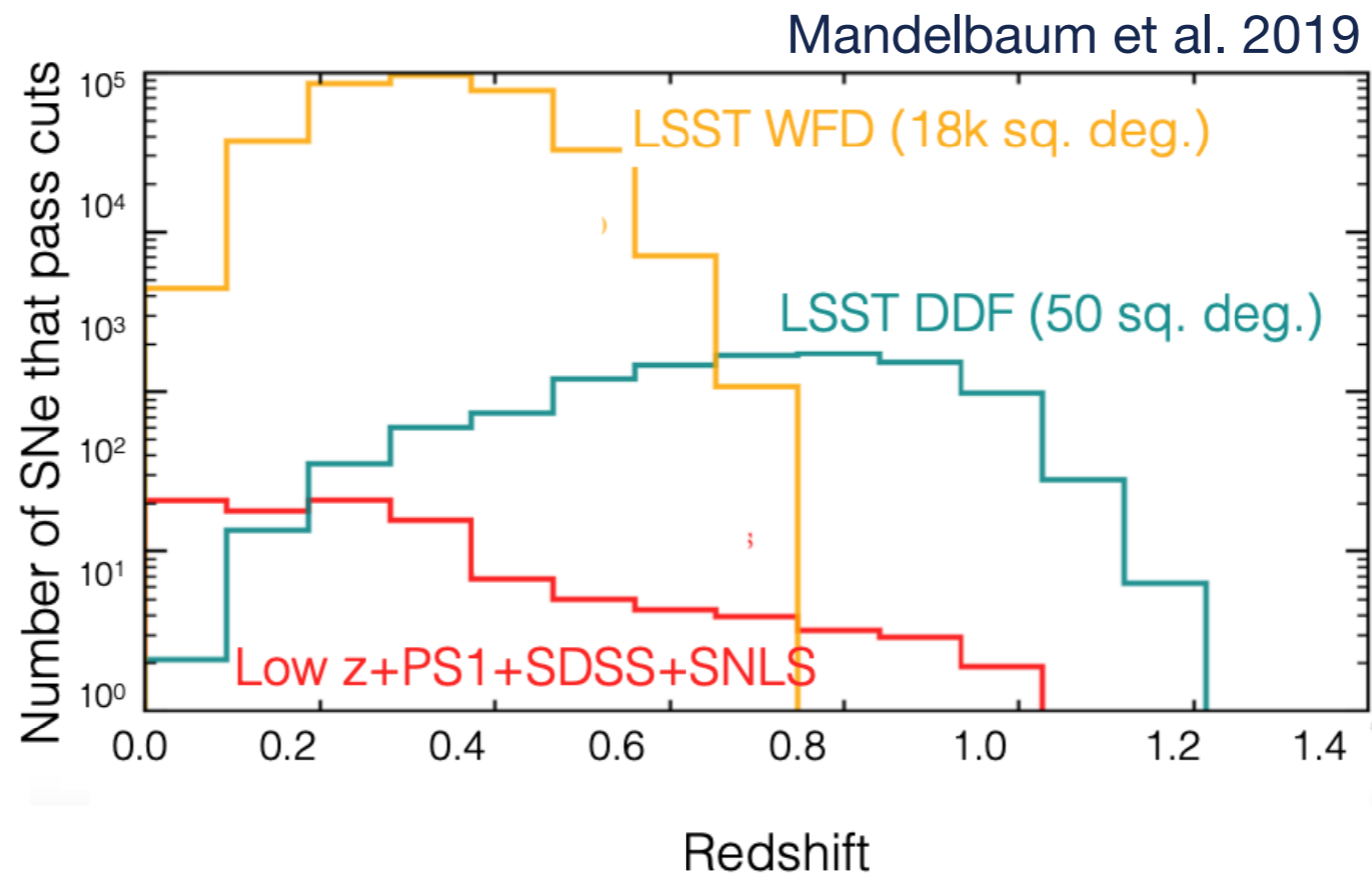


# Transient photometric classification

Obtaining large samples without spectroscopic follow-up

*Spectroscopic samples of hundreds can become photometrically identified samples of thousands!*  
***NIR data from Roman for better calibration and information ...***

*Going beyond our current samples with a rich dataset!*





# Ongoing projects & collaborators



- **Kilonovae** *J. Vlieghe, GRANDMA*
- **Microlensing** *E. Bachelet, M. Moniez*
- **GRB** (orphans, on-axis/off-axis, SVOM) *D. Turpin, J. Bregeon, O. Godet, G. Ducoin, R. Le Montagner, L. Bouchet, M. Llamas*
- **SSO** *S. Karpov, B. Carry, R. Le Montagner,*
- **Neutrino KM3NET:** *D. Dornic, G. Vannoye, V. Kulikoskiy*
- **Supernovae** *M. Leoni, T. Allam, U. Burhanudin, J. Maund*
- **PISN** *Blondin, Pruzhinskaya*
- **Fast transients** *Biswas*
- **Anomalies** *Pruzhinskaya, Kornilov, Russeil, Beschastnov*



And many others: *Arnault, Hrivnac, Pateyron, Boutigny, Hernandez, Gangler, Russeil, Nebot, Pineau*



# *Rubin community brokers allow harnessing the power of optical time-domain data*





# *Rubin community brokers allow harnessing the power of optical time-domain data*



- Built on state-of-the-art technologies
- Is already processing ZTF data stream (MoU 2020).
- First science modules deployed: SNe, GRB, microlensing, ...



## ***Rubin community brokers allow harnessing the power of optical time-domain data***



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## ***Transient science can only gain with synergies between Roman's, Rubin's and other multi-wavelength and messenger!***

- Complementary photometry
- Multi-wavelength/messenger optical counterparts
- Catalogue information for transients
- Early classification for follow-up coordination & analysis
- Large photometrically selected samples
- Automated reporting + real-time streams for follow-up

