CTA's webinars

SYNERGIES IN THE EXPLORATION OF THE EXTREME UNIVERSE

for researchers

"Alert Brokers for Astrophysical Surveys: What is in it for CTA and how to engage"

Gautham Narayan

Assistant Professor at the University of Illinois at Urbana-Champaign

Deputy Analysis Coordinator of the Rubin Observatory's Dark Energy Science Collaboration

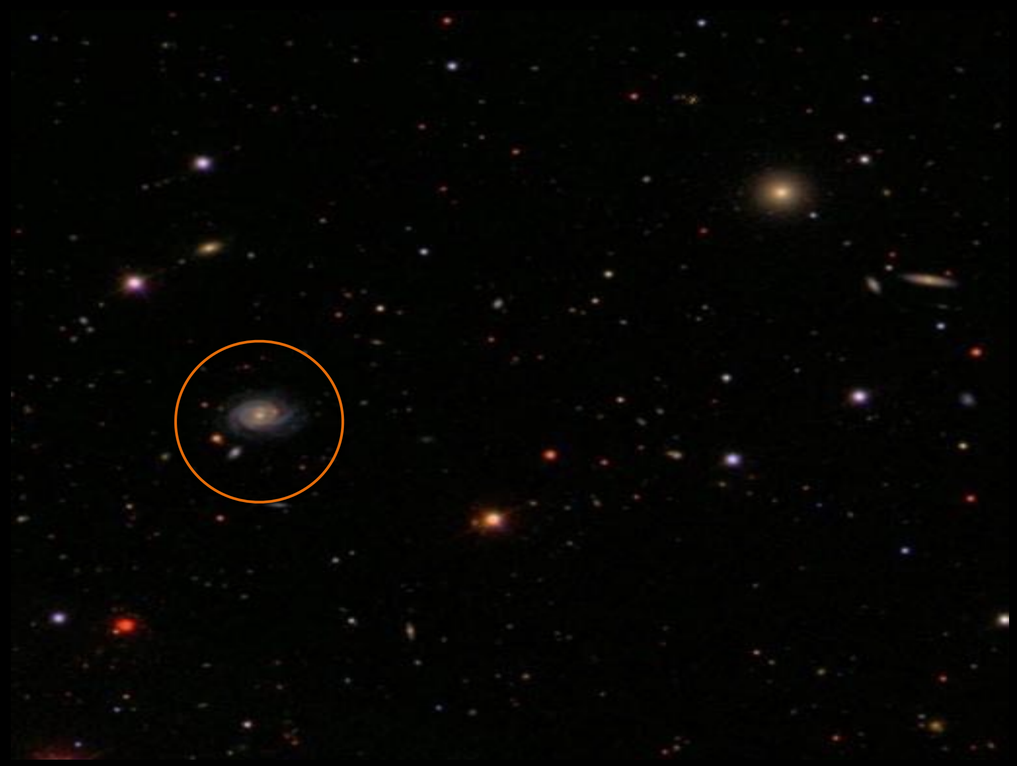
1. HOW ASTROPHYSICAL SURVEYS ARE EVOLVING

< 2000

PHOTOGRAPHIC PLATES

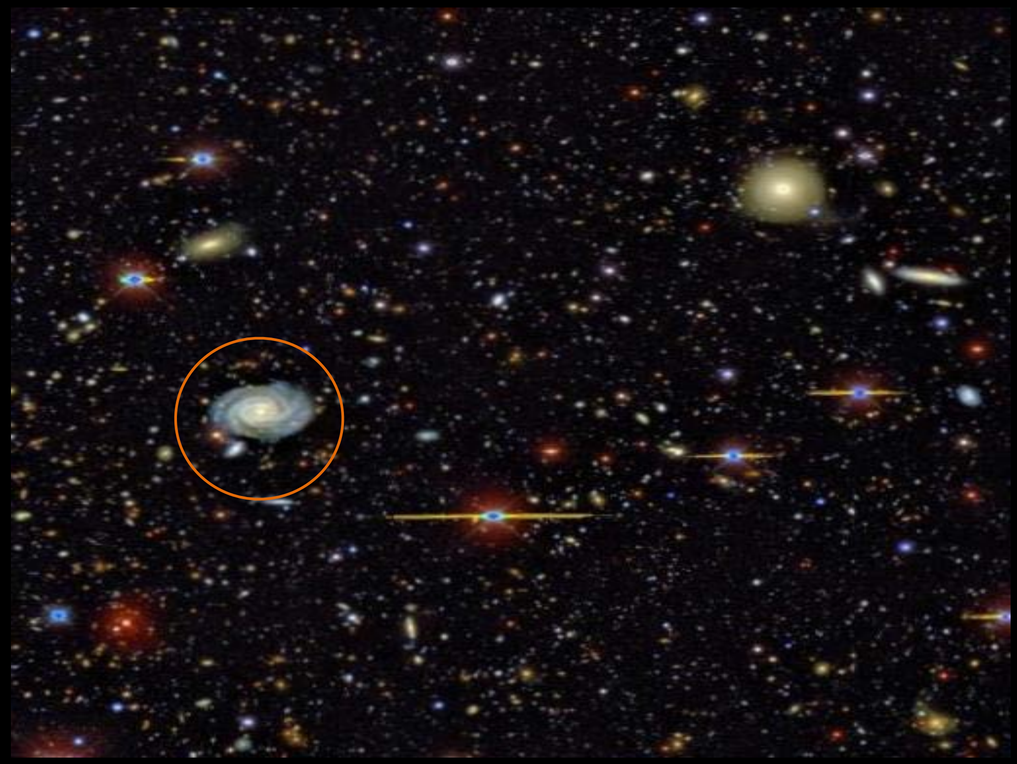
2000 - 2018+

DIGITAL SKY SURVEY



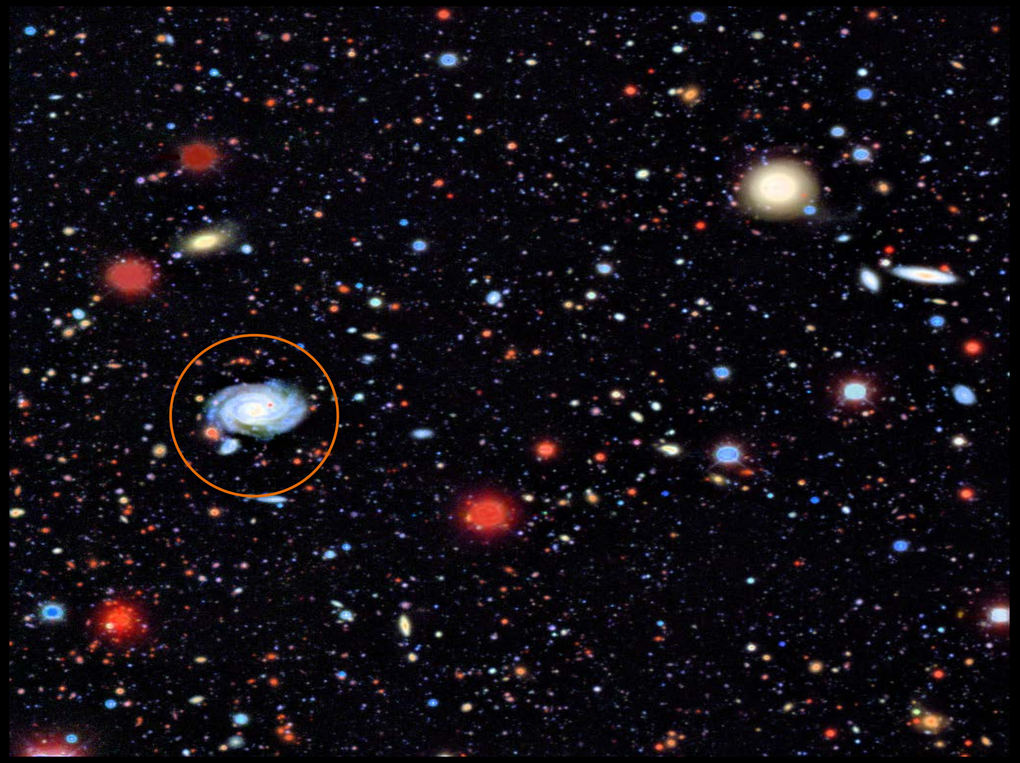
2001 - 2006

DEEP LENS SURVEY



> 2021

LEGACY SURVEY OF SPACE AND TIME

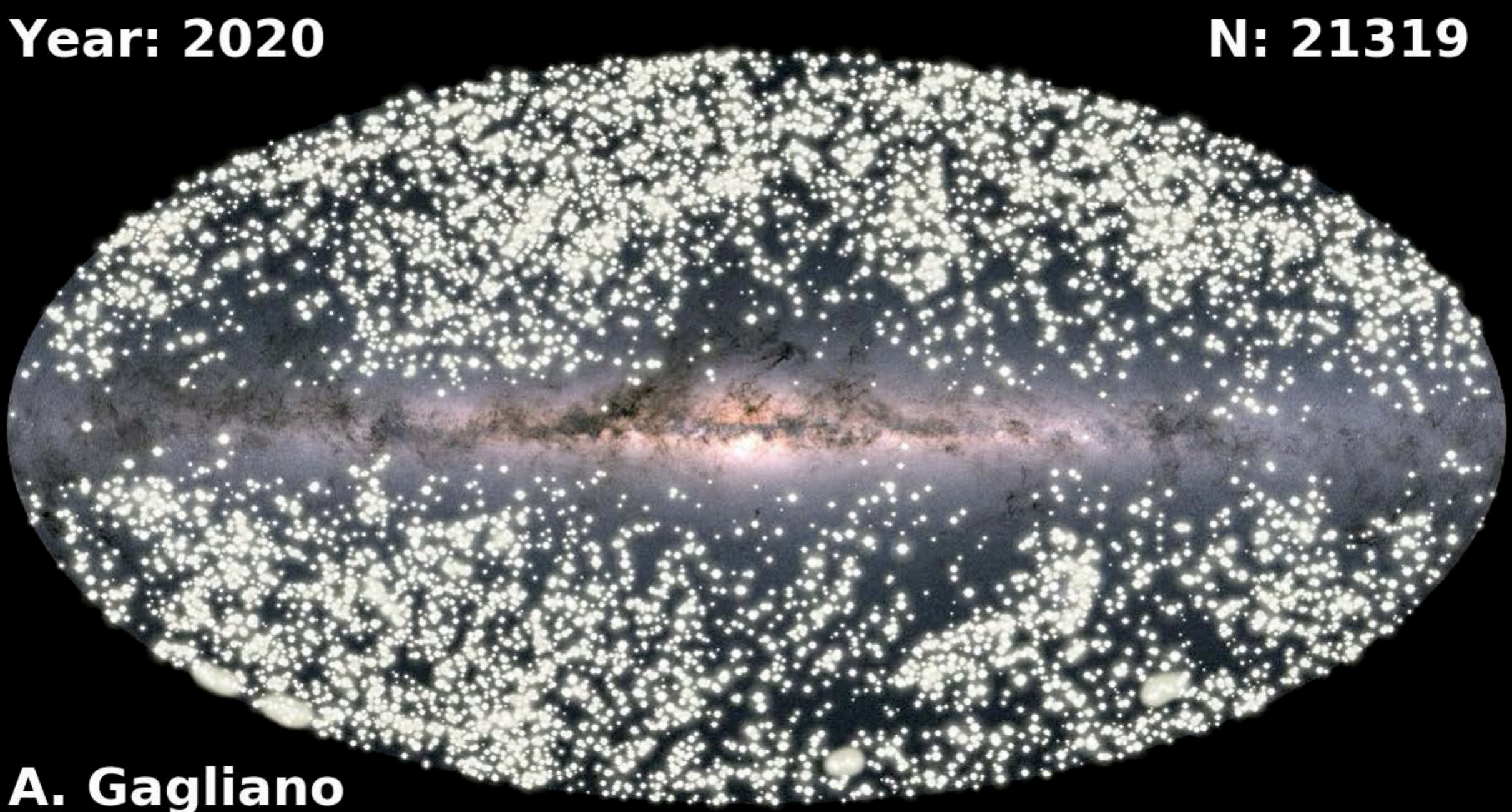


37 billion stars and galaxies (10 year survey)

10 million alerts, 1000 pairs of exposures/night

THIS IS WHAT THE DATA LOOK LIKE WHEN YOU SUBTRACT AWAY MOST OF IT

THIS IS THE CORE OF AN ALERT

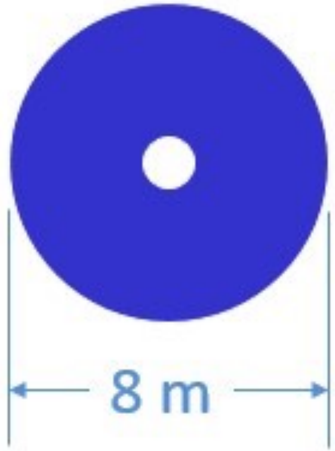


LSST watches the changing sky, discovering the deaths of stars

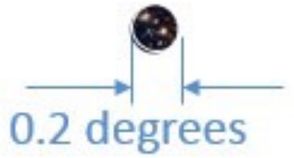
LSST'S ALERT RATE OUTSTRIPS ALL OUR FOLLOWUP RESOURCES - COMBINED

8m Class Telescope

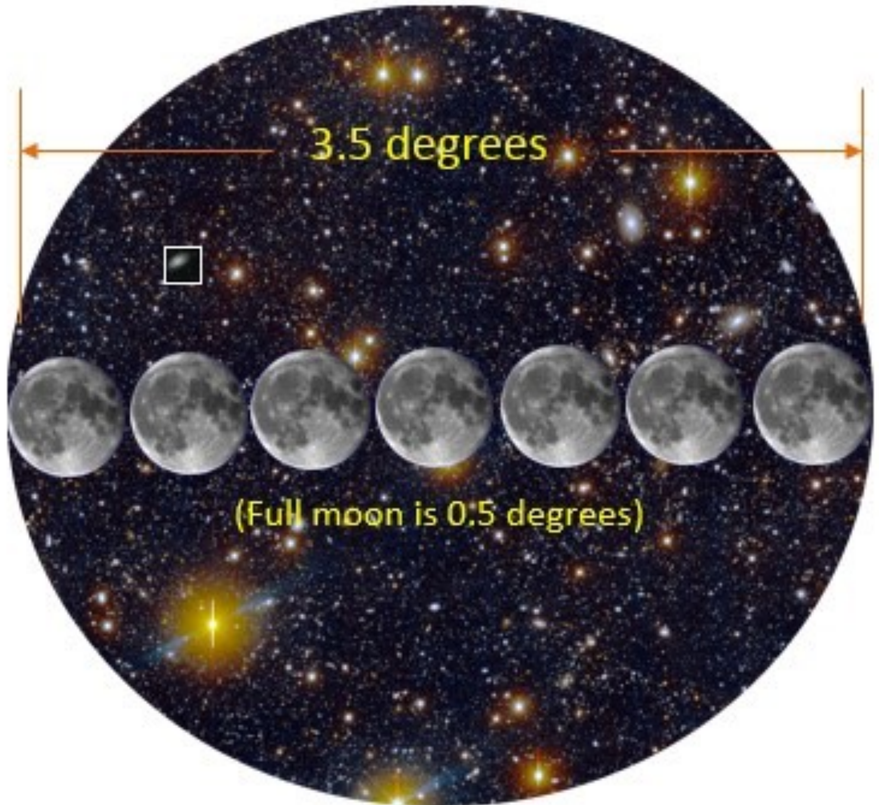
Primary Mirror Diameter



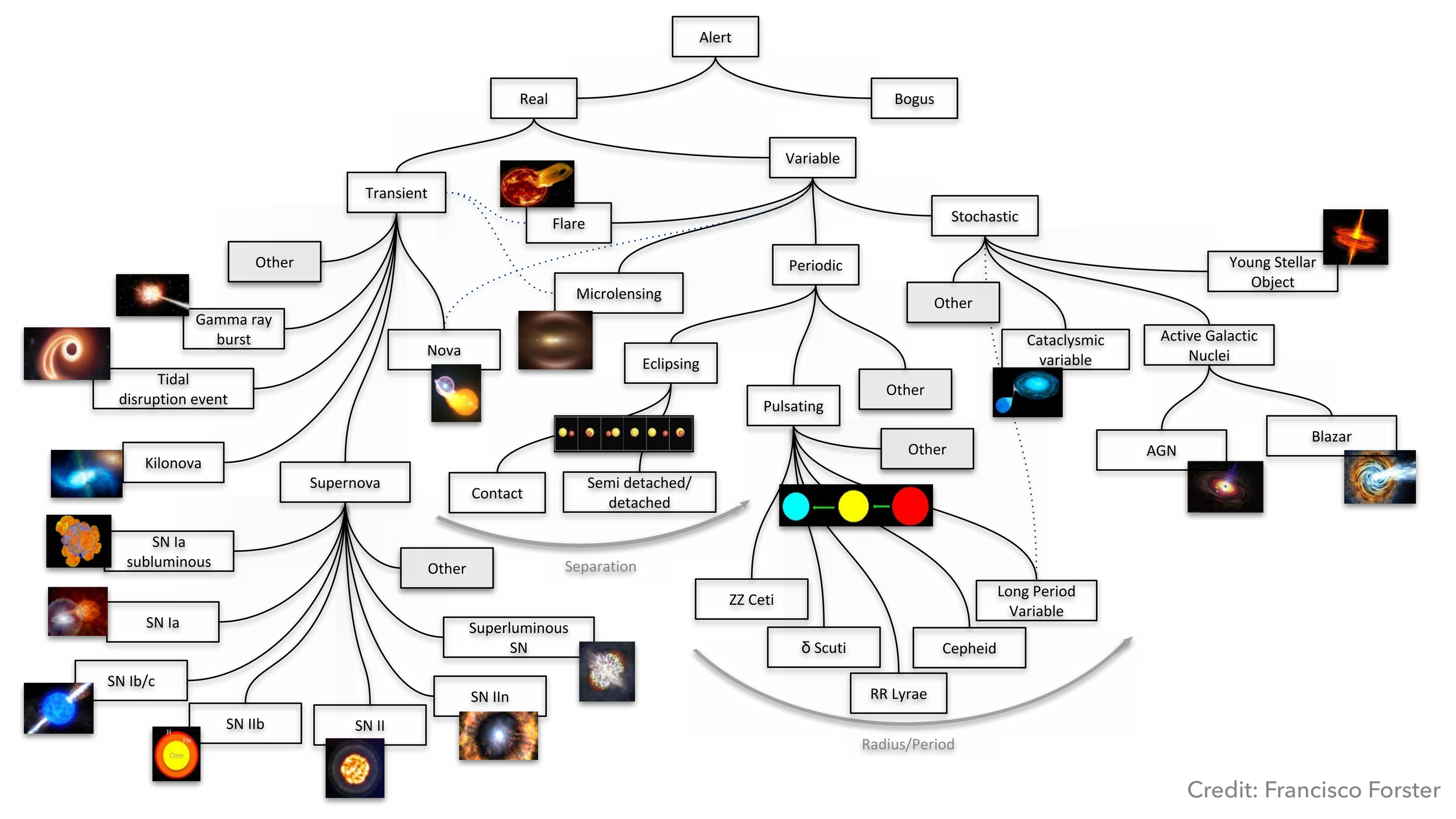
Field of View



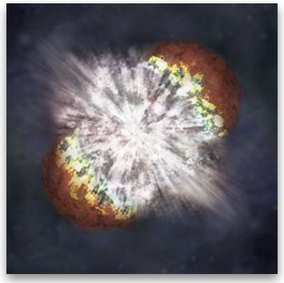
LSST



Z. Ivezic,


Alert
Real
Bogus
Variable
Transient
Flare
Stochastic
Other
Periodic
Microlensing
Young Stellar Object
Other
Gamma ray burst
Cataclysmic variable
Active Galactic Nuclei
Nova
Eclipsing
Tidal disruption event
Pulsating
Other
Other
Kilonova
AGN
Blazar
Supernova
Other
Contact
Semi detached/ detached
Separation
SN Ia subluminous
Other
ZZ Ceti
Long Period Variable
SN Ia
Superluminous SN
δ Scuti
Cepheid
SN Ib/c
SN IIn
RR Lyrae
SN IIb
SN II
Radius/Period
H
He
Core
Credit: Francisco Forster

The Bulk of LSST alerts users will be LSST DESC, TVSSC and AGNSC (in that order)



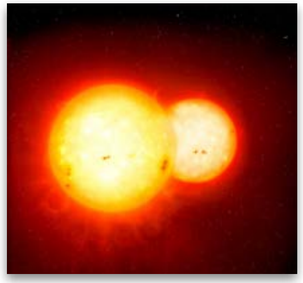
Transients

Rapid photometric & spectroscopic follow-up: **nature of the progenitors** (outermost layers) & **explosion physics** (ejecta structure).

Short-lived transients (GWs, GRBs)

Cosmological **distance rulers.**

Rare populations of events?



Variable stars

Rapid photometric & spectroscopic follow up: low mass **microlensing** events, **changing mode** stellar pulsators, rapid reaction to **eclipsing events**, **eruptive** events

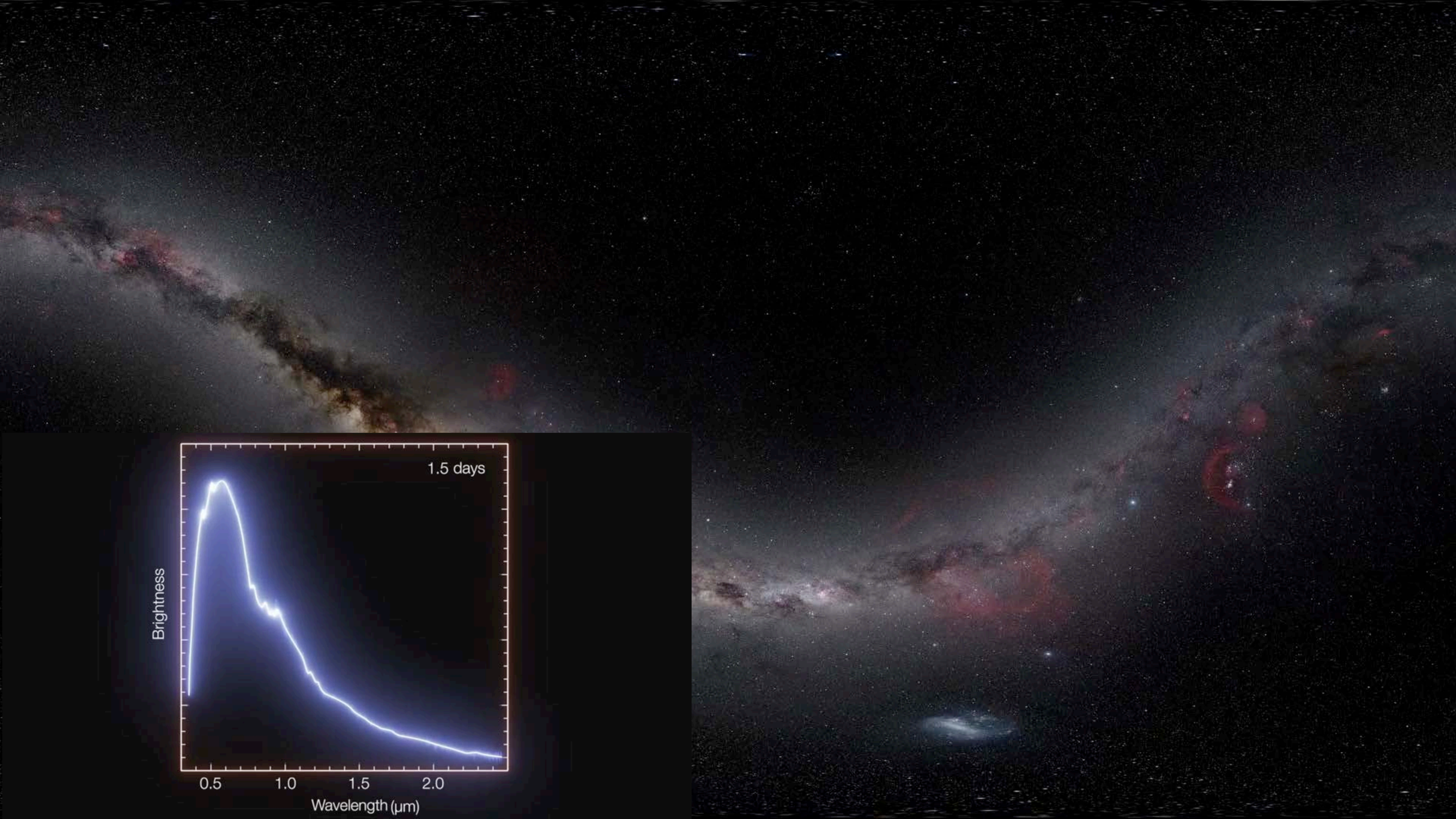
Analysis of large populations of events: study **Milky Way structure & formation.**

Active Galactic Nuclei

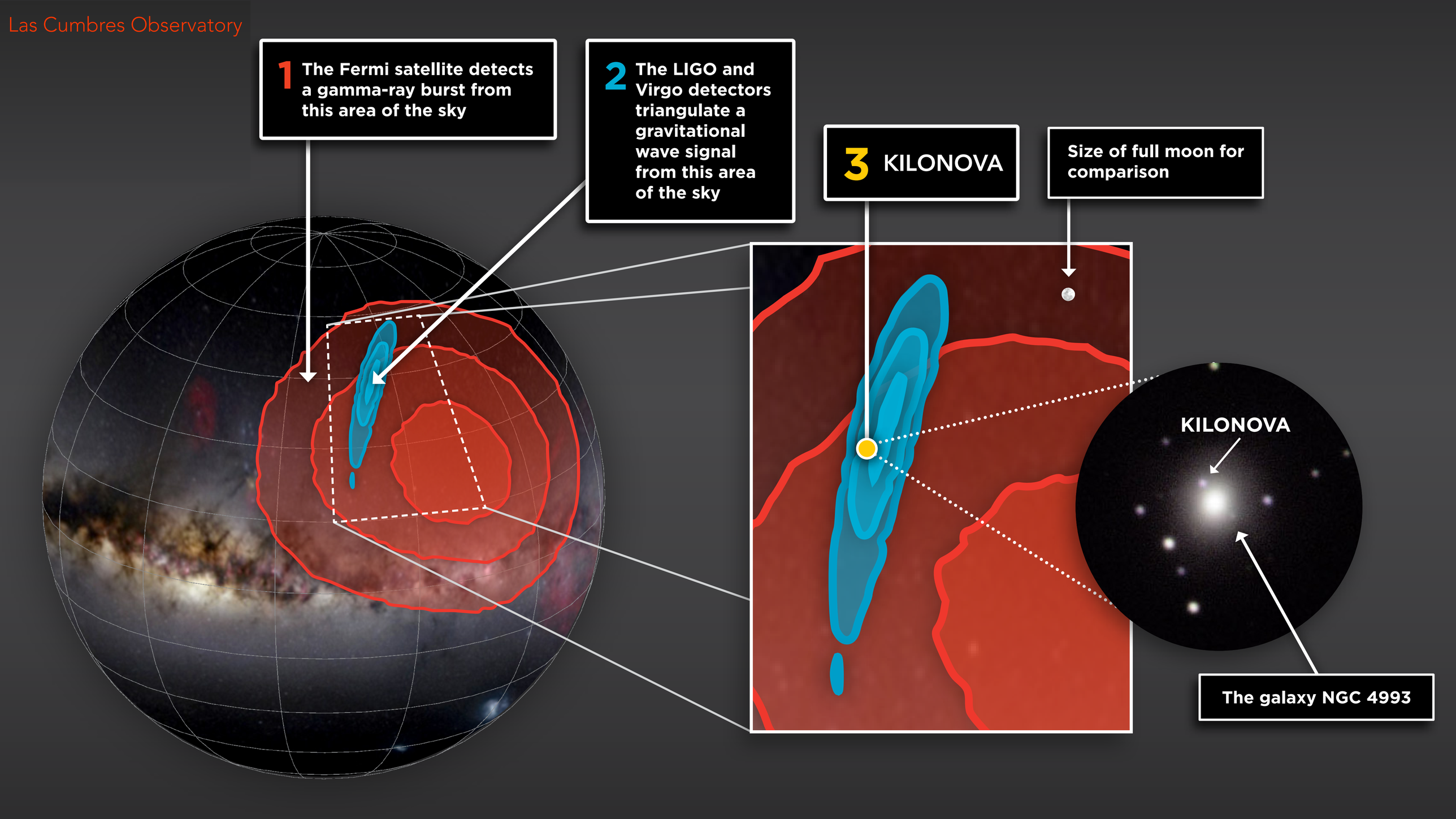
Rapid photometric & spectroscopic follow-up: **changing look AGNs**, **reverberation mapping** studies

New populations of **faster, redder, dimmer** AGNs

Detection of **intermediate mass black holes**, **tidal disruption events**


1.5 days
Brightness
0.5
1.0
1.5
2.0
Wavelength (μm)

Las Cumbres Observatory



RARE AND INTERESTING TRANSIENTS IN THE ALERT STREAM: NEEDLE IN A NEEDLESTACK

Mission Search / Missions / Contacts / STScI / MAST

Columns Help / Archive Status

HST Search Results

Edit Query

TRADITIONAL ARCHIVES

Object name M100 resolved by NED (via SANTA cache) to **MESSIER 100** (G)
RA: 12 22 54.83 **Dec:** 15 49 18.55 **(J2000)**

number of rows returned = 206

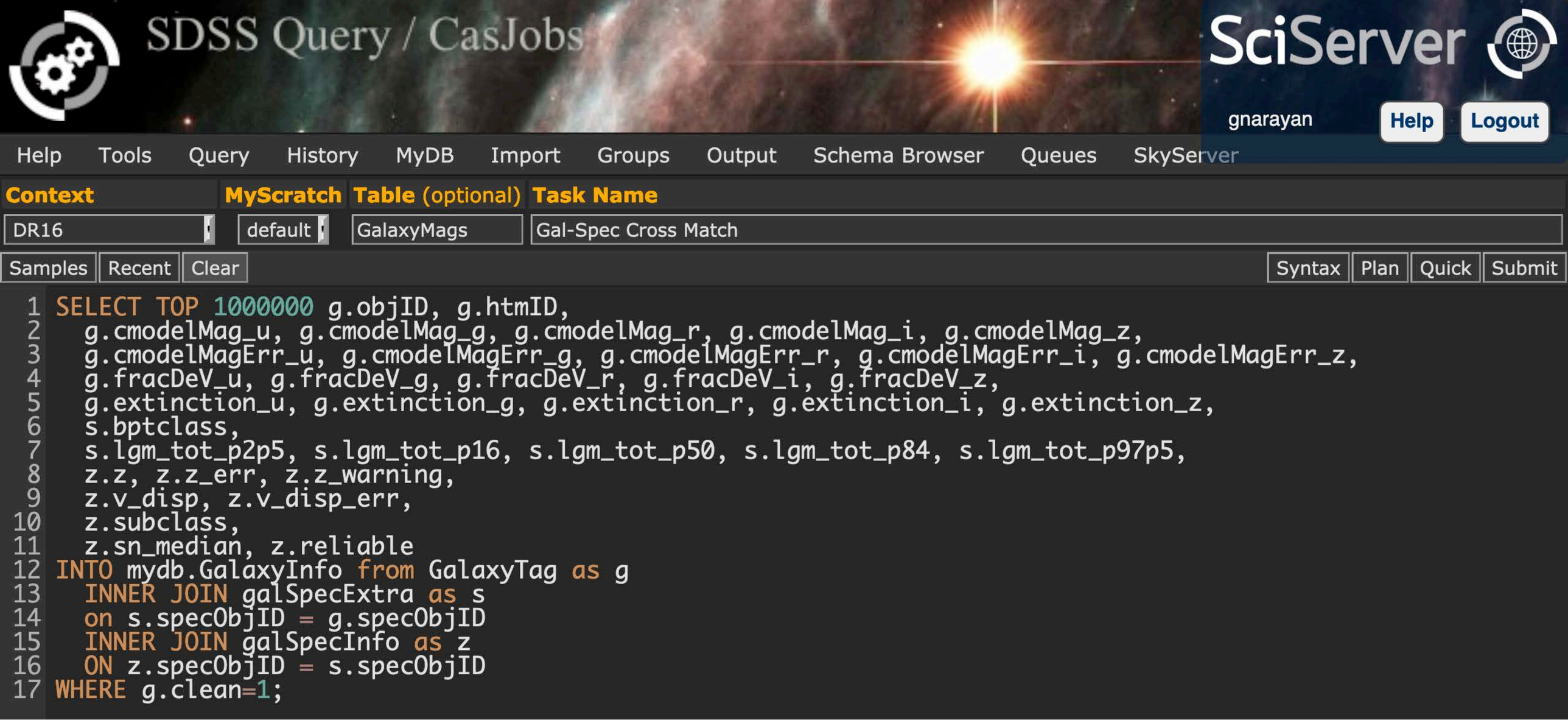
Table Info

Plot marked spectra | Submit marked data for retrieval from STDADS

Mark all | Unmark all | Mark public | Unmark public | Mark proprietary | Unmark proprietary

Mark	Dataset	Target Name	RA (J2000)	Dec (J2000)	Ref	Start Time	Stop Time	Exp Time	Instrument	Apertures	Filters/Gratings	Central Wavelength	Proposal ID	Release Date	Preview Name	Scan Type
☐	IDKV31010	NGC4321	12 22 54.831	+15 49 18.54	5	2018-02-04 17:27:37	2018-02-04 17:40:45	500.000	WFC3	UVIS2-C1K1C-SUB	F814W	8029.322	15133	2018-08-05 03:58:00	IDKV31010	
☐	IDKV31020	NGC4321	12 22 54.831	+15 49 18.54	5	2018-02-04 17:42:47	2018-02-04 17:59:15	700.000	WFC3	UVIS2-C1K1C-SUB	F475W	4772.171	15133	2018-08-05 04:00:13	IDKV31020	
☐	IDKV31030	NGC4321	12 22 54.831	+15 49 18.54	5	2018-02-04 18:01:35	2018-02-04 18:14:37	596.924	WFC3	IR	F160W	15369.176	15133	2018-08-05 03:32:06	IDKV31030	
☐	J8PP22011	NGC4321	12 22 54.900	+15 49 20.70	8	2004-05-30 19:13:28	2004-05-30 19:32:37	1100.000	ACS	HRC	CLEAR1S;F814W	8099.662	9776	2005-05-30 23:33:59	J8PP22011	
☐	J8PP22021	NGC4321	12 22 54.900	+15 49 20.70	8	2004-05-30 20:46:47	2004-05-30 21:05:56	1100.000	ACS	HRC	F555W;CLEAR2S	5355.754	9776	2005-05-30 23:35:01	J8PP22021	
☐	J8PP22W7Q	NGC4321	12 22 54.900	+15 49 20.70	8	2004-05-30 19:10:59	2004-05-30 19:12:41	100.000	ACS	HRC	CLEAR1S;F814W	8099.662	9776	2005-05-30 23:34:20	J8PP22W7Q	
☐	J8PP22WAQ	NGC4321	12 22 54.900	+15 49 20.70	8	2004-05-30 19:34:25	2004-05-30 19:36:07	100.000	ACS	HRC	F555W;CLEAR2S	5355.754	9776	2005-05-30 23:34:50	J8PP22WAQ	
☐	O8PP41010	NGC4321	12 22 54.900	+15 49 20.70	8	2004-04-08 04:42:10	2004-04-08 04:43:01	7.000	STIS	F28X50LP	MIRVIS	7210.932	9776	2006-12-17 23:20:39		
☐	O8PP41020	NGC4321	12 22 54.900	+15 49 20.70	8	2004-04-08 04:48:18	2004-04-08 05:20:42	1900.000	STIS	52X0.2	G750M	8561.000	9776	2006-12-18 01:44:00	O8PP41020	
☐	O8PP41URQ	NGC4321	12 22 54.900	+15 49 20.70	8	2004-04-08 04:36:15	2004-04-08 04:40:01	20.100	STIS	F28X50LP	MIRVIS	0.000	9776	2006-12-20 03:54:27		
☐	O8PP42010	NGC4321	12 22 54.900	+15 49 20.70	8	2004-03-26 15:51:51	2004-03-26 15:52:45	10.000	STIS	F28X50LP	MIRVIS	7210.977	9776	2006-12-20 06:15:00		
☐	O8PP42020	NGC4321	12 22 54.900	+15 49 20.70	8	2004-03-26 15:58:01	2004-03-26 16:30:25	1900.000	STIS	52X0.2	G750M	8561.000	9776	2006-12-20 08:11:48	O8PP42020	
☐	O8PP42P6Q	NGC4321	12 22 54.900	+15 49 20.70	8	2004-03-26 15:45:56	2004-03-26 15:49:42	20.100	STIS	F28X50LP	MIRVIS	0.000	9776	2005-03-26 15:49:42		
☐	O8PP43010	NGC4321	12 22 54.900	+15 49 20.70	8	2004-03-27 09:21:08	2004-03-27 09:22:02	10.000	STIS	F28X50LP	MIRVIS	7210.975	9776	2006-12-01 07:08:07		
☐	O8PP43020	NGC4321	12 22 54.900	+15 49 20.70	8	2004-03-27 09:27:18	2004-03-27 09:59:42	1900.000	STIS	52X0.2	G750M	8561.000	9776	2004-03-27 12:45:19	O8PP43020	
☐	O8PP43U9Q	NGC4321	12 22 54.900	+15 49 20.70	8	2004-03-27 08:13:58	2004-03-27 08:17:44	20.100	STIS	F28X50LP	MIRVIS	0.000	9776	2006-12-21 12:45:00		
☐	O8PP410A0	NGC4321	12 22 54.954	+15 49 20.12	8	2004-04-08 10:59:05	2004-04-08 11:43:47	2560.000	STIS	52X0.2	G750M	8561.000	9776	2006-12-19 23:11:31	O8PP410A0	
☐	J9B031010	NGC4321	12 22 54.900	+15 49 21.00	4	2006-01-26 09:55:39	2006-01-26 10:16:50	1200.000	ACS	HRC-FIX	CLEAR1S;F330W	3362.951	10548	2007-01-26 15:56:23	J9B031010	
☐	O4E013020	N4321	12 22 54.843	+15 49 21.20	28	1999-04-23 04:33:22	1999-04-23 04:48:53	931.000	STIS	52X0.2	G750M	6581.000	7361	2007-01-05 21:30:13	O4E013020	
☐	O4E013010	N4321	12 22 54.860	+15 49 21.19	28	1999-04-23 04:17:12	1999-04-23 04:32:12	900.000	STIS	52X0.2	G750M	6581.000	7361	2007-01-06 03:54:54	O4E013010	
☐	O4E013050	N4321	12 22 54.860	+15 49 21.19	28	1999-04-23 07:30:38	1999-04-23 07:44:00	802.000	STIS	52X0.2	G430L	4300.000	7361	2000-04-23 07:44:00	O4E013050	

Access to raw/de-trended data products after some proprietary period. Limited query, no compute.



SDSS – CATALOG QUERIES VIA SQL

Community access to SDSS images, spectra, catalogs in data releases + nice interfaces and API. Query but not compute.

Credit: Pete Marenfield, NOAO

THE KEY CHALLENGE FOR THE NEXT GENERATION OF SURVEYS IS NOT JUST TAKING VAST QUANTITIES OF DATA,

BUT HOW TO ENABLE THE COMMUNITY TO USE IT.

FOR THE TIME-DOMAIN, THIS IMPLIES
REAL-TIME DATA STREAMS FROM HETEROGENOUS SOURCES

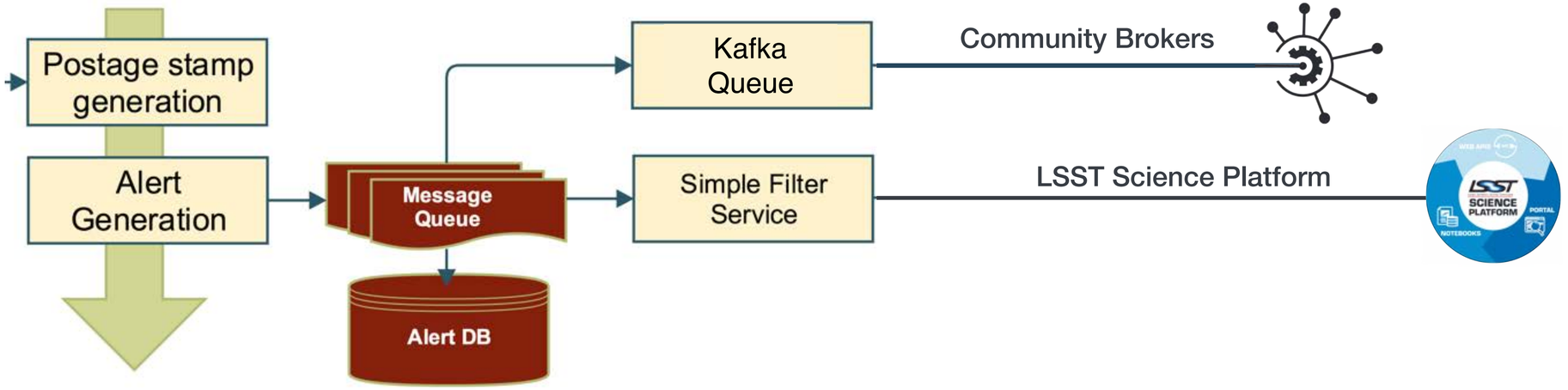
2. WHAT ALERT BROKERS CAN DO

WHAT DO WE NEED?

- Something to sift through heterogenous alert streams in real-time
- Characterize and classify events
- Identify outliers
- Prioritizes events for follow-up
- Actively learns from the follow-up
- All while providing a search, filtering and compute service to the community

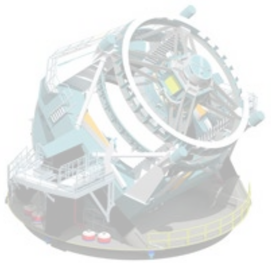
Alert Distribution and Brokers

Alerts are delivered to the community brokers that filter and classify events to enable realtime science.



Community Brokers

- Software developed independently of LSST to receive, characterize and/or redistribute Alerts.
- Added functionality such as, filtering, photometric classification & cross-matching with other surveys
- Limited number selected by a proposal process receive the full realtime stream



LSST Alert Filtering Service

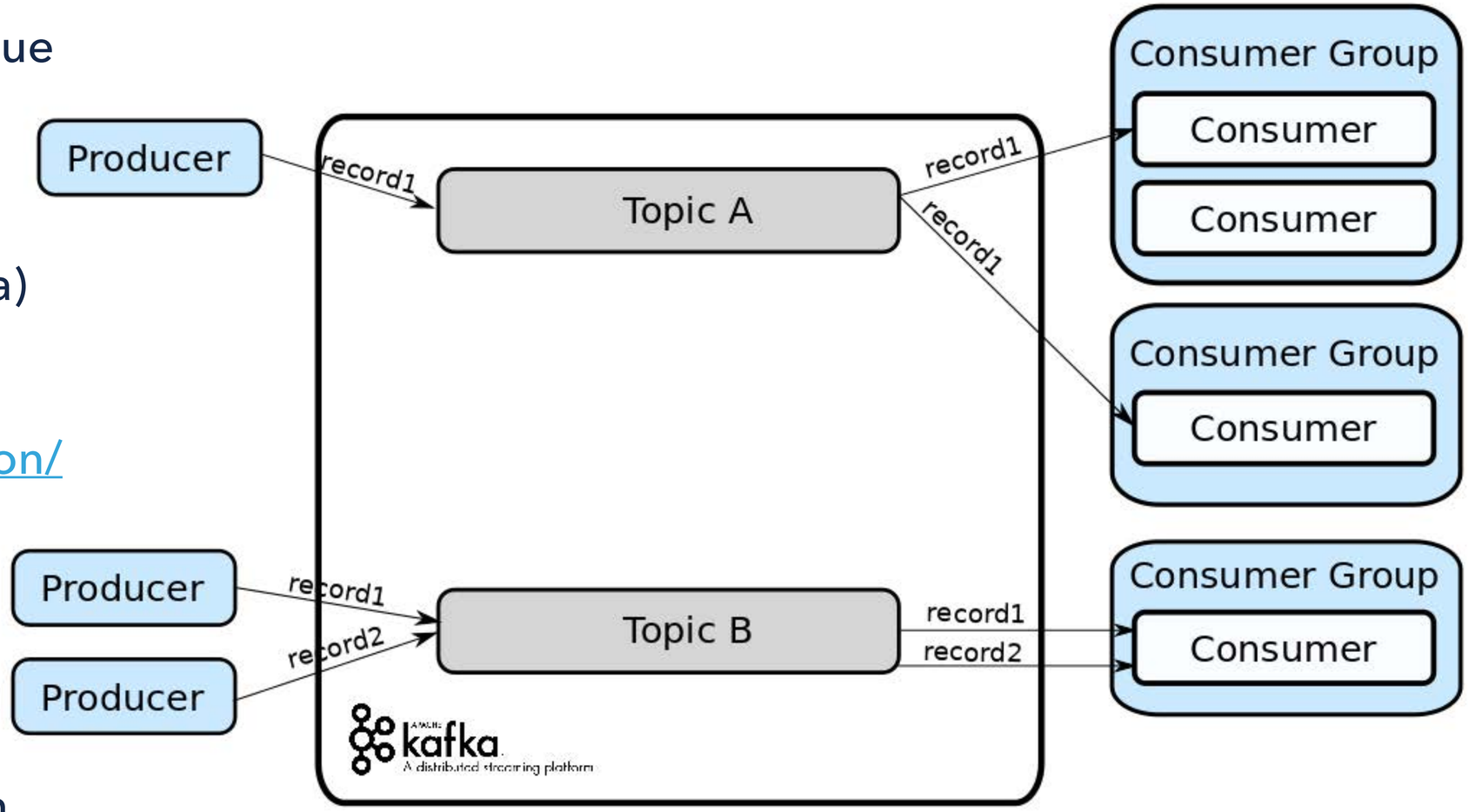
- Limited capacity service provisioned through the LSP; simple filters on alert packet contents only

Plans and Policies for LSST Alert Distribution

Courtesy: Eric Bellm/LSST AP

ALERTS

- Alerts for ZTF now and soon for LSST use an Apache Kafka queue
- Alerts are formatted using Apache Avro (effectively serialized JSON, with a schema)
- https://github.com/lsst/alert_packet/tree/master/python/lsst/alert/packet/schema/4/0
- Very much a successor to VOEvent
  - SCiMMA group is adding an IAM layer to Kafka with HopSkotch: https://scimma.org/projects.html

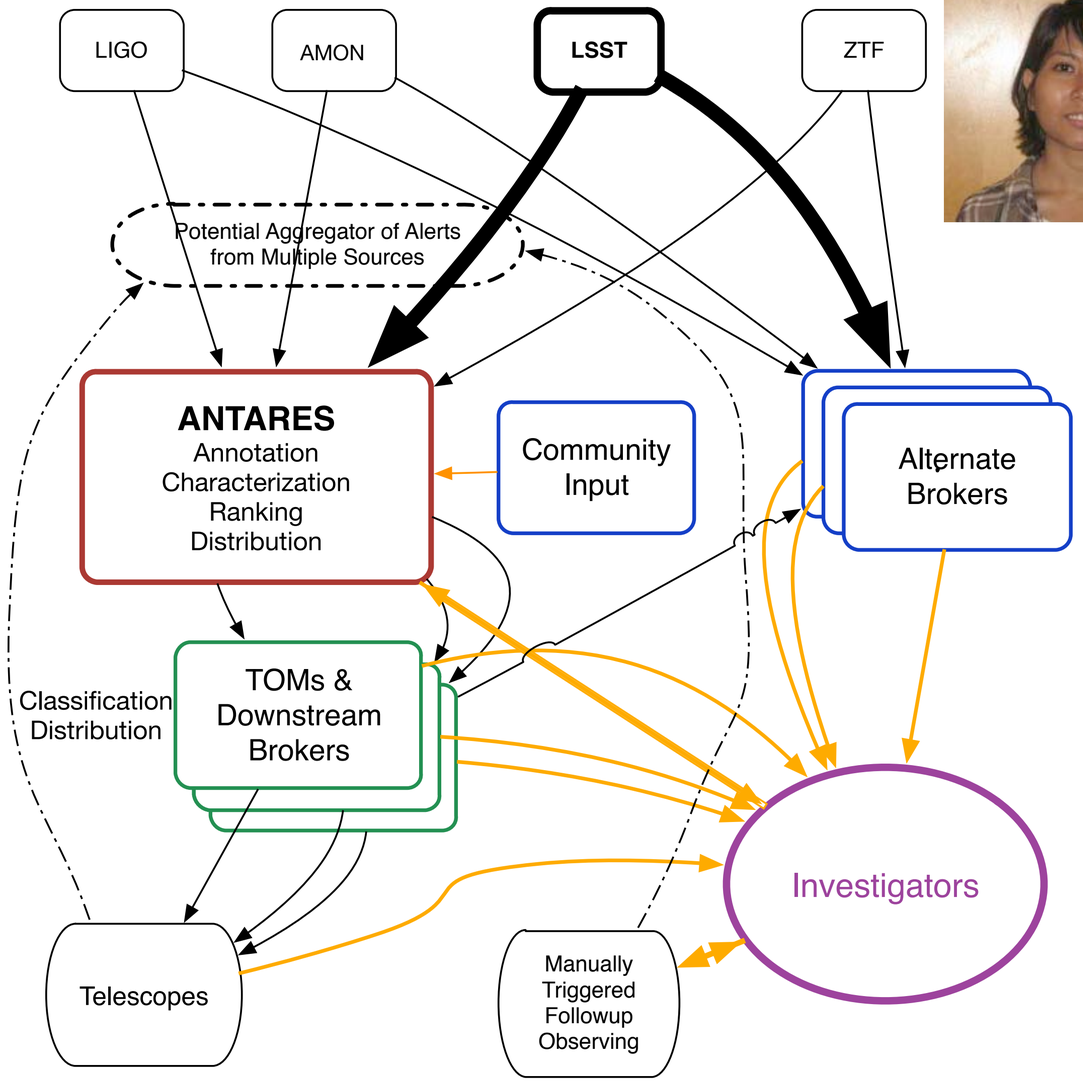


HOPSKOTCH

HOW CTA CAN ENGAGE 1: START TO WORK WITH SCIMMA/LSST/ZTF/LVK/SNEWS ON ALERTS

THE BROKER ECOSYSTEM

Monika Soraisam, Nic Wolf, Adam Scott, Carl Stubens,
Chien-Hsiu Lee (Project Scientist), and Tom Matheson (PI)



- ANTARES manages **alert streams**, adding contextual information, characterizing events, ranking & distributing
- Write your filters for complex, targeted processing, or broad analysis of large datasets - **do YOUR science!**
- Correlate optical, GW & high-energy particle/neutrino triggers - **multi-messenger astrophysics**
- Active with ZTF! Sign up! https://antares.noirlab.edu/

Scan me

DEMO

The next few slides cover the same material in the live demo in static form for those looking at the slides
In each case, I've highlighted some of ANTARES' capabilities followed by some science cases that can use them

SEARCH

ANTARES

Lookup Object by ID

NSF | NOIR Lab

Explore | Favorites | Filters | Tags | Watch Lists | Catalogs | Pipeline | Properties | FAQ | Support | gnarayan

Active Filters

- Latest alert after MJD 59382.34
- First alert after MJD 59382.34
- Catalogs: veron_agn_qso

Number of Measurements

1 — 2

Cone Search

Center: Enter a coordinate string

Radius: 1 arcsec

Catalogs

- veron_agn_qso (4)
- 2mass_xsc (3)
- 2mass_psc (2)
- allwise (2)
- bright_guide_star_cat (2)
- ned (2)
- RC3 (1)
- gaia_dr2 (1)
- nyu_valueadded_gals (1)
- sdss_gals (1)

>_

Showing 1-4 of 4 | 25 | « ‹ 1 › »

ID	ZTF ID	RA	Dec	Latest Mag	Brightest Mag	# Alerts	Latest Alert	First Alert
ANT2021q6f76	ZTF21abhotwz	28.68	27.33	18.39	18.39	2	2021-06-19 11:15:56	2021-06-19 11:12:58
ANT2021qq4ls	ZTF18abkxozh	262.30	70.55	18.69	18.69	1	2021-06-18 05:14:08	2021-06-18 05:14:08
ANT2021qqh76	ZTF18aaqdill	195.50	27.78	19.07	19.07	1	2021-06-18 04:42:25	2021-06-18 04:42:25
ANT2021qp26k	ZTF19abahorj	48.76	42.04	18.74	18.74	1	2021-06-17 11:15:00	2021-06-17 11:15:00

You can think of ANTARES as a search engine for astrophysical variabilityYou can conesearch, cross-match against existing catalogs
https://antares.noirlab.edu/catalogs

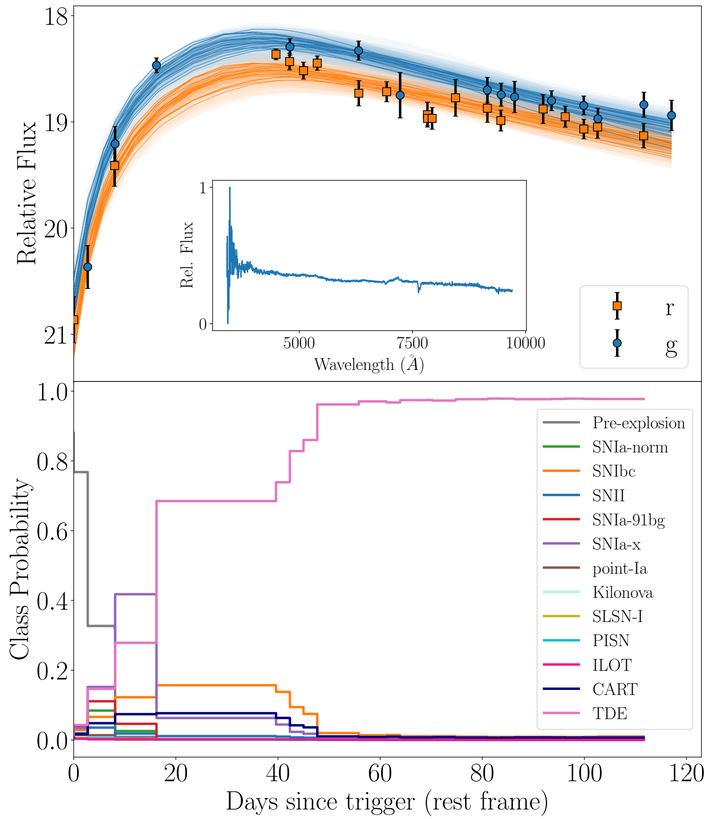
Even require objects that have “tags” attached to them
https://antares.noirlab.edu/tags

Or create a private watch list to monitor activity for your own sources
https://antares.noirlab.edu/watch-lists

Science Use Cases

Nuclear Activity: AGN and TDEs

- Identify by location (currently using Van Velzen criteria)
- Multiwavelength catalogs can help distinguish AGN from TDE
- Multiwavelength variability would be useful

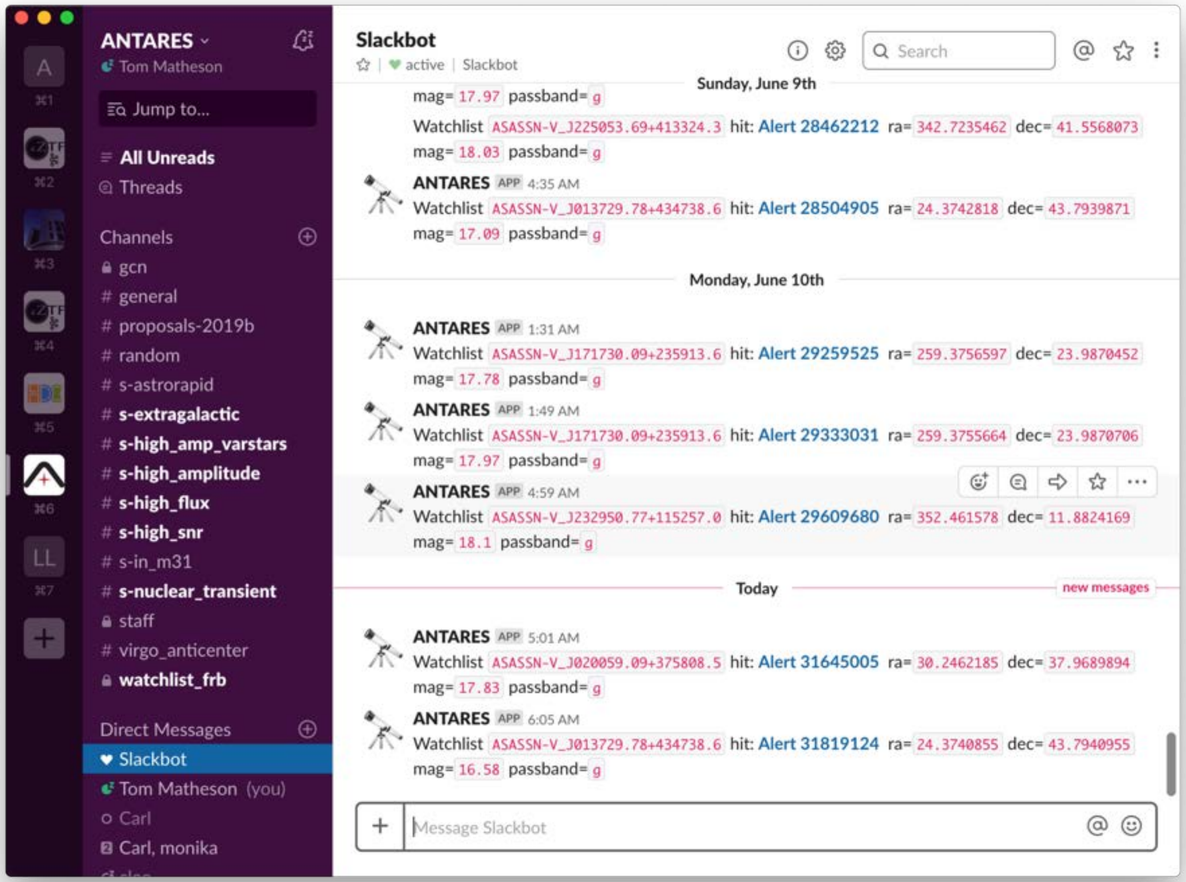


RAPID classifier identifying ZTF18abxftqm as TDE, Muthakrishna et al. 2019

Science Use Cases

Watchlists

- Users upload csv file
- Direct notification when your object of interest alerts
- Slack configuration controls intrusiveness of notifications
- Watch all known strong lensing systems for transients, e.g.



Level 2 Filters FILTERS

After alerts are ingested, aggregated, and associated with catalogs, ANTARES runs the L2 filters. The purpose of the L2 filters is to detect the interesting science alerts based on custom criteria.

Nuclear Transient — *Finding alerts in the nuclear region of a source in the ZTF reference.*

```python
import antares.devkit as dk

class nuclear_transient(dk.Filter):
    NAME = "Nuclear Transient"
    ERROR_SLACK_CHANNEL = "UERMCJQ1W"  # Put your Slack user ID here
    REQUIRED_LOCUS_PROPERTIES = [
        'ztf_object_id',
    ]
    REQUIRED_ALERT_PROPERTIES = [
        'ztf_sgscore1',
        'ztf_distpanr1',
        'ztf_magpsf',
        'ztf_magnr',
        'ztf_distnr',
    ]
    OUTPUT_LOCUS_PROPERTIES = []
    OUTPUT_ALERT_PROPERTIES = []
    OUTPUT_TAGS = [
        {
            'name': 'nuclear_transient',
```

Tags are set by “filters” https://antares.noirlab.edu/tags

ANTARES already has several filters, both created by our staff, and by community users (you!)

YES! We run YOUR code as part of OUR pipeline!

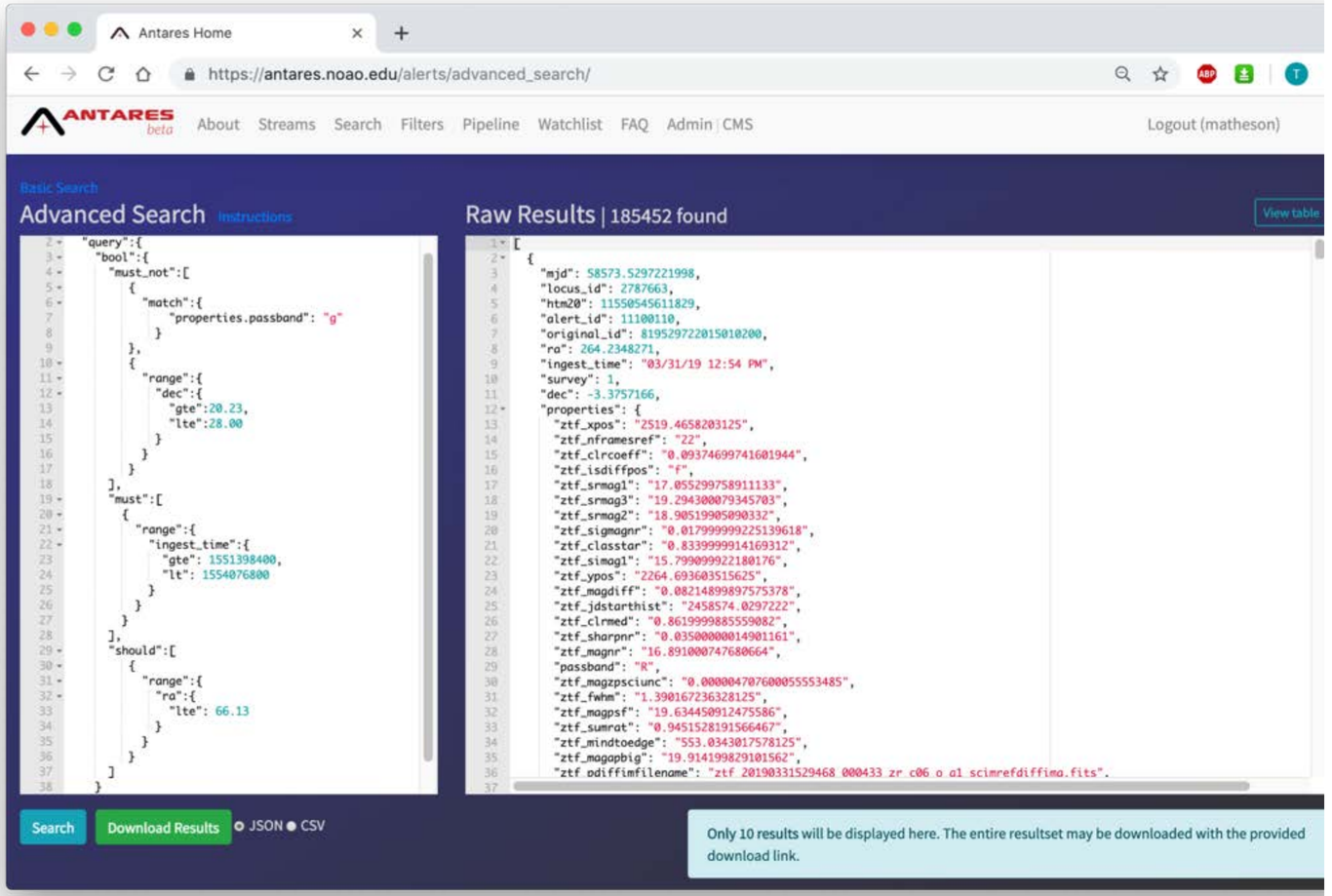
You can develop your own filters using the DevKit Jupyter notebook on AstroDataLab: https://datalab.noirlab.edu/

and there’s even documentation: https://noao.gitlab.io/antares/filter-documentation/devkit/index.html#devkit

Science Use Cases

Longer-timescale Transients/Variables

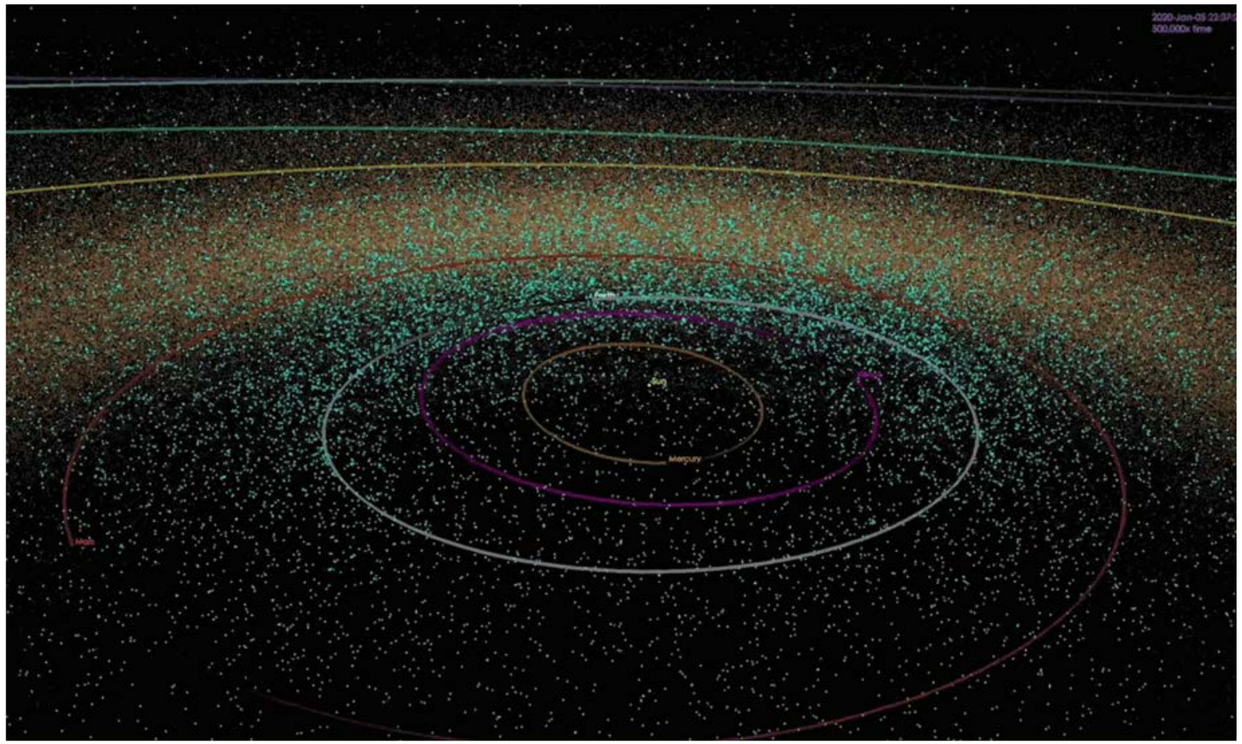
- Many classes don’t require immediate response
- Searchable annotated archive provides resource to discover these
- Useful for developing filters for shorter-timescale objects



Science Use Cases

Known Solar System Objects

- New Solar System objects are on-project task
- Known Solar System objects flagged in the alert stream can be redirected to a moving-object broker
- Already doing this with ZTF stream and SNAPS team
- Filter on streaked sources

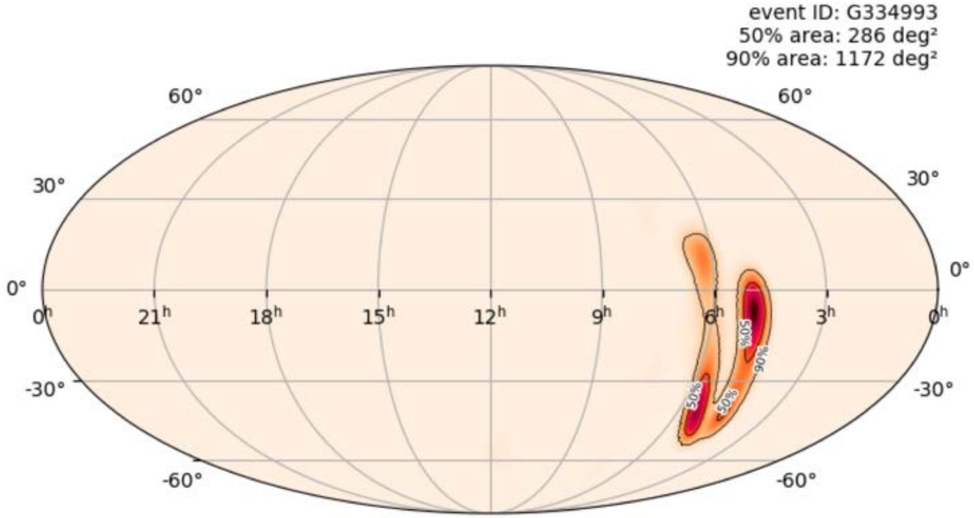


NASA/JPL-Caltech

Science Use Cases

Enabling Multi-Messenger Astronomy

- Automatic retrieval of LIGO/Virgo skymaps
- Associate all subsequent alerts within recent skymaps
- Filter using distance and other features



LIGO/Virgo Gracedb

PYTHON CLIENTS TO INTERFACE WITH YOUR OWN PIPELINES

Anything you can do on the website, you can do through out python client - enables much richer pipeline development

In [4]:
```
import antares_client
from astropy.coordinates import Angle, SkyCoord
center = SkyCoord("227.285d 67.222d")
radius = Angle("0.25d")

locusid=[]
locus_gr=[]
locus_r=[]
print("#Locus, RA, Dec, Num_alerts")
for locus in antares_client.search.cone_search(center, radius):
    if locus.properties['num_mag_values'] > 30:
        print("https://antares.noirlab.edu/loci/lookup/%s" % (locus.properties['ztf_object_id']), locus.ra, locus.dec, locu
s.properties['num_mag_values'], locus.alerts[-1].properties['ztf_sgmag1'] - locus.alerts[-1].properties['ztf_srmag1'], locu
s.alerts[-1].properties['ztf_srmag1'])
        locusid.append(locus.properties['ztf_object_id'])
        locus_gr.append(locus.alerts[-1].properties['ztf_sgmag1'] - locus.alerts[-1].properties['ztf_srmag1'])
        locus_r.append(locus.alerts[-1].properties['ztf_srmag1'])
```

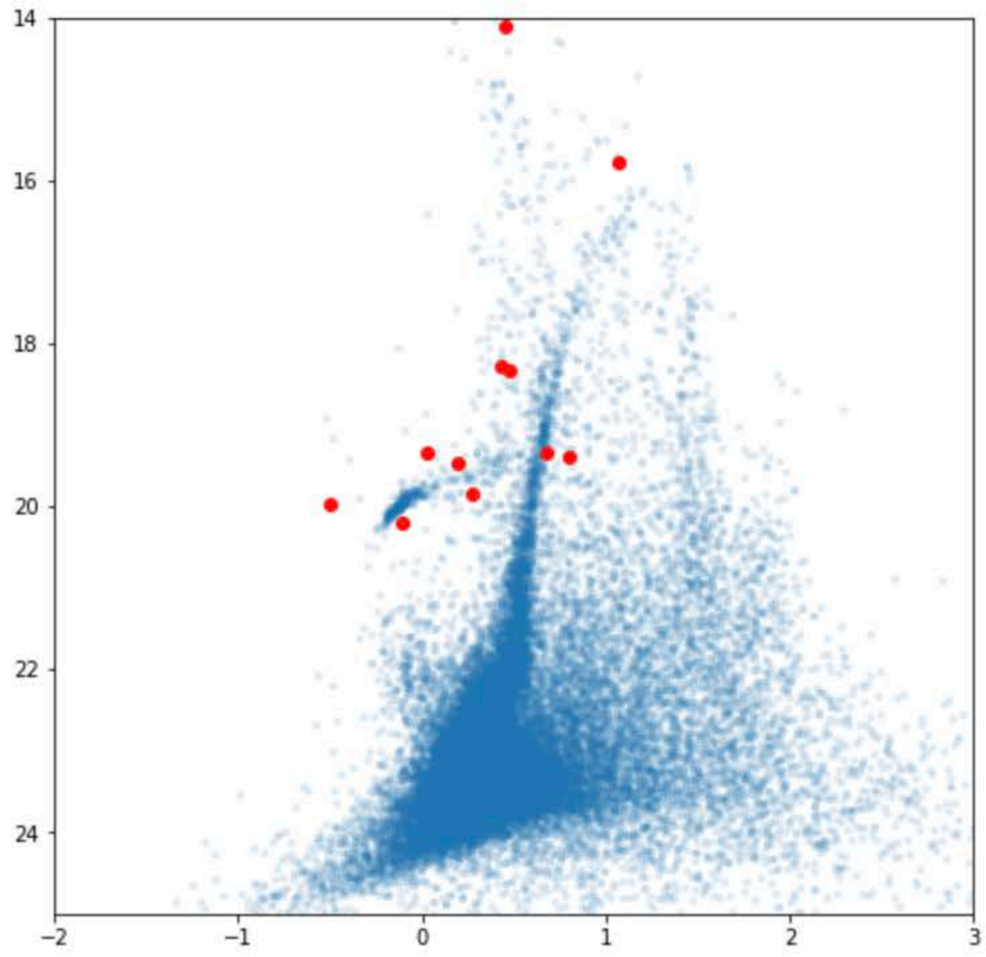
```
#Locus, RA, Dec, Num_alerts
https://antares.noirlab.edu/loci/lookup/ZTF18aapnpxp 227.4650415090125 67.23184959776788 45 -0.10289955139160156 20.20050048
828125
https://antares.noirlab.edu/loci/lookup/ZTF18aavahko 227.26304767490103 67.1691137945075 37 0.028499603271484375 19.33889961
2426758
https://antares.noirlab.edu/loci/lookup/ZTF18aaqmbqs 227.3569277820102 67.203745733418 74 0.2775993347167969 19.853000640869
14
https://antares.noirlab.edu/loci/lookup/ZTF18aaqowgh 227.3502061211087 67.10099379691194 98 0.6824989318847656 19.3421001434
32617
https://antares.noirlab.edu/loci/lookup/ZTF18aapscwd 227.6100967449605 67.124552552642 41 0.796600341796875 19.3950996398925
78
https://antares.noirlab.edu/loci/lookup/ZTF18aaqmvlf 226.96067721846745 67.15751626751334 44 -0.5004005432128906 19.96330070
4956055
https://antares.noirlab.edu/loci/lookup/ZTF18aaoexnp 227.3073308554661 67.25926222542068 376 1.073699951171875 15.7742996215
82031
https://antares.noirlab.edu/loci/lookup/ZTF18aapmlzb 227.58436607491905 66.99700820060137 181 0.47480010986328125 18.3330993
65234375
https://antares.noirlab.edu/loci/lookup/ZTF18aapklkb 227.1058624585155 67.1582211012635 88 0.19550132751464844 19.4722995758
05664
https://antares.noirlab.edu/loci/lookup/ZTF18aaotfbe 227.64738291707317 67.0454438 41 0.4519996643066406 14.103400230407715
https://antares.noirlab.edu/loci/lookup/ZTF20aabqwer 227.70058449230774 67.21825292417583 91 0.43070030212402344 18.27829933
166504
```

REAL-TIME COMPUTE ON DATA STREAMS

In [6]:
```
import requests
import json
from dl import queryClient as qc
df0 = qc.query(sql=sql,fmt='pandas')
```

In [7]:
```
plt.figure(figsize=(8,8))
plt.xlim(-2,3)
plt.ylim(25,14)
plt.scatter(df0['g_r'],df0['mag_r'],marker='.',alpha=0.1)
#plt.scatter(dfhb0['g_r'],dfhb0['mag_r'],marker='.')
plt.scatter(locus_gr, locus_r,c='r')
```

Out[7]: <matplotlib.collections.PathCollection at 0x7f63a49794a8>



As an example, instead of looking at sources singly, you can write an SQL query as you might with SDSS CASJobs

Submit it to ANTARES, and get all matching objects from the real-time alert stream (NO WAITING FOR A DATA RELEASE!)

You can make plots like a CMD interactively to select outlying sources

This notebook is available here: https://github.com/broker-workshop/tutorials/blob/main/ANTARES/ExploringVariabilityWithANTARES.ipynb

REAL-TIME FOLLOWUP WITH TOMS

In [69]:
```
from antares_client.search import get_by_id, get_by_ztf_object_id
#get locus by ANTARES ID
locus = get_by_id("ANT2018c7igm")

#get locus by ZTF ID
#locus = get_by_ztf_id("ZTF18abhjrcf")

print(locus.locus_id, locus.ra, locus.dec)

import os
os.environ["DJANGO_ALLOW_ASYNC_UNSAFE"] = "true"
from tom_targets.models import Target
t = Target.objects.create(name=locus.locus_id, type='SIDEREAL', ra=locus.ra, dec=locus.dec)
```

```
ANT2018c7igm 280.6927190683333 -12.904117143333334
```

In [64]:
```
from tom_observations.facilities.lco import LCOFacility, LCOBaseObservationForm

target = Target.objects.get(name=locus.locus_id)

form = LCOBaseObservationForm({
    'name': 'Programmatic Observation',
    'proposal': 'TOM2020A-012',
    'ipp_value': 1.05,
    'start': '2020-10-09T00:00:00',
    'end': '2020-10-10T00:00:00',
    'filter': 'R',
    'instrument_type': '1M0-SCICAM-SINISTRO',
    'exposure_count': 1,
    'exposure_time': 20,
    'max_airmass': 4.0,
    'observation_mode': 'RAPID_RESPONSE',
    'target_id': target.id,
    'facility': 'LCO'
})
```

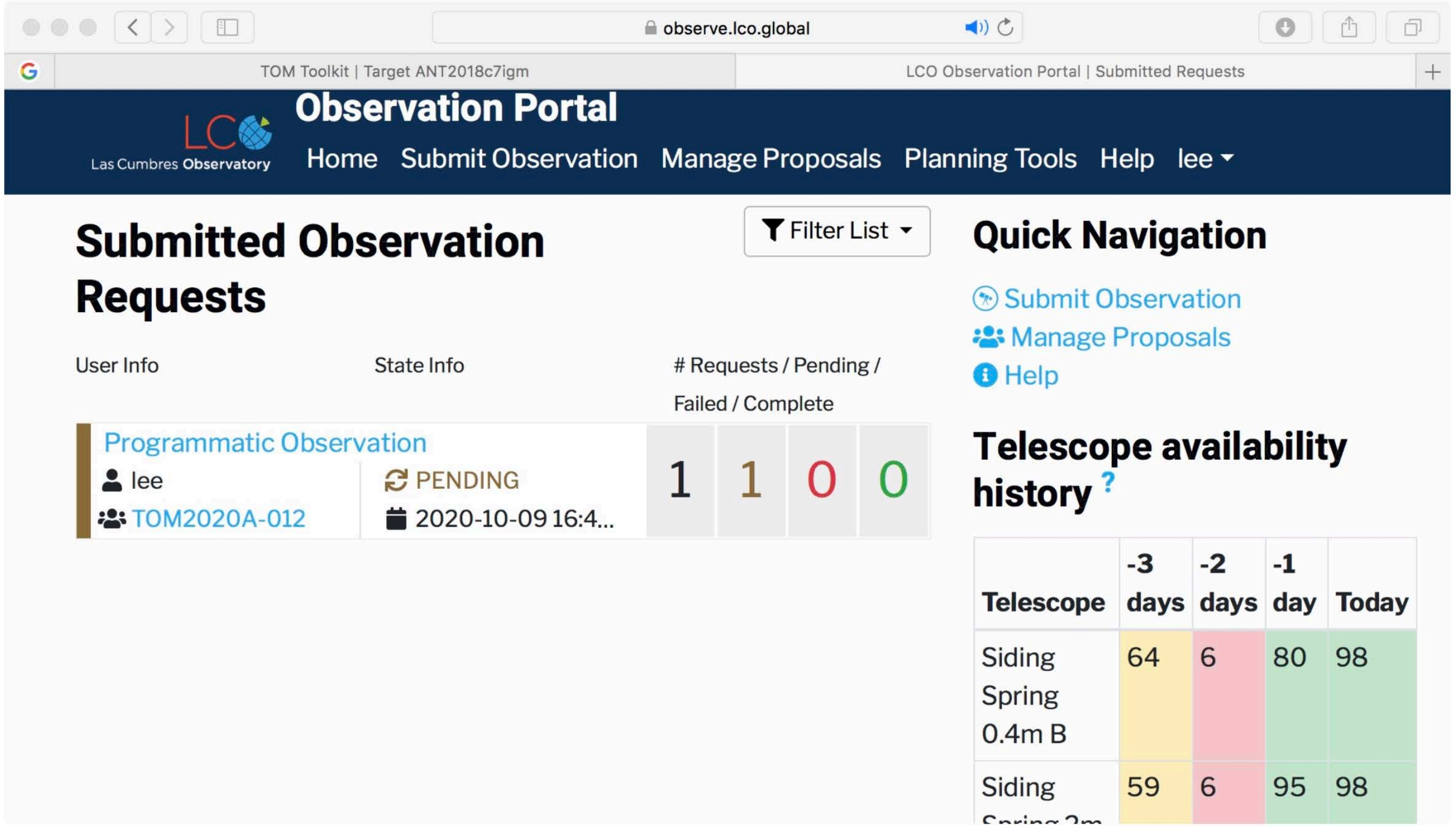
Convince a TAC to give you time

Find object of interest in the stream

Create a followup observation request and submit

This notebook is available here:
https://github.com/broker-workshop/tutorials/blob/main/ANTARES/ANTARES-TOM-AEON.ipynb

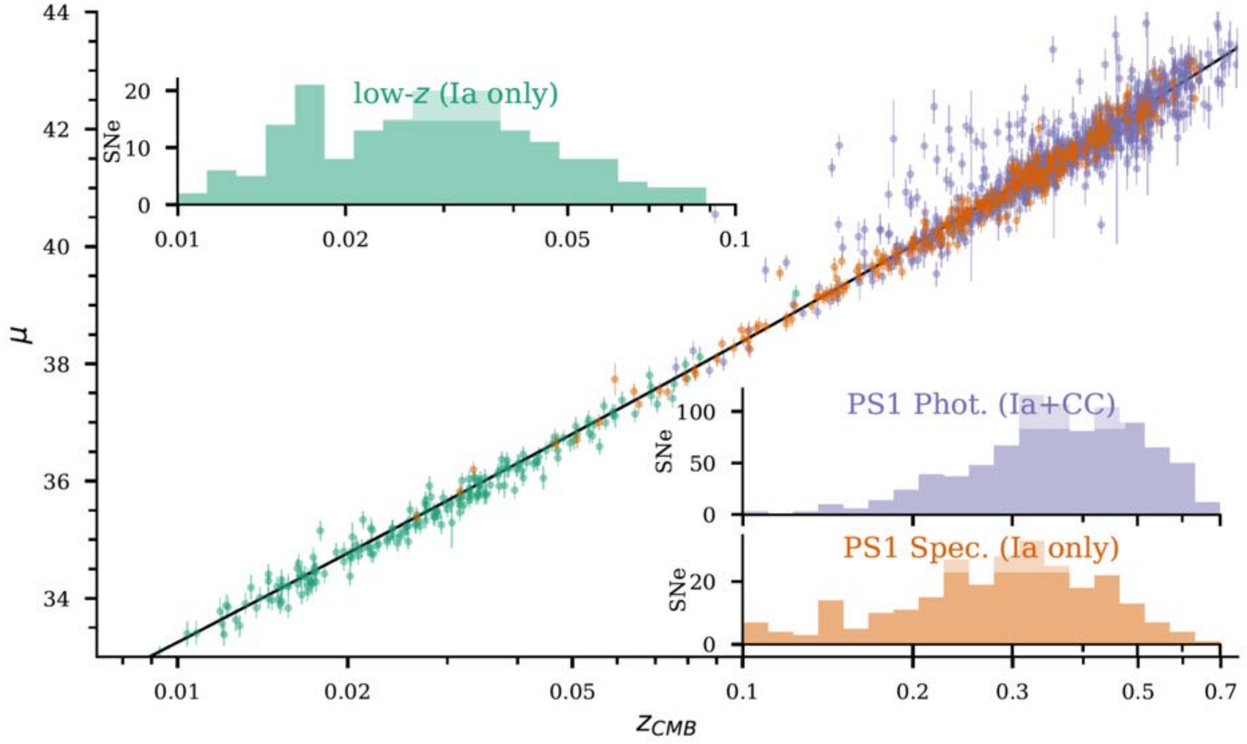
We can also see the observation request at the LCO observation portal:



Science Use Cases

Transients on Demand

- Common transients don’t all need follow up
- Targeted/scheduled programs can get transients as needed
- Filters can be flexibly scheduled to accommodate a variety of needs



Pan-STARRS Type Ia Supernovae, Jones et al. 2018

SN 2021pkt

RA/DEC (2000)	Type	Redshift
16:42:21.584 +57:04:06.18	**SN Ia**	**0.167**
250.58993258752503		
+57.0683840375256		

Discovery Report Classification Report

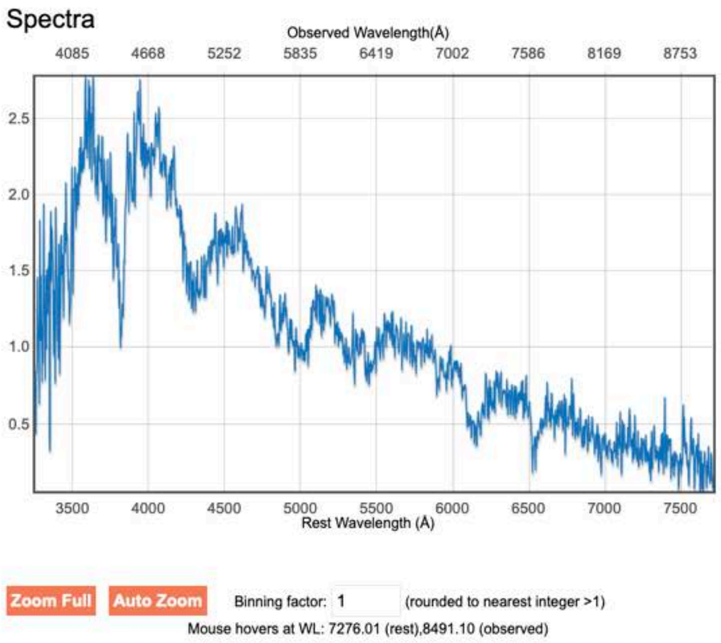
Reporting Group	Discovering Data Source	Discovery Date	TNS AT	Public	Discovery Mag
ANTARES	ZTF	2021-06-10 09:14:15.360	Y	Y	19.9404

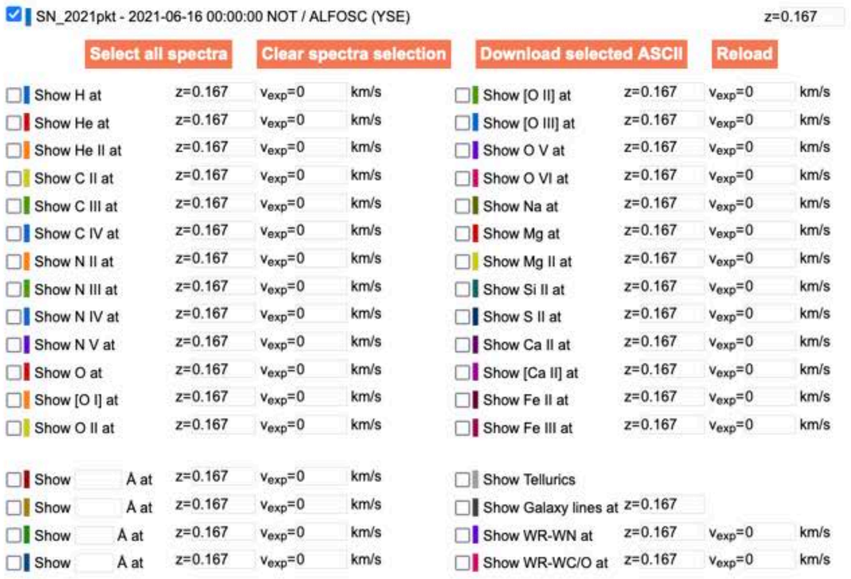
Filter
r-ZTF

Reporter/s
Patrick Aleo (UIUC), Chien-Hsiu Lee (NSF's NOIRLab), Konstantin Malanchev (UIUC), Thomas Matheson (NSF's NOIRLab), Gautham Narayan (UIUC), Abhijit Saha (NSF's NOIRLab), Carlos Scheidegger (U. Arizona), Adam Scott (NSF's NOIRLab), Monika Soraisam (UIUC), Carl Stubens (NSF's NOIRLab), Nicholas Wolf (NSF's NOIRLab)

NED | SIMBAD | DECaLS
PanSTARRS-1 | SkyMapper | VizieR
WISE | DSS | ADS

Patrick Aleo, Chien-Hsiu Lee, Konstantin Malanchev





The Python Client + TOMs integration means you can roll a full real-time followup pipeline easily

- Find an interesting source in CTA data
- Send it out in your alert stream
- Use the client to see if it is associated with anything in optical or gets tagged if it passes your filter criterion
- Report to TNS automatically
- Use TOM Toolkit to schedule followup https://www.wis-tns.org/object/2021pkt

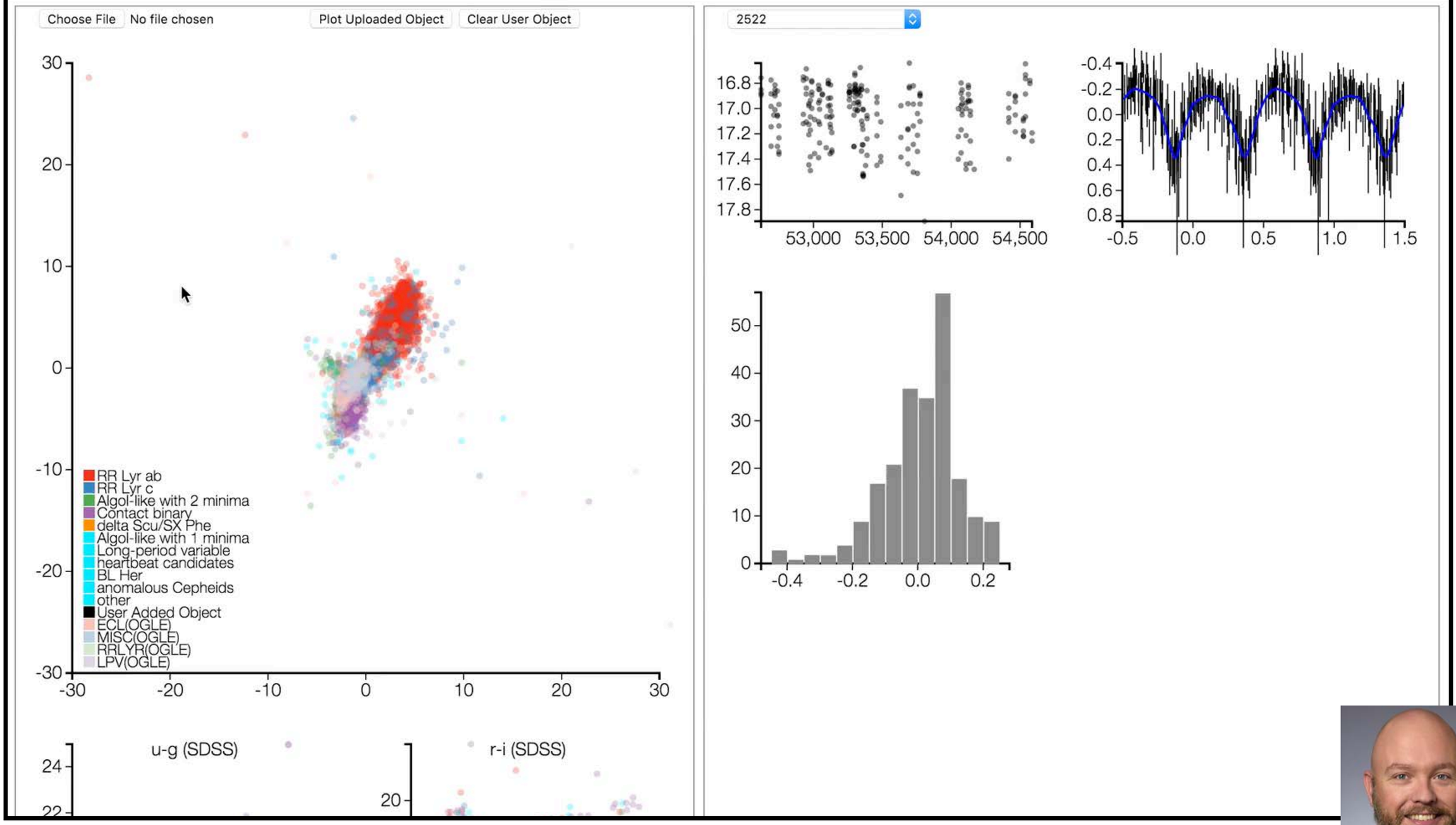
HOW CTA CAN ENGAGE 2-4:

IF YOU HAVE A CATALOG OF SOURCES ALREADY, YOU CAN START MONITORING THEM IN OTHER BANDS ALREADY

PATHFINDER FACILITIES ARE GREAT SOURCES OF ALERTS FOR TESTING! REACH OUT TO ANTARES IF YOU WANT TO PUBLISH THEM!

SCIENCE USE CASES IMPLICITLY DEFINE FILTERS – WE CAN HELP DEVELOP THEM!

3. USING BROKERS TO OPTIMIZE SURVEYS



ML FOR CLASSIFYING SOURCES

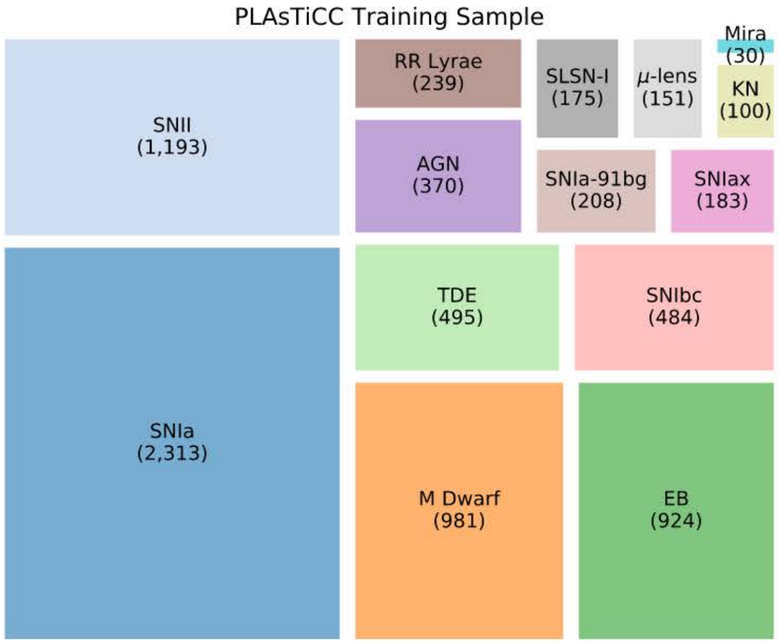
If you are looking at the slides PDF, this video can be found at: https://www.youtube.com/watch?v=jgO0JU_l5-s

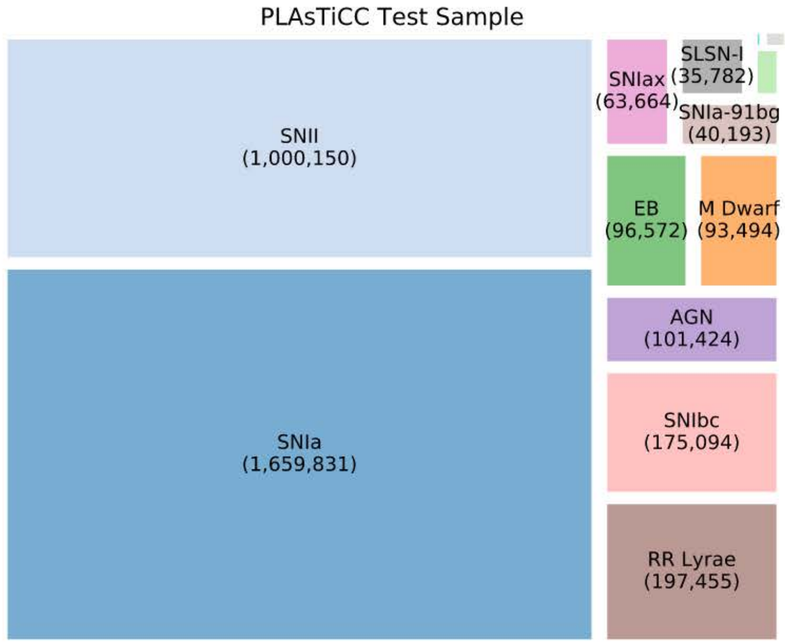
Carlos Scheidegger

PLAsTiCC Version 1 (Dec. 2018 - Feb 2019)

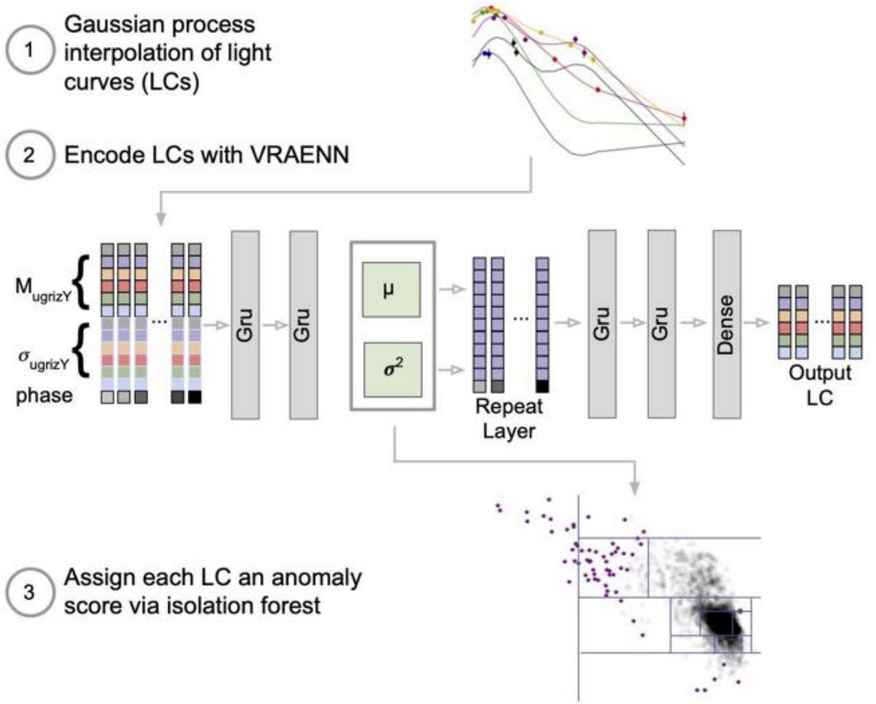
- Public $25k Kaggle challenge for photometric classification of time-domain sky (15 models, 1 million new SEDs, unrepresentative training sample)
- Data: 3M VRO-simulated *ugrizY* lightcurves
- Primary goal: setup massive time-domain simulation infrastructure, **jump start ML photometric classification efforts**

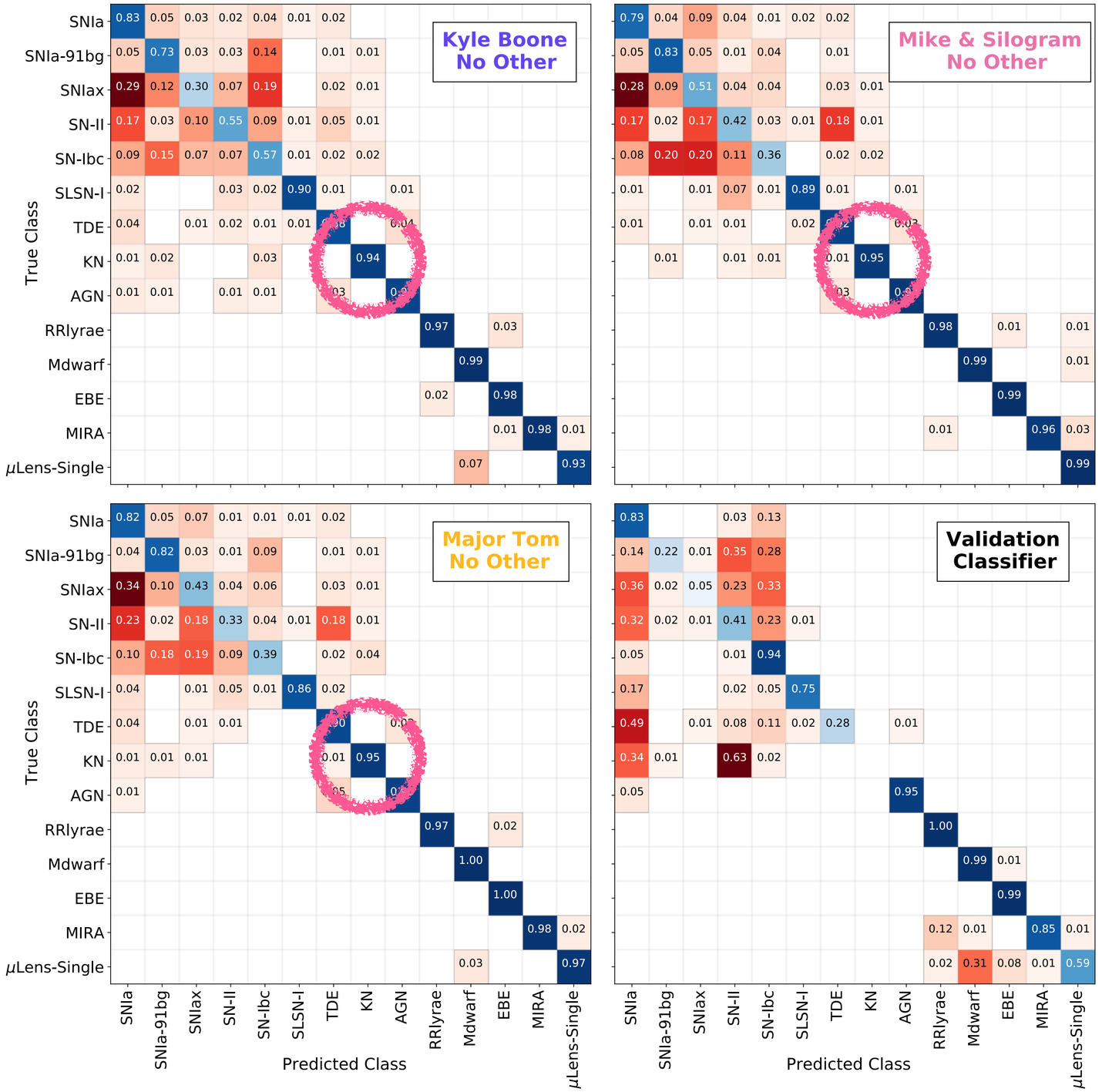
(Villar+2021)





(Hložek+2020)





- If you believe the outcome of PLAsTiCC, then MMA source discovery will not be a problem!
- <Narrator>: But it will be a problem!
- LSST Cadence has a median intranight gap of ~4 days across all filters, and ~10 days in any single filter
- Classifiers only as good as their training data and their loss function.

(Some known) shortcomings of v1

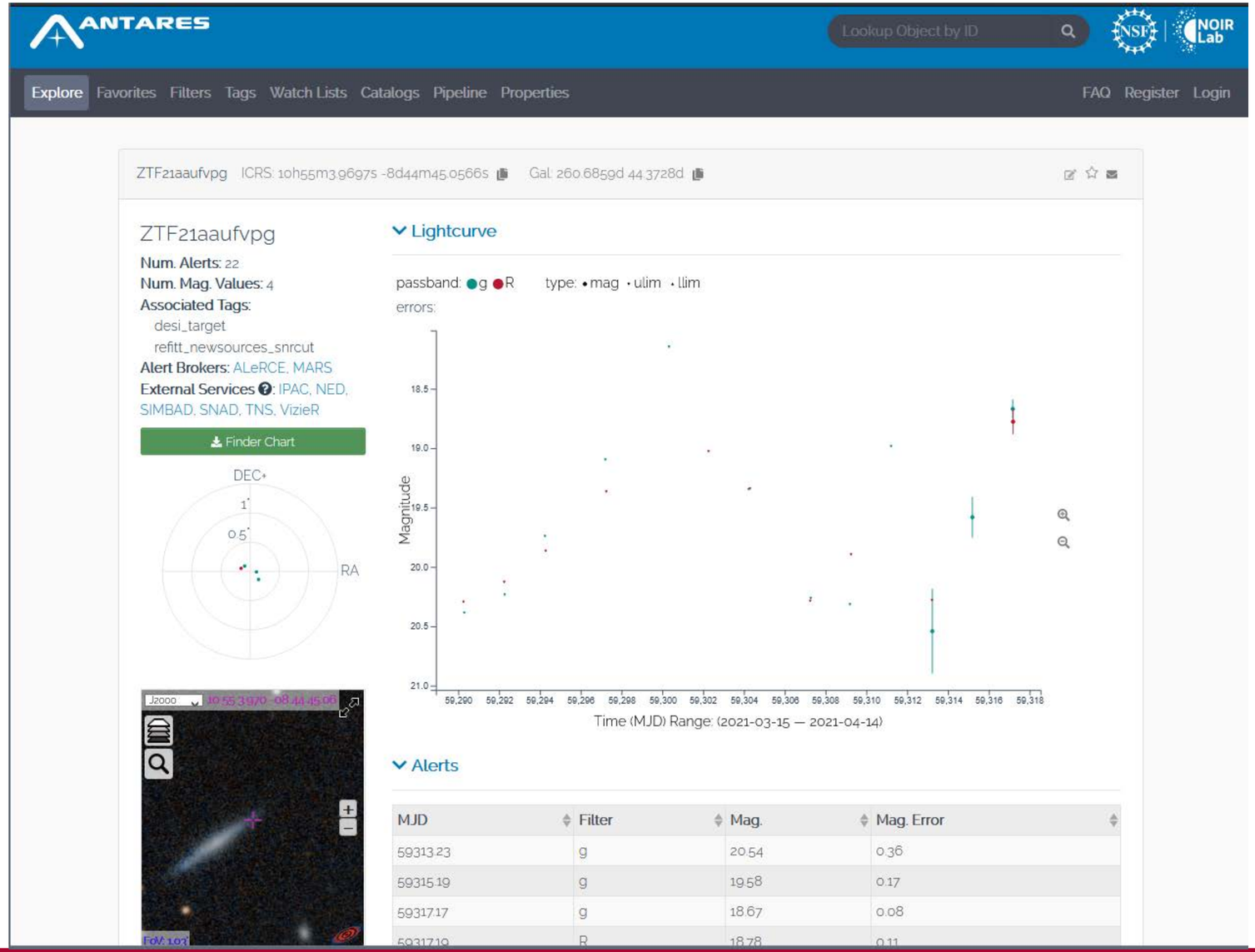
What tells you that 21jap at right is real?

Simply, flat light curves with full phase coverage aren't a realistic model for how the science collaborations will interact with LSST data

No host galaxy information, postage stamps, or alerts

Surveys cannot afford to act independently

http://antares.noirlab.edu/



Goal for PLAsTiCC v2 (~September 2021)

To evaluate real-time Broker performance on a realistic LSST alert stream.*

Broker Roles

- Storing, processing, classifying alerts, informing follow-up
- *Potential additional roles:*
  - Collecting active source features
  - Maintaining source databases

Alert Stream

- Set of simulated LSST-like alert packets
- must preserve environmental correlations
- Should contain a representative sample of expected events

VERIFICATION

VALIDATION

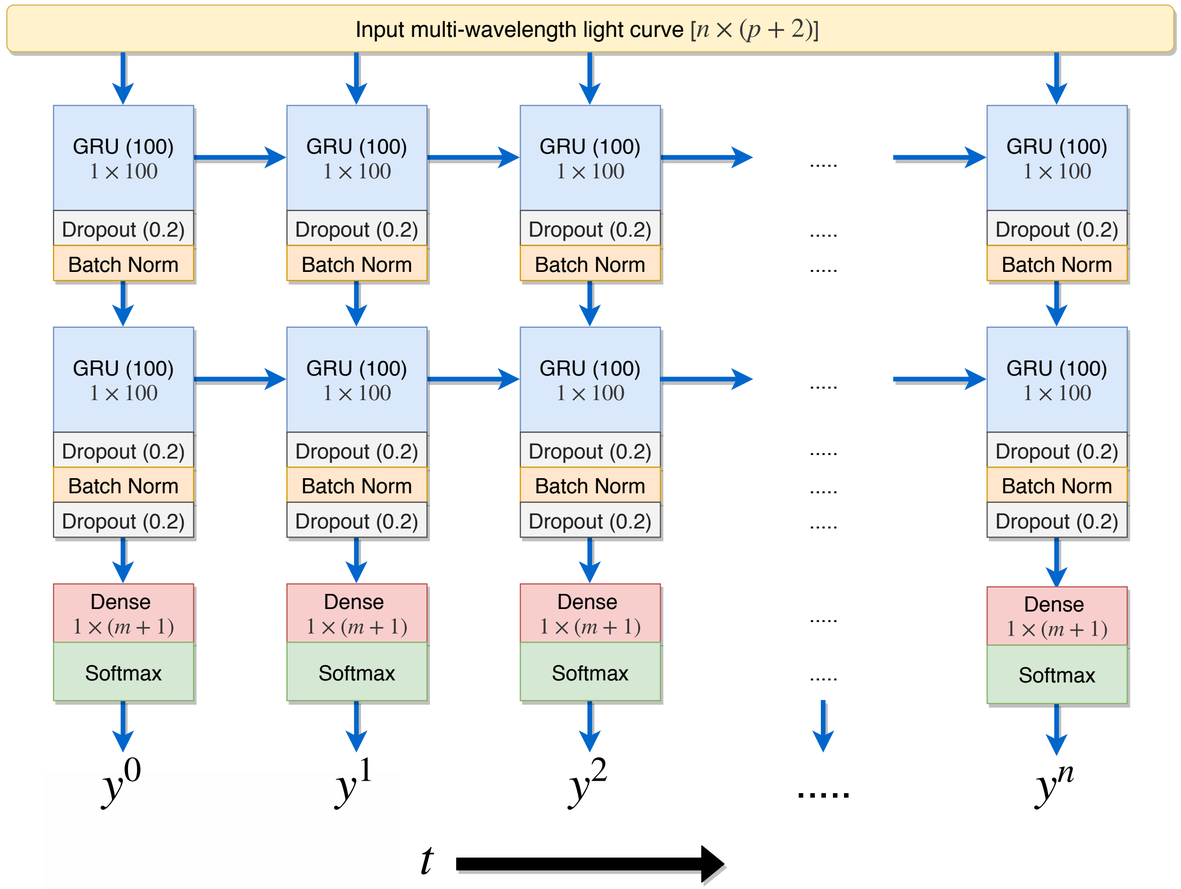
Iterative process to ensure compatibility between brokers and alert stream.

**metrics in progress!*

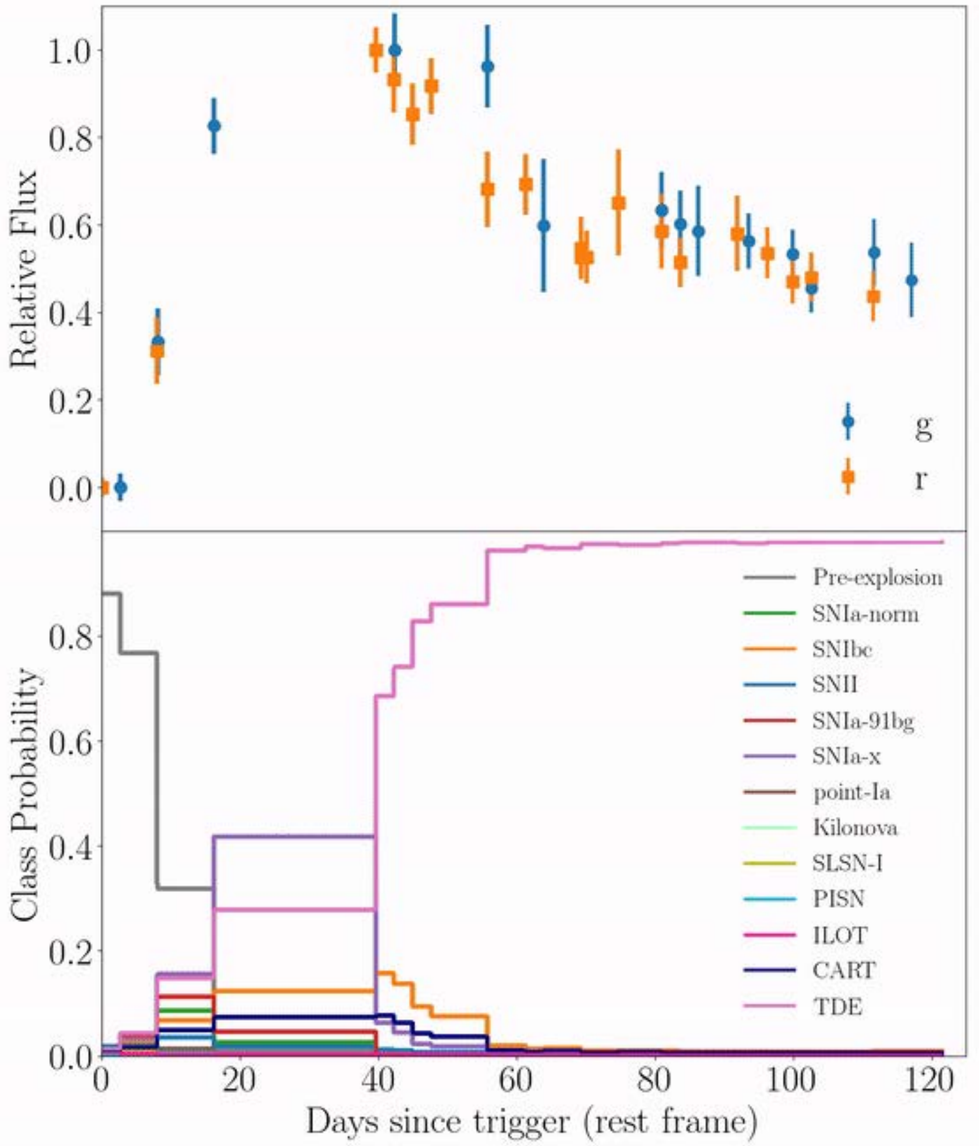
RAPID: REAL-TIME AUTOMATED PHOTOMETRIC IDENTIFICATION

=

DEEP LEARNING TO IDENTIFY TRANSIENTS EARLY!



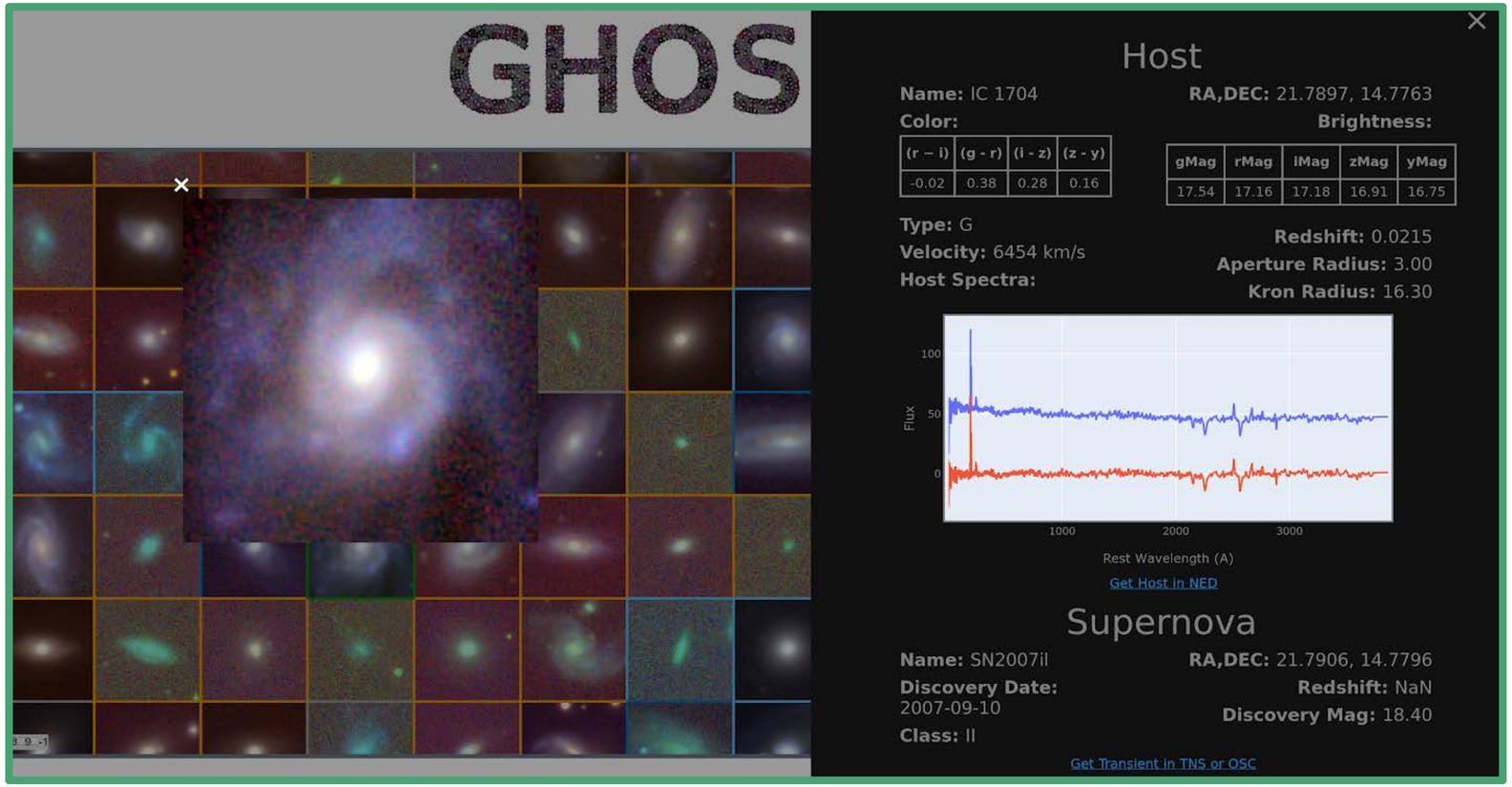
Dr. Daniel Muthukrishna (Cambridge)
uses the same tech in predictive text to predict light curve behavior

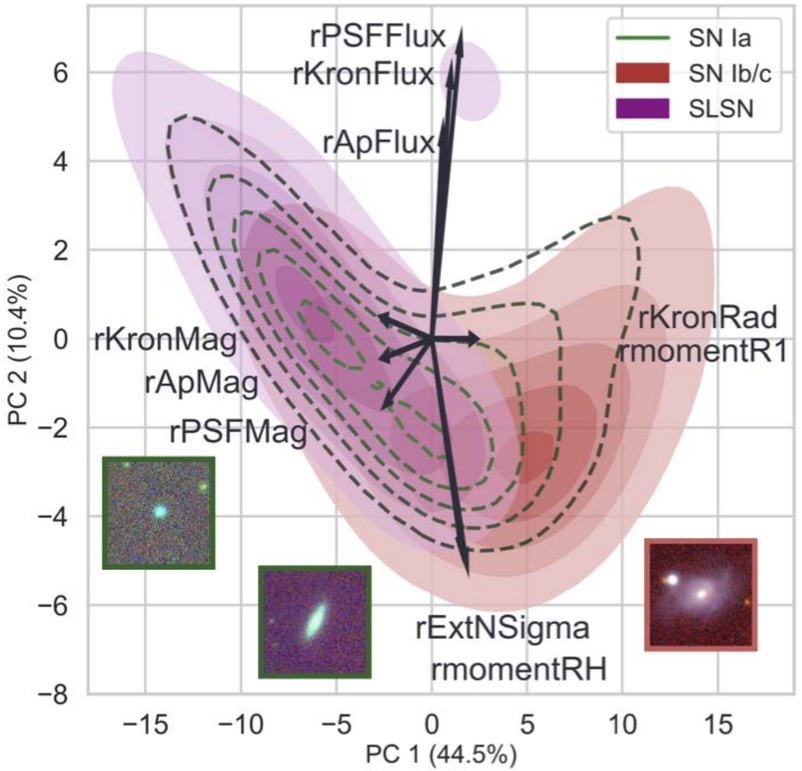


GHOST

Galaxies **HO**sting **S**upernovae and other **T**ransients

Alex Gagliano (UIUC, NSF Fellow) figures out correlations between transients and their hosts *http://ghost.rubin.science/*





(Gagliano+2021)

- 16,228 SNe-host galaxy pairs: 78% of unique events reported on TNS/OSC.
- PS1,NED photometric & derived properties (color, redshift, radial moments)

v2: Simulating Transients & Hosts

Pre-processing *Simulation* *Validation*

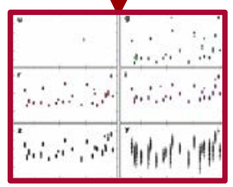
GHOST
16.5k SNe, host galaxies
arXiv:2008.09630
Gagliano+2021

cosmoDC2
DESC Synthetic Sky Catalog
arXiv:1907.06530
Korytov+2019

SNANA
Simulated transient photometry (with host galaxy properties)
arXiv:0908.4280
Kessler+2009

EmpiriciSN
Simulated transient parameters
arXiv:1611.00363
Holoien+2016

LIGO
Localized Event Skymaps
D. Chatterjee



(Oluseyi+2012)

(Abolfathi+2021)

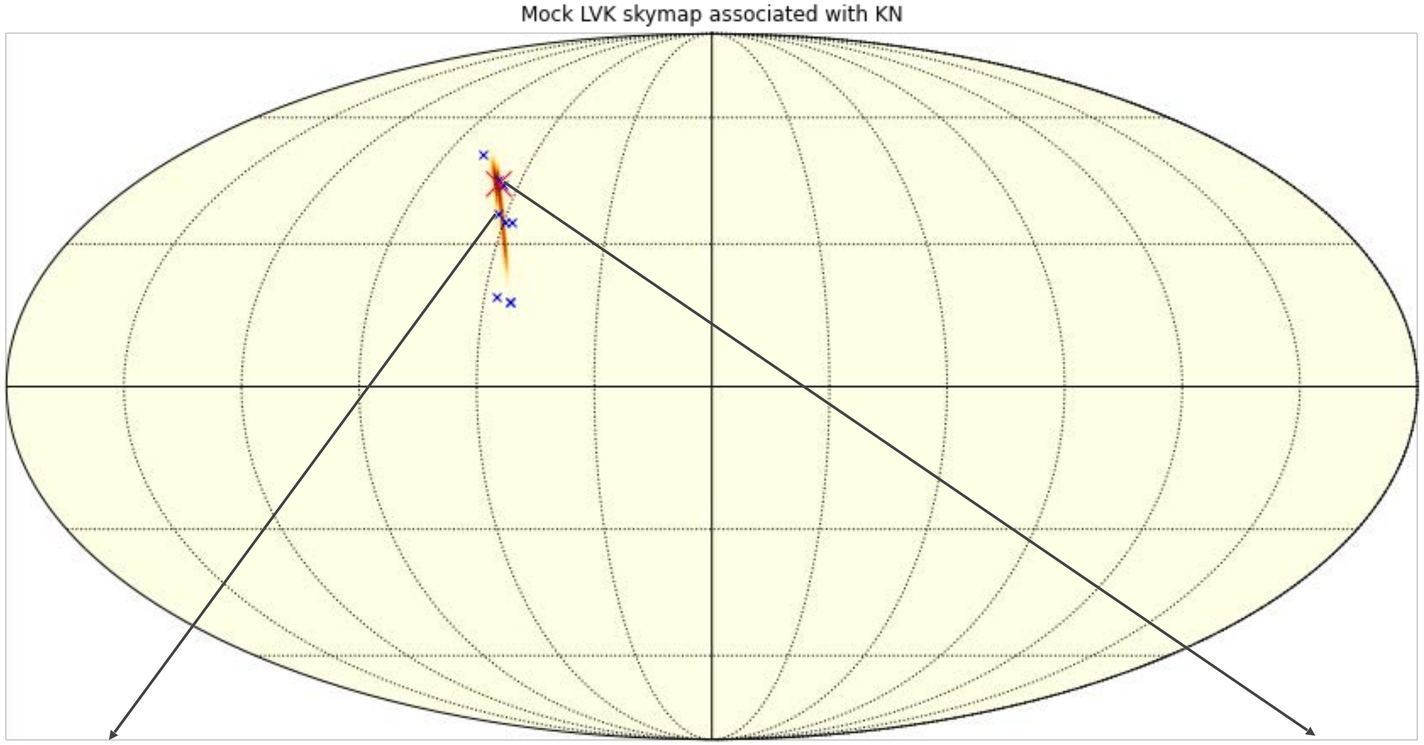
Brokers

- ANTARES
- Pitt - Google
- ALeRCE
- LASAIR
- Fink
- AMPEL
- MARS
- INAF broker
- Fritz
- Babamul
- South African broker team
- NYU Anomalies
- SNAPS
- UW Genesis

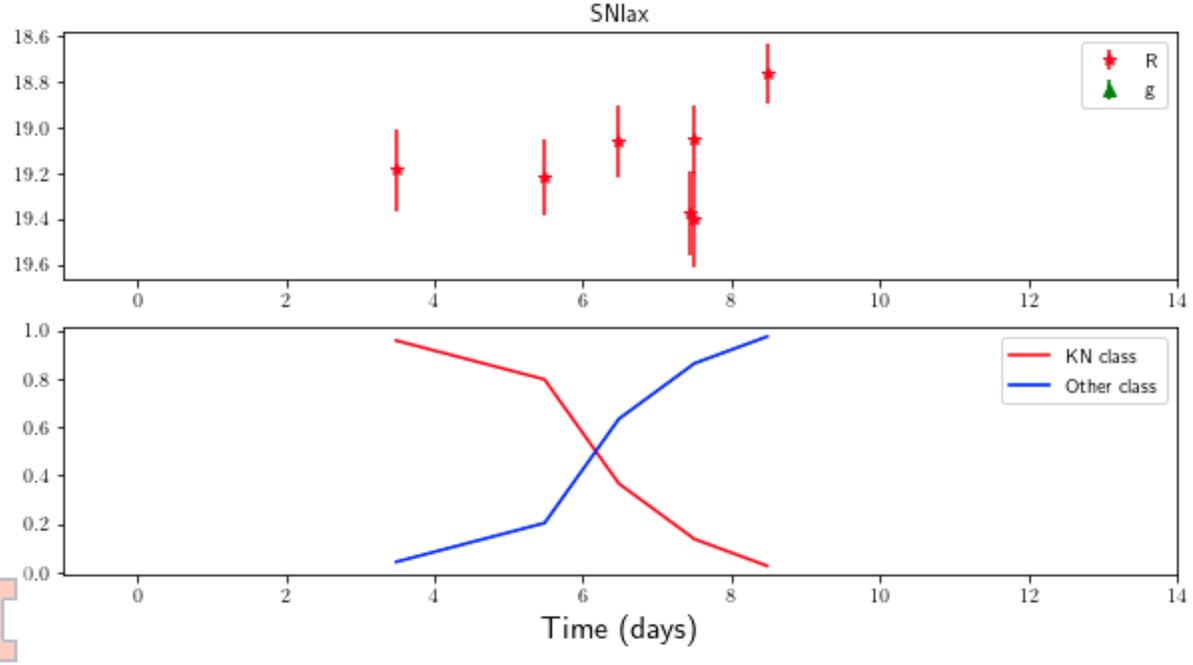
v2 Alert Stream

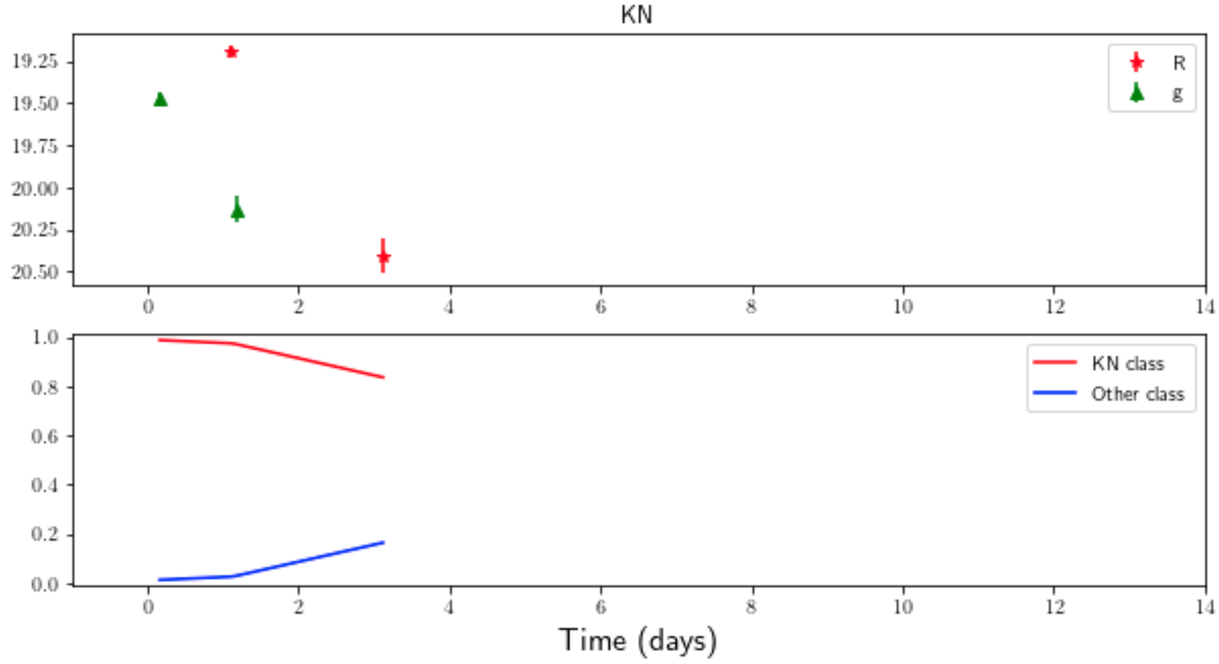
El-Cid

Electromagnetic Counterpart Identification

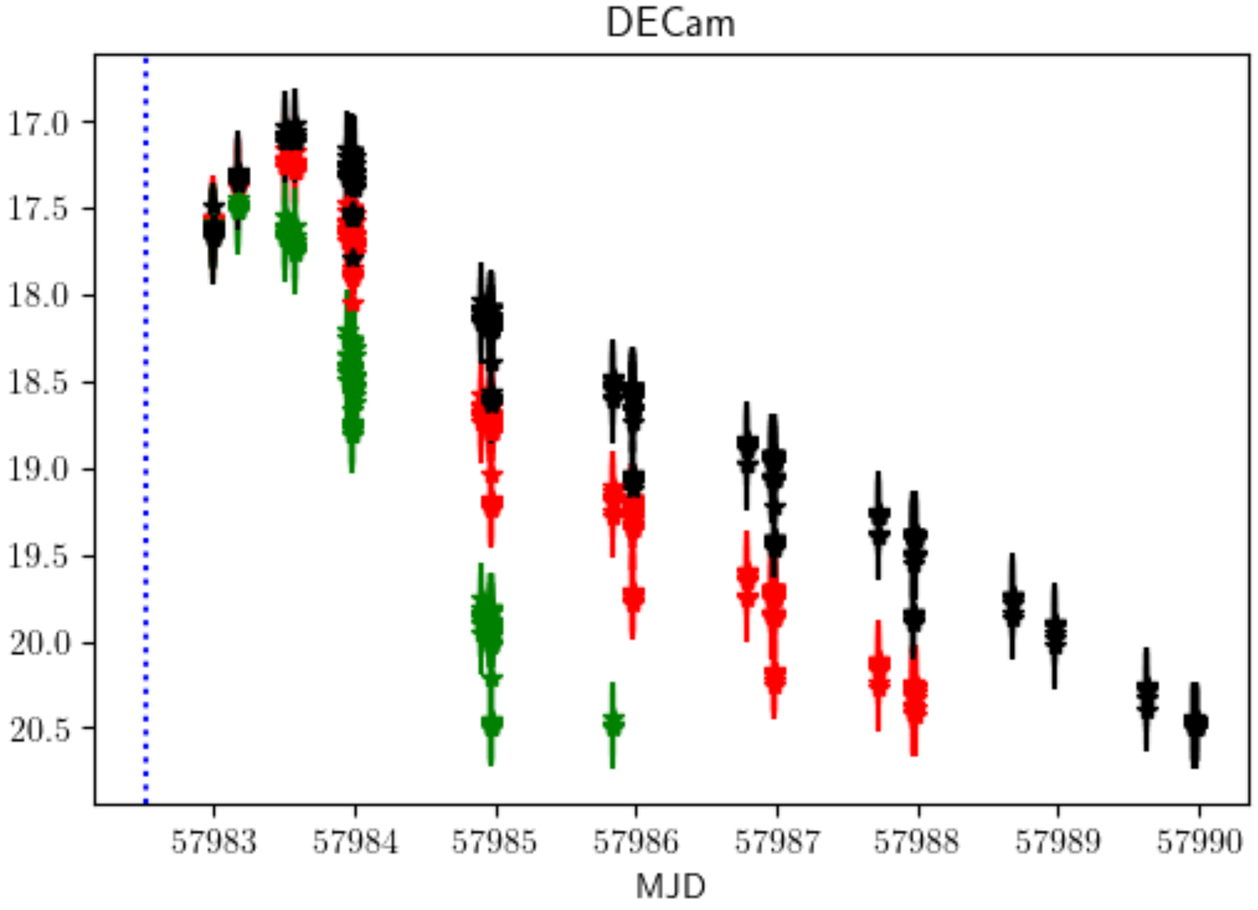


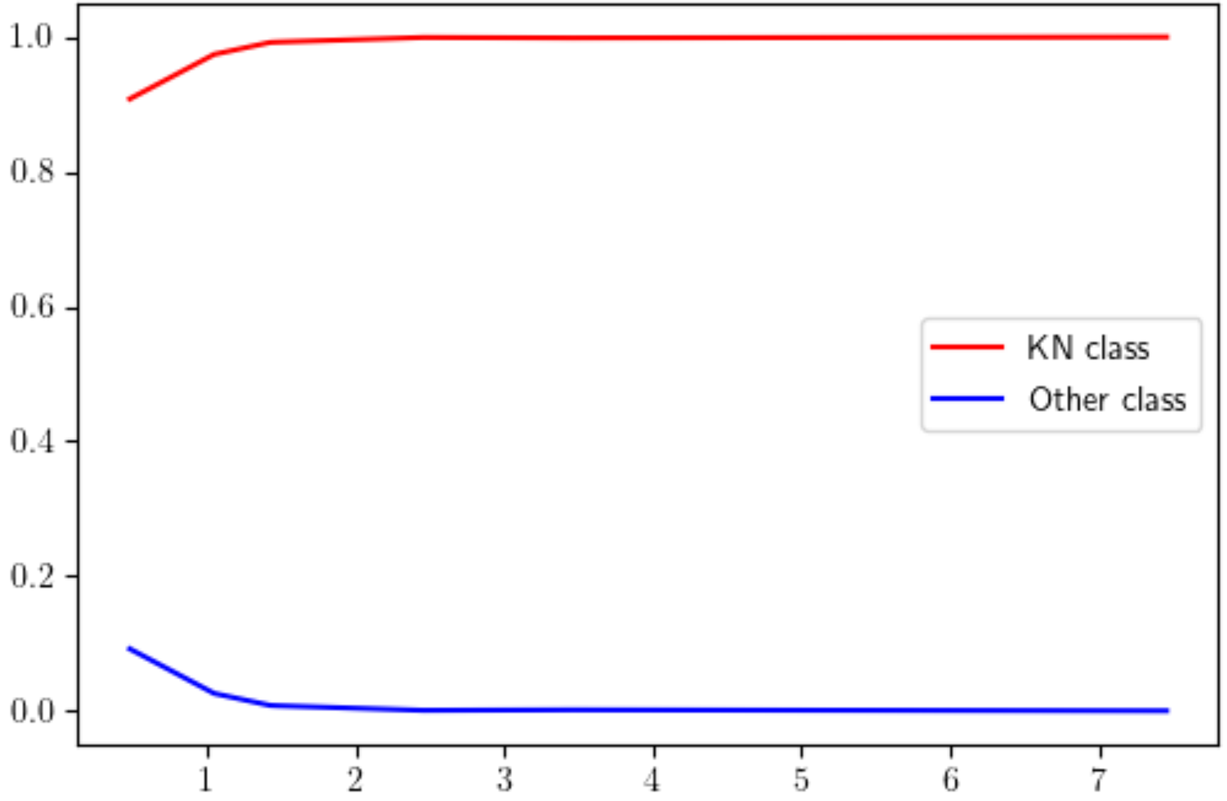
Deep Chatterjee (UIUC, Illinois Survey Science Fellow, LVK EM Followup Team)





Performance on GW170817





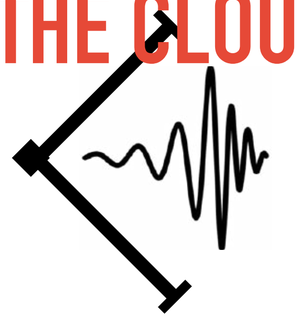
HOW CTA CAN ENGAGE 5:

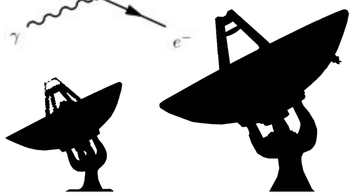
EVERY SURVEY CREATES LARGE SIMULATIONS OF WHAT THEY EXPECT TO SEE TO TEST SURVEY DESIGN

THIS NEED NOT BE JUST INFRASTRUCTURE WORK, AND CAN REALLY ENGAGE THE COMMUNITY SCIENTIFICALLY – E.G. PLASTICC

PLASTICC V2 ALREADY INCLUDES LVK AND LSST. V3 COULD HAVE THE CTA SKY
WE'D LOVE TO WORK WITH YOU!

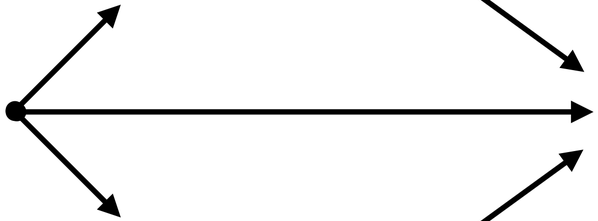
RESEARCH PLATFORMS IN THE CLOUD ARE COMING





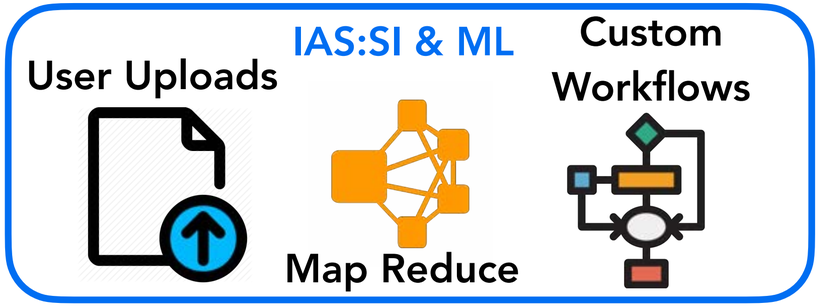
Observatories & Surveys

External Databases & Archives

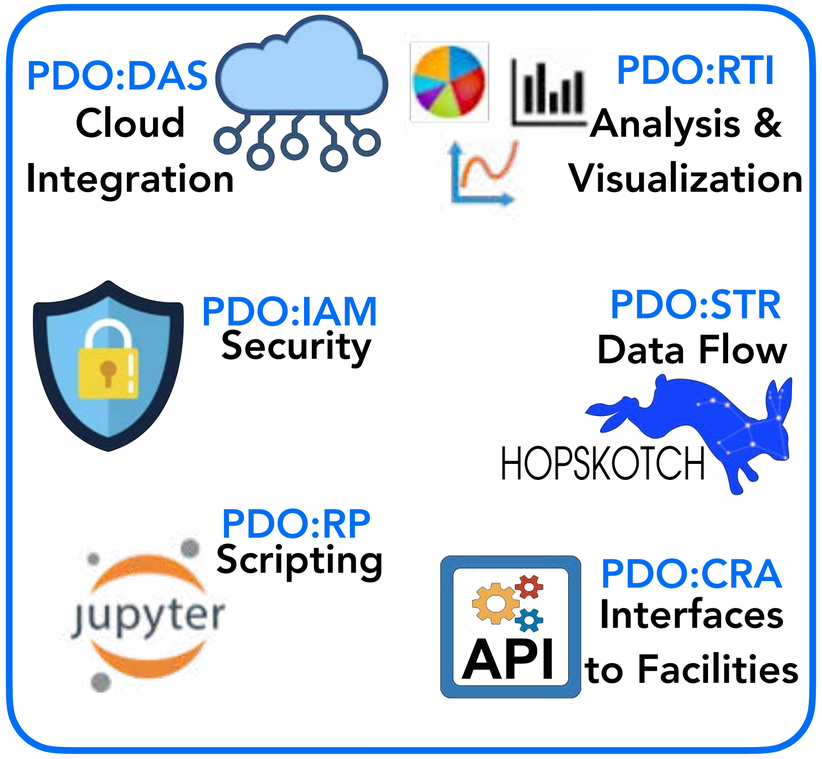


Streaming & Filtering

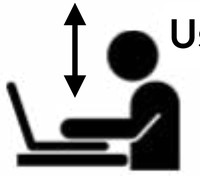
Live Alerts & Notifications



Innovative Algorithms & Systems Research

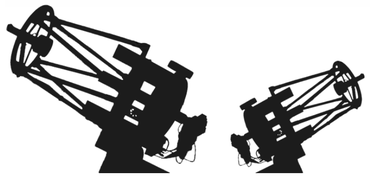


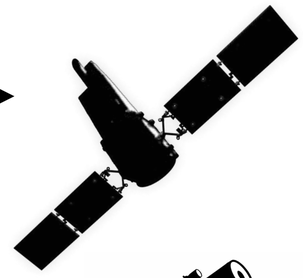
Platform Development & Operations



User Interface

Sharing





Reactive Realtime Followup

- LSST and CTA both build on current-generation surveys to discovery many new sources
- Maximizing scientific utility from these experiments requires providing data in real-time
  - Get away from just the concept of an archive with periodic data releases!
- Alert brokers are a key tool for this and give the community ways to search, characterize, filter, and follow-up events
  - They enable machine learning in real-time for astrophysical surveys
- There are already de facto standards for alert format and systems to stream them, as well as existing brokers - you don't have to start from zero!!!
  - As CTA builds out it's pipeline, and creates simulations for survey design, interact with broker teams and the scientific community and define interesting questions that also spur infrastructure development
- The best science will come from combining real-time streams from several experiments - challenge but also a tremendous opportunity