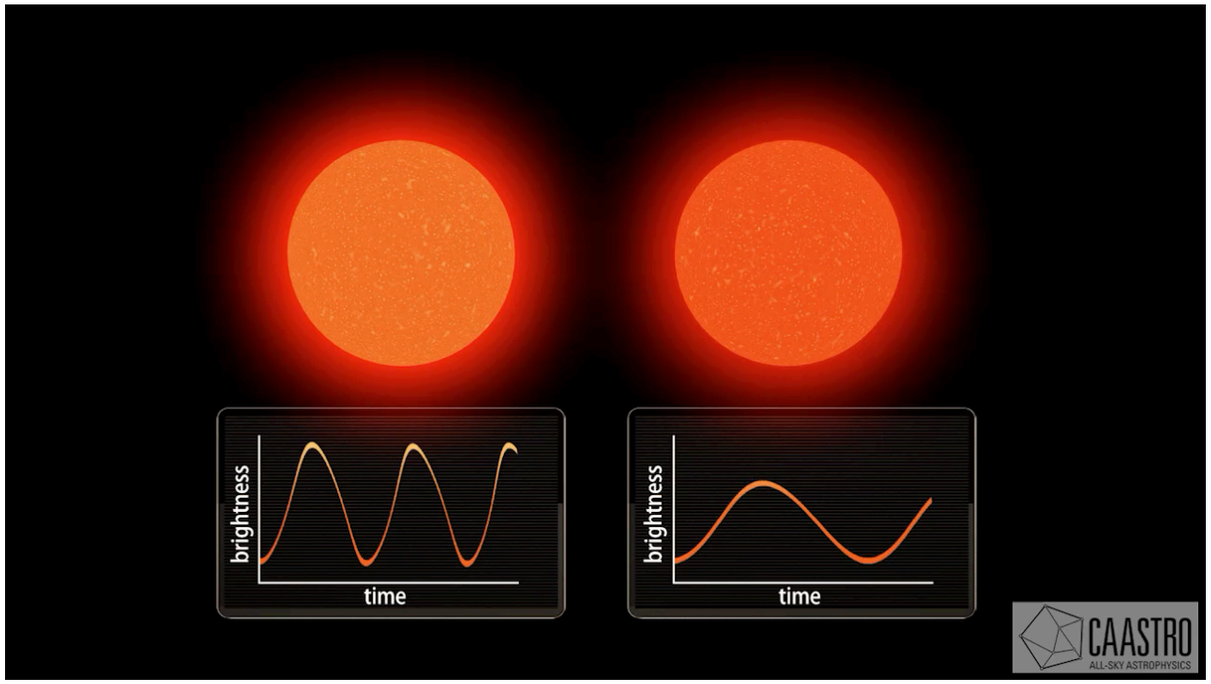
broker

enabling time-domain astronomy with ML

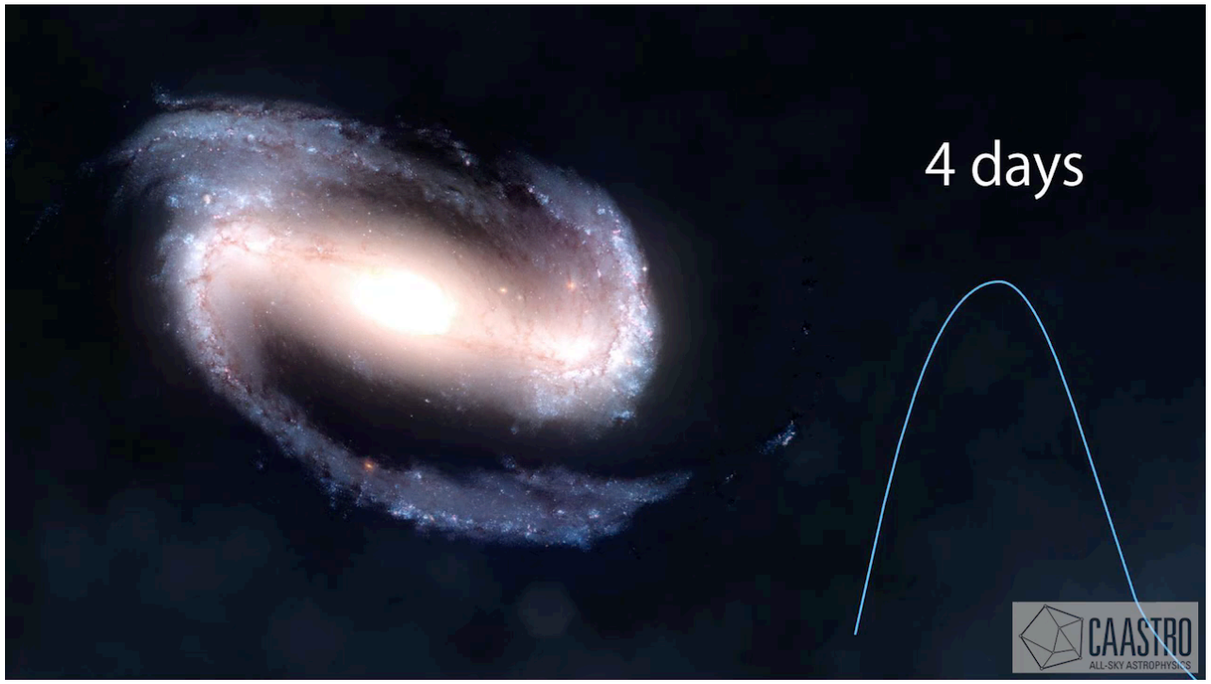
Anais Möller LPC for the Fink team

Time-domain astronomy (transients)

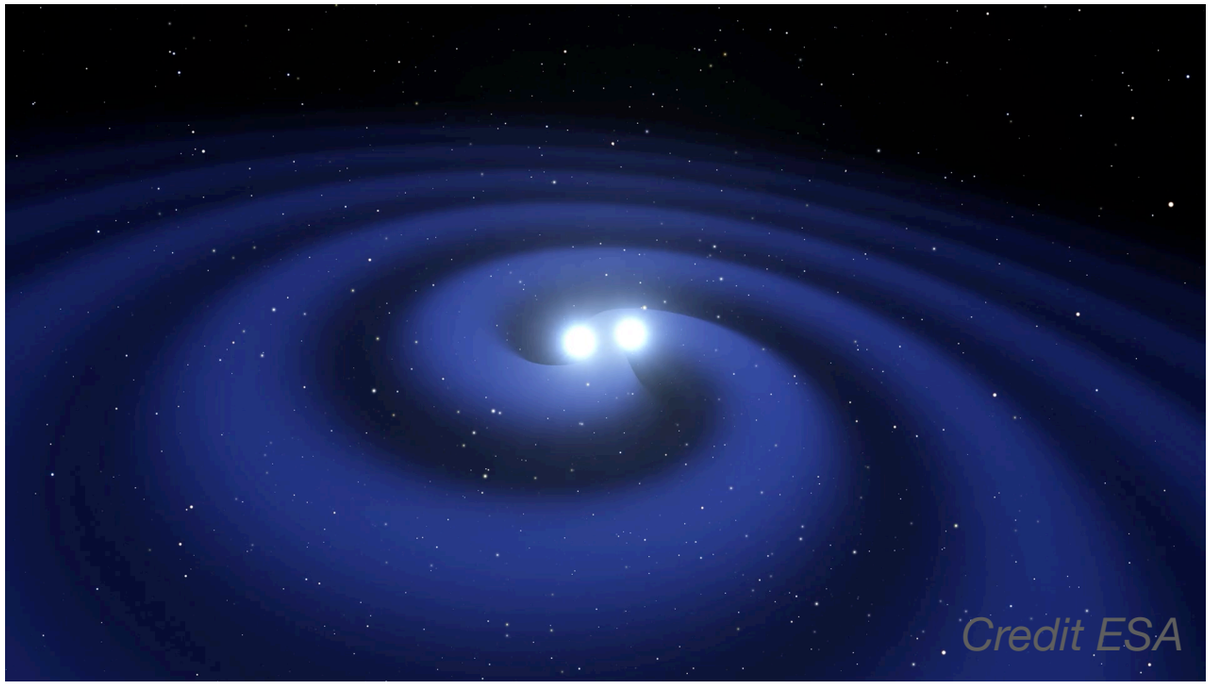
Variable stars



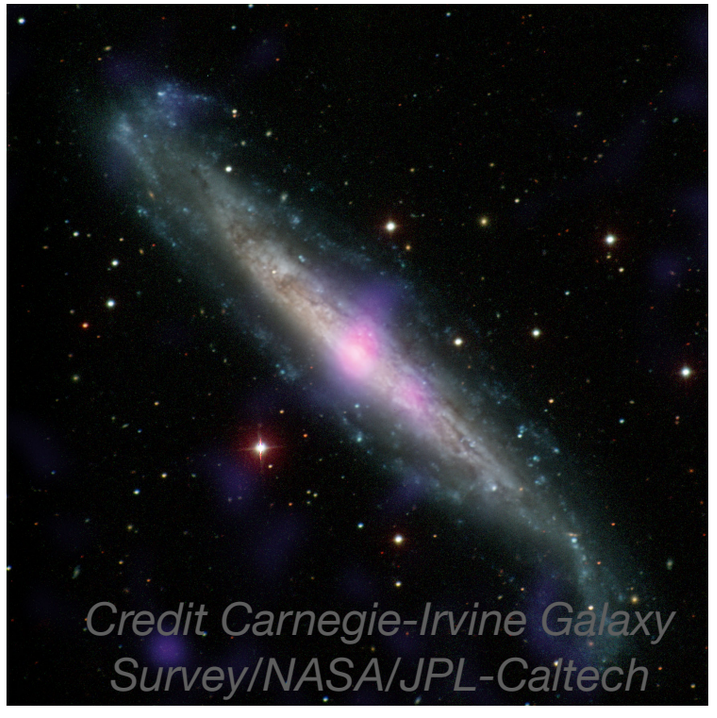
Supernovae: exploding stars



Neutron star mergers: kilonovae

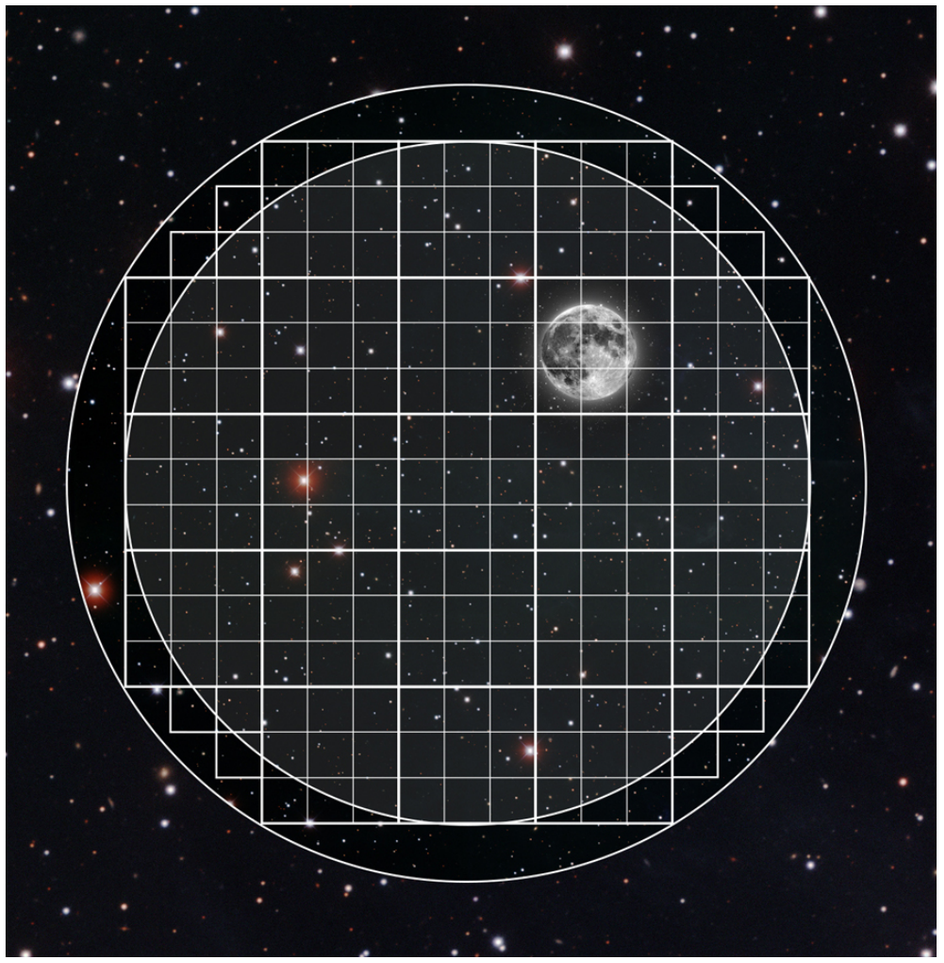


Active Galactic Nucleii



RR Lyrae, novae, cataclismic transients, tidal disruption events, asteroids, fast transients, calcium-rich transients, microlensing events, exoplanets transits…

Legacy Survey of Space and Time (LSST)



in a nutshell:

- telescope: 6.7-m equivalent
- world's largest CCD camera: 3.2 * 10^9 pixels

in numbers:

- 10-year survey, starting 2022
- 1,000 images/night = 15 TB/night
- 10 million transient candidates per night

LSST ~ 10 million transient alerts per night

?

Select promising:

- **SNe, kN, fast transients, variable stars, AGNs …**
- **Multi-wavelength/messenger transients**

Coordinate follow-up

LSST ~ 10 million transient alerts per night

Select promising:

- **SNe, kN, fast transients, variable stars, AGNs …**
- **Multi-wavelength/messenger transients**

Coordinate follow-up

FINK

- a community driven effort, open to anyone
- designed for the LSST alert stream

Goal: Multi-science transient broker

MNRAS 2021, arXiv: 2009.10185
A. Möller, J. Peloton, E. Ishida et al. (>30 coauthors)

LSST ~ 10 million transient alerts per night

pyLIMA (Bachelet et al. 2017)
SuperNNova (Möller et al. 2020)
Active Learning (Ishida et al. 2019)
Kilonovae (Biswas et al. in prep.)
Early SNe (Leoni et al. in prep)

Enriching ***ML classification*** ***Filtering***

- **Supernovae**
- **Microlensing**
- **Kilonovae**
- **Gamma Ray Bursts**

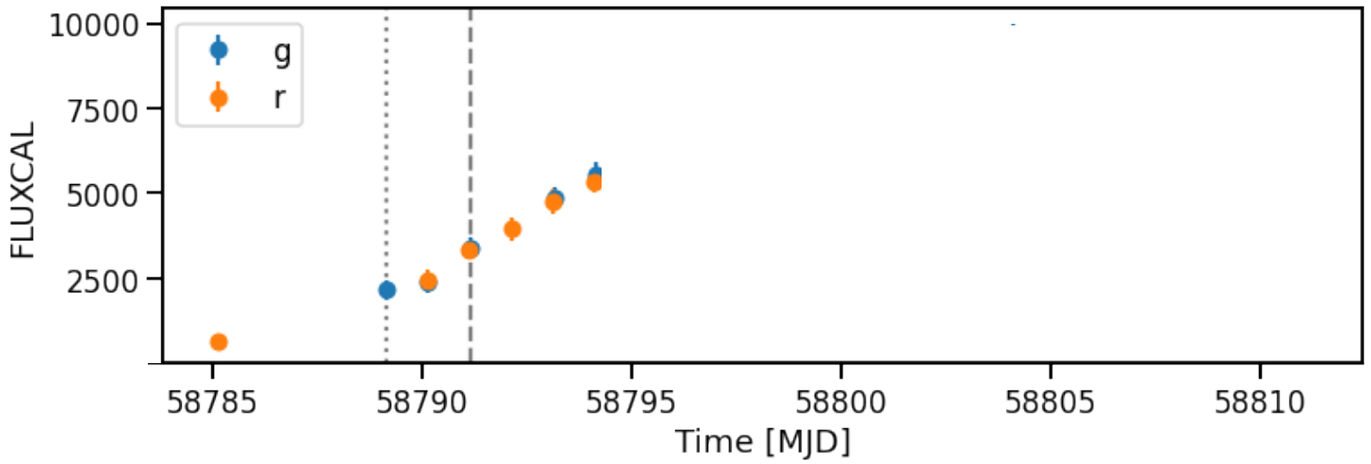
- **Solar system objects**
- **Variable stars**
- **…**

using ZTF alert stream

Möller, Peloton, Ishida et al. 2020 arXiv:2009.10185

ML: supernovae

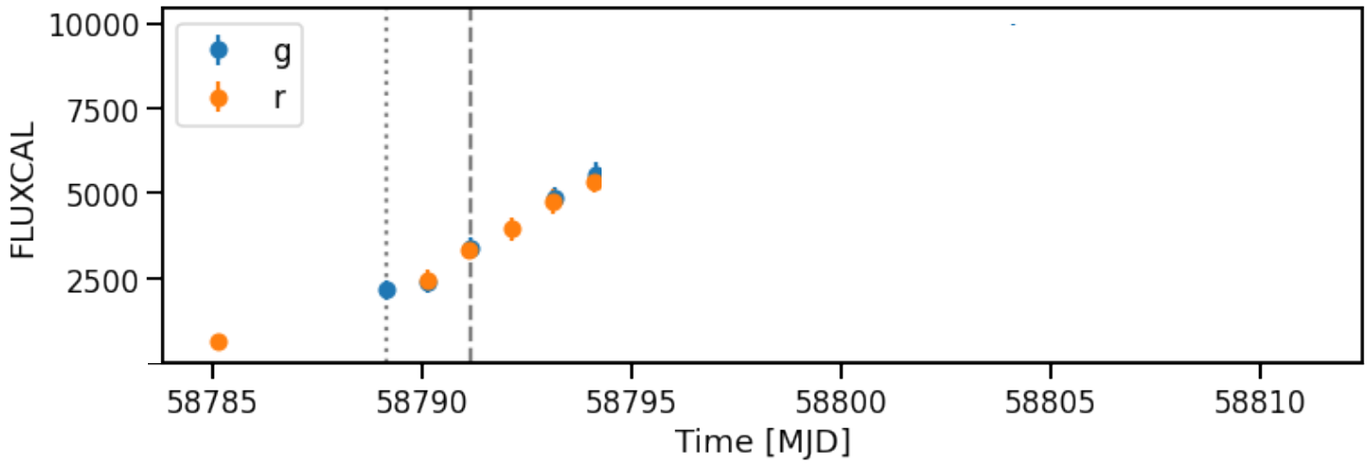
Early classification: follow-up coordination, early selection



ML: supernovae

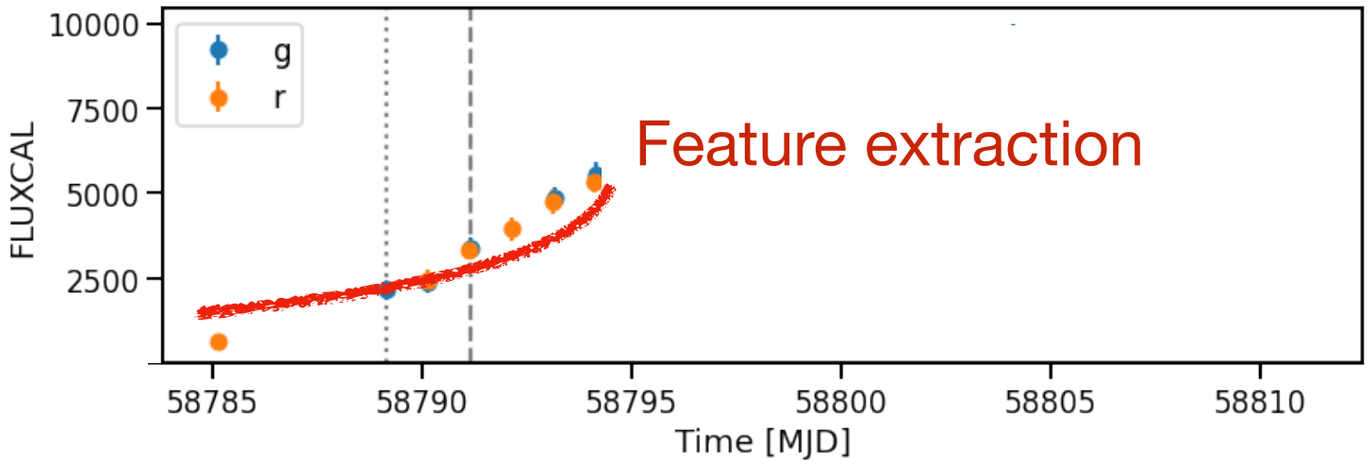
Early classification: follow-up coordination, early selection

Irregular time series



ML: supernovae

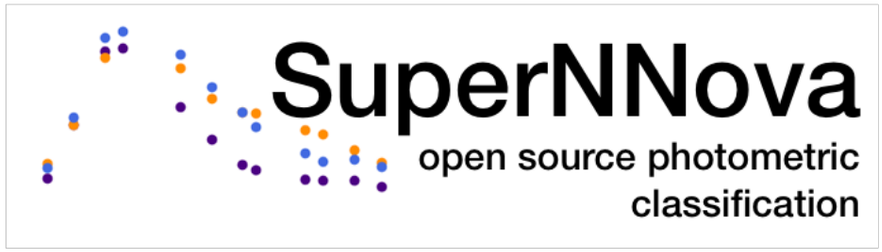
Early classification: follow-up coordination, early selection

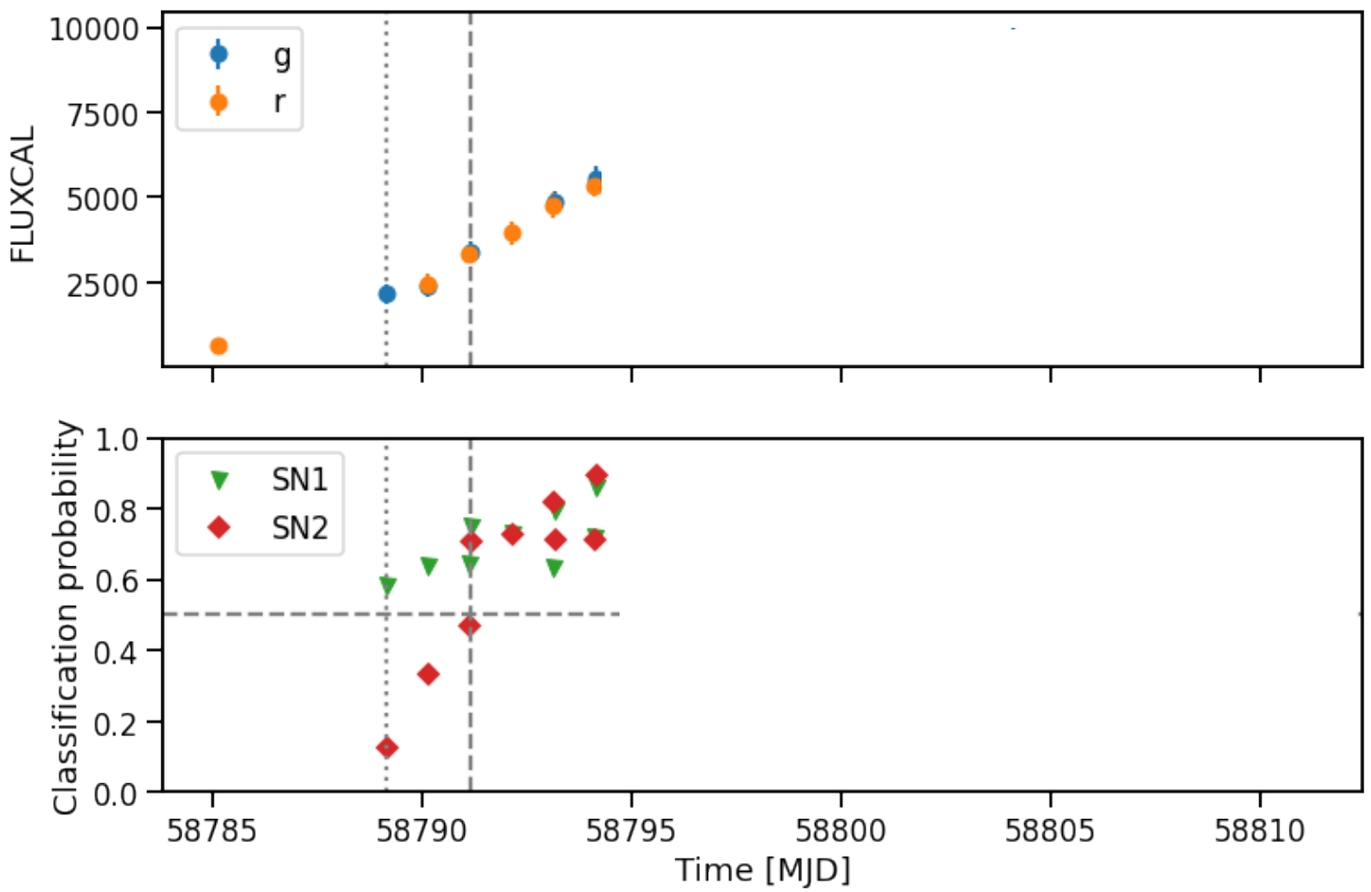


- Depends on transient target
- Can bias samples (cosmology)

ML: supernovae

Early classification: follow-up coordination, early selection





Time series:
Recurrent Neural Networks

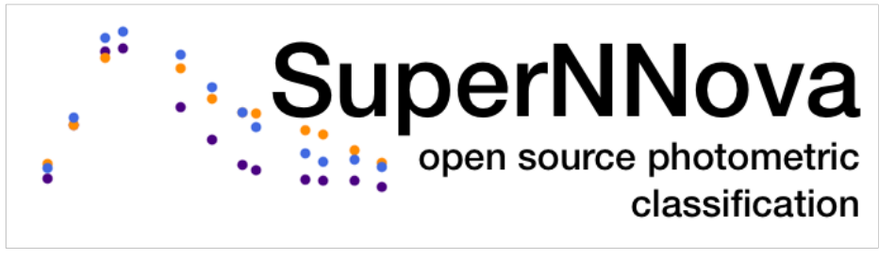
Flexible architecture:
LSTM, GRU

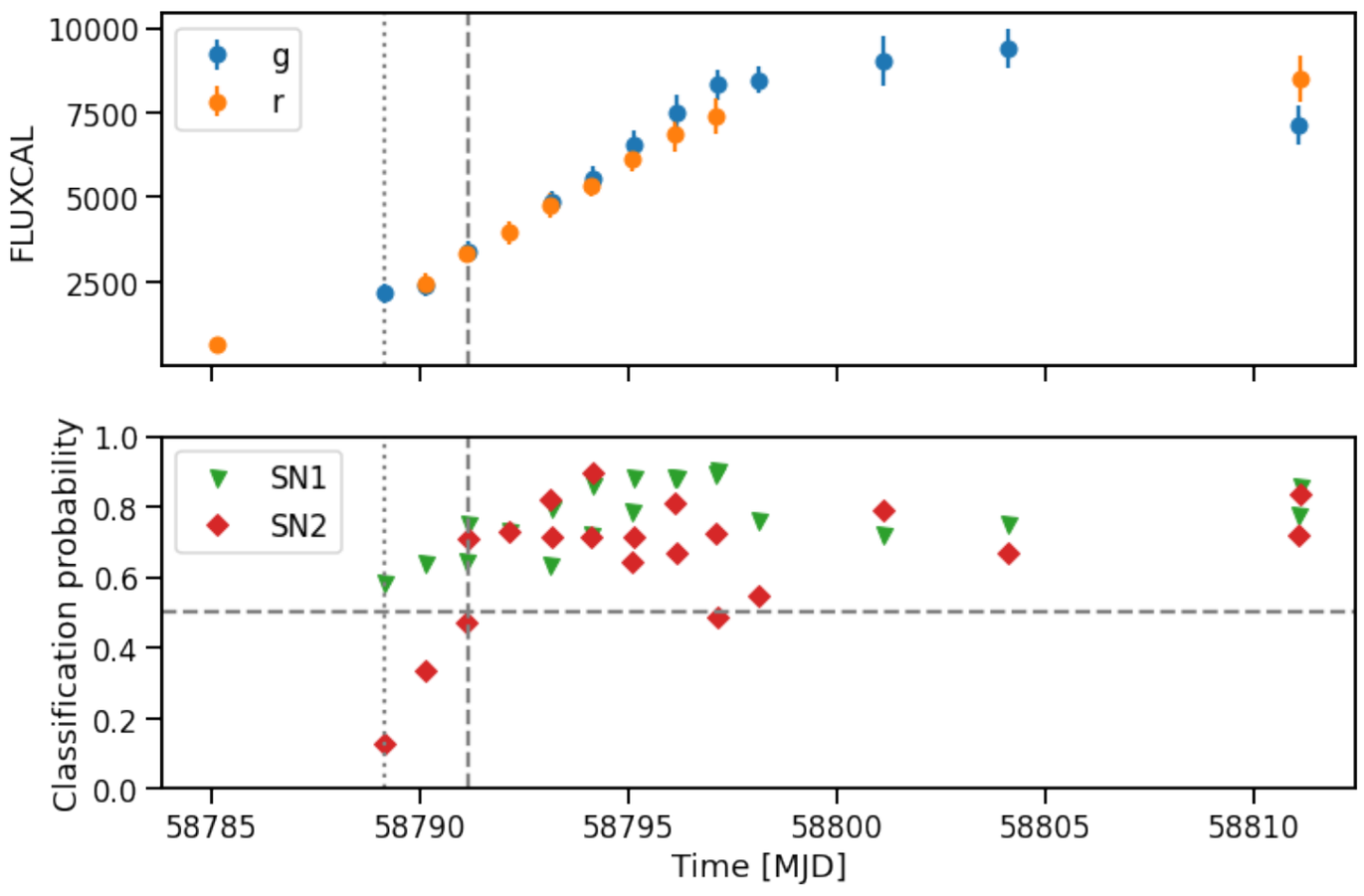
Accuracy with sims:
>98%

Möller, et al. 2020 MNRAS arXiv:1901.06384

ML: supernovae

Early classification: follow-up coordination, early selection





Data != Sims

Interpretable uncertainties

Robustness:
Bayesian Neural Networks

- MC Dropout
  Gal+2016
- Bayes by Backprop
  Fortunato+2017

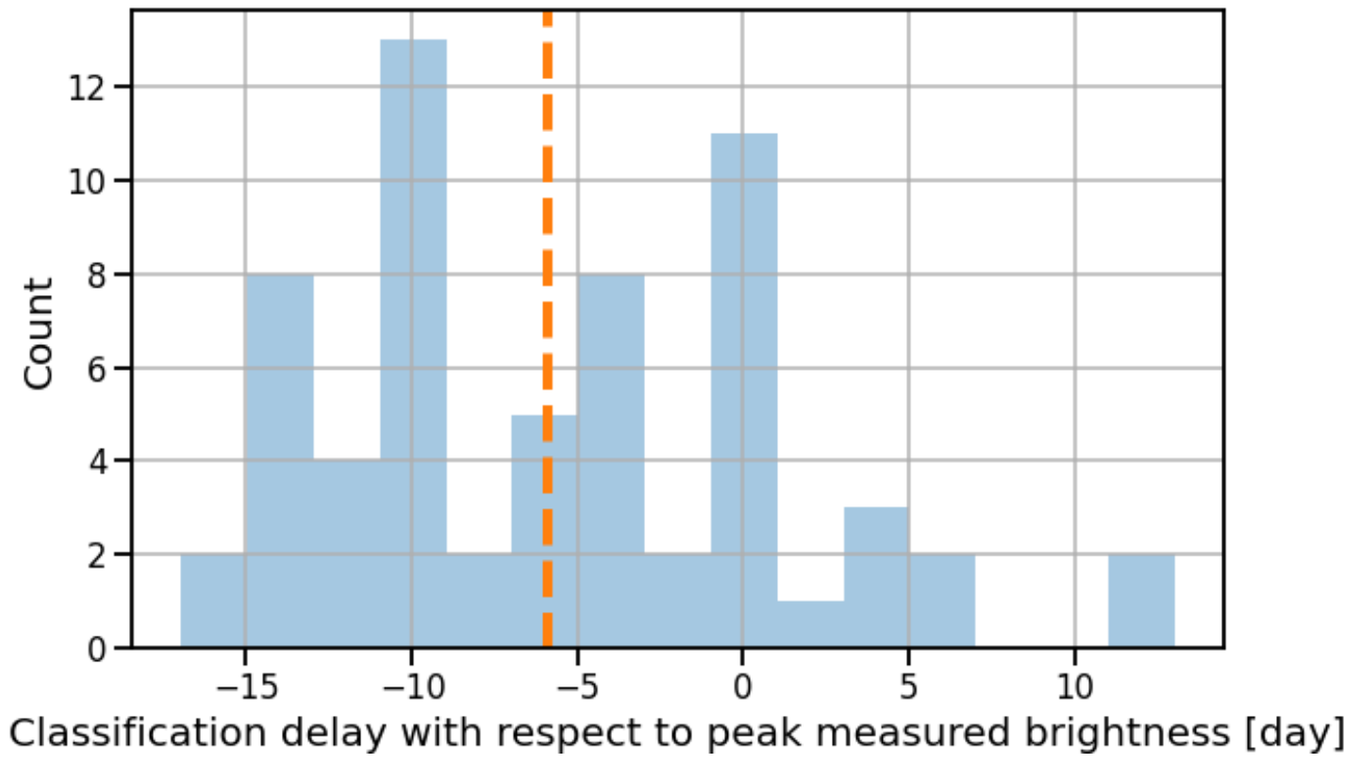
Möller, et al. 2020 MNRAS arXiv:1901.06384

Möller, Peloton, Ishida et al. 2020 arXiv:2009.10185

ML: supernovae

Early classification: follow-up coordination, early selection

SuperNNova
open source photometric classification



ZTF alert stream November-December 2019

Möller, Peloton, Ishida et al. 2020 arXiv:2009.10185

ML: supernovae

Early classification: follow-up coordination, early selection

sample	# alerts	% alerts
quality cuts	2,417,284	100%
selection cuts	576,190	23.84%
SN1>0.5	365,228	15,11%
SN2>0.5	208,978	8.65%
SN1>0.6	308,822	12.78%
SN2>0.6	145,736	6.03 %

Can be further reduced to achieve: high-purity SNIa samples, more diversity in SNe Ia/galaxy properties

ZTF alert stream November-December 2019

Möller, Peloton, Ishida et al. 2020 arXiv:2009.10185

ML: supernovae

Improve training sets for classification

Data != Sims

ML: supernovae

Improve training sets for classification

- Select SNe or transients not well characterised for follow-up

ML: supernovae

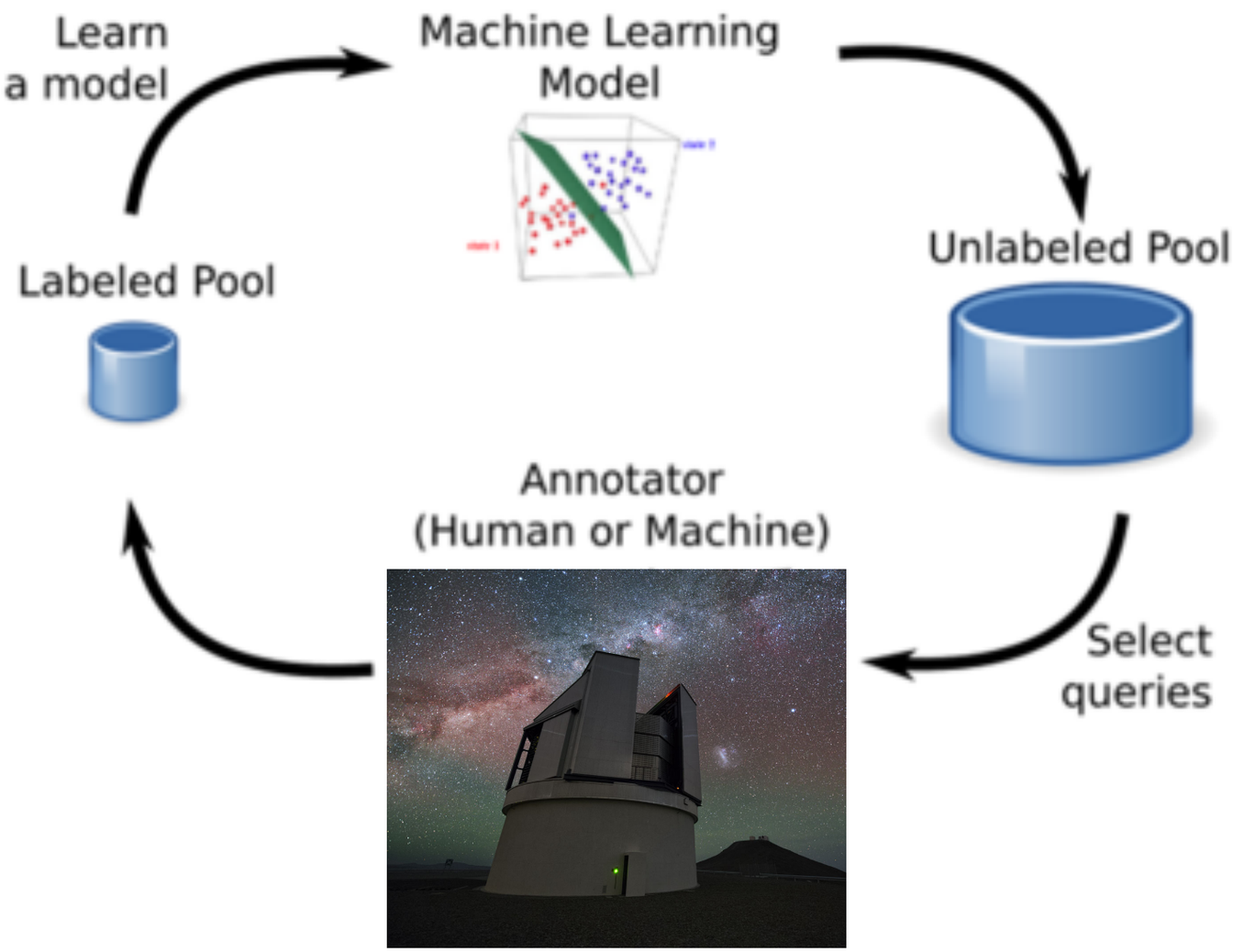
Improve training sets for classification

- Active Learning approach

ML: supernovae

Improve training sets for classification

- Active Learning approach

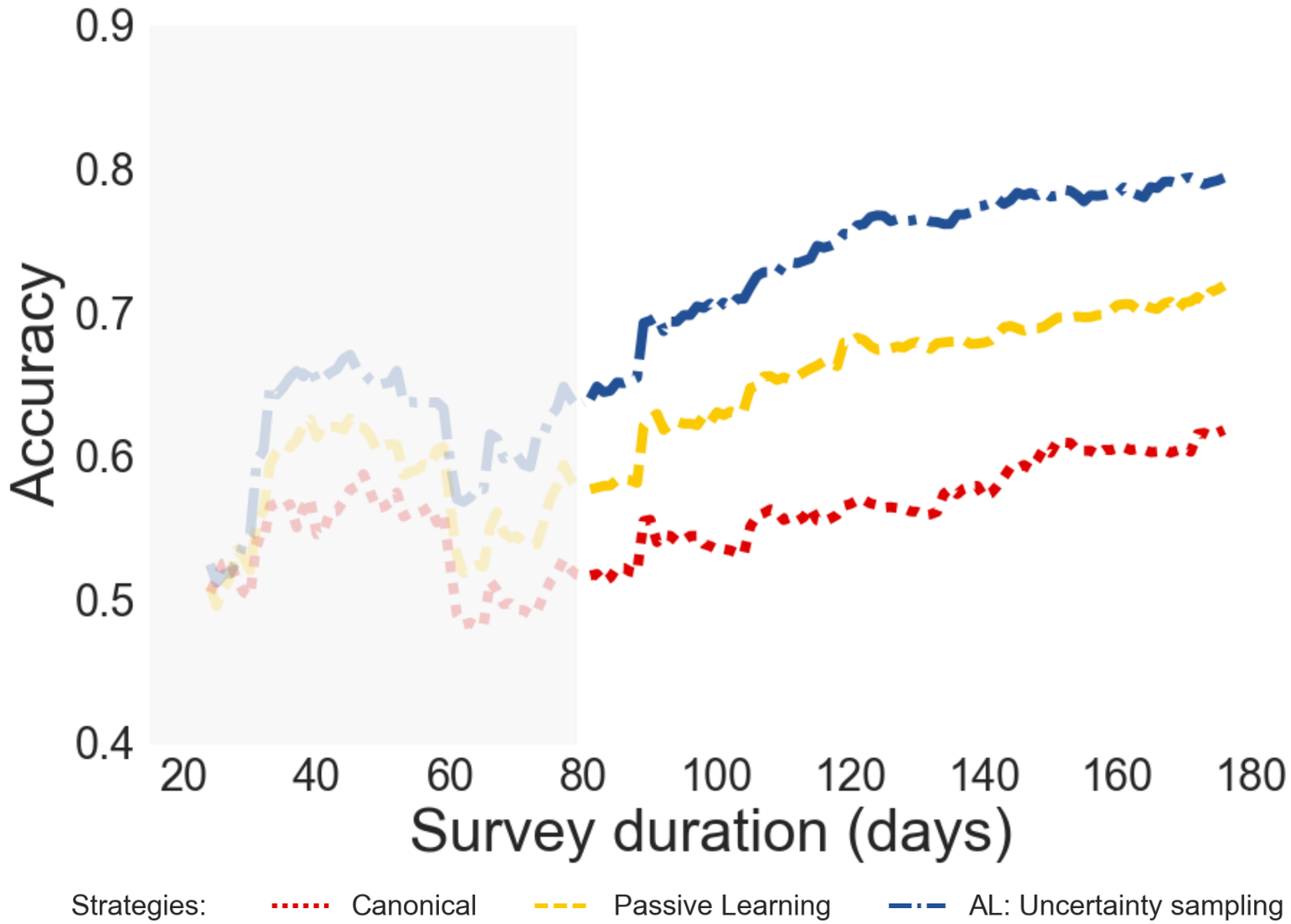


VISTA telescope Y. Beletsky (LCO)/ESO

Ishida et al. 2019 arXiv:1804.03765

ML: supernovae

Improve training sets for classification

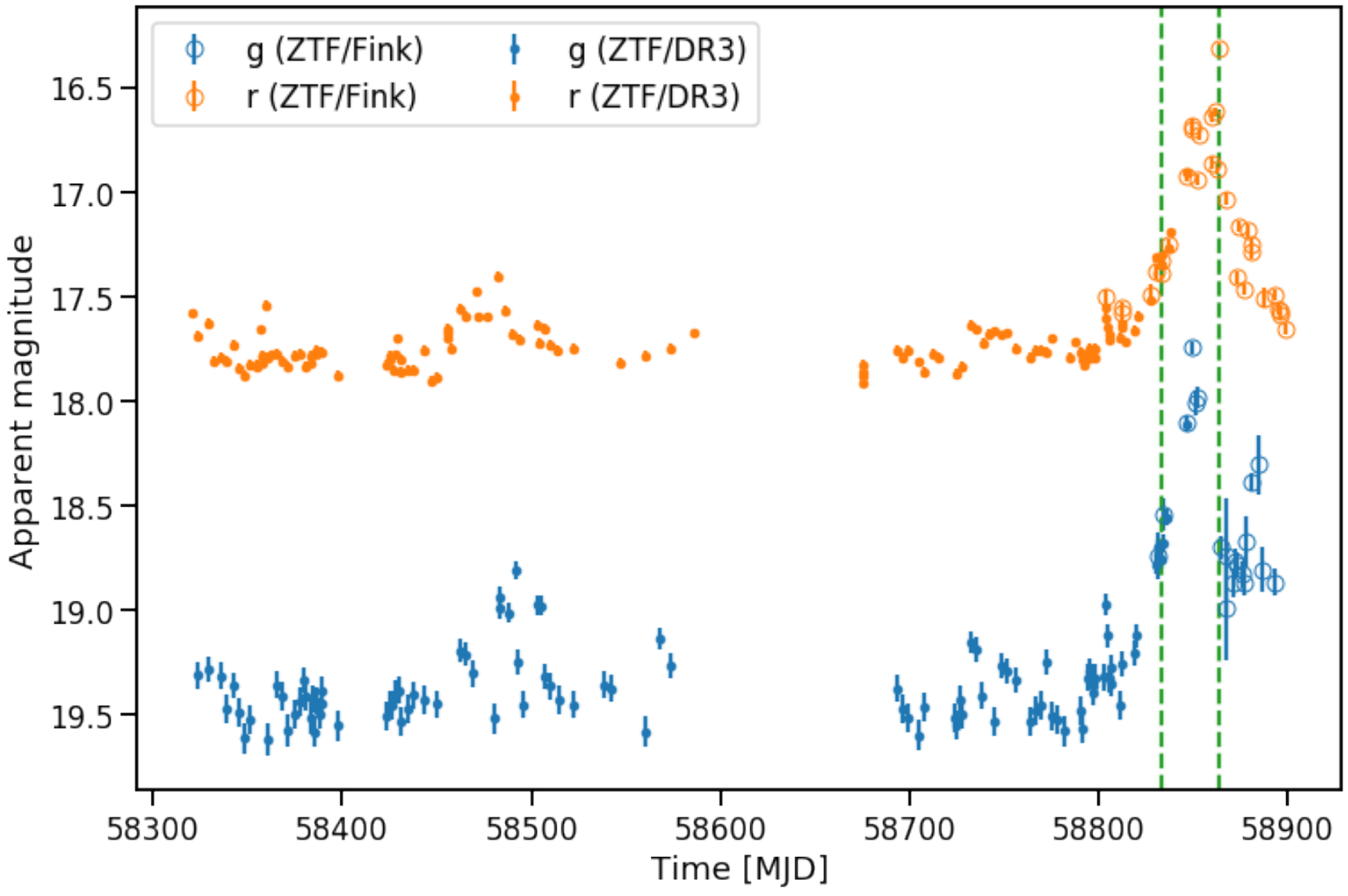


Randomly drawn (canonical=similar to training distribution, passive=all possible)

Ishida et al. 2019 arXiv:1804.03765

Leoni et al. in prep

ML: microlensing



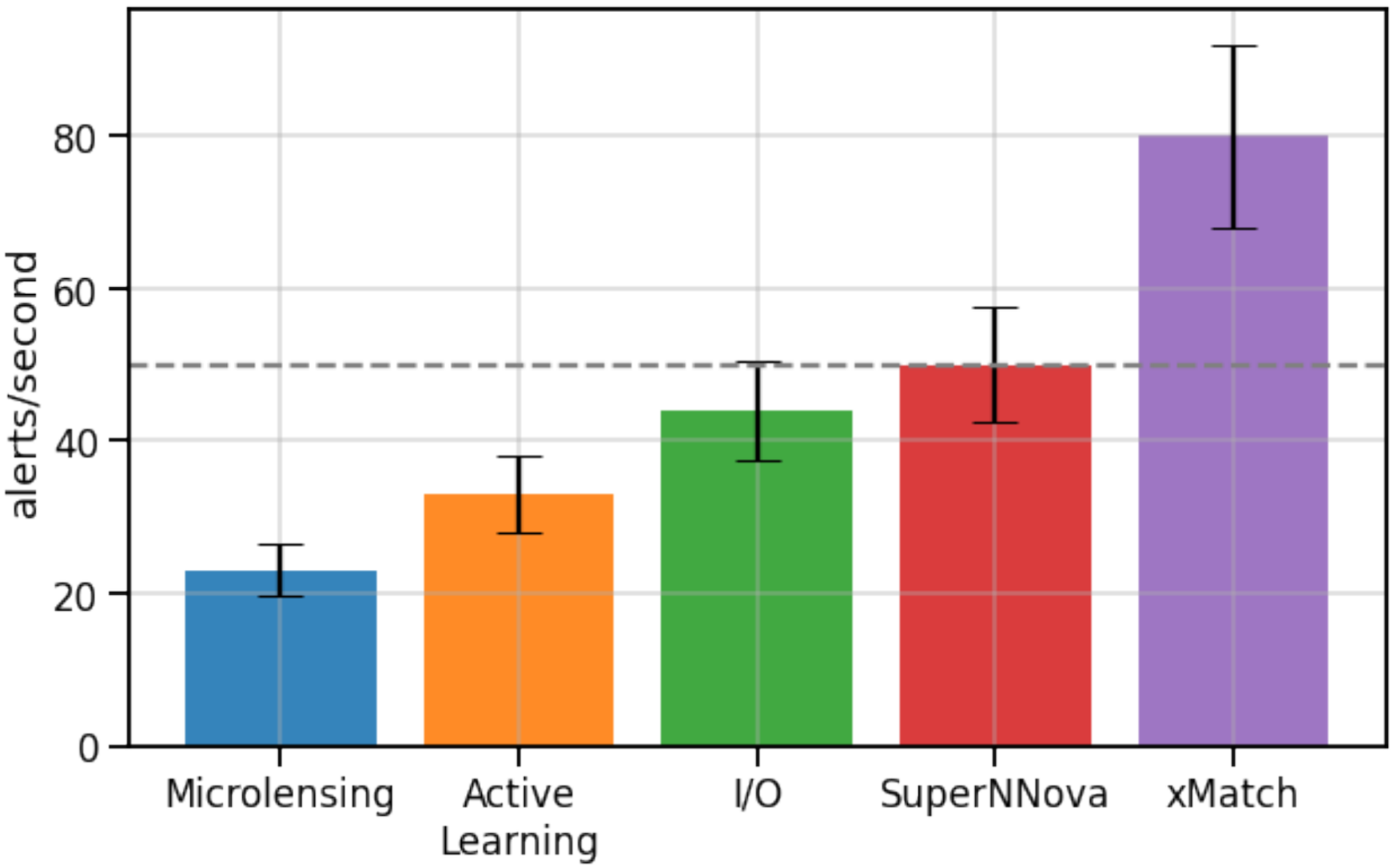
LIA:
Lens Identification Algorithm

Large baselines
Ideal cadence != reality

Godines et al. 2020

ML: supernovae

Fast!



Möller, Peloton, Ishida et al. 2020 arXiv:2009.10185

Fink deployment with ZTF

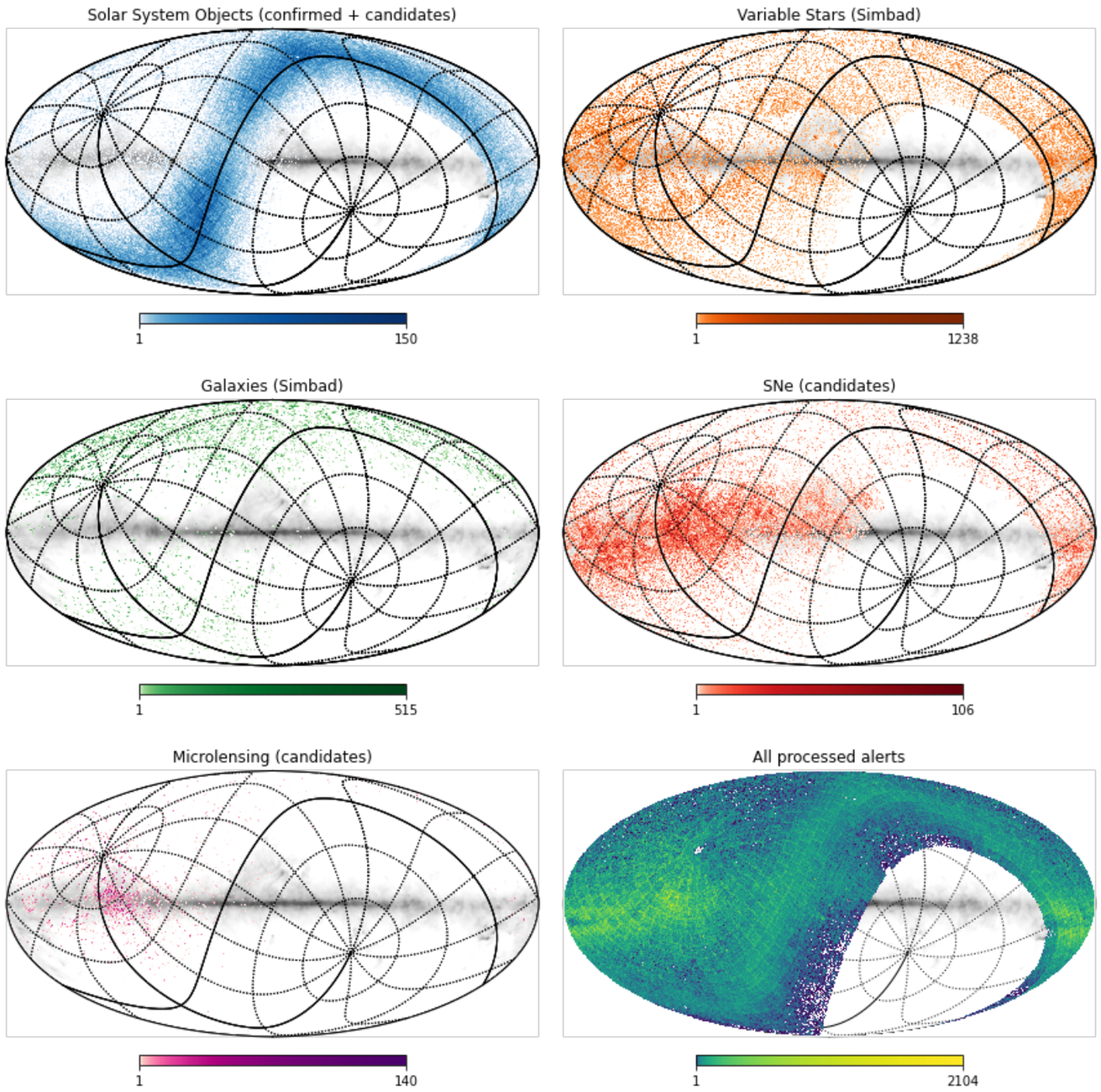
Cross-matching CDS xmatch

Classification machine learning

Filtering with several categories out

- Supernovae
- Microlensing
- Variable stars
- Solar System objects

Including early classification!



ZTF alerts November 2019 to June 2020

Möller, Peloton, Ishida et al. 2020 arXiv:2009.10185

Summary

- ML is key for selecting promising events
- Fink is already processing ZTF data stream (MoU 2020).
- First science modules deployed: SNe, GRB, microlensing, kilonovae…

- ***We want to connect to new teams and continue applying state-of-the art ML algorithms!***

See E. Ishida talk on anomaly detection tomorrow!

Möller, Peloton, Ishida et al. 2020
arXiv:2009.10185

https://fink-broker.org