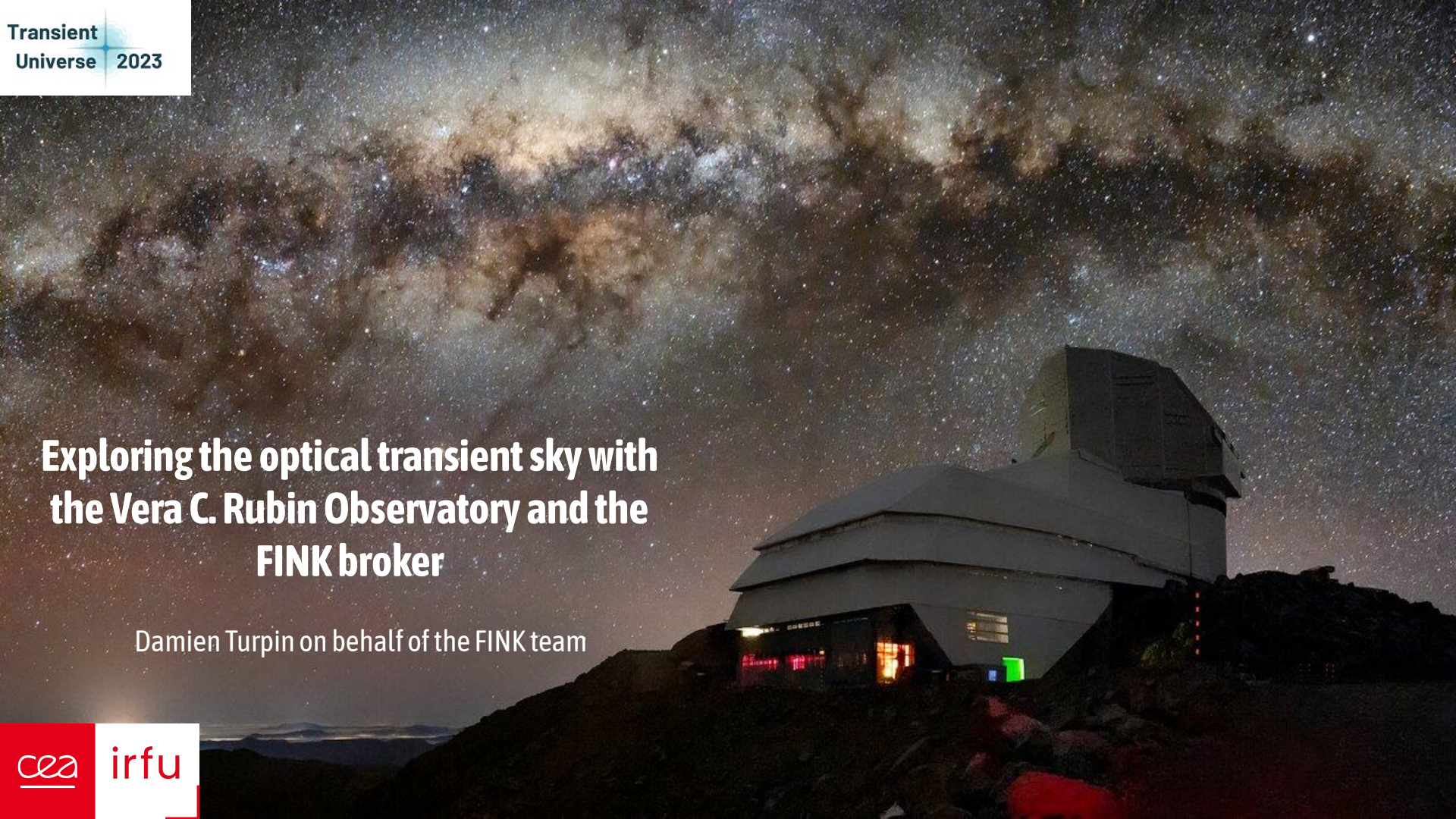
Transient Universe 2023

Exploring the optical transient sky with the Vera C. Rubin Observatory and the FINK broker

Damien Turpin on behalf of the FINK team



cea irfu

Transient Universe 2023

Outlines

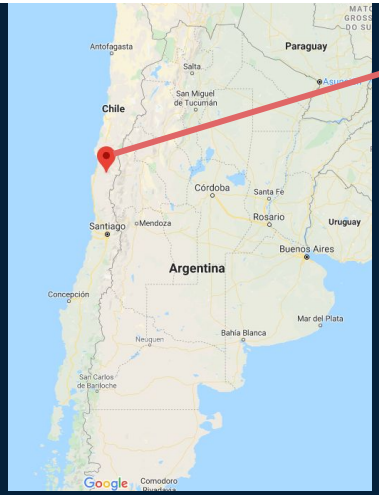
1. *The Rubin Observatory and its LSST survey*
2. *The landscape of the optical transient phenomena*
3. *FINK: the broker born in France devoted to the time-domain astronomy*
4. *How to use the FINK outputs for your science*

1

The Rubin Observatory and its LSST survey

https://rubinobservatory.org/for-scientists

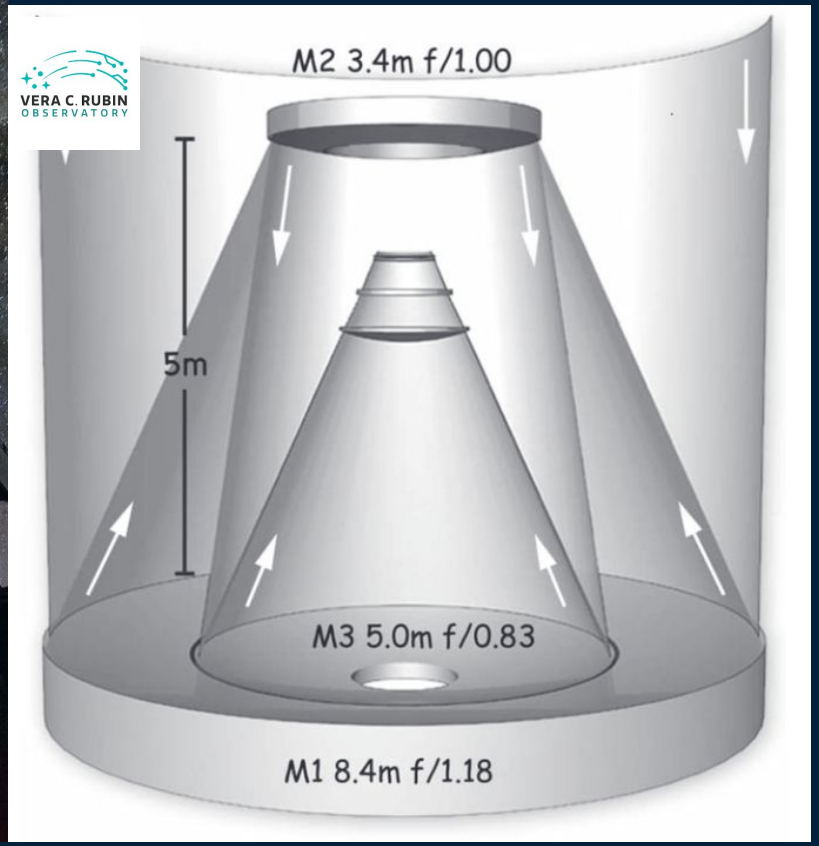
The Vera C. Rubin Observatory: a new comer in Chile!



Cerro Pachon Mountain

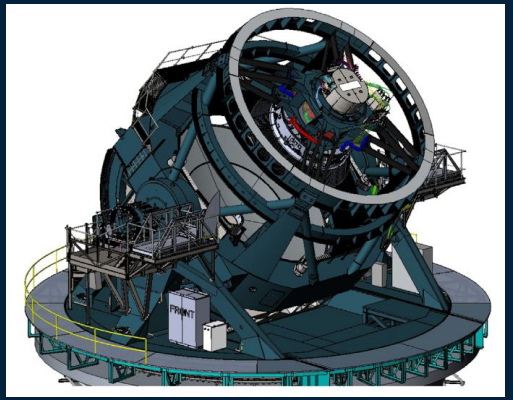
- **Site coordinates:** latitude -30:14:40.68 longitude -70:44:57.90
- **Altitude:** 2647m
- **Average annual rainfall:** 46cm
- **Average clear nights per year:** 256

The Rubin Observatory with a new large optical telescope

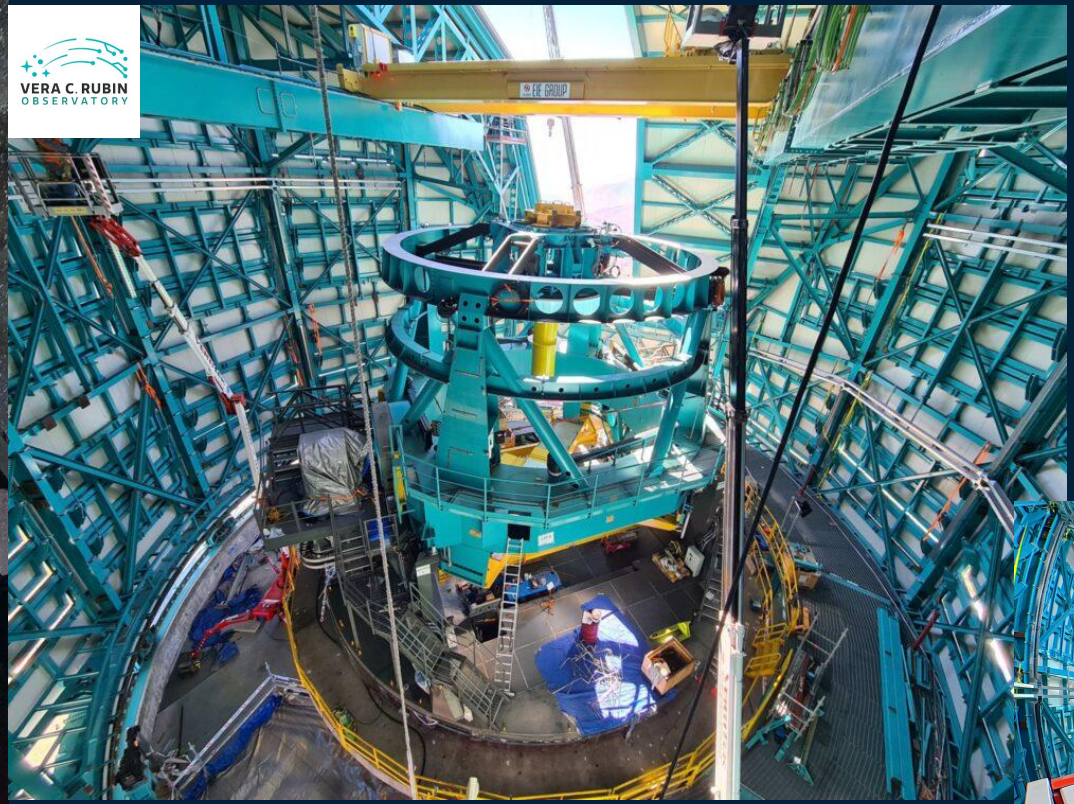


Telescope System:

- Field of View : 3.5 degrees (9.6 square degrees)
- Primary mirror diameter : 8.4 m
- Mean effective aperture : 6.423 m (area weighted over FOV)
- Final f-ratio : f/1.234
- Camera weight : 6,746 lbs (3,060 kg)
- Mirror (M1+M3 glass mirror only) weight : 35,900 pounds (16,284 kg)



The Rubin Observatory's Simonyi Survey Telescope



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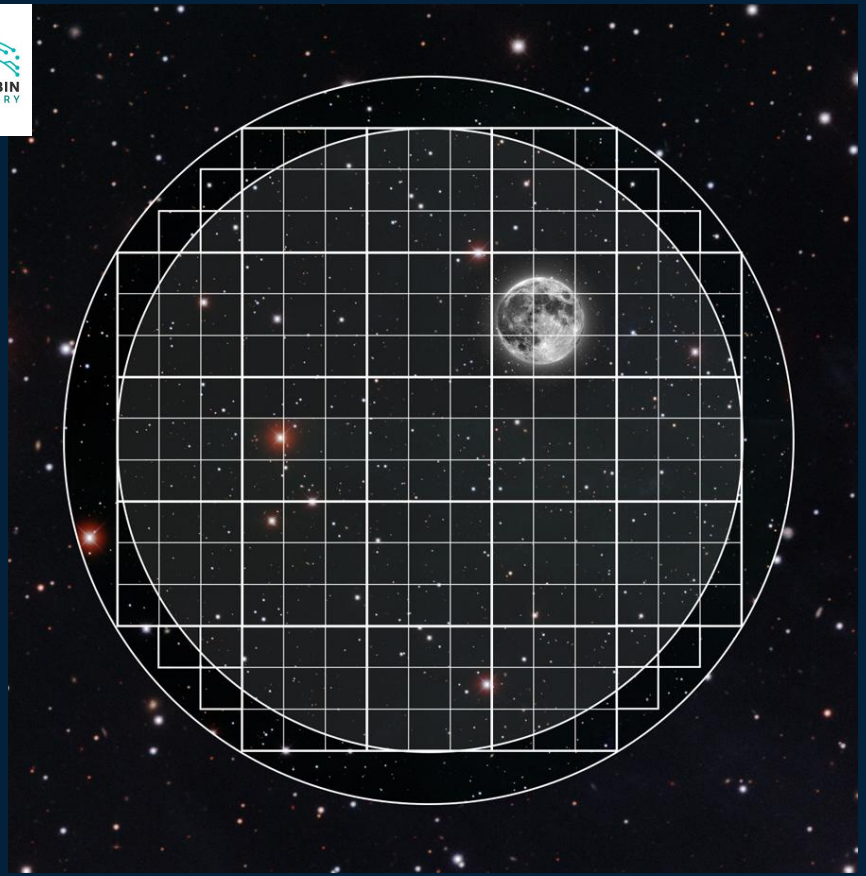
The Rubin Observatory's Simonyi Survey Telescope with a huge camera!

Image Credit: Jacqueline Ramseyer Orrell/SLAC National Accelerator Laboratory

Imaging System:

- Pixel count : 3.2 Gpixels
- Focal plane : 189 4kx4k science CCD chips
- Pixel pitch : 0.2 arcsec/pixel
- Pixel size : 10 microns
- Filling factor : >90%
- Minimum exposure time : 1 sec

The Rubin Observatory's Simonyi Survey Telescope with a huge field of view (FoV)



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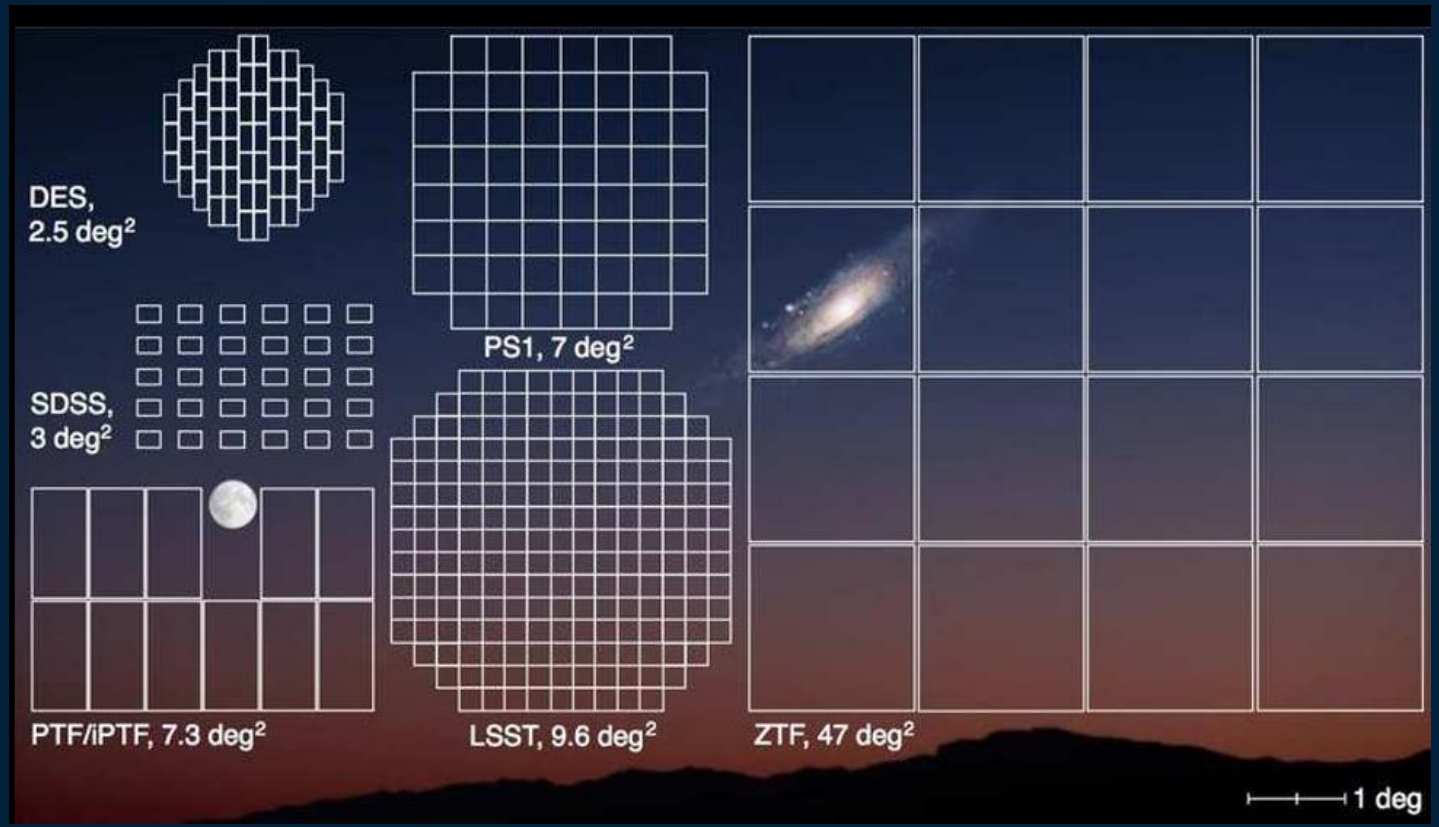
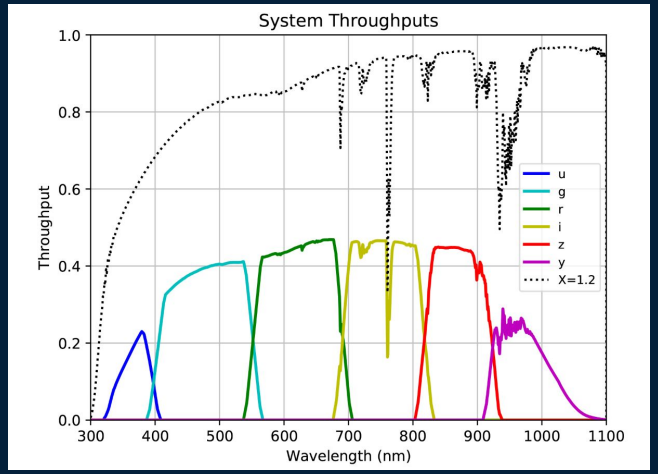
The Rubin Observatory's Simonyi Survey Telescope FoV compared to the past and current surveys

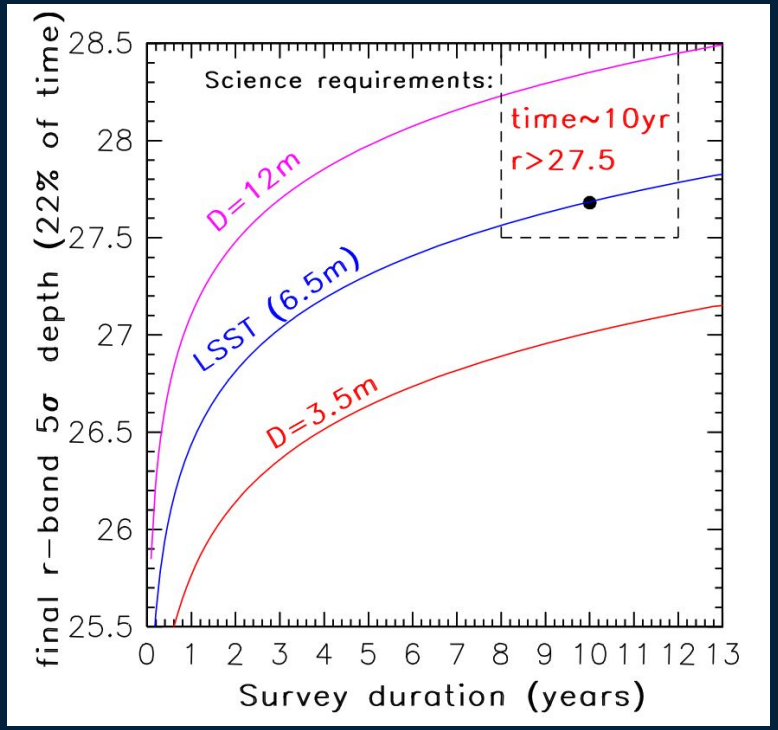


The Rubin Observatory's Simonyi Survey Telescope with a deep sensitivity in 6 bands



5σ Sensitivity (30s / survey life time)

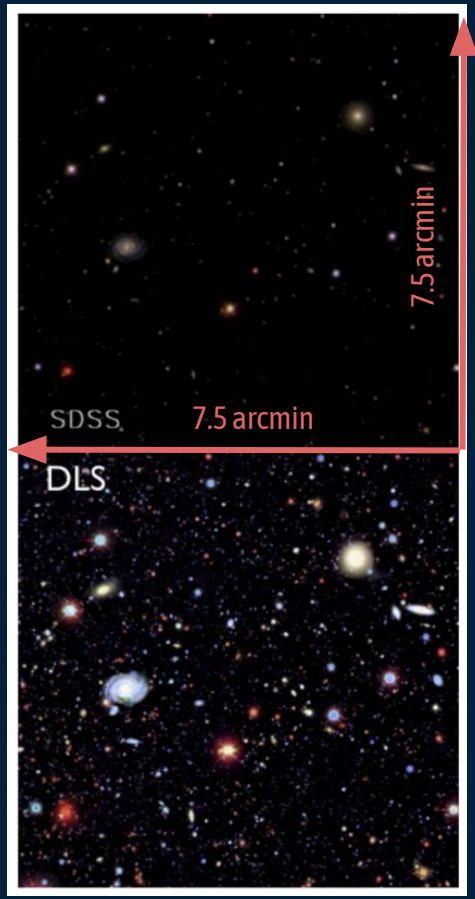
- u: 23.9 / 26.1
- g: 25.0 / 27.4
- r: 24.7 / 27.5
- i: 24.0 / 26.8
- z: 23.3 / 26.1
- y: 22.1 / 24.9



Evolution of the survey depth in r-band (22% of the survey time)

Izevic et al. 2019 https://arxiv.org/abs/0805.2366

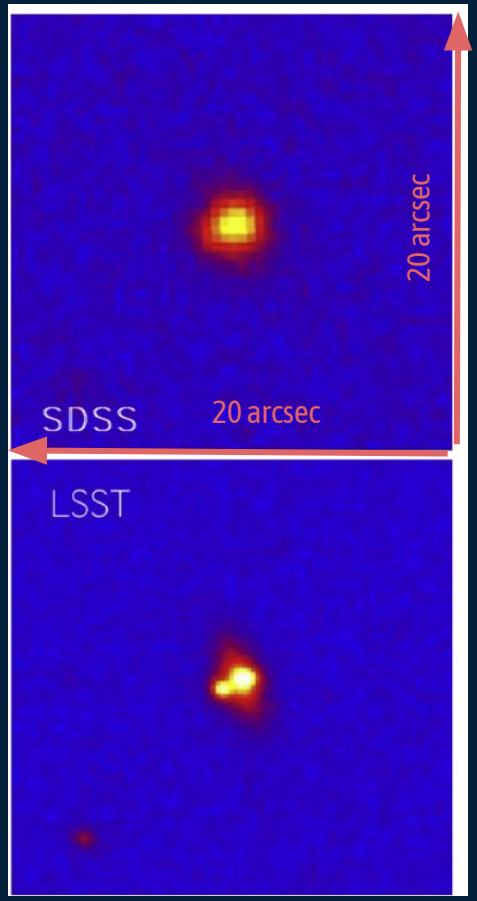
The LSST expected images compared to previous surveys



- SDSS gri image (r<22.5)

- Deep Lens Survey (4m Blanco telescope) gri image (r<24.5)

LSST 10 yrs coadded image will be 3 mag deeper than DLS

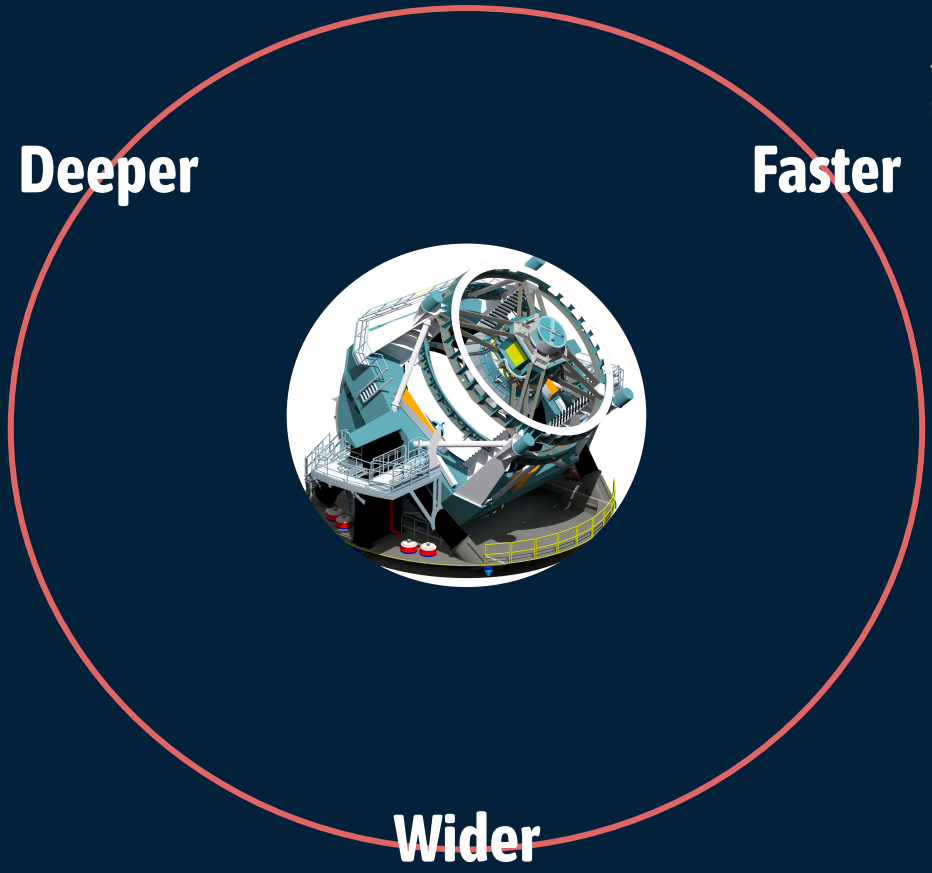


- The lensed Quasar SDSS J1332+0347 seen in SDSS images

- Same from a Suprime-Cam Subaru image adapted to the LSST seeing and angular resolution

Izevic et al. 2019 https://arxiv.org/abs/0805.2366

A Legacy Survey of Space and Time (LSST): a new generation of synoptic survey



- the 270k kg structure have to move at 10°/sec in rotation

- ~5 sec to move and stabilize from a pointing to another one

A Legacy Survey of Space and Time (LSST) for 4 main science cases

- The galaxies evolution
- Test cosmological models
- Find an answer to the Dark energy and dark matter origin

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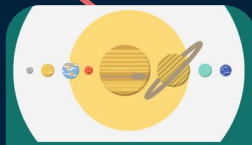
Understanding Dark Matter



Cataloging the Solar System

- Reveal the fainter SS objects
- a catalog of objects 10-100 times bigger than any previous one before
- Study of body's properties and motion in the SS. Accurate classification of the SSO.

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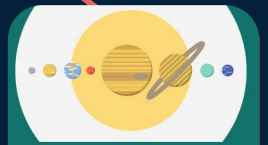

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Mapping the Milky Way

- Reconstruct the MW evolution history
- Reveal the old and faint trace of MW -galaxy mergers

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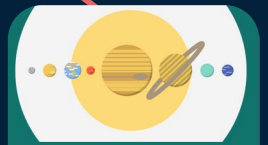

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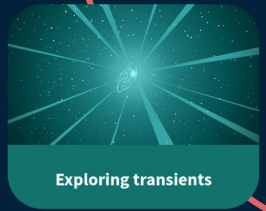
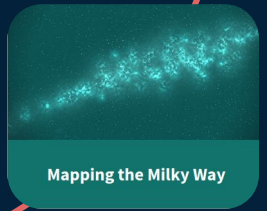
- Continuous monitoring of the visible and NIR variable sky over 10 years
- Moving objects
- Variable objects
- Transient phenomena





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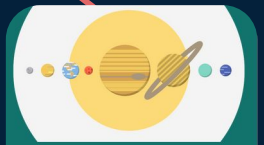

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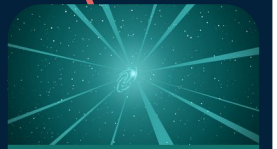


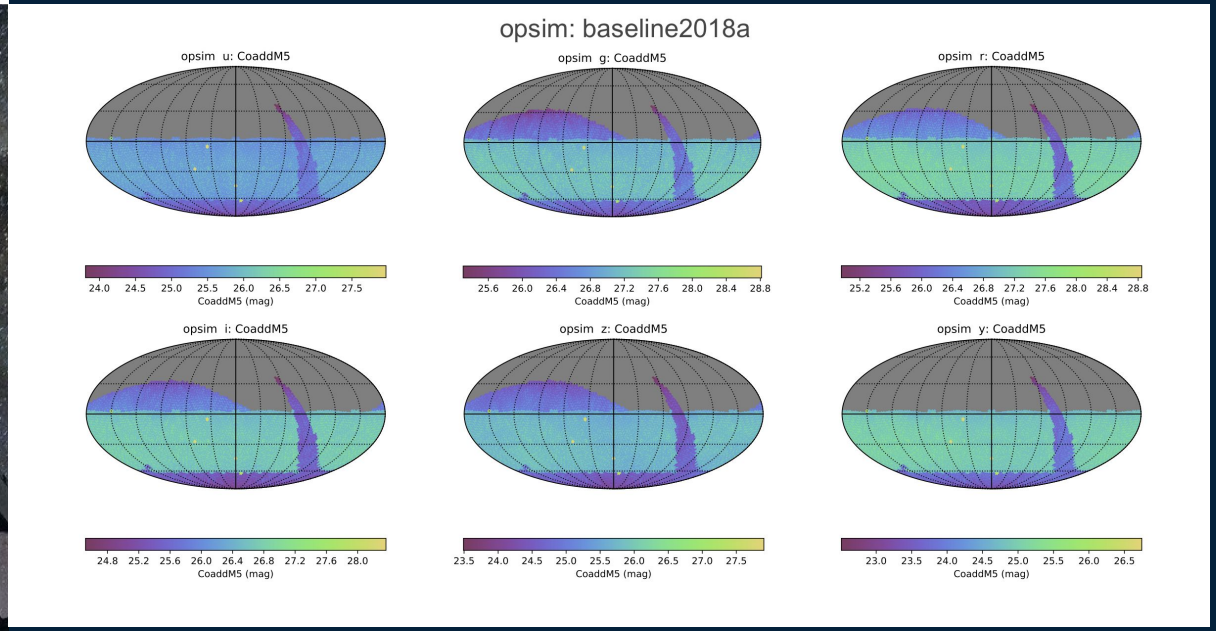
Exploring transients

Mapping the Milky Way

- Reconstruct the MW evolution history
- Reveal the old and faint trace of MW -galaxy mergers

Our topic of interest today!

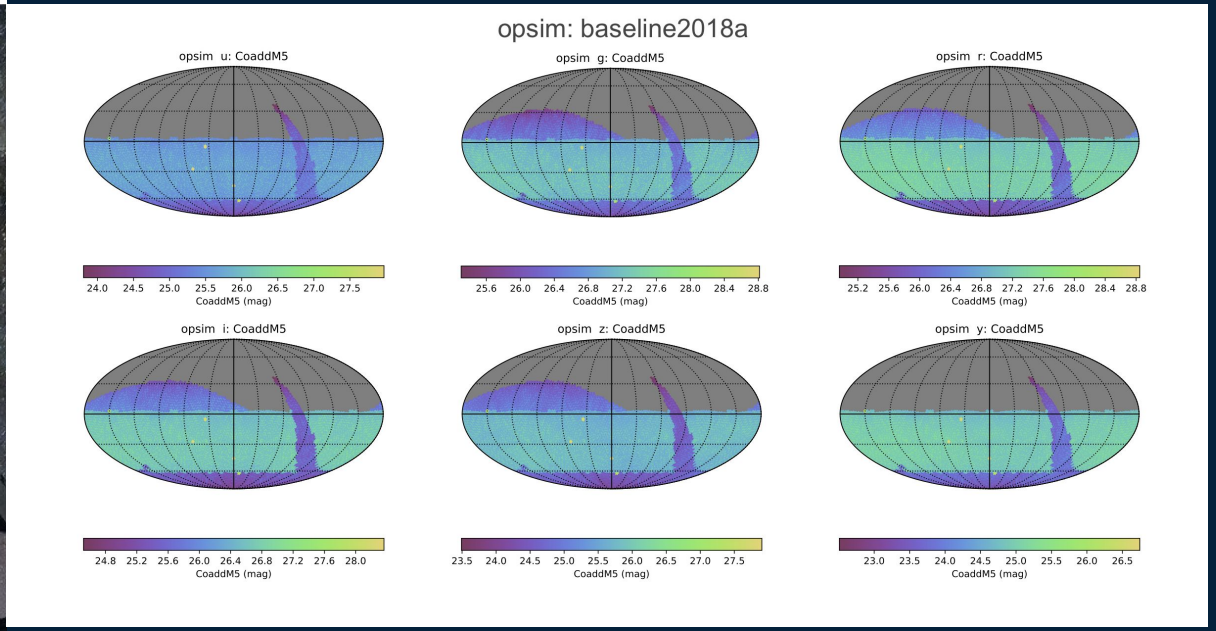
The LSST survey in a nutshell



Baseline Survey Strategy (Wide-Faster-Deep):

- 90% of the telescope time
- declination range : [-72° - +12°]
- 2 millions of images (10-yrs)
- ~100 revisit of each field / year
- 20 Tb /night - 60 Pb over 10 yrs
- 38×10^9 detected objects (10 yrs)
  - galaxies = 52.6%
  - stars = 44.7%
  - SNe = ~0.03%
  - SSO = ~0.02%

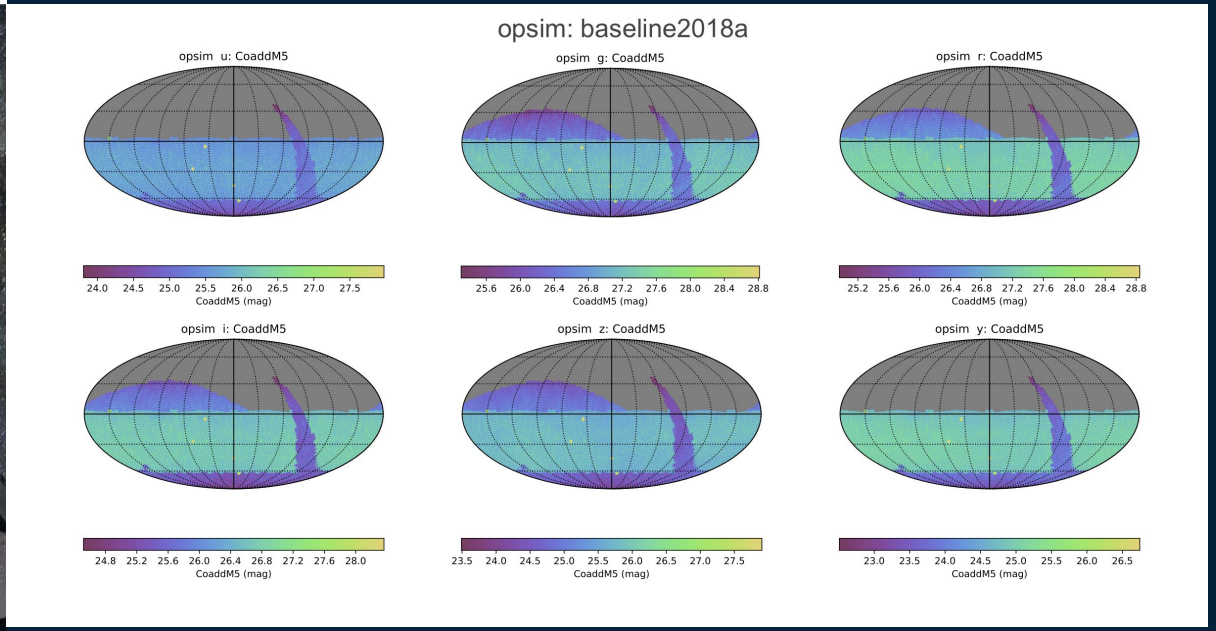
The LSST survey in a nutshell



The Deep Drilling Fields (DDF):

- ~5-10% of the telescope time
- 4 South field identified
  - ELAIS-S1
  - XMM-LSS
  - CDF-S
  - COSMOS
- **deeper** (by 1-2 mag) and **more frequent temporal sampling** (1 revisit /night or per two nights at maximum) than the WFD survey
- Enable a more comprehensive analysis of the changing sky objects in these fields
  - AGNs
  - SNIa
  - etc.

The LSST survey in a nutshell



Mini-surveys:

- ~3% of the telescope time
- Observations "that cover specific sky regions such as the ecliptic plane, Galactic plane, and the Large and Small Magellanic Clouds, or that vary survey parameters such as the depth of a single visit"

from Bianco et al. 2022

LSST: A revolution in the time-domain astronomy

10^7

alerts / night

10k

alerts / exposure

60s

latency for the alert delivery after the image taking

10x

SSO detected than in the MP DB

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Table 1. A comparison between ZTF, LSST, and other next generation surveys in terms of scale.

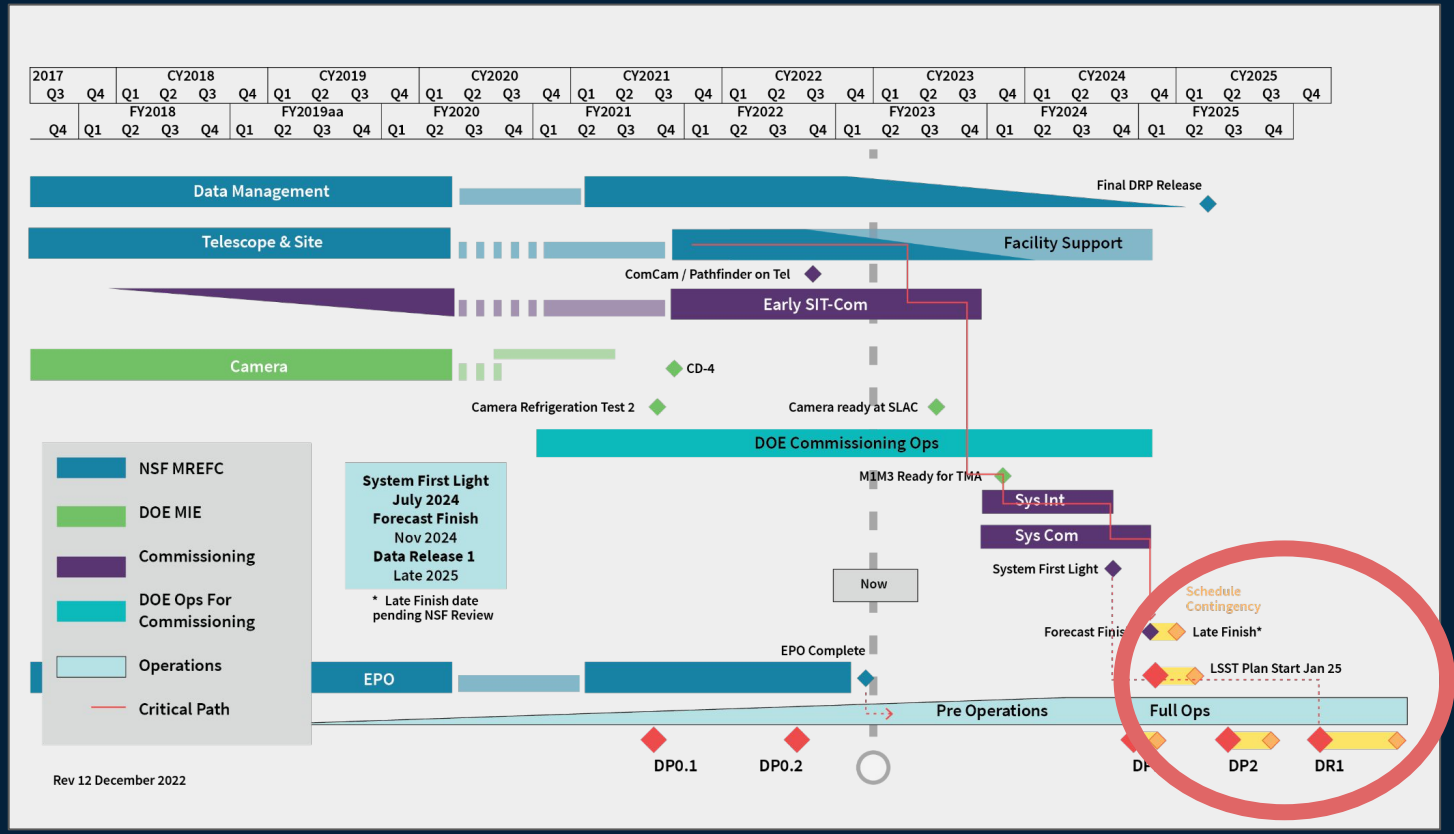
Category	ATLAS	ASAS-SN	Pan-STARRS	ZTF	LSST
Number of total sources	-	1×10^8	1×10^{10}	1×10^9	37×10^9
Number of total detections	1×10^{12}	1×10^{11}	1×10^{11}	1×10^{12}	37×10^{12}
Annual visits per source	1000[c]	180[d]	60[e]	300[a]	100[b]
Number of pixels	1×10^8	4×10^6 (x 4)	1×10^9	6×10^8	3.2×10^9
CCD surface area (cm^2)	90	9	1415	1320	3200
Field of view (deg^2)	30	4.5	7	47	9
Hourly survey rate (deg^2)	3000	960	-	3760	1000
5σ detection limit in r	19.3	17.3	21.5	20.5	24.7
Nightly alert rate	-	-	-	1×10^6	1×10^7
Nightly data rate (TB)	0.15	-	-	1.4	15
Telescope (m)	0.5	4×0.14	1.8	1.2	6.5
No. of telescopes	2 (6)	5	2	1	1

[a] - in 3 filters; [b] - in 6 filters; [c] - in 2 filters; [d] - in 2 filters; [e] - in 5 filters

Graham et al. 2019

The Rubin Observatory LSST data management

Project status: LSST DR1 foreseen to start in Early 2025



Take-away message

The Rubin Obs. telescope design
(photometric sensitivity, cam. pixel scale and FoV, Obs. seeing,, filter set, image cadence & fast slew)
will definitely bring breakthrough discoveries in the next decade

The LSST survey is actually split into:

1. the WFD survey (90% of the survey time)
2. the DDFs (~5-9% of the survey time)
3. the mini-surveys (~1% of the survey time)

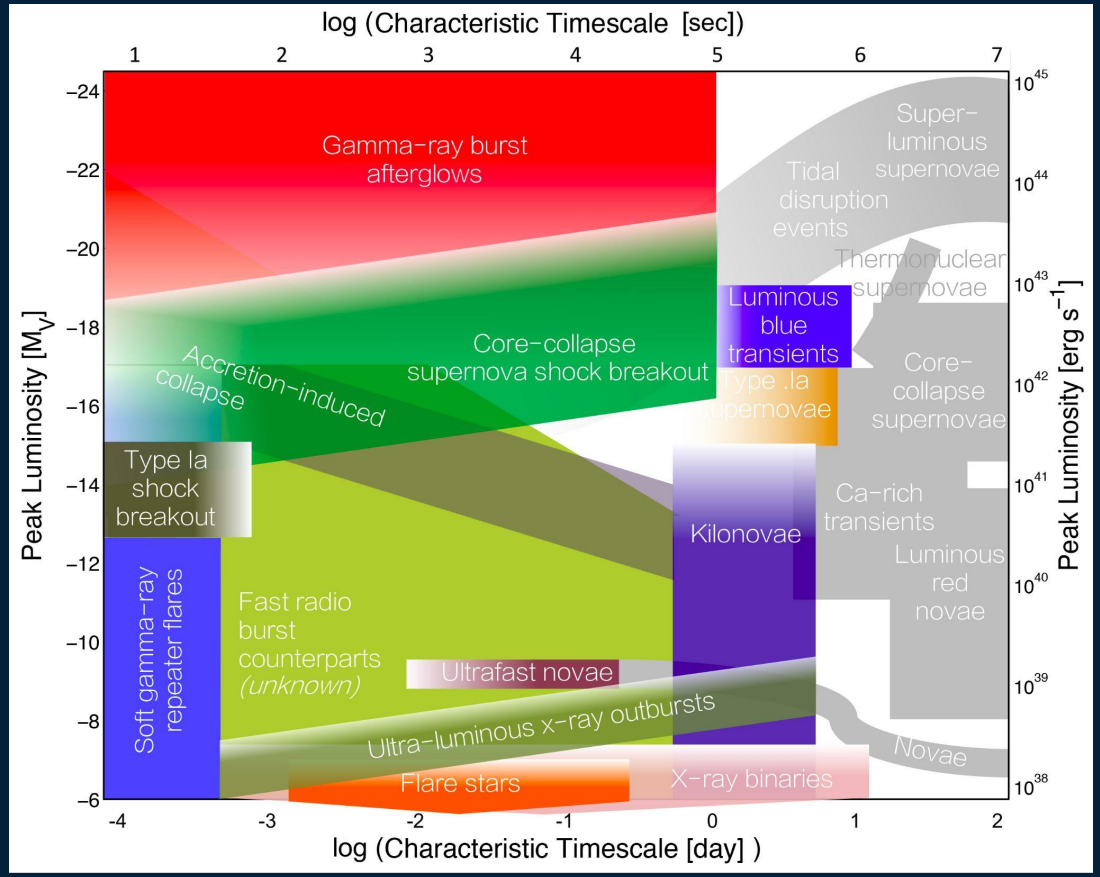
The LSST survey is truly bringing the astronomy in the big data era:
new data, alert infrastructure and follow-up strategy must be adapted

The Rubin Observatory telescope is made for the LSST survey,
this is not a ToO telescope dedicated to the time-domain astronomy
BUT.....let's be optimistic

2

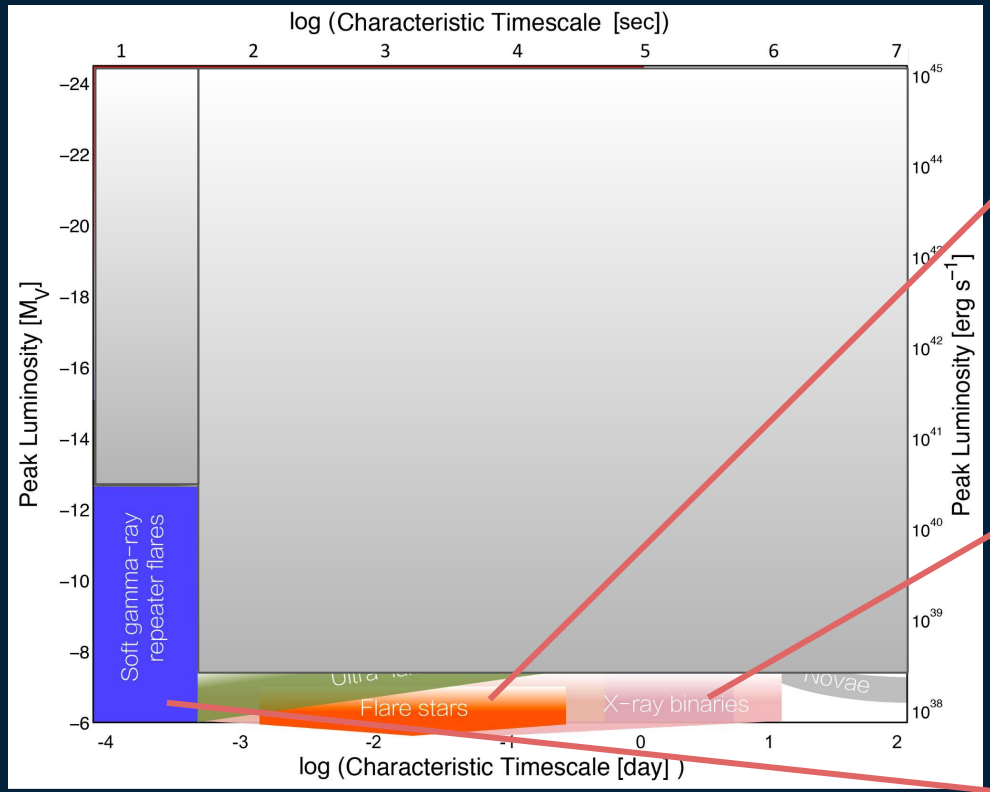
The landscape of the optical transient phenomena

The optical transient sky zoo



credits: J. Cooke

The optical transient sky zoo in the **Milky Way and "around"**



credits: J. Cooke

Very nearby stars (mainly red dwarfs)

- powered by **magnetic turbulence and activity in stellar atmospheres**

See **V. Grinberg and J. Wilms lectures**

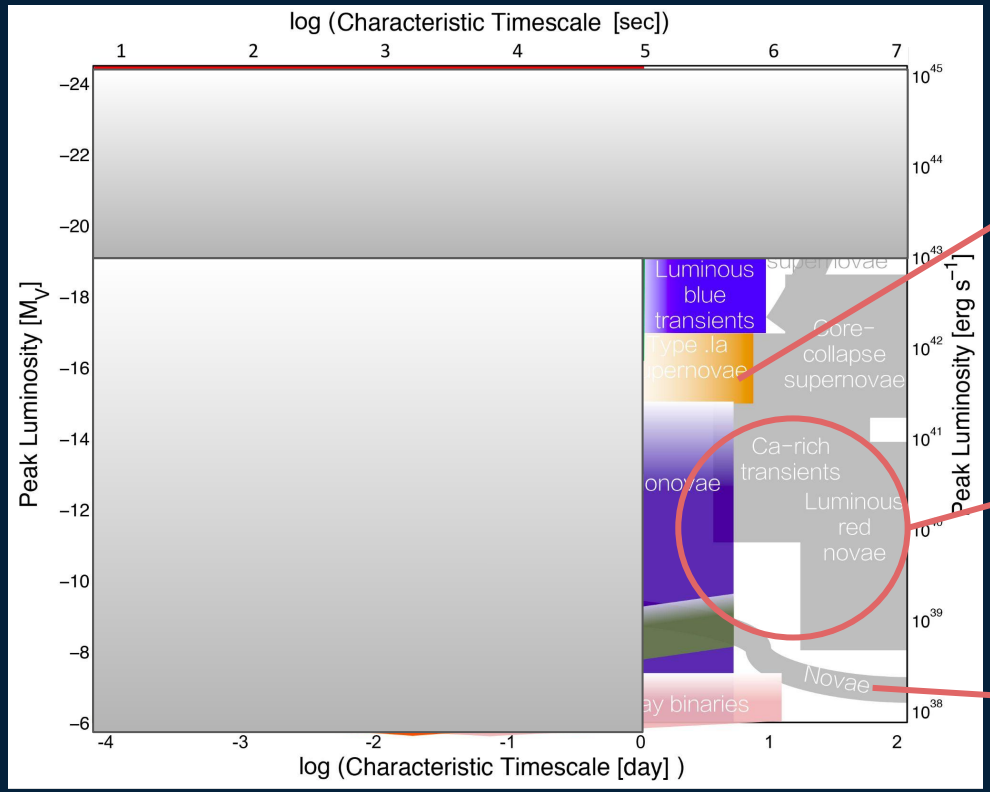
- LMXB
- HXMB
- ULX

  powered by **accretion & ejection processes** (**V. Grinberg & J. Wilms lecture**)

(Giant flares can be seen in very nearby galaxies too, **D. Götz lecture**)

- powered by **strong magnetic field and NS crust instabilities**

The optical transient sky zoo in the **local** Universe (z< 0.1)



credits: J. Cooke

The "Classical" Supernova world

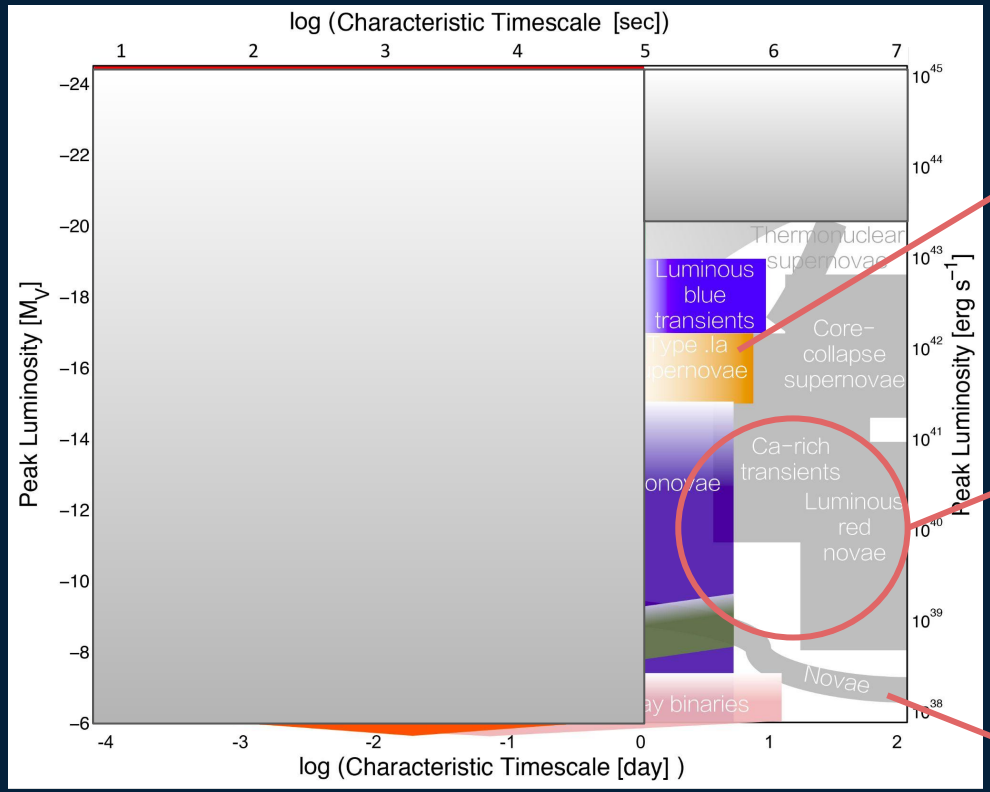
- Ia
- IIn, IIP, IIL
- IIb
- Ib/c

The Gap Transient world

- Faint CA-rich SNe stellar explosion
- Luminous red Novae (new class of Nova)
- GW-Kilonovae
- others...

The nova world

The optical transient sky zoo in the **local** Universe (z< 0.1)



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The "Classical" Supernova world

- heat central source: **Radioactive decay (^{56}Ni, ^{56}Co, ^{56}Fe, ^{44}Ti, ^{27}Al, etc.)**

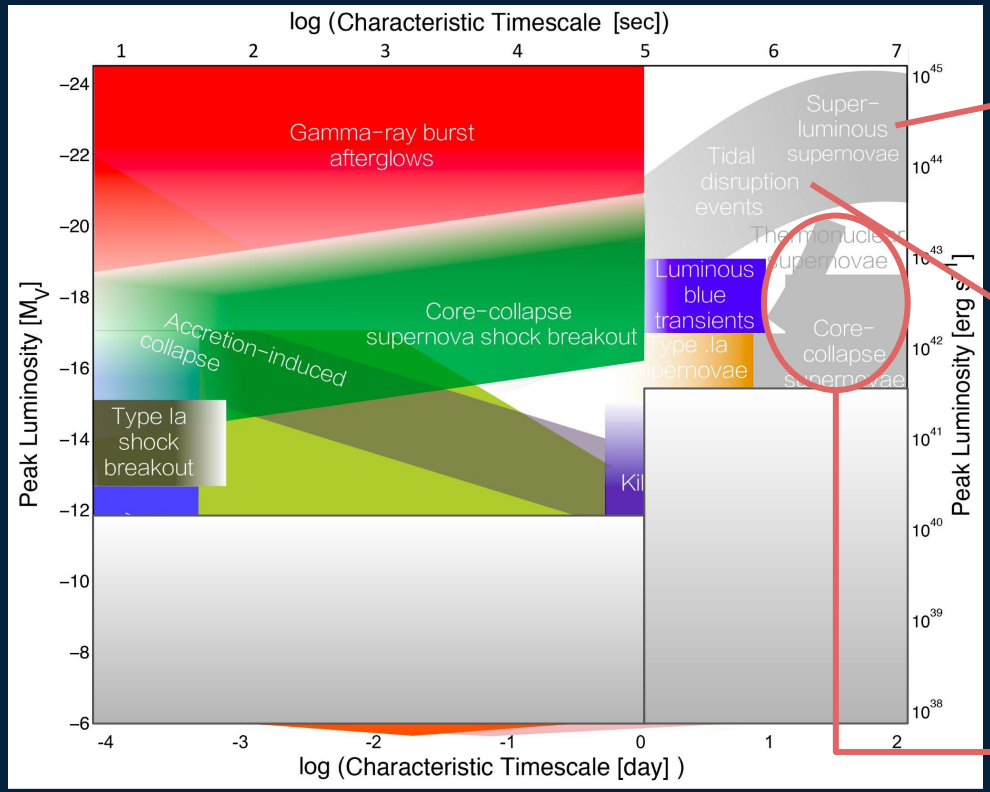
The Gap Transient world

- Faint CA-rich SNe : **?? white dwarf in binary system with a WD or NS, old massive star explosion ?**
- Luminous red Novae: **binary low-L star merger**
- GW-Kilonovae: **r-processed element radioactive decay**

The nova world

- heat central source: **accreting white dwarf (thermonuclear explosion)**

The optical transient sky zoo in the **very distant** Universe (z > 0.1)



credits: J. Cooke

The Super Luminous Supernova world

- heat central source: **central engine driven explosion (fast spinning magnetar) or ejecta/CSM interaction or else ?** (see Nicholl 2021 and reference therein)

TDE

- heat central source: **Fallback accretion disk from stellar debris onto a massive BH, possible relativistic jet/CSM interaction, disk wind-driven explosion** (see Gezari 2021)

The "Classical" Supernova world

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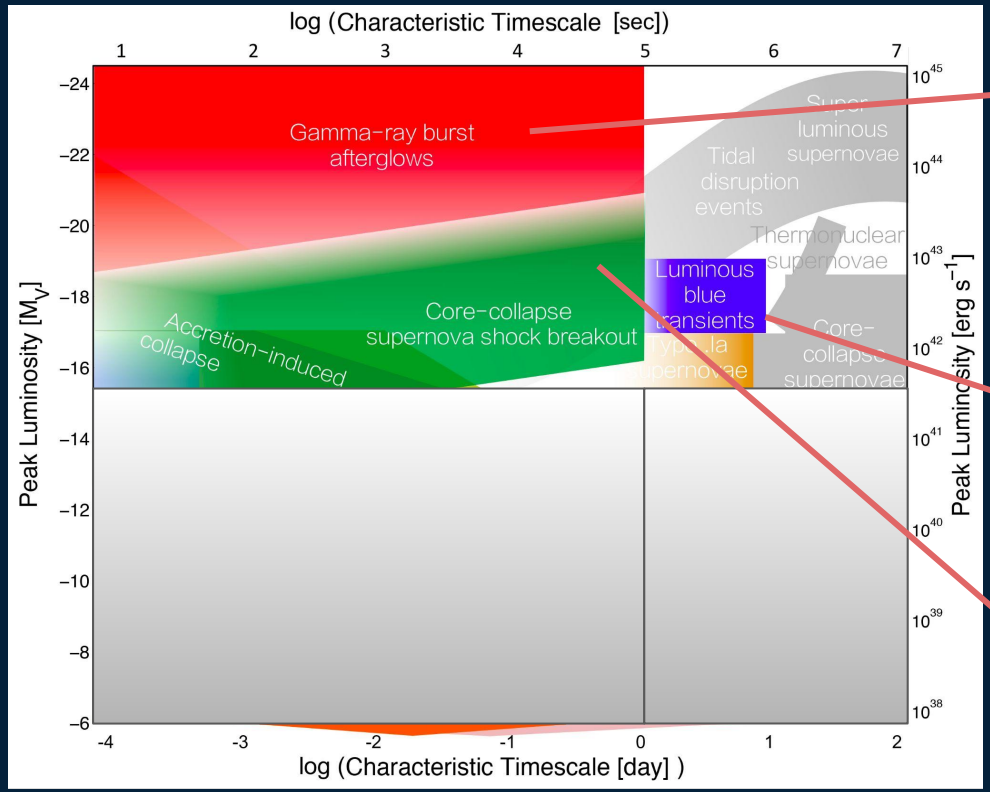
The optical transient sky zoo in the **very distant** Universe (z > 0.1)



credits: J. Cooke

GRBs (see lectures from **F. Daigne, S. Vergani, D. Götz, S. Schanne**)

- heat central source: **relativistic jet/ISM interaction, internal or reverse shocks**

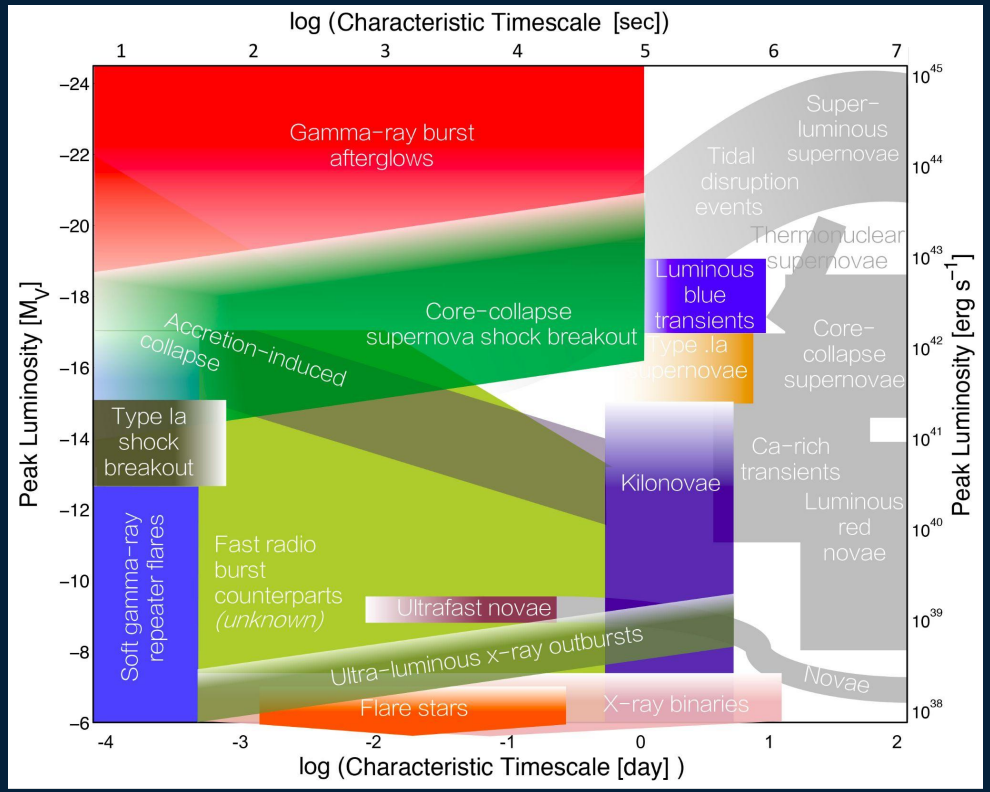
Fast Blue Optical Transients

- heat central source: ????????
  central engine driven explosion, accretion disks onto BH, mildly relativistic outflow/CSM ejecta accretion-induced collapse of white dwarfs new class of ultra-stripped SNe

Shock breakout

- heat central source: **Initial SN shockwave heating up and emerges from the progenitor CSM**

The optical transient sky zoo to be explored by the LSST survey



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KEY MESSAGES

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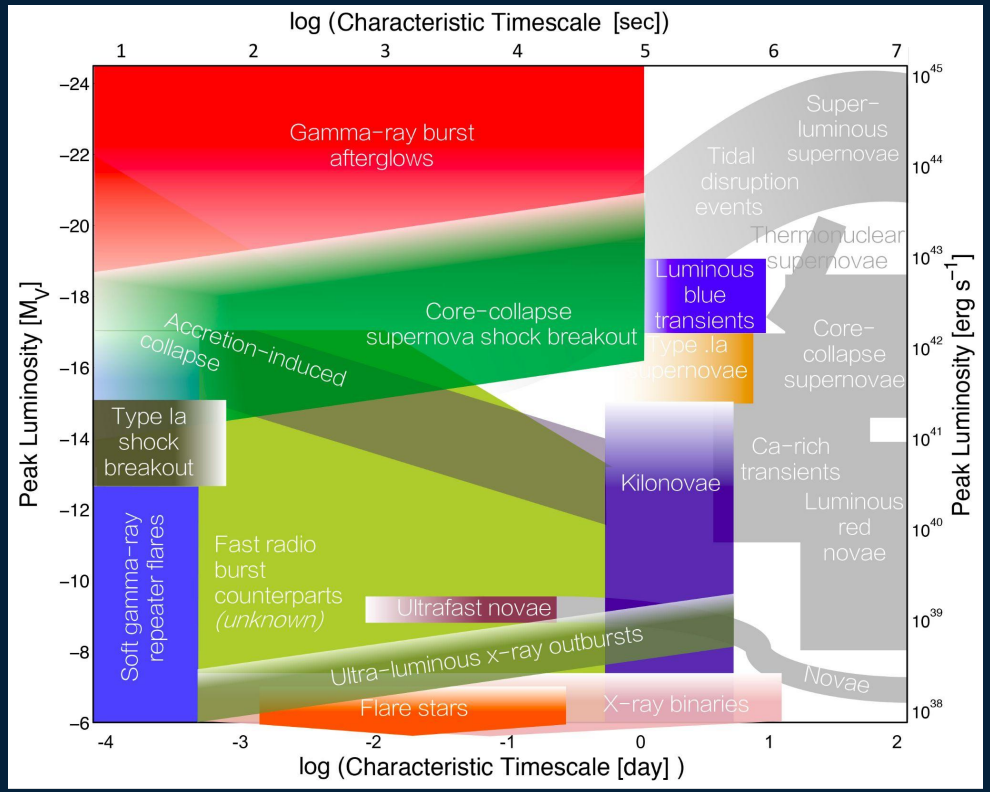

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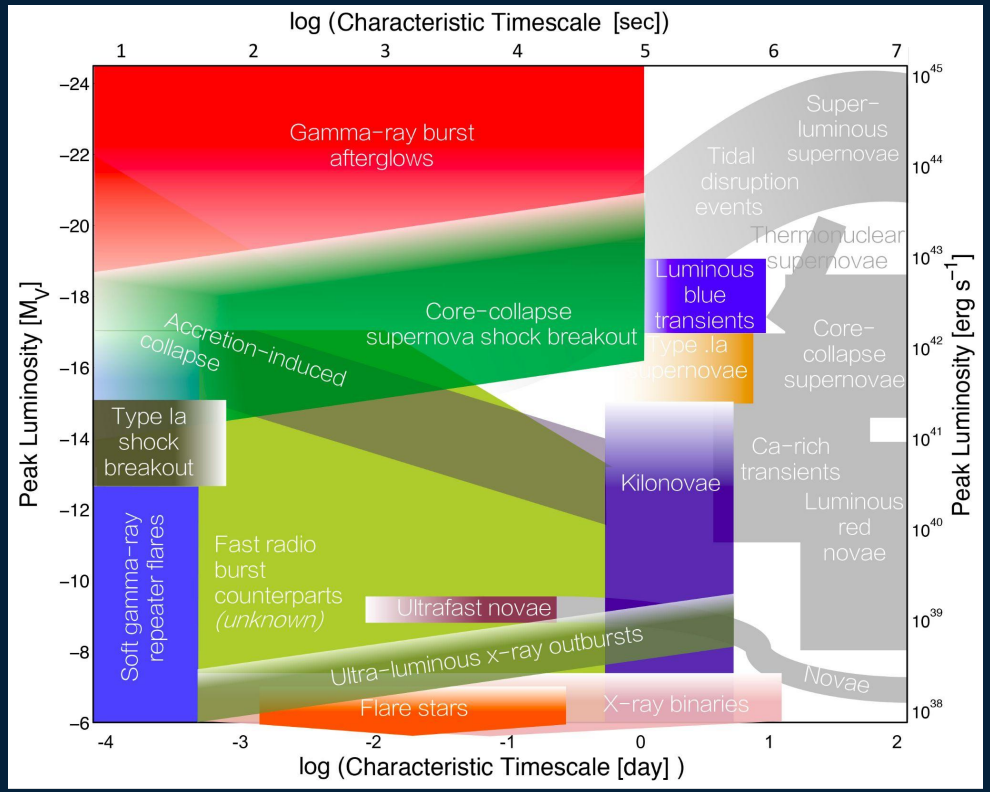

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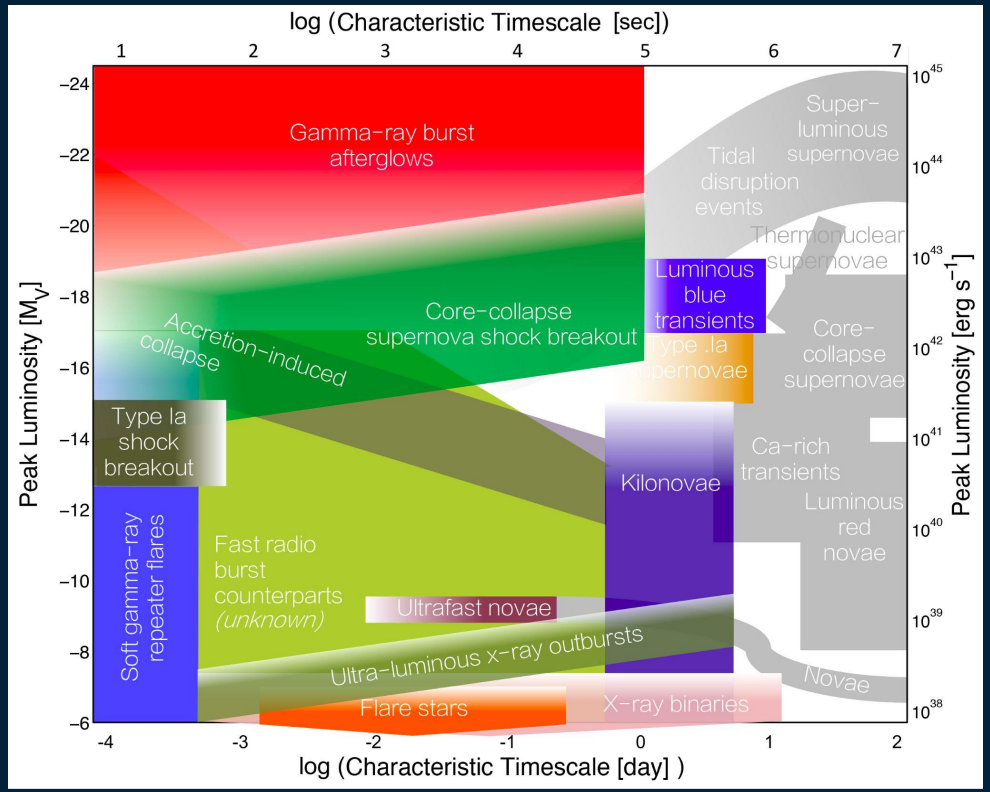

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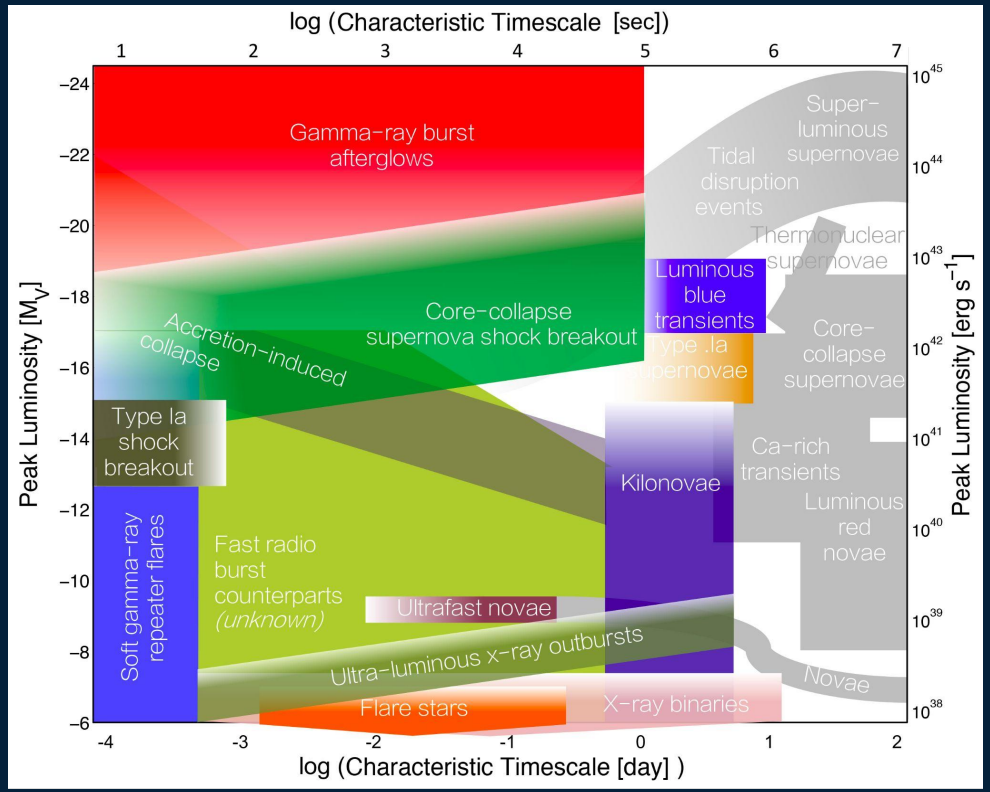
4. **A lot of unknowns in the astrophysical scenarios**

The optical transient sky zoo to be explored by the LSST survey

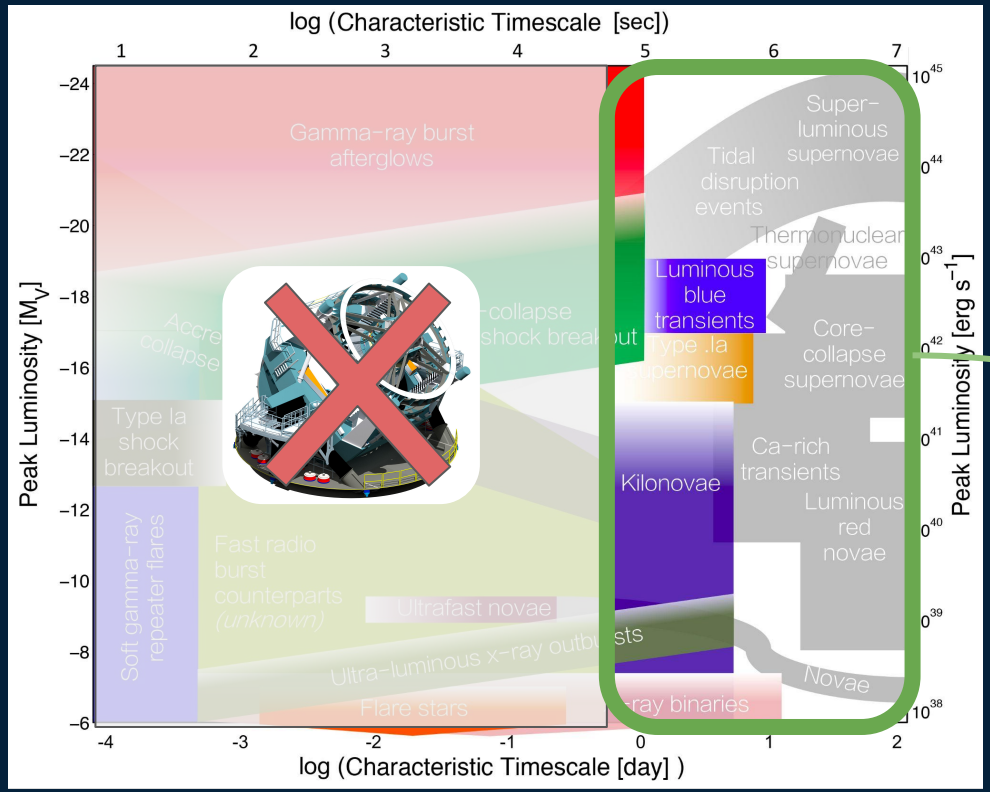


credits: J. Cooke

KEY MESSAGES

1. A lot of different physics at play
2. NOT only at optical wavelength, think multi-λ and multi-messenger
3. All the scientific communities working on the time-domain astronomy are represented in this diagram
4. A lot of unknowns in the astrophysical scenarios
5. A lot of fun coming with the crazy LSST transient detection rate

The optical transient sky zoo to be explored by the LSST survey



credits: J. Cooke

KEY MESSAGES

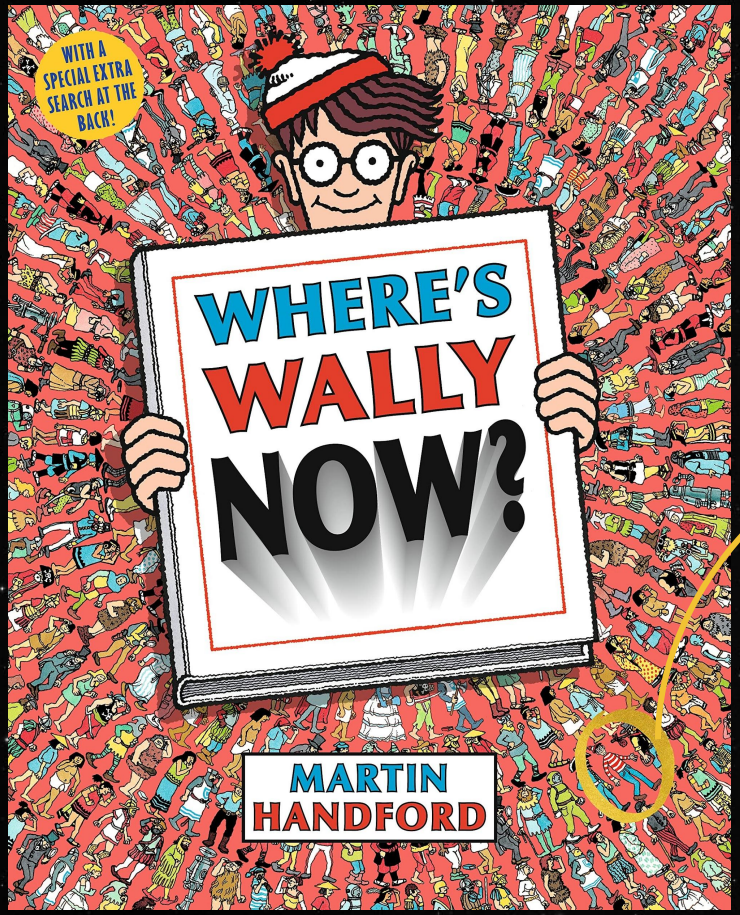
The **LSST image cadence** is more adapted to explore the **long lasting transients** that evolve at **>daily timescales**

3
FINK the broker born in France devoted to the time-domain astronomy

These slides are largely inspired from J. Peloton, E. Ishida, A. Möller previous FINK presentations

Exploring the time-domain sky at optical wavelengths with LSST and FINK

10M alerts / night

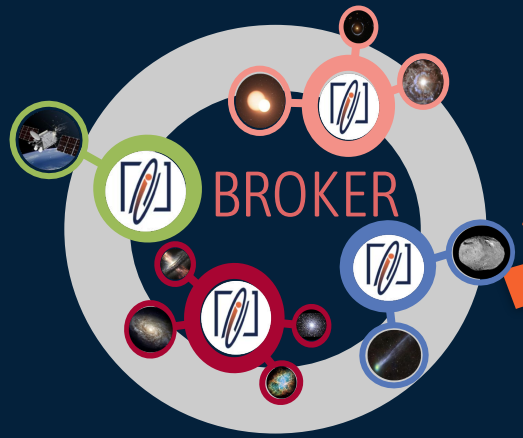


The one you wan
find

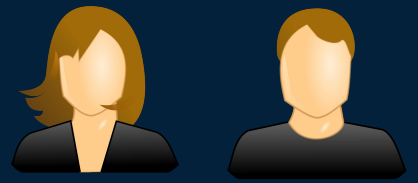
The LSST broker alert system

every ~30 seconds down to mag ~24

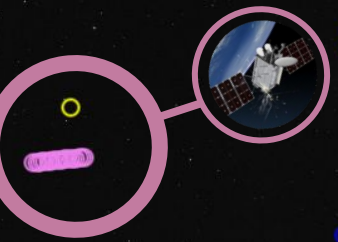
10 million alerts per night...

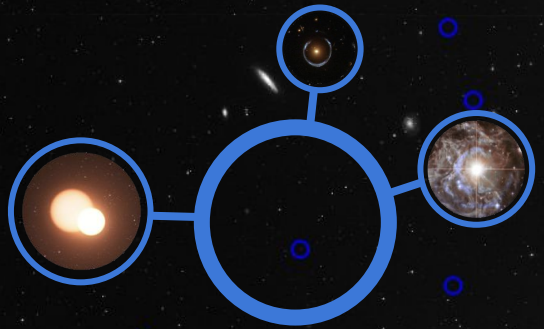


Machine learning
Catalog association
Streams join



Users





The FINK broker in the LSST broker landscape

Transient Universe 2023

FINK: management team

Anais Moller
ARC DECRA Fellow
CAS Swinburne - Australia

Transients, Supernovae
Dark Energy
Machine learning
AI ARC CoE OzGrav

Julien Peloton
Ingénieur de Recherche
CNRS/IJCLab - France

Infrastructure, big data, distributed computing

Emille Ishida
Ingénieure de Recherche
CNRS/LPC-Clermont - France

Adaptive machine learning
Science of Team Science

Recommendations systems

Don't hesitate to reach them for more information about Fink

contact@fink-broker.org

Transient Universe 2023

FINK: a global network

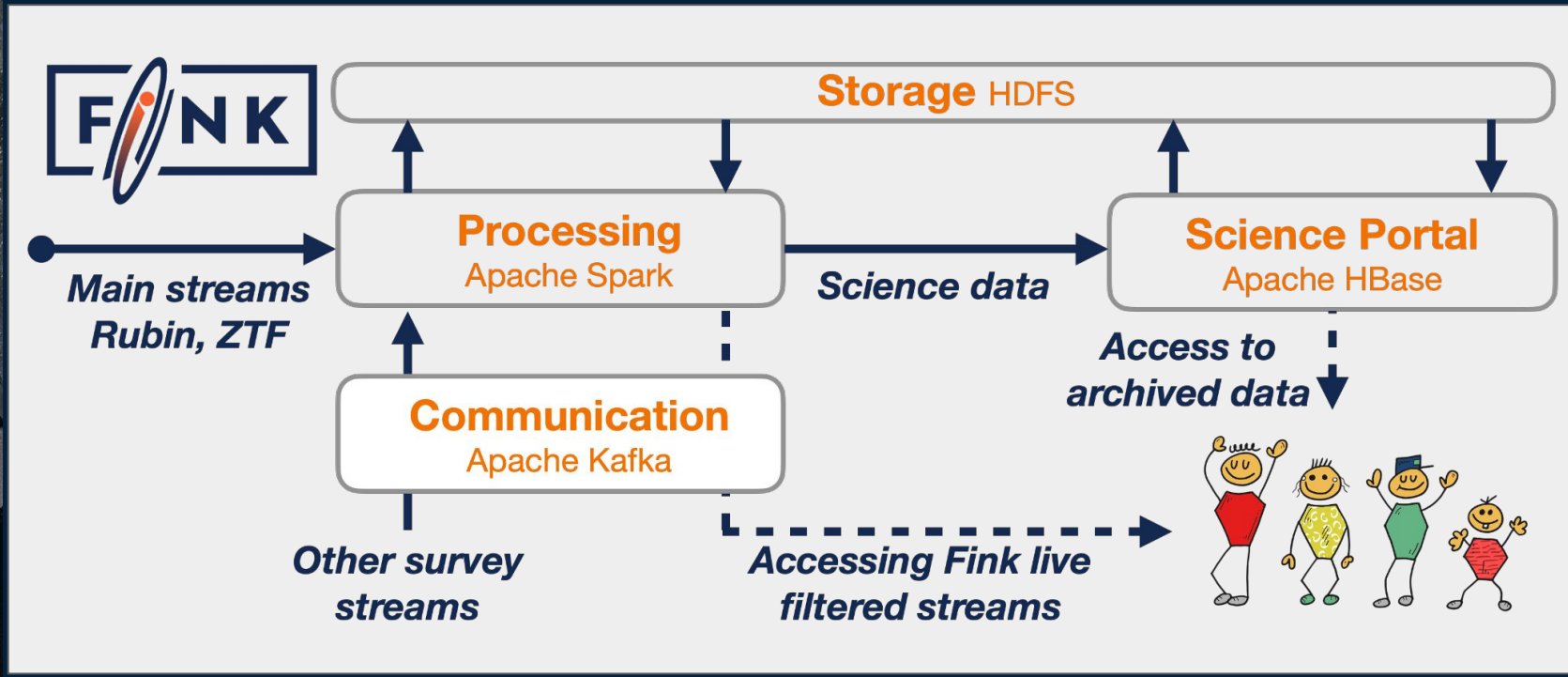
In France: IN2P3 project -- under the Master Project: LSST

- Development platform: VirtualData cloud @ Université Paris-Saclay
  - *About 200 cores, 10TB storage*
- Production: Openstack cloud @ CC-IN2P3
  - *About 500 cores, 1PB storage*
- 3 PhD students working on Fink (IJCLab, LPC Clermont, LPSC Grenoble)
- 1 Postdoc on Fink (LPC Clermont)

Worldwide: 59 members from 13 countries (~30 from France)

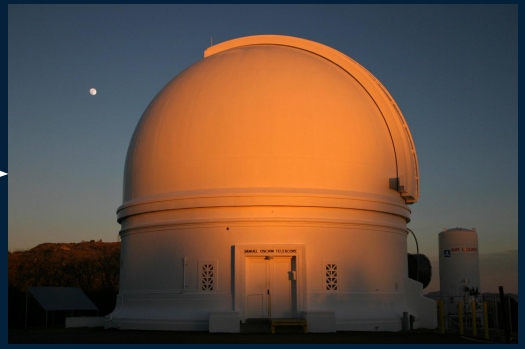
- *Argentina, Australia, Brazil, Czech Republic, Denmark, Italy, France, Portugal, Russia, South Korea, Switzerland, Ukraine, United Kingdom - https://fink-broker.org/members/*
- Coordinator of European Brokers initiative *Fink (France), Lasair (UK), Ampel (Germany)*
- Organizer: LSSTC enabling science 2021 broker workshop *In collaboration with Alerce (Chile) & funded by LSST Enabling Science Grant*
- Fink Hackathon in Switzerland
- OzFink workshop in Australia

How FINK actually works ?

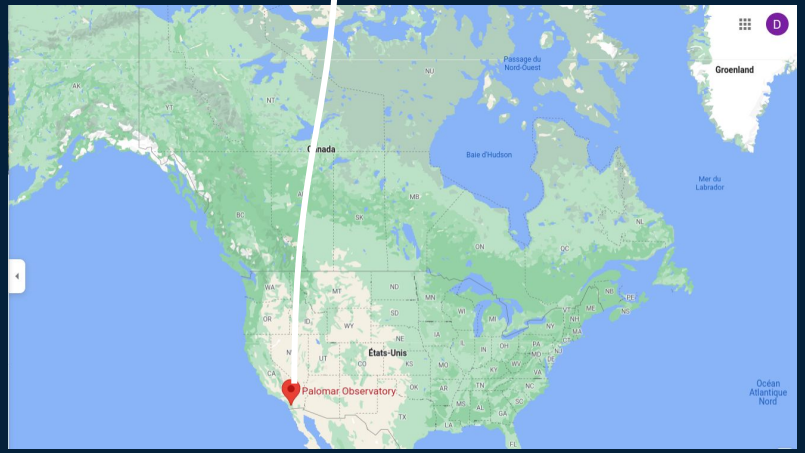


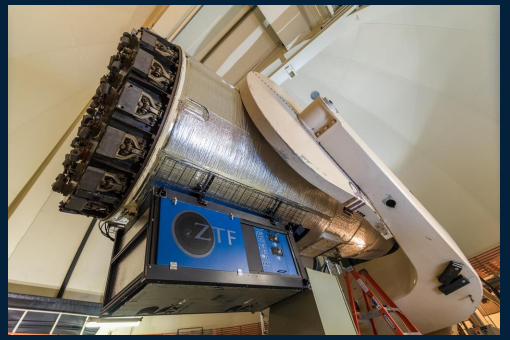
Testing the FINK design prior to the LSST era : The ZTF survey

The Palomar Observatory
credit: Palomar Observatory/Caltech



The P48-inch dome (1.2m telescope)





The Zwicky Transient Facility Camera (ZTF)

The ZTF survey: a small LSST in the Northern sky

March 2018 - Now

g & r daily observation at r > 20.5

the Northern sky is covered in 2-3 nights

Table 1. A comparison between ZTF, LSST, and other next generation surveys in terms of scale.

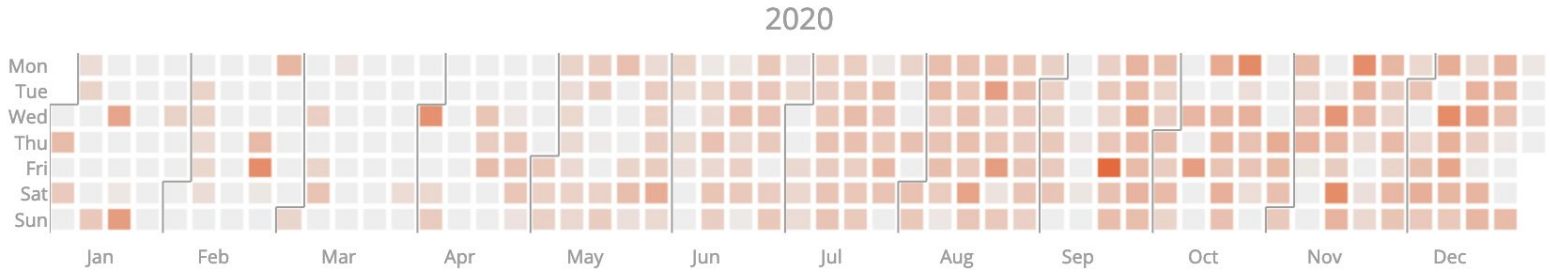
Category	ATLAS	ASAS-SN	Pan-STARRS	ZTF	LSST
Number of total sources	-	1×10^8	1×10^{10}	1×10^9	37×10^9
Number of total detections	1×10^{12}	1×10^{11}	1×10^{11}	1×10^{12}	37×10^{12}
Annual visits per source	1000[c]	180[d]	60[e]	300[a]	100[b]
Number of pixels	1×10^8	4×10^6 (x 4)	1×10^9	6×10^8	3.2×10^9
CCD surface area (cm^2)	90	9	1415	1320	3200
Field of view (deg^2)	30	4.5	7	47	9
Hourly survey rate (deg^2)	3000	960	-	3760	1000
5σ detection limit in r	19.3	17.3	21.5	20.5	24.7
Nightly alert rate	-	-	-	1×10^6	1×10^7
Nightly data rate (TB)	0.15	-	-	1.4	15
Telescope (m)	0.5	4×0.14	1.8	1.2	6.5
No. of telescopes	2 (6)	5	2	1	1

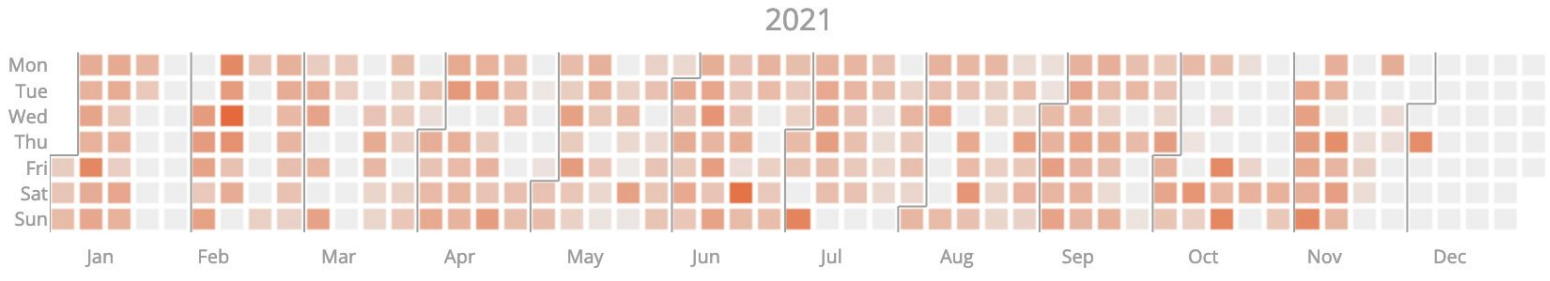
[a] - in 3 filters; [b] - in 6 filters; [c] - in 2 filters; [d] - in 2 filters; [e] - in 5 filters

Monitoring the ZTF data flow with FINK

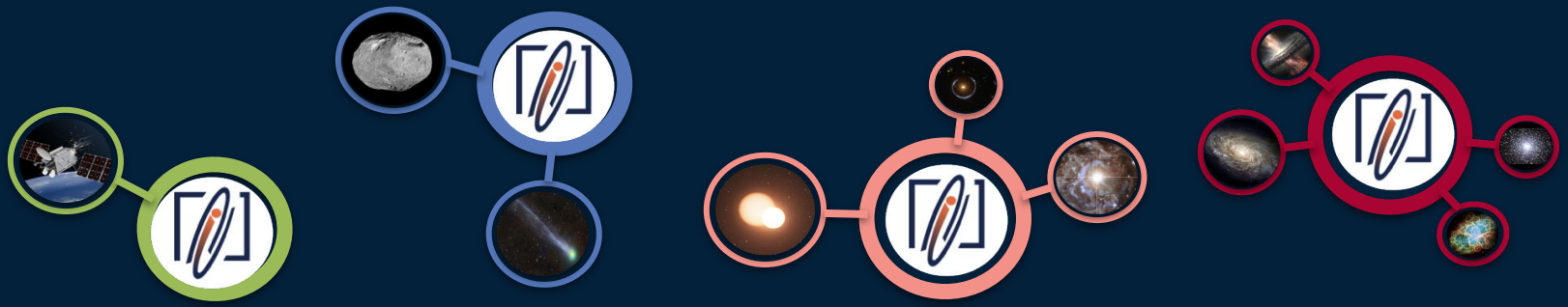
We can already test Fink on real alert data

MoU with Zwicky Transient Facility (ZTF), preparation for LSST.





The FINK philosophy: turning information into knowledge



Alert information solely is not enough – we need experts to extract the science!

More than 30 scientists worldwide contribute to the project. ~100 daily users.

- Our ambition is to study the transient sky as a whole, from solar system objects to galactic and extragalactic science.
- Fink provides personalized services
- **Search for things the Fink community can give meaning to**
- **All science modules/filters are developed by community members**

Transient Universe 2023

Information inside a ZTF alert

1- Alerts* based on Difference Image Analysis and 5σpositive residual detection!

-> serialized into Avro format.

- Several alerts can be associated to the same object

Information inside a ZTF alert

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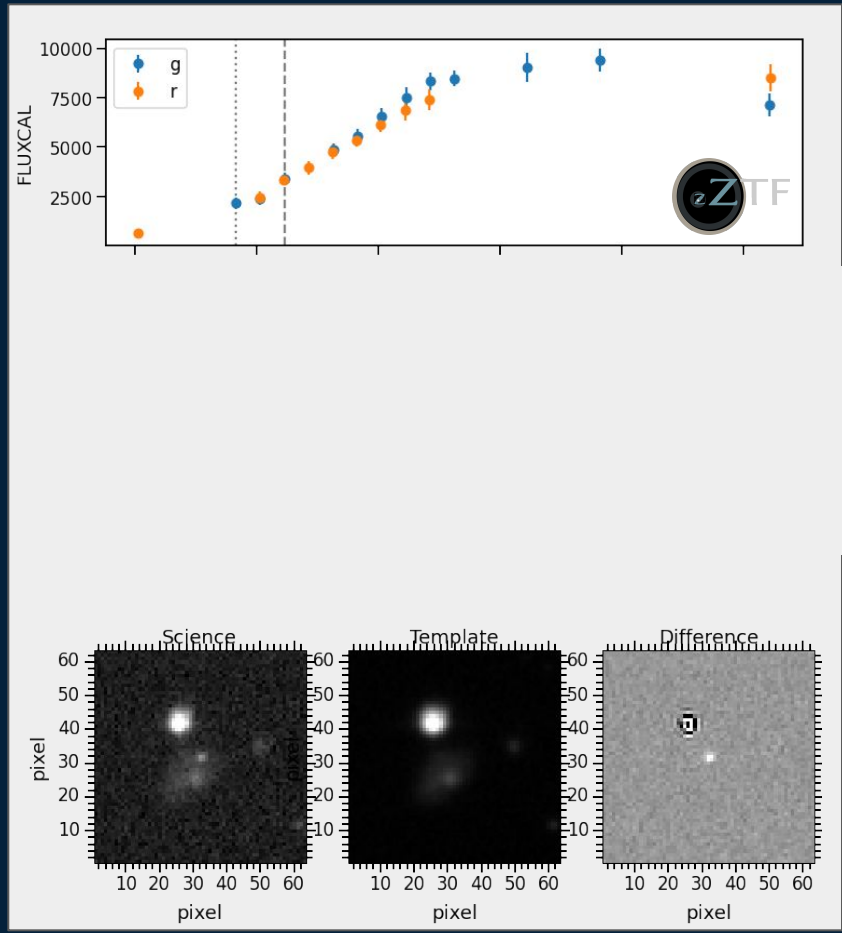
2- Each ZTF alert contains

- 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)



Information inside a ZTF alert

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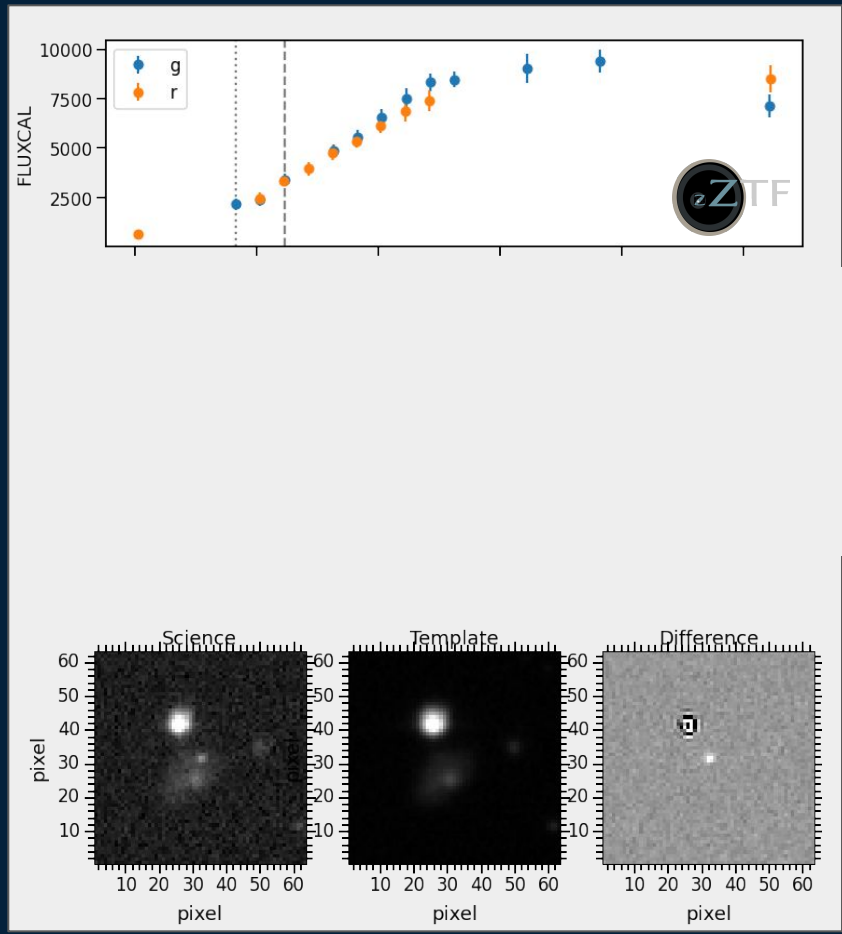
3- LSST alert content will be similar (with even more information!): sample

- The survey cadence will generate image from the same field every ~3 days.
- A non-zero difference at 5 sigma between previouses (aggregated) and the new observation produces an alert. Combination of *ugrizy* filters



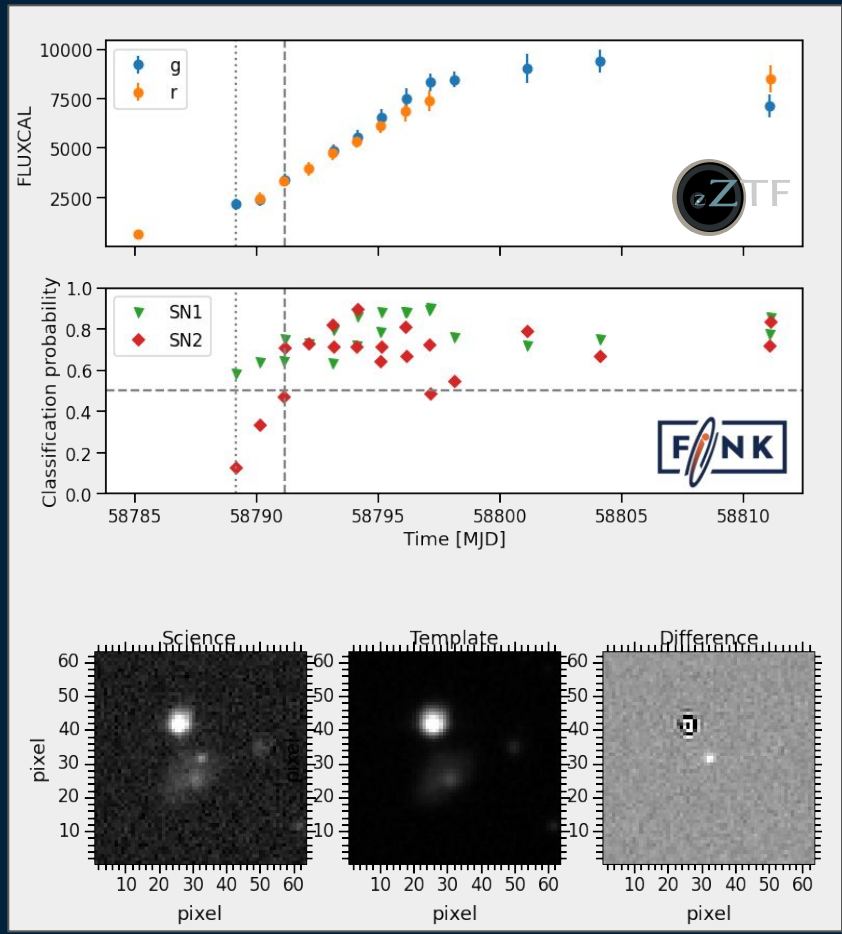
Information inside a ZTF alert + FINK added value

Each ZTF alert contains

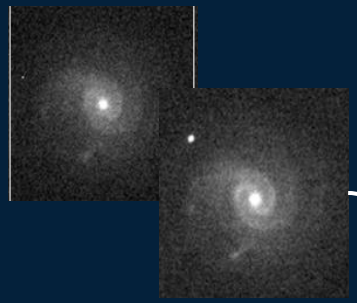
- Information about the new detection (magnitude, position, ...)
- Neighbours information (Gaia, Panstarrs)
- Historical information if the object has been seen previously
- Small images around the detection (60x60 pixels)

+FINK added-values

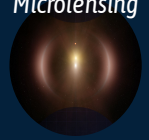
- Scores of the ML classifiers
- Results of the catalog Xmatch (SIMBAD, NED, AGN, Variable stars, Minor Planet, etc.)
- color information if possible
- mag rate over the available archival data
- **more to come with your ideas...**



How the knowledge is extracted from the alert ?



ML classifiers

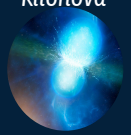
Microlensing 

SNIa 

SLSN 

SNIa 

RNN

Kilonova 

AGN 

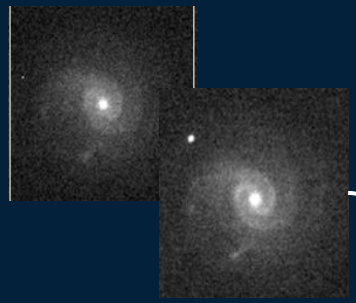
Random Forest

Anomaly

?

Isolation Forest

How the knowledge is extracted from the alert ?



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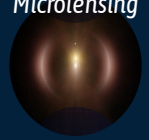
Microlensing 

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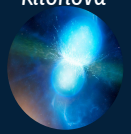
Kilonova 

AGN 

Random Forest

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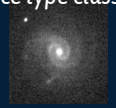
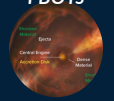
Science algo with no ML (Xmatch, threshold on properties)

Source type classifier 

Asteroid 

GRB 

FBOTs 

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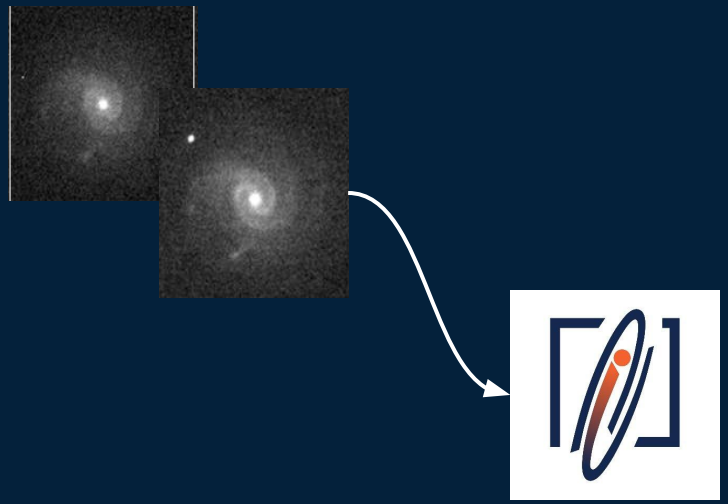

ML classifiers

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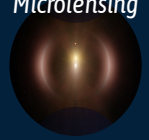

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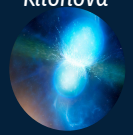


AGN

Random Forest

Anomaly

?

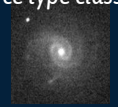
Isolation Forest

These science modules are applied

- on real-time
- in a batch of 10k alerts every 30 sec
- a fast computation is needed to not slow down the alert ingestion process

Science algo with no ML (Xmatch, threshold on properties)

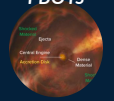
Source type classifier



Asteroid

GRB

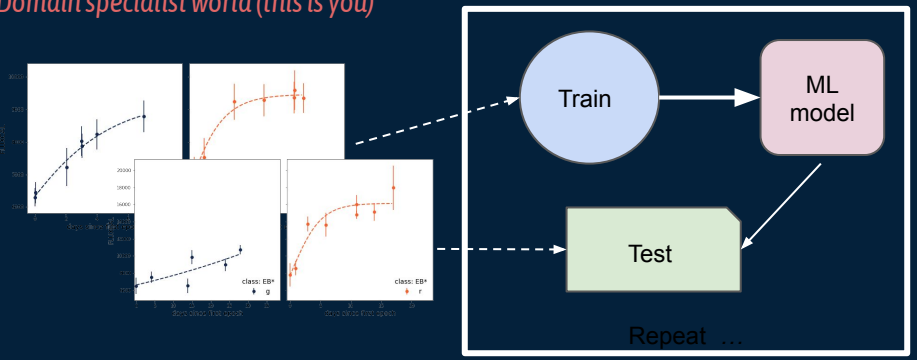
FBOTs



Let's see with a concrete example : Early SNIa classifier

The broker world (what do we do with all these alerts?)

Domain specialist world (this is you)



Build a ML model to be quickly applied to LSST data

Let's see with a concrete example : Early SNIa classifier

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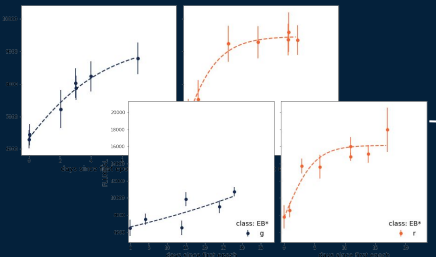
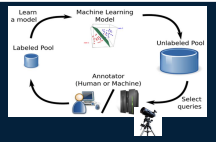




Optimized training with active Learning

Leoni et al., 2022

SuperNNova
open source photometric classification

Moller et al. 2020

Build a ML model to be quickly applied to LSST data

Trained ML models

\+

Auxiliary information, feature extraction, metadata, etc.

Cross-match with catalogs

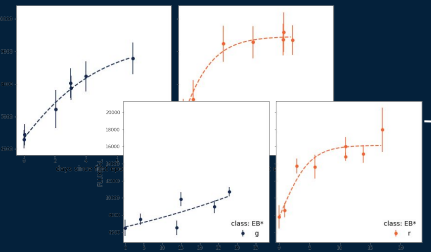
Send your ML model and catalogs to be used in FINK

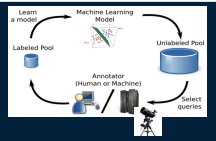
Let's see with a concrete example : Early SNIa classifier

The broker world (what do we do with all these alerts?)

python scripts integrated into the FINK software science module architecture

Domain specialist world (this is you)





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The broker world (what do we do with all these alerts?)

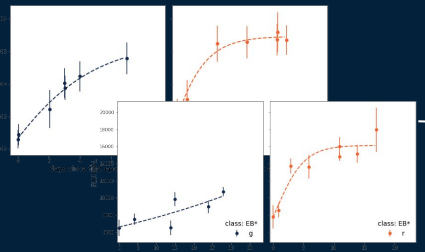
Early-Supernova stream

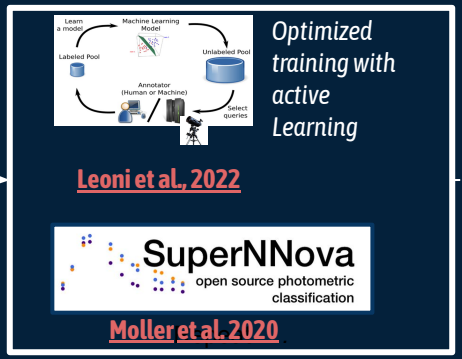
Kilonova

Variable Stars

python scripts integrated into the FINK software science module architecture

Domain specialist world (this is you)





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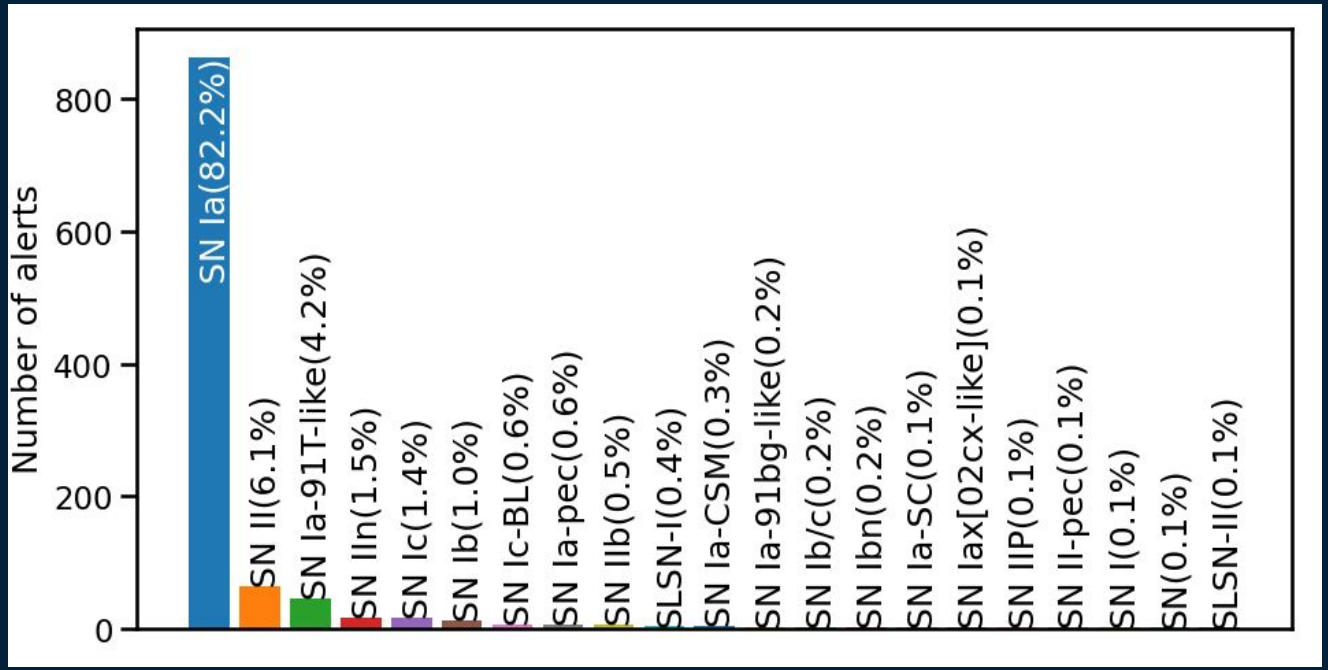
Let's see with a concrete example : Early SNIa classifier

Fink Early SN Ia candidates reported to TNS from Nov./2020 - 2023:

- 1847 unique objects were sent by Fink to TNS
- 1057 received spectroscopic follow-up
- 918 were spectroscopically classified as SN Ia



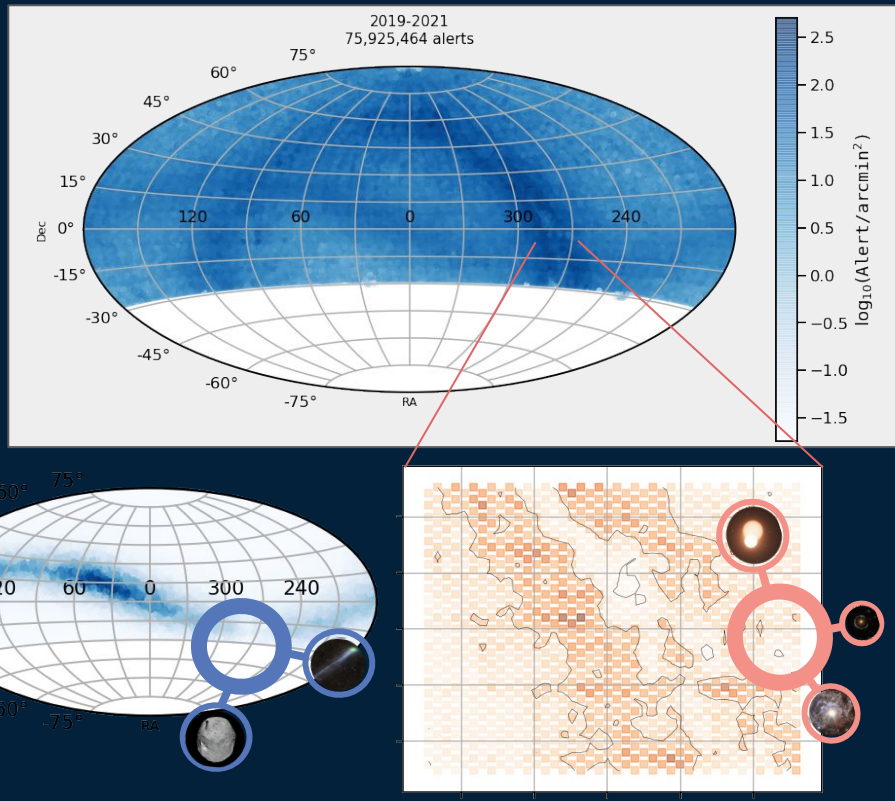
Plot by Julien Peloton (CNRS/IJCLab)

ZTF transient sources classification

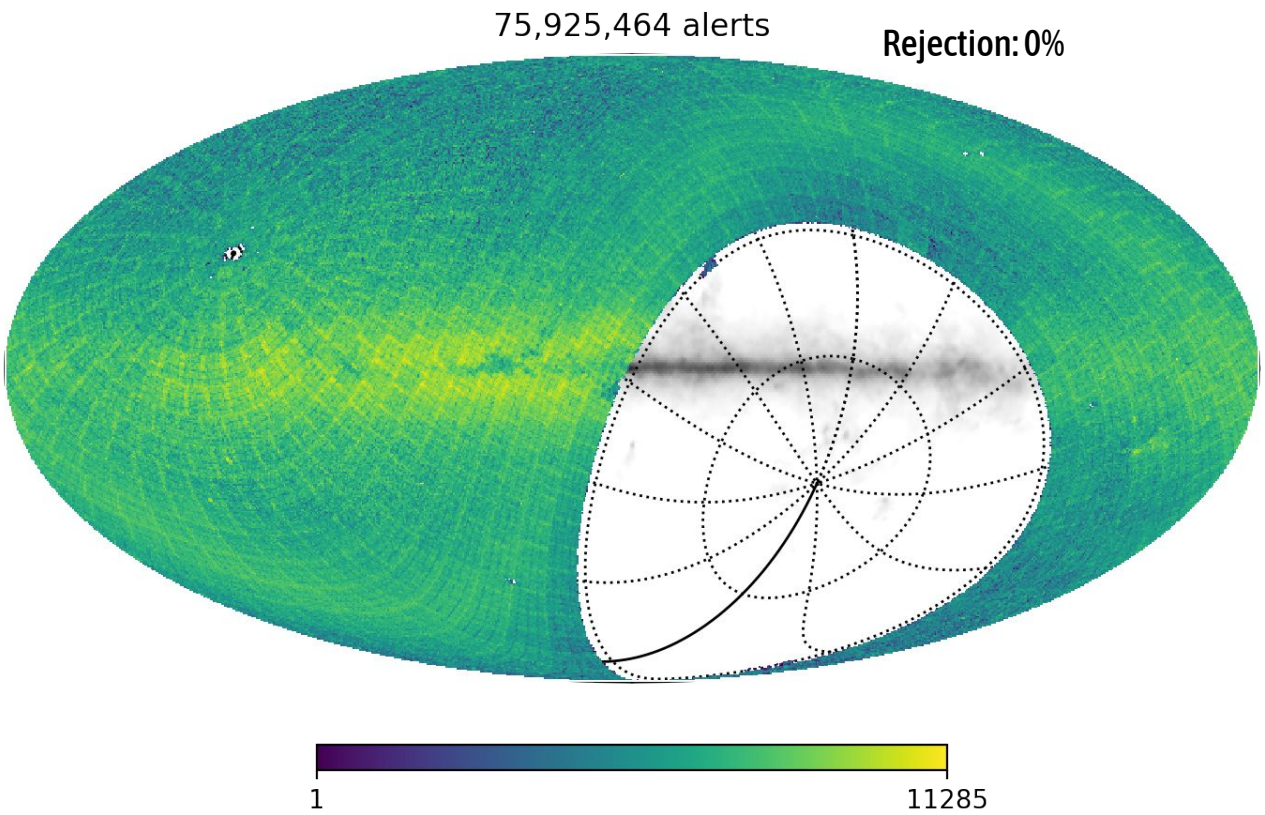
163 million alerts received, 110 million processed (https://fink-portal.org/stats)

Typical nightly rates (200,000 alerts,~20GB/night -- 2/3 survives quality cuts and out of this -> ½ get a label):

- ~75,000 known variable stars
- ~25,000 known SSO
- ~100 new SSO candidates
- ~100 new supernovae & core-collapse candidates
- ~10 (un)identified satellite glints
- ~5 new SN Ia candidates
- ~1 fast transient candidate (KN, GRB, CV ...)
- ~1 new microlensing candidate

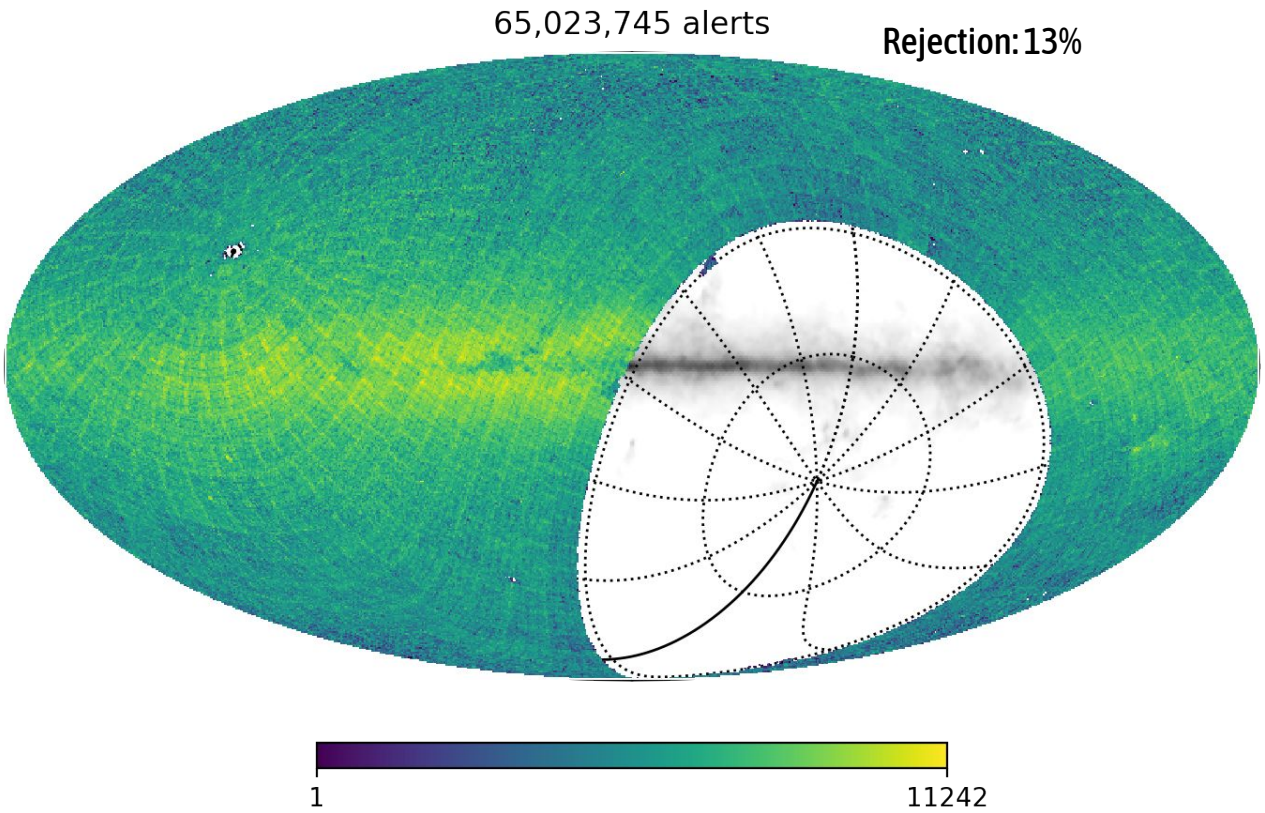


The ZTF transient sky



All transients for 2 years of ZTF (about 10 days for LSST...)

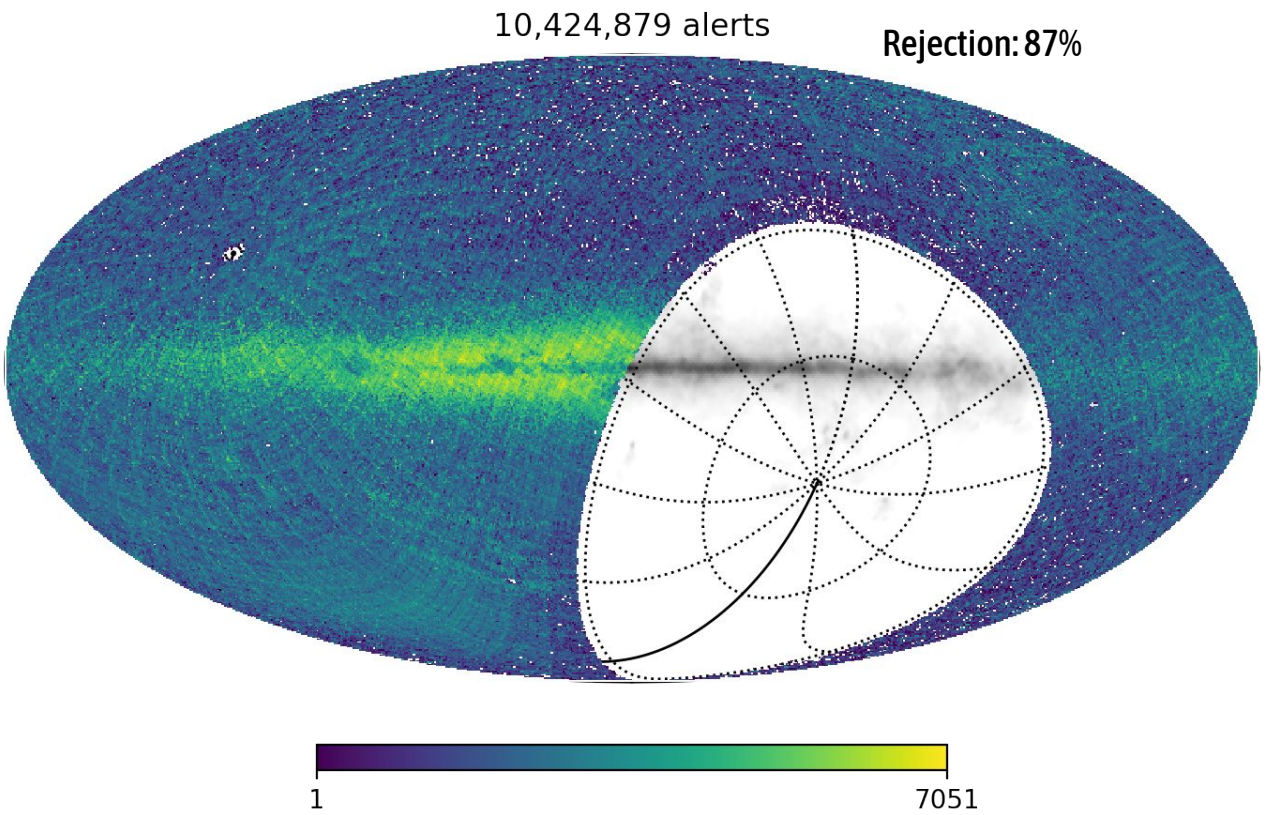
The ZTF changing sky sources



All transients for 2 years of ZTF (about 10 days for LSST...), then removing

- Known moving objects removed

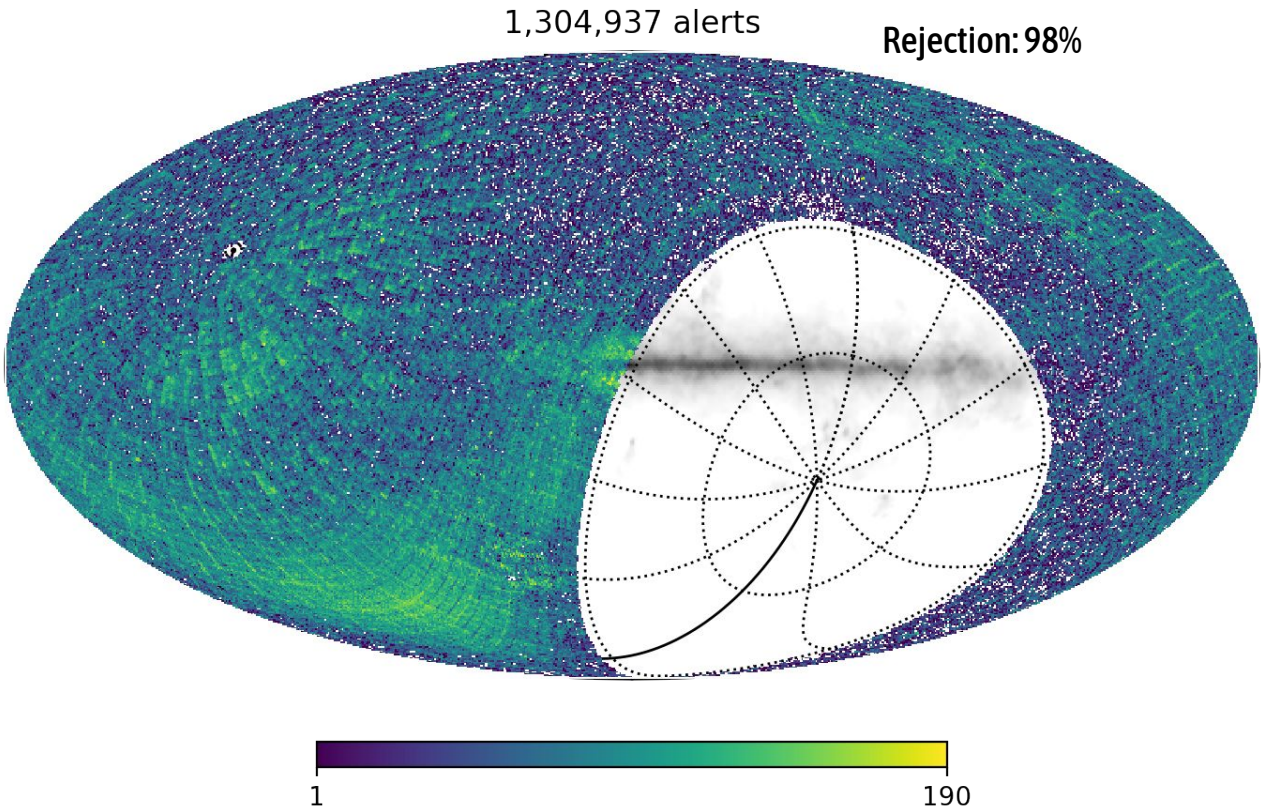
The ZTF changing sky sources



All transients for 2 years of ZTF (about 10 days for LSST...), then removing

- Known moving objects removed
- Known variable galactic sources removed

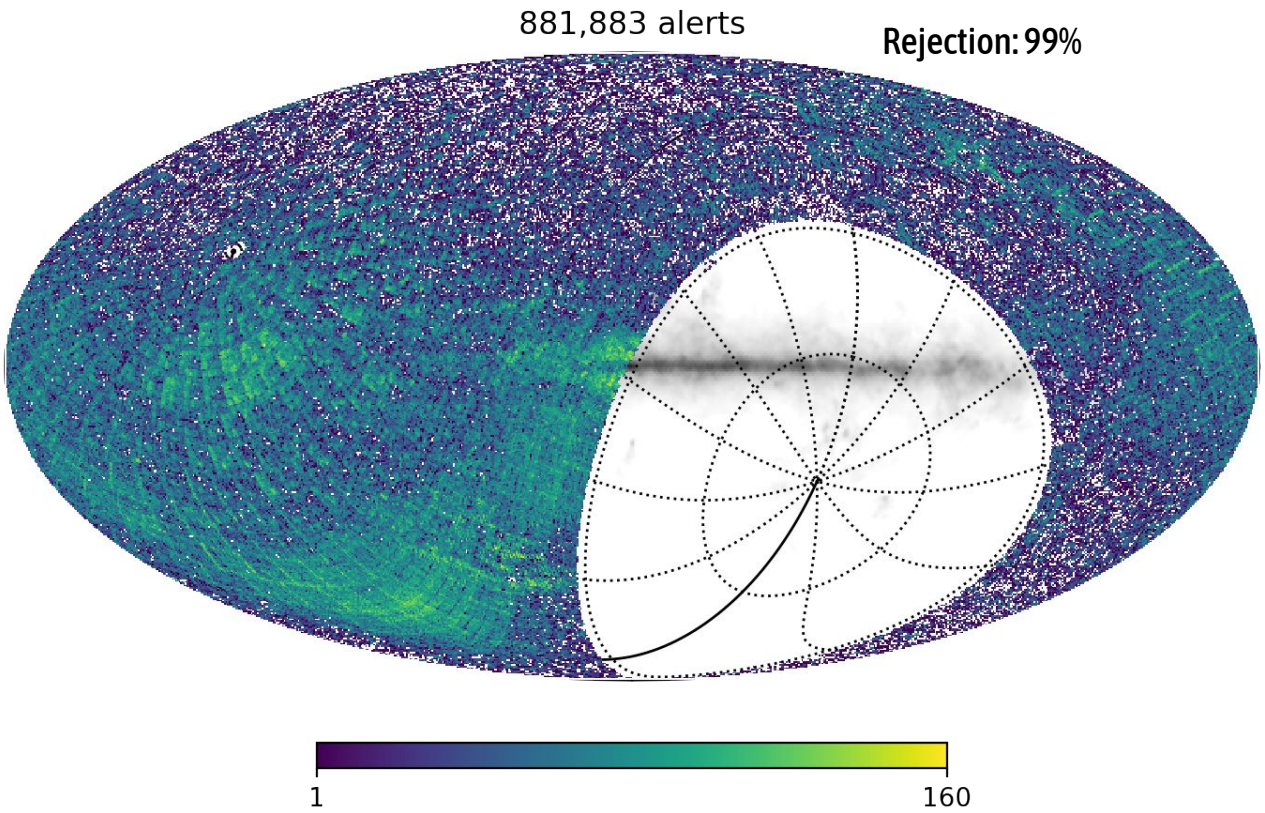
The ZTF changing sky sources



All transients for 2 years of ZTF (about 10 days for LSST...), then removing

- Known moving objects removed
- Known variable galactic sources removed
- Long trends removed

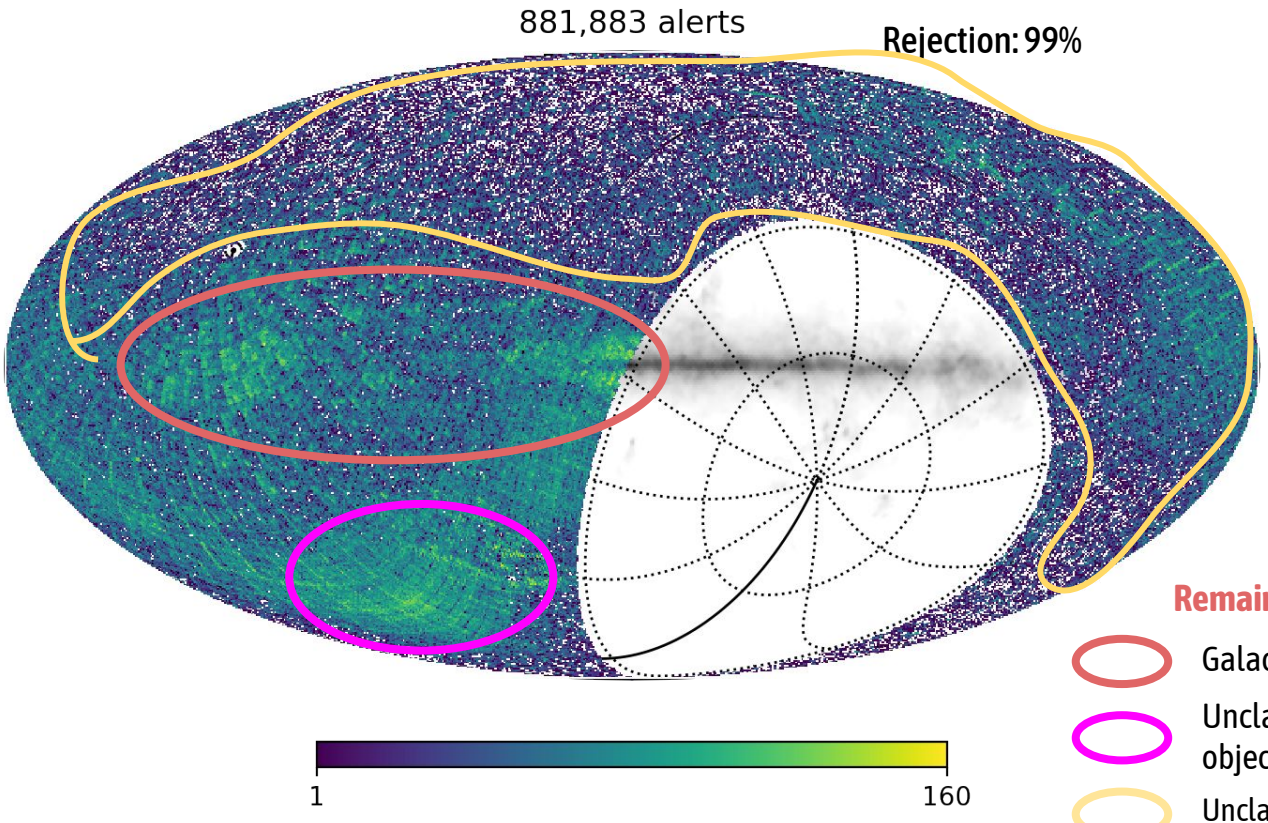
The ZTF changing sky sources



All transients for 2 years of ZTF (about 10 days for LSST...), then removing

- Known moving objects removed
- Known variable galactic sources removed
- Long trends removed
- Candidate sources removed

The ZTF changing sky sources



All transients for 2 years of ZTF (about 10 days for LSST...), then removing

- Known moving objects removed
- Known variable galactic sources removed
- Long trends removed
- Transient candidates photometrically classified by FINK removed

Remaining transient candidates

- Galactic sources? Flares, CV, ...
- Unclassified Solar System objects ?
- Unclassified extragalactic transients

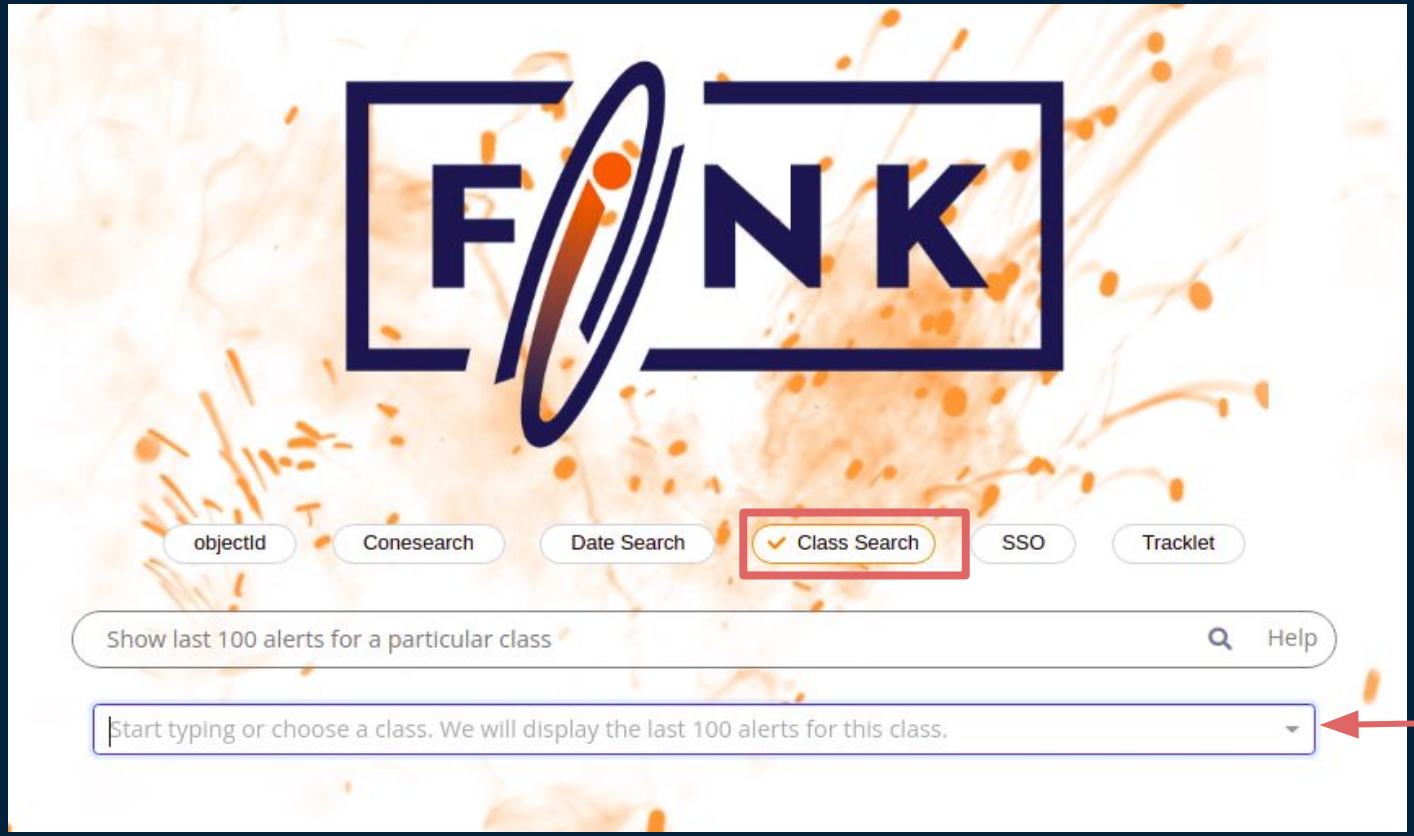
Once a module is integrated… you can also make offline analysis!

https://fink-portal.org/

Tutorials: https://github.com/astrolabsoftware/fink-tutorials

Thanks to Nicolas Dagoneau you all have a github account!

Once a module is integrated... you can also make offline analysis!



Once a module is integrated... you can also make offline analysis!

objectId | Conesearch | Date Search | ✓ Class Search | SSO | Tracklet

Show last 100 alerts for a particular class | Help

Early Supernova Ia candidates

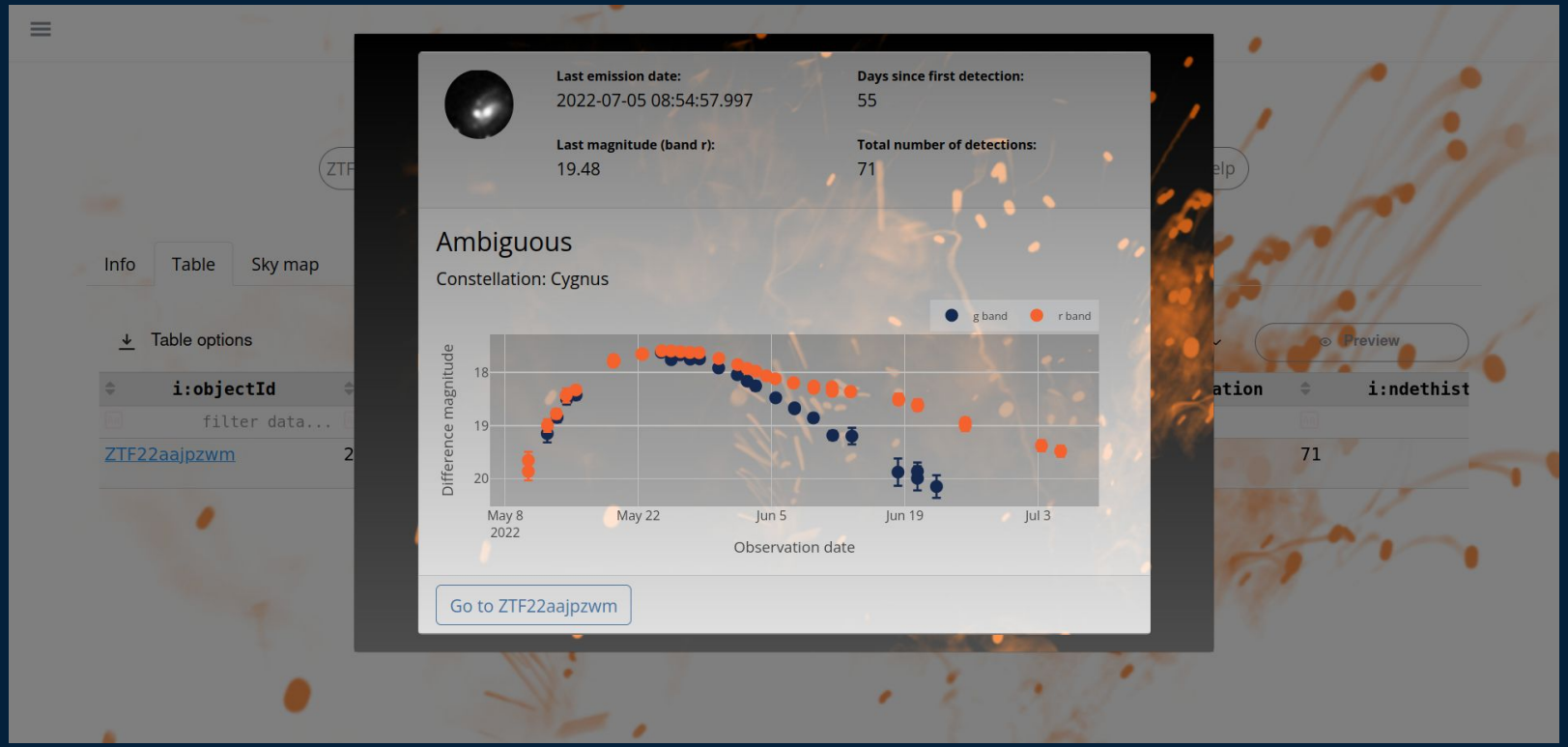
Info | Table | Sky map

Add more fields to the table | Preview

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

Transient Universe 2023

Once a module is integrated... Visualize the alert data



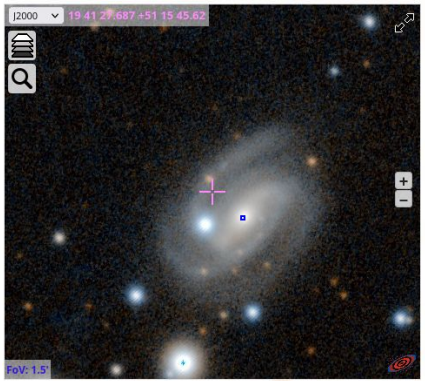
Once a module is integrated... Visualize the classifier results

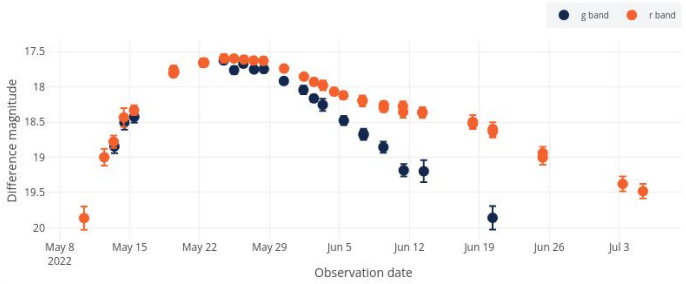
Summary | Supernovae | Variable stars | Microlensing | Solar System | Tracklets | GRB

ZTF22aajpzwm

AMBIGUOUS · EARLY SN IA CANDIDATE · SN CANDIDATE · UNKNOWN

Discovery date: 2022-05-10 10:24:23.999
Last detection: 2022-07-05 08:54:57.997
Number of detections: 59
Number of low quality alerts: 5
Number of upper limits: 59





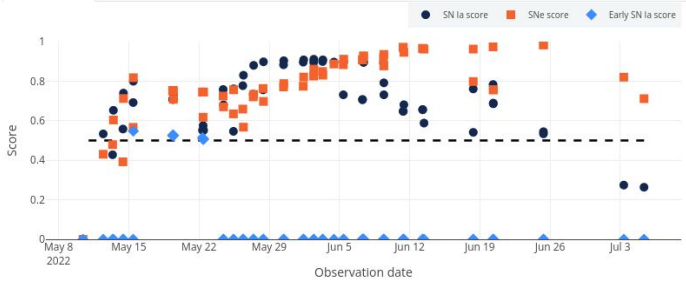
Click on a point in the lightcurve to update parameters below.

AMBIGUOUS

Date: 2022-07-05 08:54:57.997

```
# SuperNNova classifiers
SN Ia score: 0.26
SNe score: 0.71
# Early SN Ia classifier
RF score: 0.00

# Variability (DC magnitude)
Rate g-r (last): nan mag/day
Rate g (last): 0.07 mag/day
Rate r (last): 0.02 mag/day

# Extra properties
Classtar: 0.98
DL Real bogus: 0.99
```

SN scores | T2 scores | Color and mag evolution | Color and mag rate | Info



Once a module is integrated... Analyze a bunch of alerts

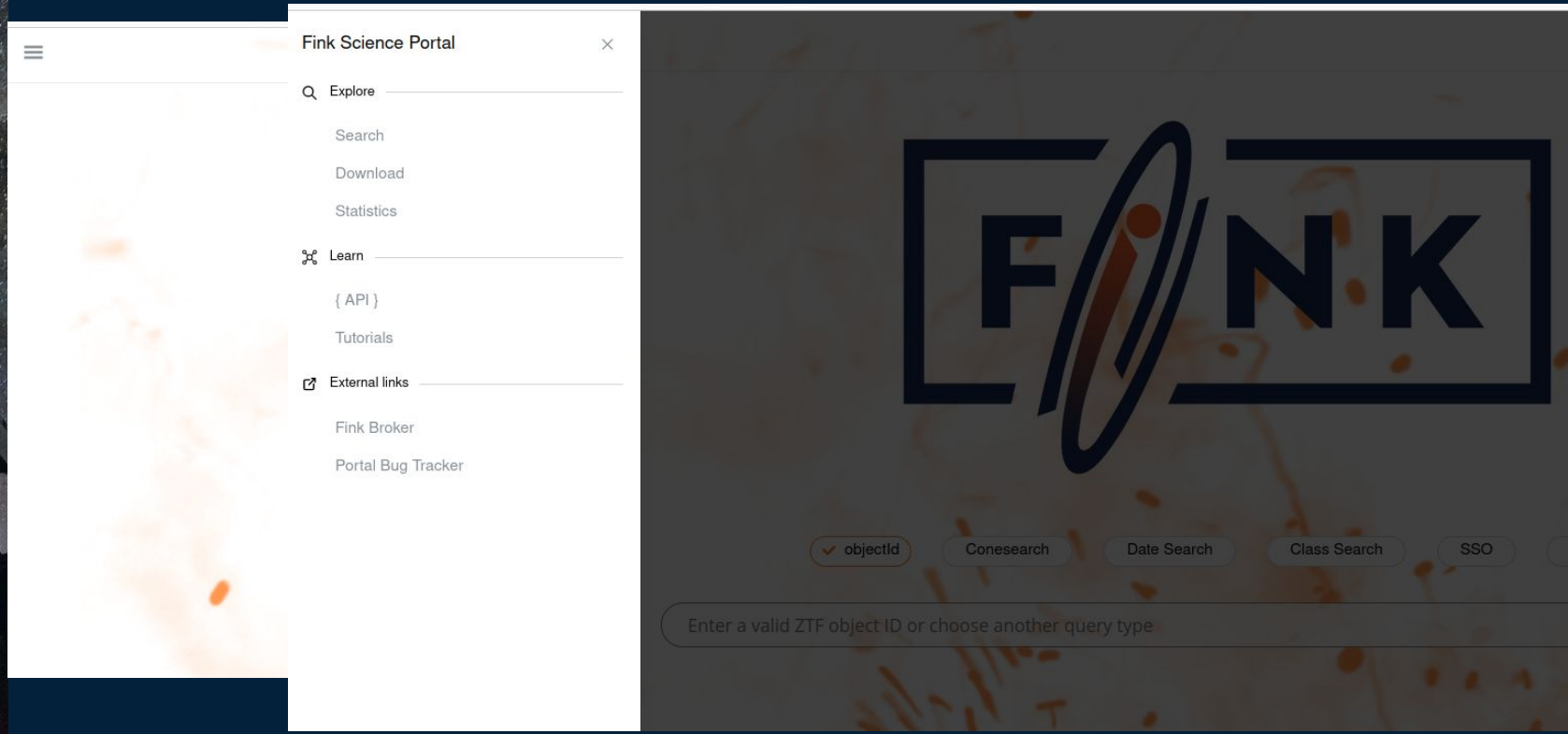
API: https://fink-portal.org/api

Extragalactic tutorial:
https://github.com/astrolabsoftware/fink-notebook-template/blob/main/extragalactic/extragalactic.ipynb

Implement your own filter in Fink:
https://fink-broker.readthedocs.io/en/latest/science/filters

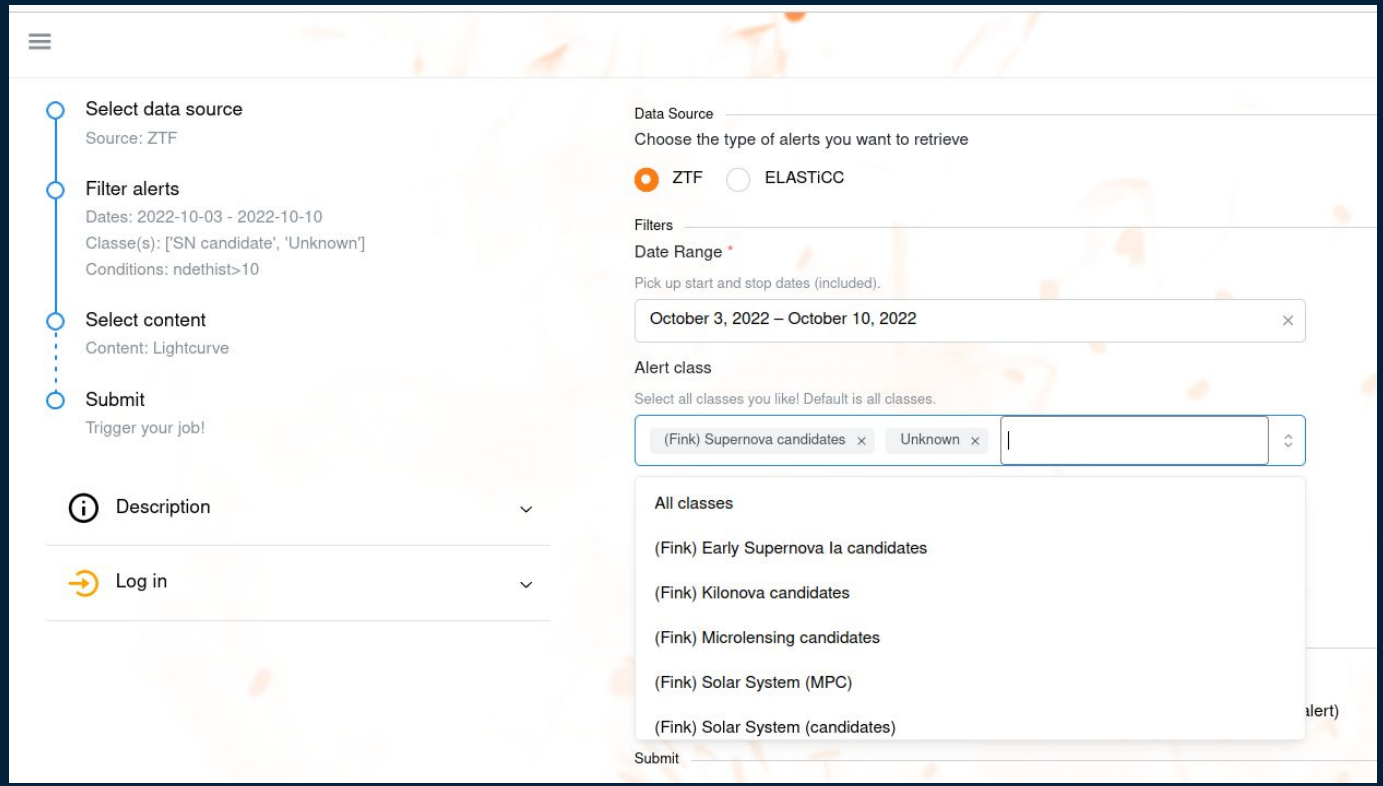
```
# Get latests Early SN candidates (200 max)
r = requests.post(
  '{}/api/v1/latests'.format(APIURL),
  json={
    'class': 'Early SN Ia candidate',
    'n': '200',
    'startdate': '2021-04-01', # use a start date
    'stopdate': '2021-04-13', # use a stop date
  }
)

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

Once a module is integrated... Download a large amount of alerts



Documentation: https://fink-broker.readthedocs.io/en/latest/services/data_transfer

Once a module is integrated... Download a large amount of alerts



Documentation: https://fink-broker.readthedocs.io/en/latest/services/data_transfer

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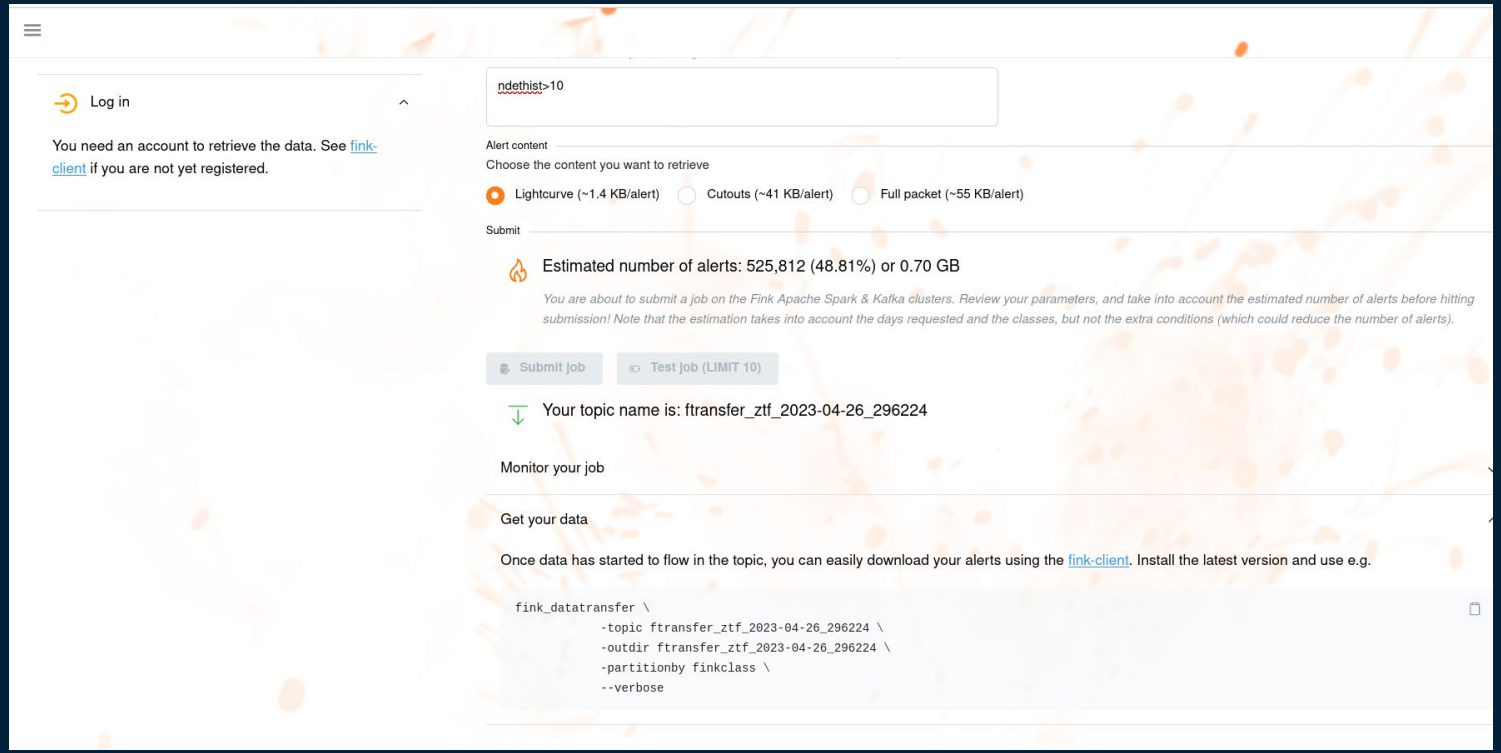

Documentation: https://fink-broker.readthedocs.io/en/latest/services/data_transfer

FINK at your service! Have a look!

Documentation at: https://fink-broker.readthedocs.io/en/latest/services/summary

- **Live streams** (Kafka streams): fink-client
  - *What for? Live inspection, Follow-up*
  - Personalisable filters to select objects/parameters of interest
- **Science Portal** (dash-based) & REST API: https://fink-portal.org
  - *What for? Visual inspection, small queries, daily monitoring*
  - All data processed remains accessible
- **Data Transfer service**: fink-client, post, link
  - *What for? Bulk download, complex queries, ML/DL training, exotic analyses*
- **TOM module**
  - *What for? Follow-up*
  - https://github.com/TOMToolkit/tom_fink

FINK extracted knowledge from different science cases

Satellites – Karpov & Peloton 2022 : arxiv:2202.05719

Solar System Objects – MITI grant – Rubin x Euclid

Variability in our Galaxy – Fink hackathon in Nov 2022

Young Stellar objects – COIN residence in Sept 2022 Kuhn et al. 2023: arxiv:2303.09409

Microlensing effect

Kilonova – Aivazyan et al. 2022: arxiv:2202.09766, Biswas et al. 2022: arxiv:2210.17433

AGN – **Russeil Etienne et al. 2022: arxiv:2211.10987 -> Ask Etienne ;)**

Supernovae & Core-collapse – Leoni et al. 2021: arxiv:2111.11438; Möller & de Boissière arxiv:2207.04578; Allam Jr et al. 2023 arxiv:2303.08951

Pair-instability Supernovae – MITI grant

On-axis GRB: Le montager et al. in prep; Orphan GRB – **see Marina's talk - Ask Marina**

\+ Multi-messenger analysis, Anomaly detection, and others!

Transient Universe 2023

My last take-away messages

You are lucky because

- you will enter into an exciting era of discoveries (new generation of facilities = breakthrough discoveries)
- Thanks to the VRO/LSST survey, there will be **scientific targets publicly available for everyone** from GRBs to novae!
- you will have plenty of **broker services** that will **help** you to select your favored transients for further studies
- you will have the opportunity to show how smart you are in **building a scientific program** to find what you want to find or what you did not expect to find ;)

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BUT....

You will need to be proactive

(LSST and the broker will not find things for you)!

4
How to use the FINK outputs for your science

Time to practice for real