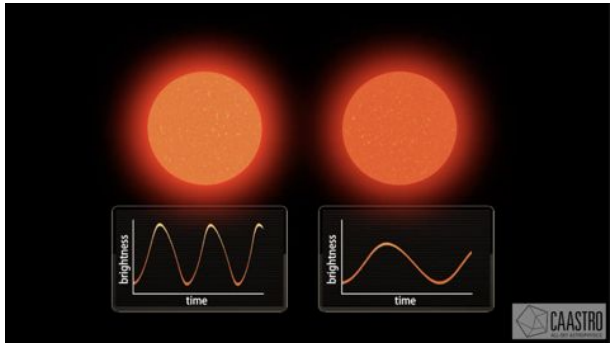
SciOps 2022: Artificial Intelligence for Science and Operations in Astronomy
Garching - Germany, 16 May 2022

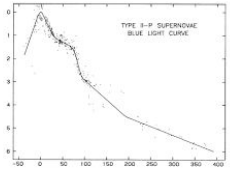
Emille Ishida, Julien Peloton and Anais Möller
on behalf of the Fink Team

The transient sky

Variable stars

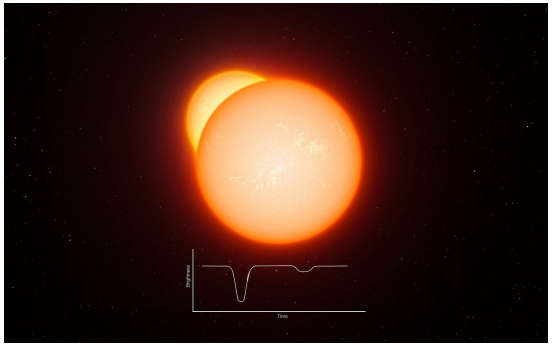


Supernovae: exploding stars

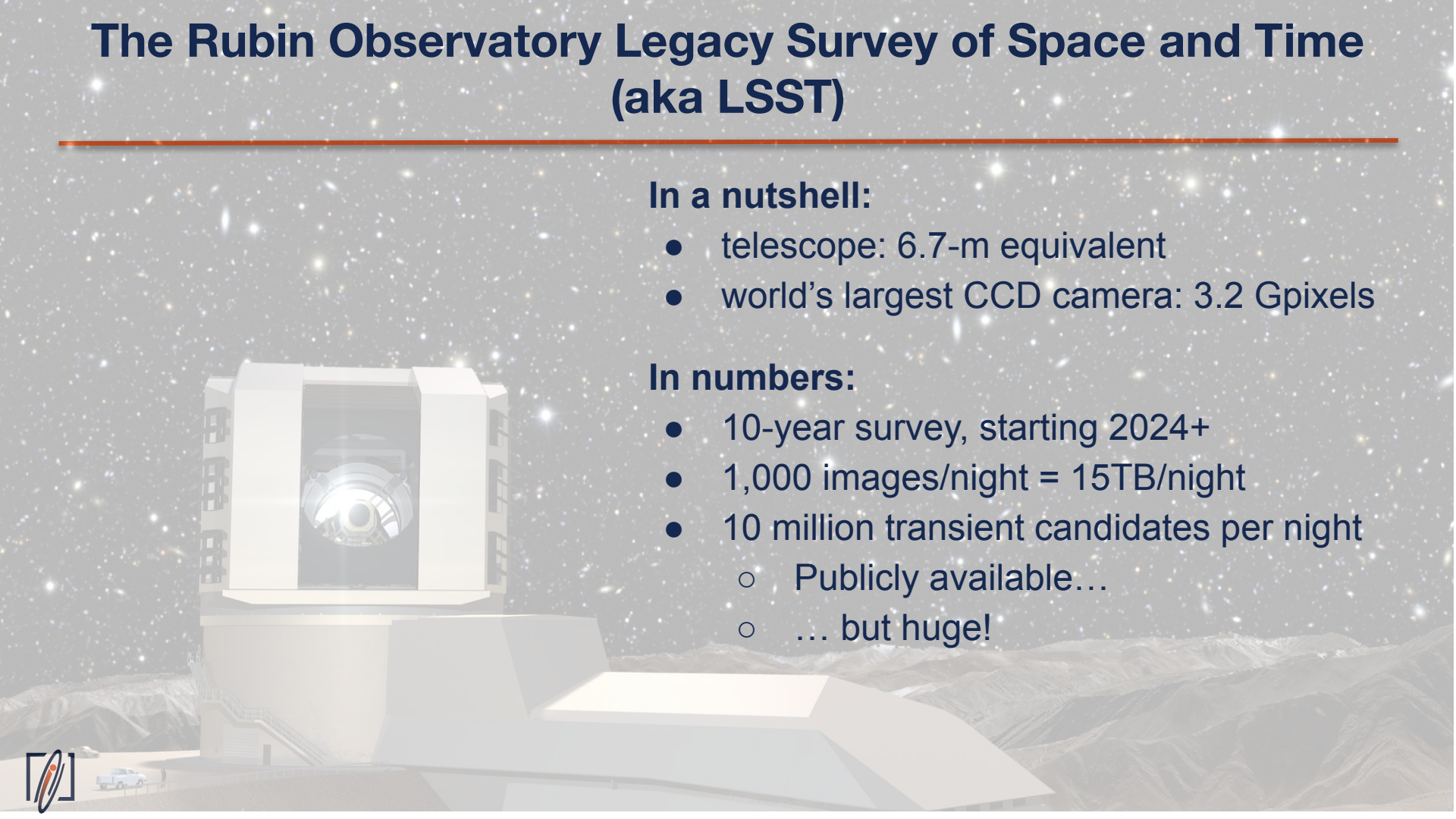


Neutron star mergers: kilonovae

Eclipsing binary



The Rubin Observatory Legacy Survey of Space and Time (aka LSST)



In a nutshell:

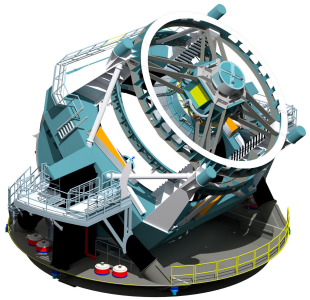
- telescope: 6.7-m equivalent
- world's largest CCD camera: 3.2 Gpixels

In numbers:

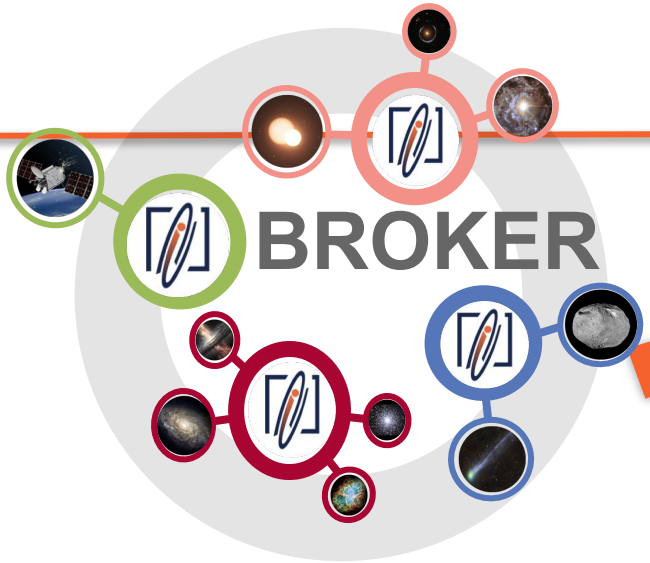
- 10-year survey, starting 2024+
- 1,000 images/night = 15TB/night
- 10 million transient candidates per night
  - Publicly available…
  - … but huge!

Data path

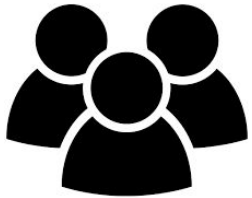
XX deg2 every ~30 seconds
down to mag ~24



10 million alerts
per night…



Machine learning
Catalog association
Streams join



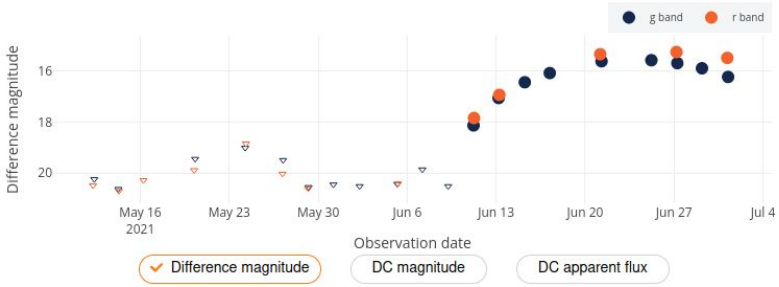
We would like the interesting ones ..

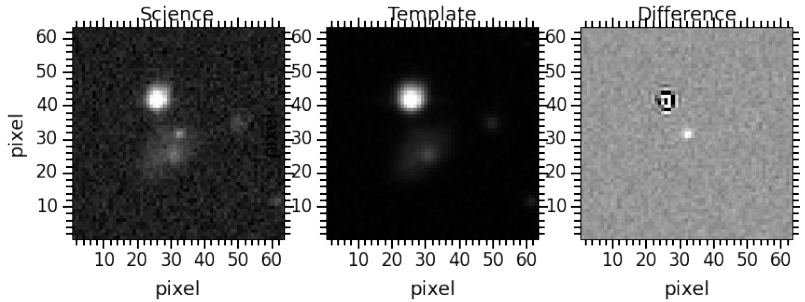
(What is an alert?)

Alerts based on Difference Image Analysis

Each alert contains

- Information about the new detection (magnitude, position, ...)
- Neighbours information (xmatches, etc)
- Historical information if the object has been seen previously
- Small images around the detection (60x60 pixels)

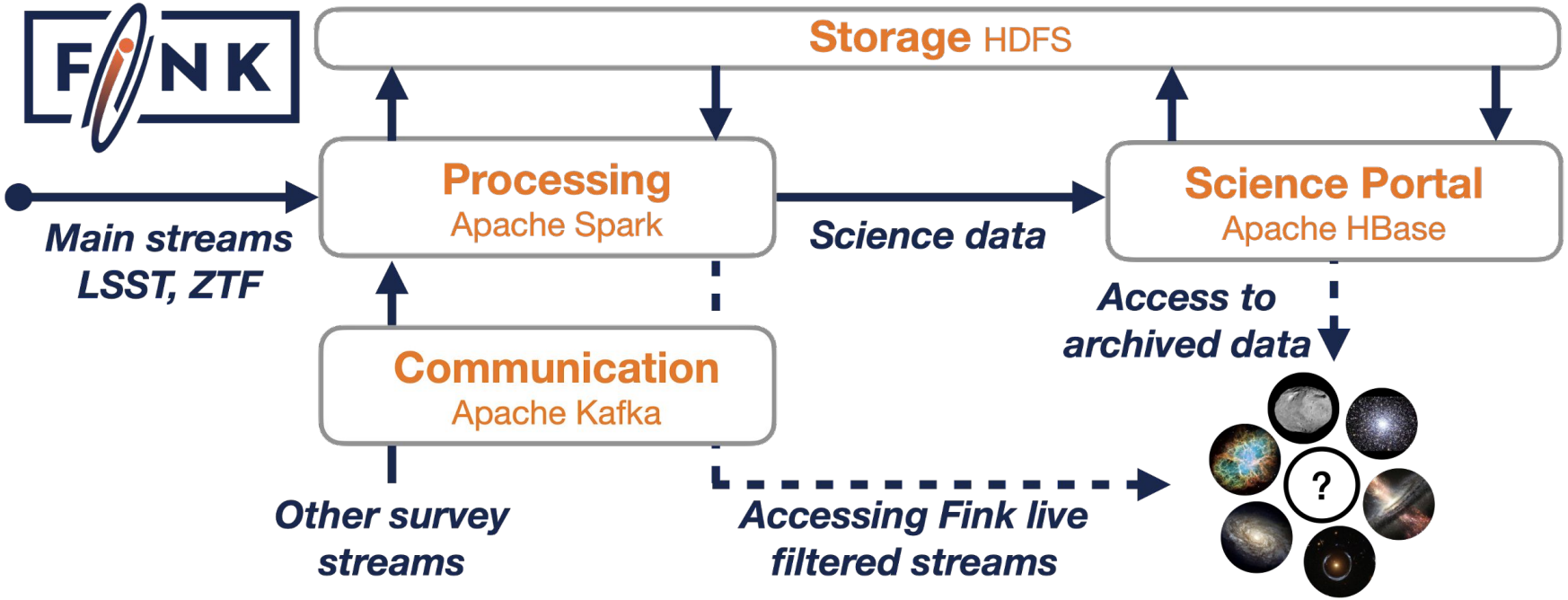




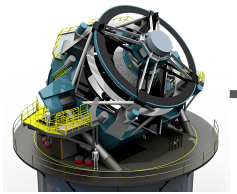
Fink design

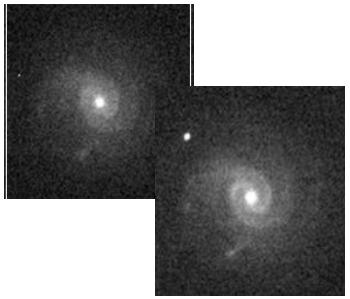
- ✓ Deployed in the cloud (VirtualData, *CC-IN2P3**)
- ✓ Collecting alert data from ZTF
- ✓ Benchmarked for LSST data volumes

- ✓ Survey cross-match
- ✓ Public catalogue cross-match
- ✓ Classification (ML, BNNs, Adaptive Learning)



How to classify alerts?





Brokers

FINK

Early-Supernova

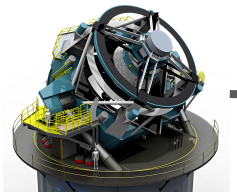
Kilonova

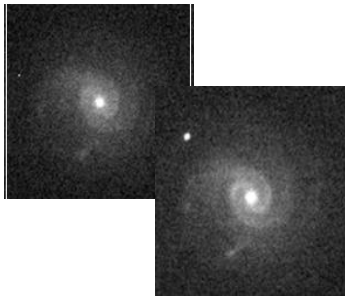
Variable Stars

Data stream contains ***alerts***

How to classify alerts?

Broker world





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Domain specialist world (the expert)

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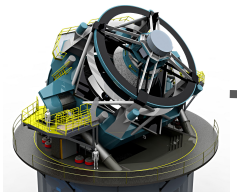

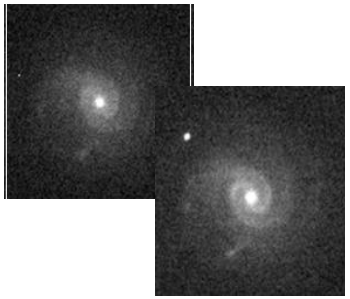

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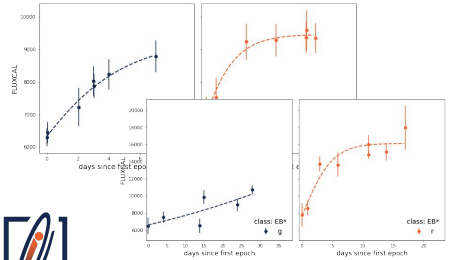

You can access this via de Fink Science portal or the API

All alerts data is public!

https://fink-portal.org/

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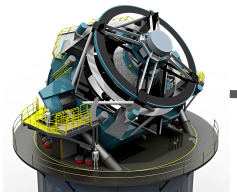

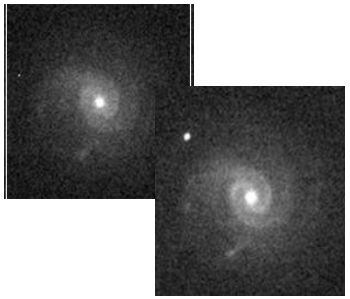

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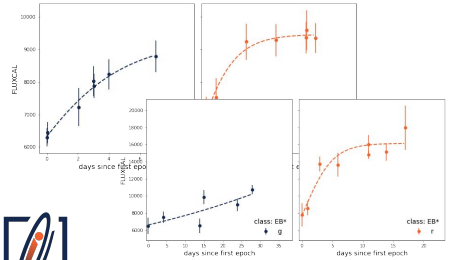
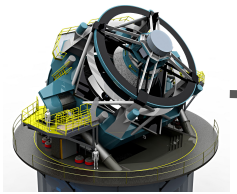
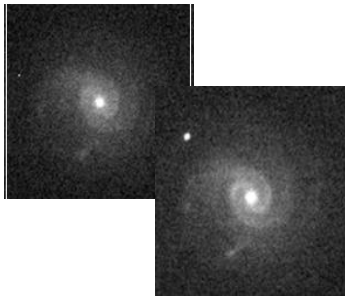


Filter
Catalog xmatch
Taylored science module

How to classify alerts?

Broker world





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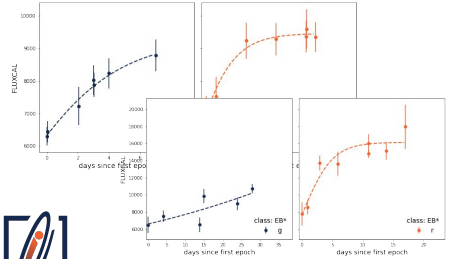
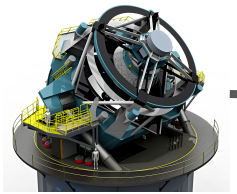


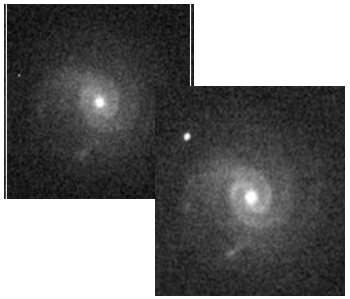
Taylored science module

f(alerts; ++) => class scores
Boolean

How to classify alerts?

Broker world





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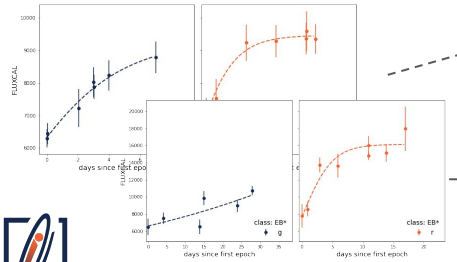
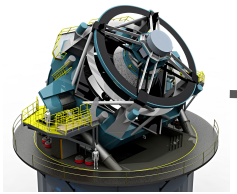


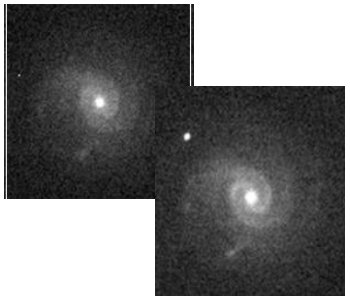
Train

Test

How to classify alerts?

Broker world





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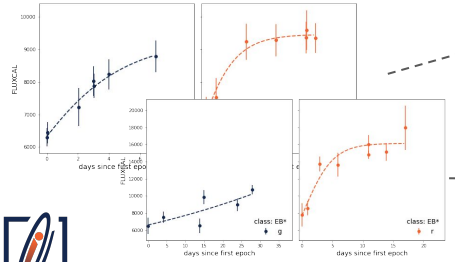


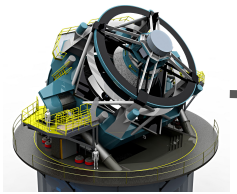
Train

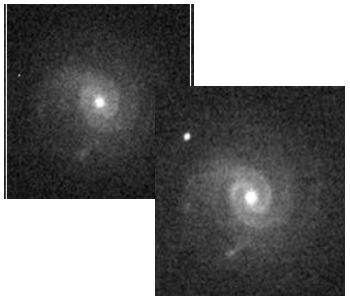
ML model

Test

How to classify alerts?

Broker world





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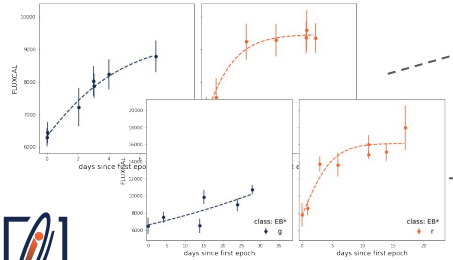

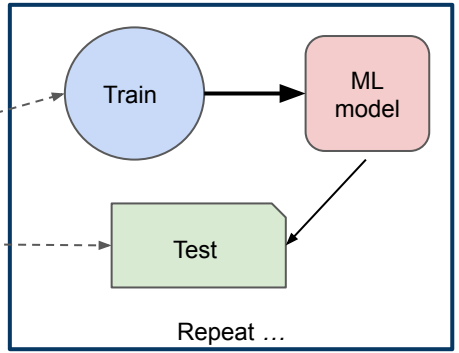

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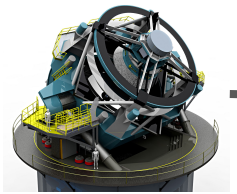

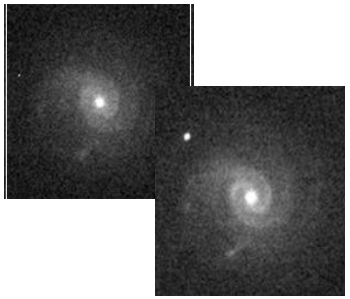

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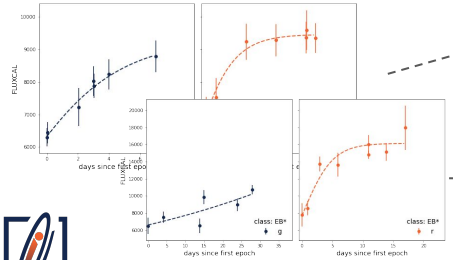


Train

ML model

Test

Repeat …

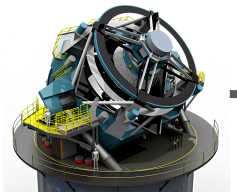
Trained ML model

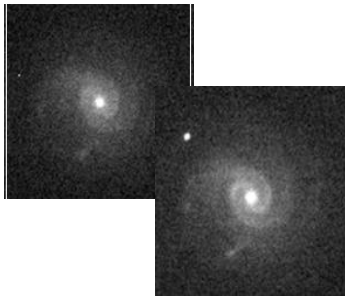
+

Feature extraction, selection cuts, auxiliary data, etc...

How to classify alerts?

Broker world





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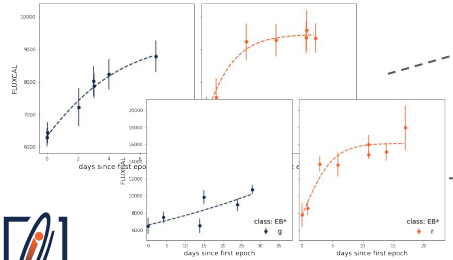

Train

ML model

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Repeat …

Trained ML model

+

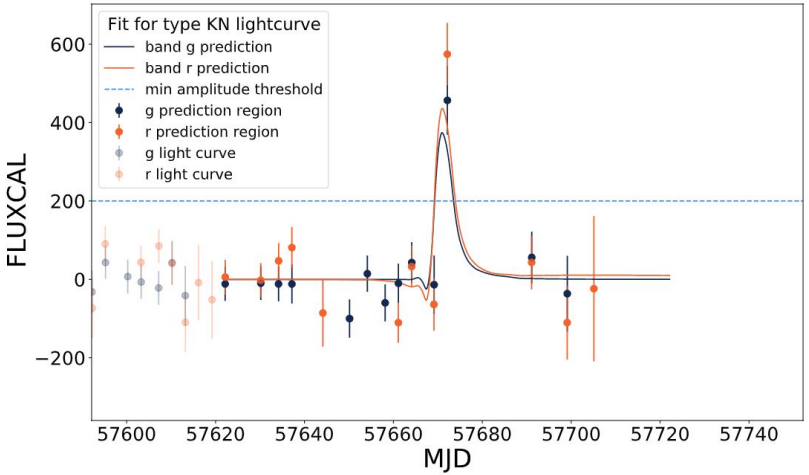
Feature extraction, selection cuts, auxiliary data, etc...

You can also use any other information already available in the broker

Case study: Kilonova

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

Problem 2: *we need to find it fast*

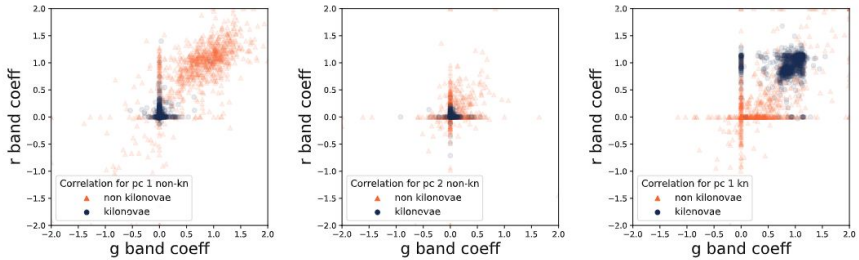


(c) KN event, at $z \approx .04$

Data set:
Simulated ZTF light curves

Feature extraction:
Principal components from perfect sims

Classifier:
Random Forest



Biswas et al., in prep

Case study: Kilonova

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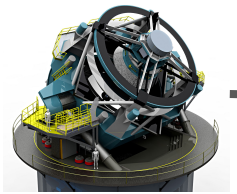

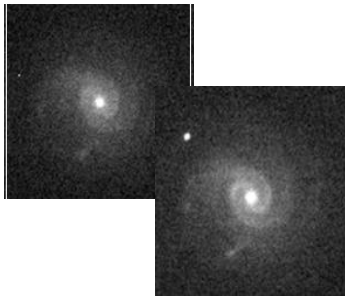

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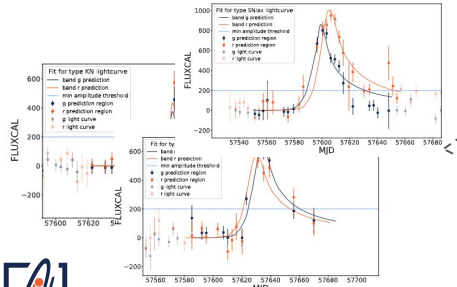

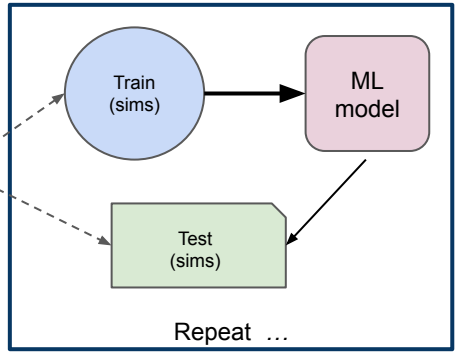

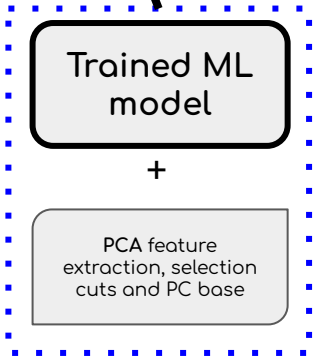

Extra imaging from professional and amateur astronomers

Case study: Kilonova

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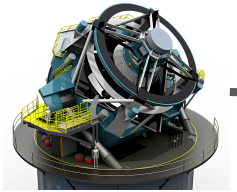

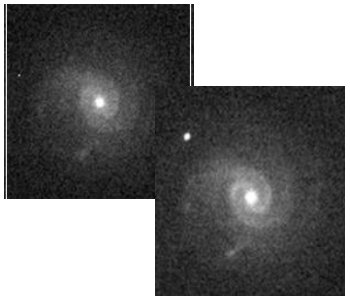

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GRANDMA Observations of ZTF/Fink Transients during Summer 2021

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

- 35 million candidate alerts
- 100 surviving selection cuts
- 6 followed-up by GRANDMA

Extra imaging from professional and amateur astronomers

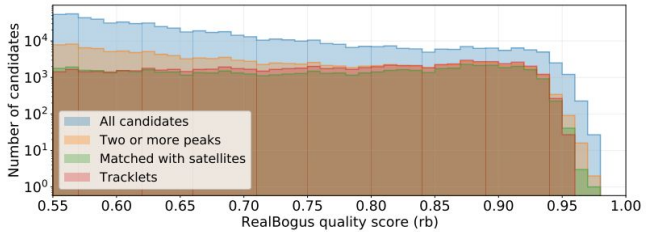
Case study: Satellite tracks

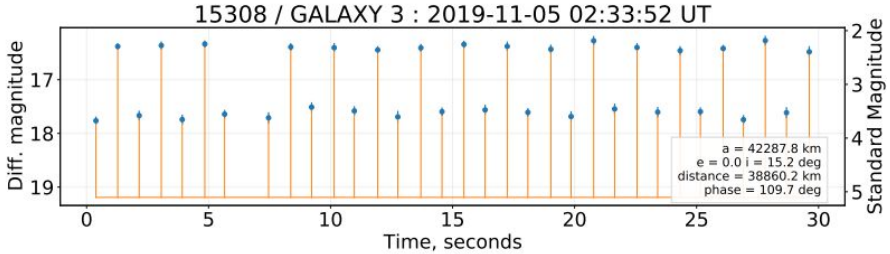
Problem 1: *they hide in plein sight, labels must evolve*

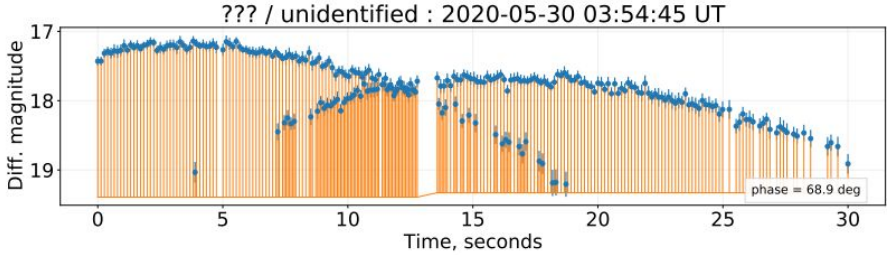
Not mega-constellations

Problem 2: *they move fast and may confuse difference image analysis*

- Module to identify satellite glints
- 11.5 % all single-frame events
- 30% of those with real-bogus > 0.8
- 140 per night

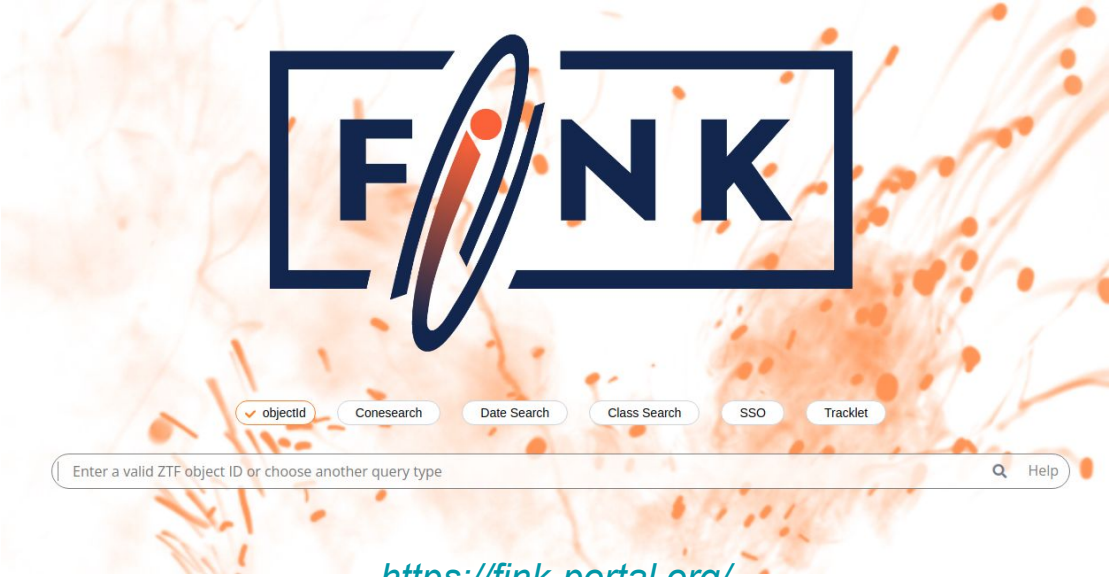






Karpov and Peloton, 2021, arXiv:astro-ph/2202.05719

Once the module is integrated…

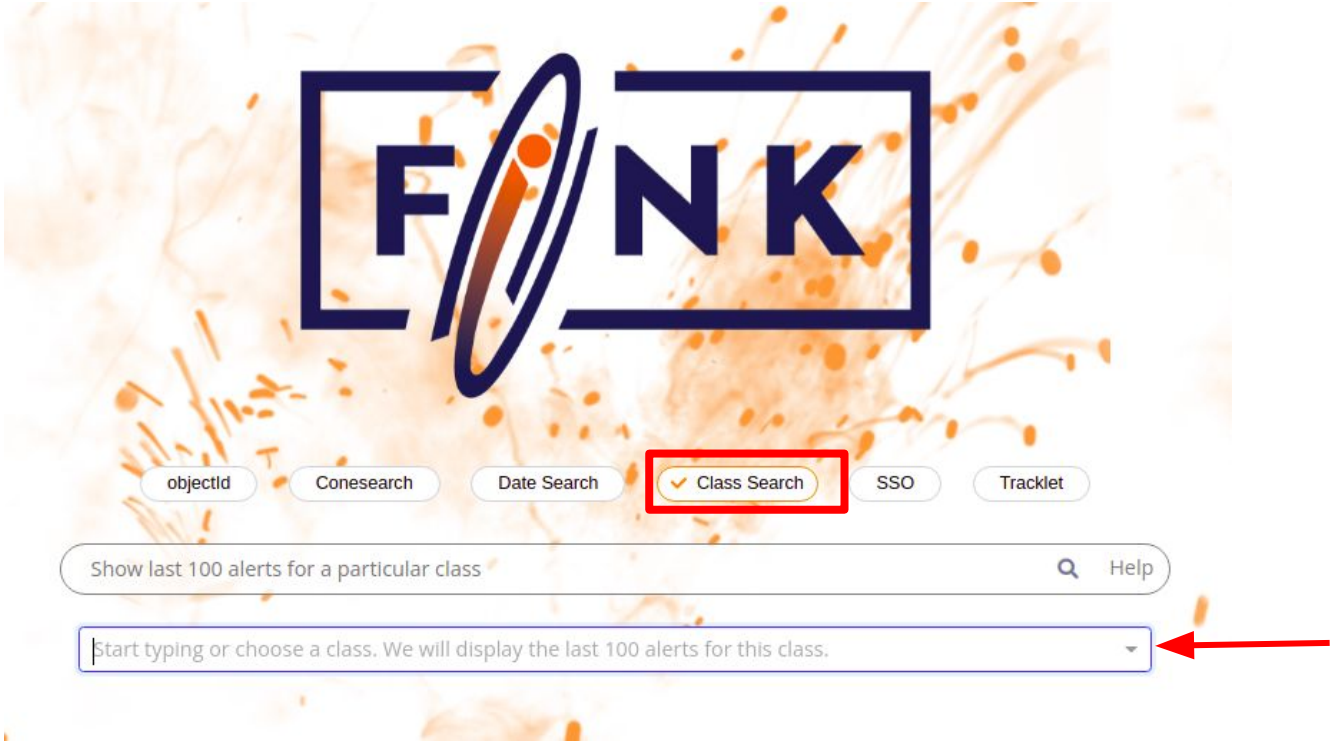


https://fink-portal.org/

Tutorials: https://github.com/astrolabsoftware/fink-notebook-template

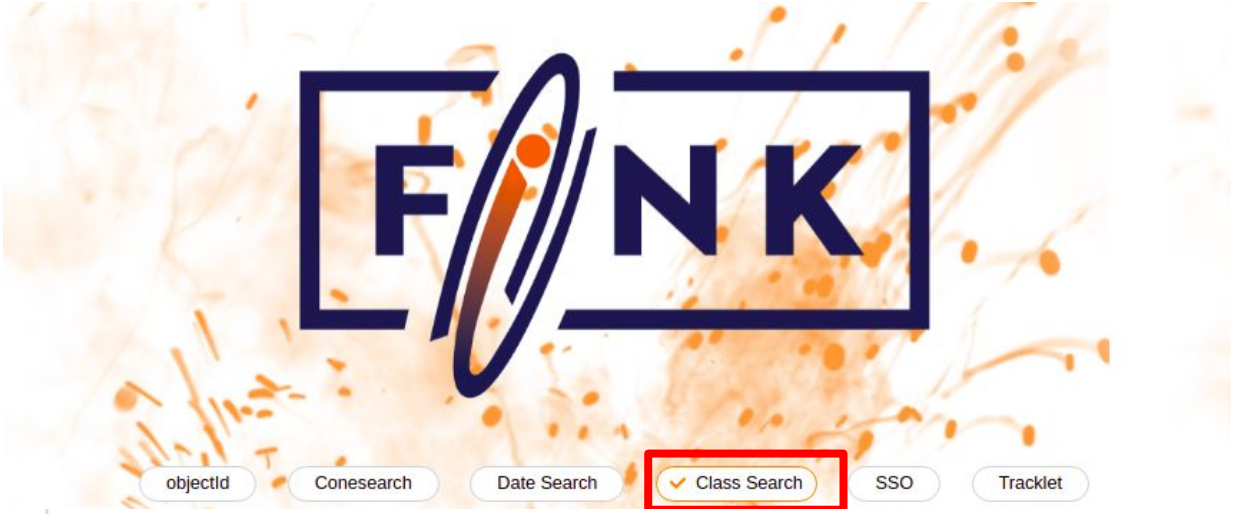
PS: while LSST does not arrive, we are operating with ZTF (~ 200k alerts/night)

Once the module is integrated…

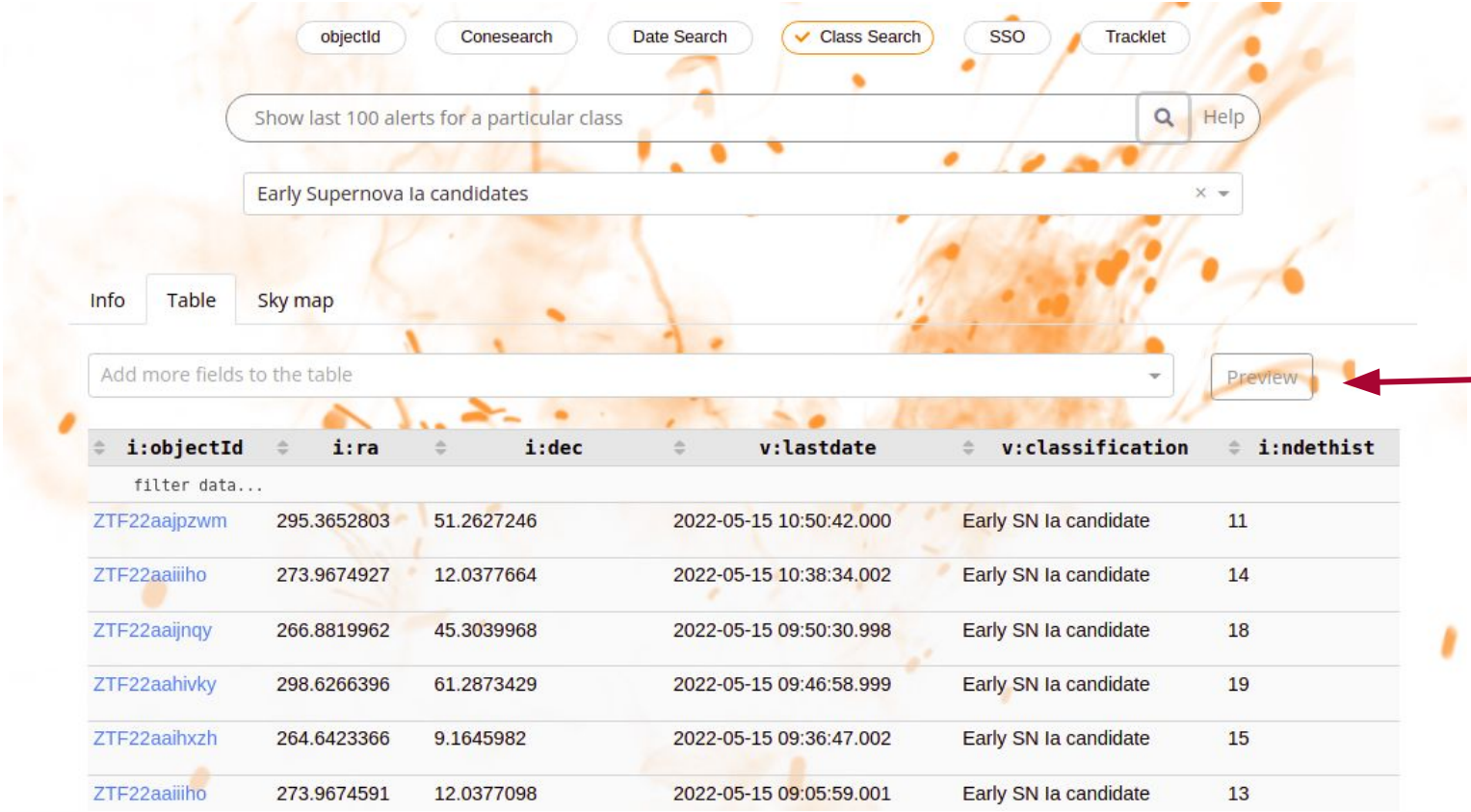


https://fink-portal.org/

Once the module is integrated…



Once the module is integrated…



i:objectId	i:ra	i:dec	v:lastdate	v:classification	i:ndethist
filter data...					
ZTF22aajpzwm	295.3652803	51.2627246	2022-05-15 10:50:42.000	Early SN Ia candidate	11
ZTF22aaiiiho	273.9674927	12.0377664	2022-05-15 10:38:34.002	Early SN Ia candidate	14
ZTF22aaijnqy	266.8819962	45.3039968	2022-05-15 09:50:30.998	Early SN Ia candidate	18
ZTF22aahivky	298.6266396	61.2873429	2022-05-15 09:46:58.999	Early SN Ia candidate	19
ZTF22aaihxzh	264.6423366	9.1645982	2022-05-15 09:36:47.002	Early SN Ia candidate	15
ZTF22aaiiiho	273.9674591	12.0377098	2022-05-15 09:05:59.001	Early SN Ia candidate	13

On

Search Statistics API Tutorials Info

Load fail, refresh the page

Last emission date:
2022-05-15 10:50:42.000

Days since first detection:
5

Last magnitude (band g):
18.43

Total number of detections:
11

Early SN Ia candidate

Constellation: Cygnus

Go to ZTF22aajpzwm

ihxzh	264.6423366	9.1645982	2022-05-15 09:36:47.002	Early SN Ia candidate	15
iiiho	273.9674591	12.0377098	2022-05-15 09:05:59.001	Early SN Ia candidate	13

Load fail, refresh the page

Last emission date:
2022-05-15 10:38:34.002

Days since first detection:
16

Last magnitude (band g):
18.71

Total number of detections:
14

Early SN Ia candidate

Constellation: Ophiucus

Go to ZTF22aaiiiho

Info | Table | S

Add more fields to

i:objectId					i:ndethist
filter data...					
ZTF22aajpzwm					1
ZTF22aaiiiho					4
ZTF22aaijnqy					8
ZTF22aahivky					9
ZTF22aaihxzh	264.6423366	9.1645982	2022-05-15 09:36:47.002	Early SN Ia candidate	15
ZTF22aaiiiho	273.9674591	12.0377098	2022-05-15 09:05:59.001	Early SN Ia candidate	13

Load fail, refresh the page

Last emission date:
2022-05-15 09:36:47.002

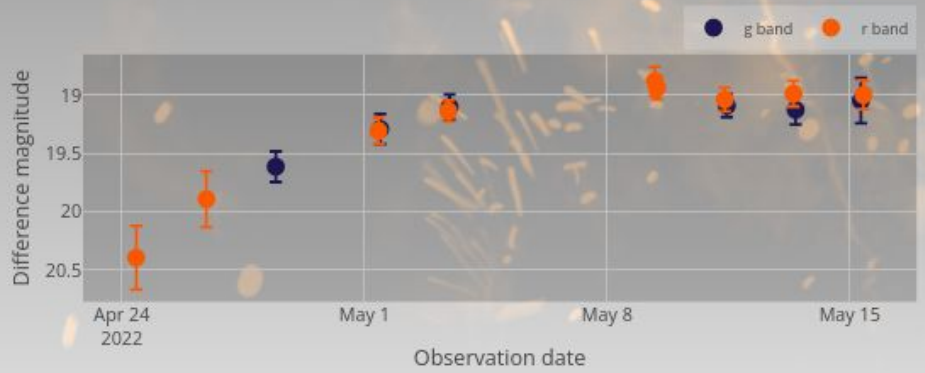
Days since first detection:
20

Last magnitude (band r):
19.00

Total number of detections:
15

Early SN Ia candidate

Constellation: Ophiucus



Go to ZTF22aaihxzh

Info Table S

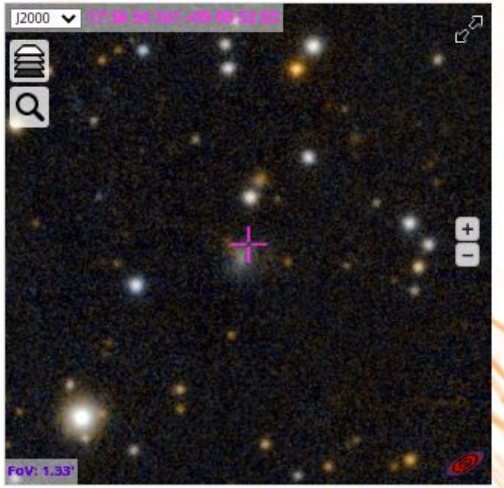
Add more fields to

review

i:objectId					i:ndethist
filter data...					
ZTF22aajpzwm					1
ZTF22aaiiiho					4
ZTF22aaijnqy					8
ZTF22aahivky					9
ZTF22aaihxzh	264.6423366	9.1645982	2022-05-15 09:36:47.002	Early SN Ia candidate	15
ZTF22aaiiiho	273.9674591	12.0377098	2022-05-15 09:05:59.001	Early SN Ia candidate	13

Fink Science portal 1.1 Search Statistics API Tutorials Info

ZTF22aaihxzh



Inspect alert data | Get object data

Summary | Supernovae | Variable stars | Microlensing | Solar System | Tracklets | GRB

Individual alert classification — Early SN Ia candidate: 45% — SN candidate: 55%

Science	Template	Difference
Load fail, refresh the page	Load fail, refresh the page	Load fail, refresh the page

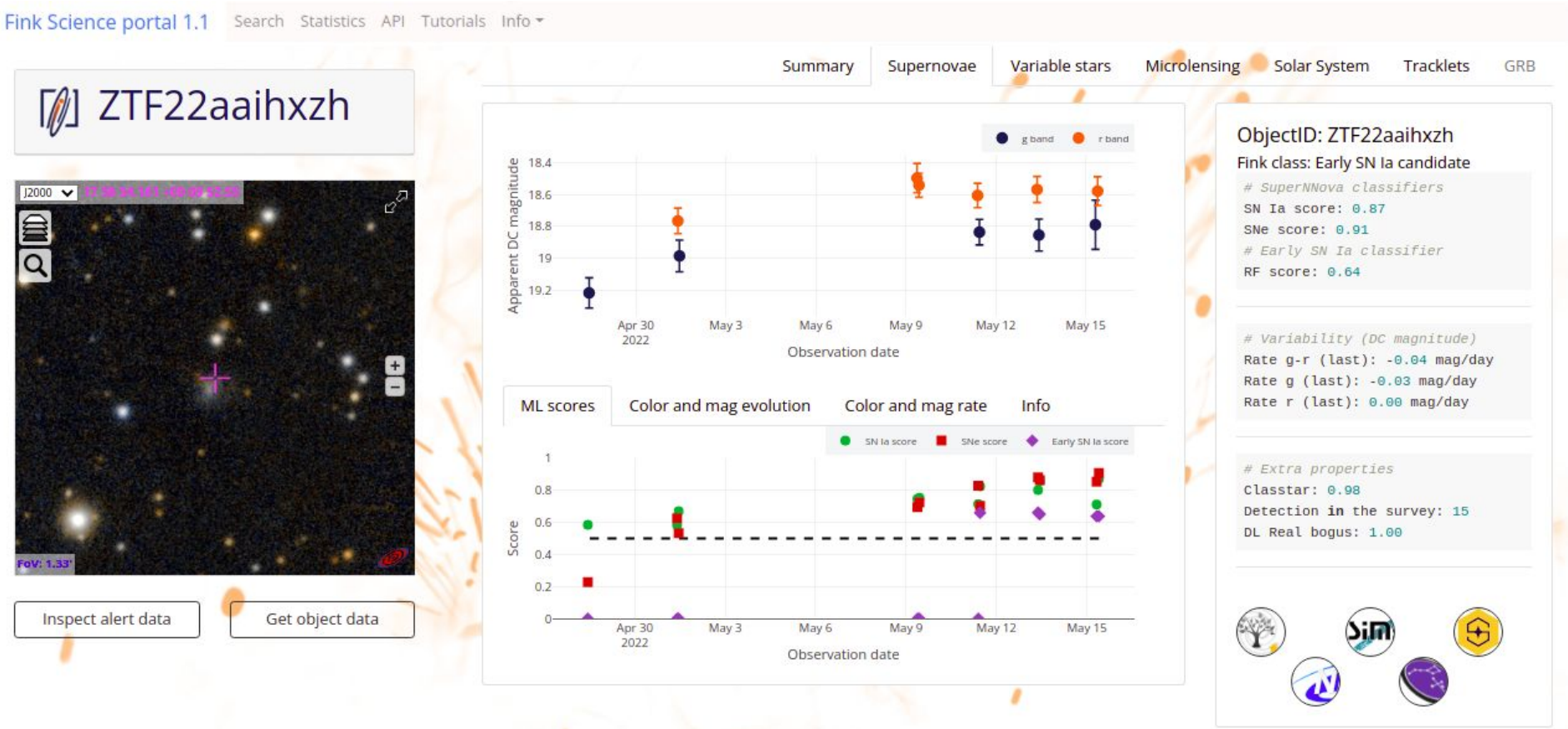
Difference magnitude | DC magnitude | DC apparent flux

Information
What am I seeing?

ObjectID: ZTF22aaihxzh

Last class: Early SN Ia candidate

```
# General properties
Date: 2022-05-15 09:36:47.002
RA: 264.6423366 deg
Dec: 9.1645982 deg

# Variability (DC magnitude)
Rate g (last): -0.03 mag/day
Rate r (last): 0.00 mag/day

# Neighbourhood
Constellation: Ophiucus
SIMBAD: Unknown
MPC: null
Distance (PS1): 2.91 arcsec
Distance (Gaia): 8.36 arcsec
Distance (ZTF): 2.73 arcsec
```



More detailed information from different science modules
These are the capabilities now, working with ZTF data

Once the module is integrated…

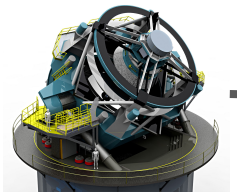
API: https://fink-portal.org/api

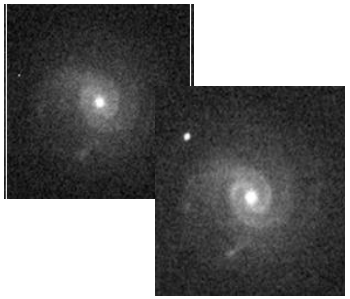
```
import requests
import pandas as pd

# Get all classified SN Ia from TNS between March 1st 2021 and March 5th 2021
r = requests.post(
  'https://fink-portal.org/api/v1/latests',
  json={
    'class': '(TNS) SN Ia',
    'n': '100',
    'startdate': '2021-03-01',
    'stopdate': '2021-03-05'
  }
)

# Format output in a DataFrame
pdf = pd.read_json(r.content)
```

Your class

For LSST …

Broker world





Brokers

FINK

Early-Supernova

Wishlist

Kilonova

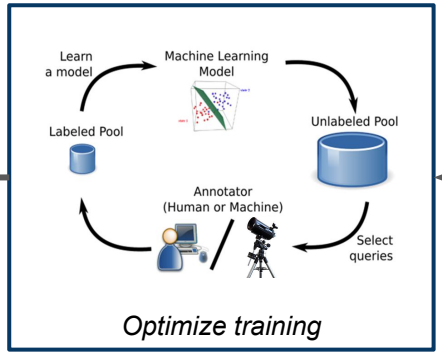
Variable Stars

Automatic re-training once informative new labels are made available

Trained ML model

+

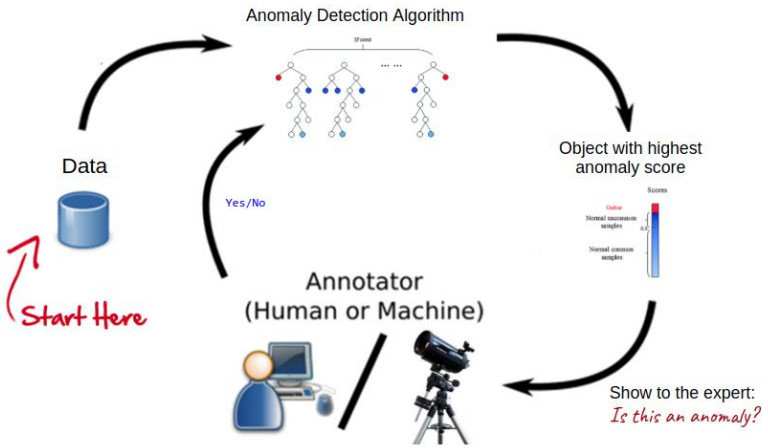
Sigmoid feature extraction and selection cuts



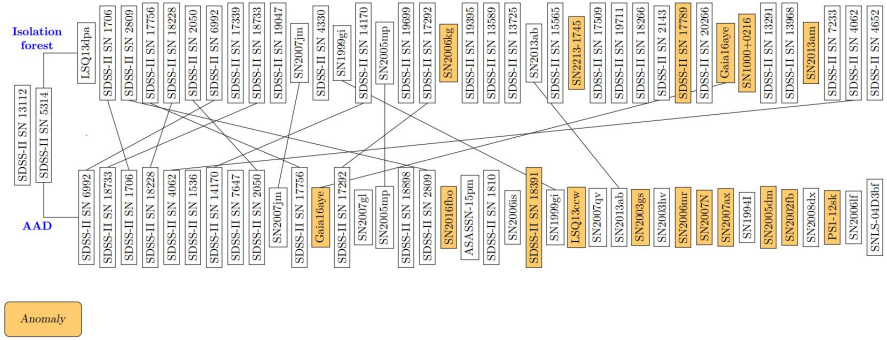
labels

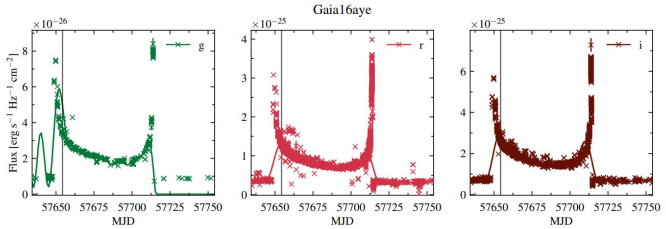
Extension to the unknown

Same philosophy can be applied to *Anomaly Detection*



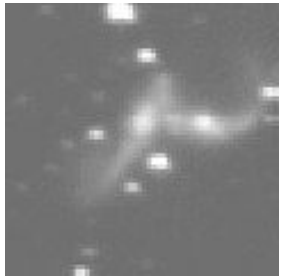
Expert feedback is crucial here!





Ishida et al. 2021, A&A, Active anomaly detection for time-domain discoveries
See also: https://snad.space/

Accessing Fink data



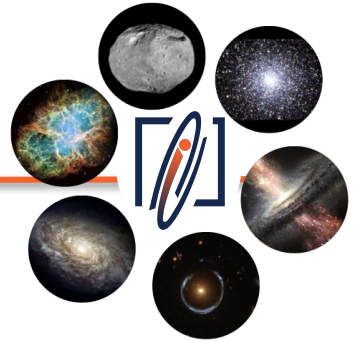
Two entry points for users:

- 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
- Statistics information:
  - https://fink-portal.org/stats

Take home message

- Preparing for LSST means be prepared to define what is interesting
- Automatization of recommendation systems can enable improved classification and discovery
- Fink was specifically designed to enable incorporation of complex queries (domain knowledge)

Summary



- Fink is a broker designed specifically for LSST
- Enabling science by applying state-of-the-art technology.
- Technology Readiness Level (TRL) 6/9.
- Currently digesting ZTF stream

First science modules deployed and testing capabilities beyond expectations: SNe, GRB, KNe, microlensing, …

New proposals for science modules are welcome! https://fink-broker.org/joining.html

More info:

- Fink white paper, *arXiv: astro-ph/2009.10185*
- Website & Science Portal: *https://fink-broker.org*
- API Tutorials: *https://github.com/broker-workshop/tutorials/tree/main/fink*