



ALeRCE
Automatic Learning for the
Rapid Classification of Events



The ALeRCE Broker



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<http://alerce.science/>

CMM
Center for
Mathematical
Modeling

**INSTITUTO
MILENIO DE
ASTROFÍSICA**

DO
DATA OBSERVATORY



REUNA
Ciencia y Educación en Red

aws

NLHPC
National Laboratory
for High Performance
Computing
Chile





ALeRCE is a Chilean-led broker officially selected as one of the Community Brokers for the Vera Rubin Observatory and its Legacy Survey of Space and Time (LSST).

Presentation paper: Förster et al. 2021, AJ; Stamp classifier: Carrasco-Davis et al. 2021, AJ; Light curve classifier: Sánchez-Sáez et al. 2021, AJ



Future time domain astronomy ecosystem

Survey telescopes



Low-latency!

Alert brokers/TOMs



+ other brokers/TOMs



Follow up telescopes



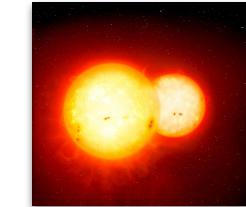


Science cases



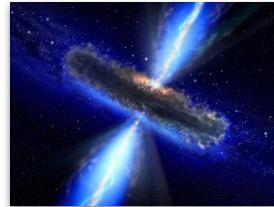
Transients

Progenitors of stellar explosions (outermost layers) & explosion physics (ejecta structure).



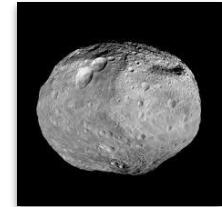
Variable stars

Microlensing events, changing mode stellar pulsators, rapid reaction to eclipsing events, eruptive events.



Supermassive black holes

Changing state AGNs, reverberation mapping, detection of intermediate mass black holes, tidal disruption events.



Asteroids

Near earth objects, size distribution, collisional or rotational disintegration.

How does the Universe expand?

How is matter distributed in our galaxy?

How do black holes affect the evolution of galaxies?

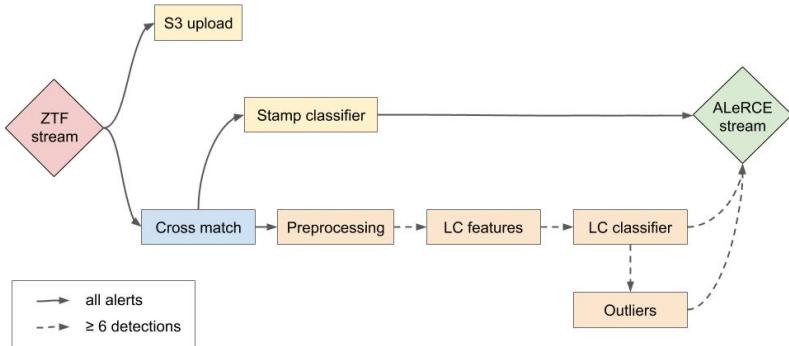
How was the solar system formed?



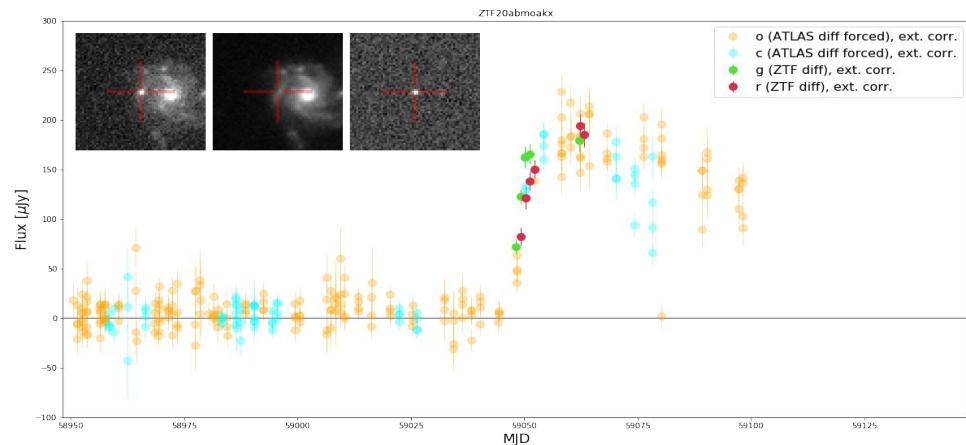
ALeRCE highlights

Ingesting the ZTF alert stream since early 2019.

Bridging ZTF - ATLAS: Collaboration with ATLAS and Lasair, building **multi-stream broker**



Modular pipeline in AWS, using Docker containers and scaling with Kubernetes.



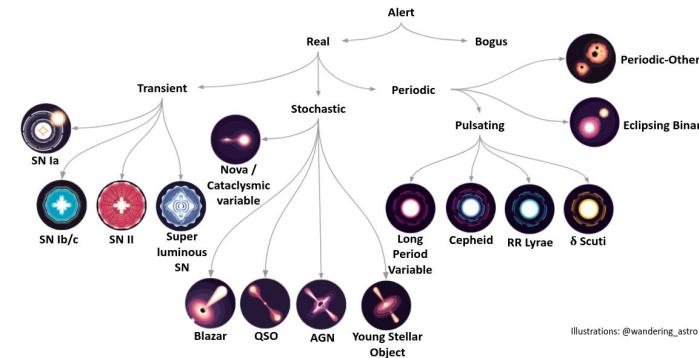


ALeRCE classifiers

Two machine learning classifiers:

Stamp based (Carrasco-Davis+2021) (fraction of a sec.)

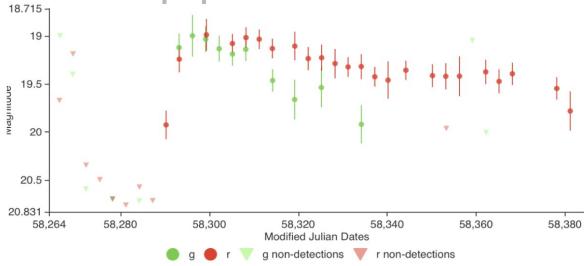
Light curve based (Sánchez-Sáez+2021) (few tens of secs.)



Illustrations: @wandering_astro

Light curve classifier

Stamp classifier



Stamp class.

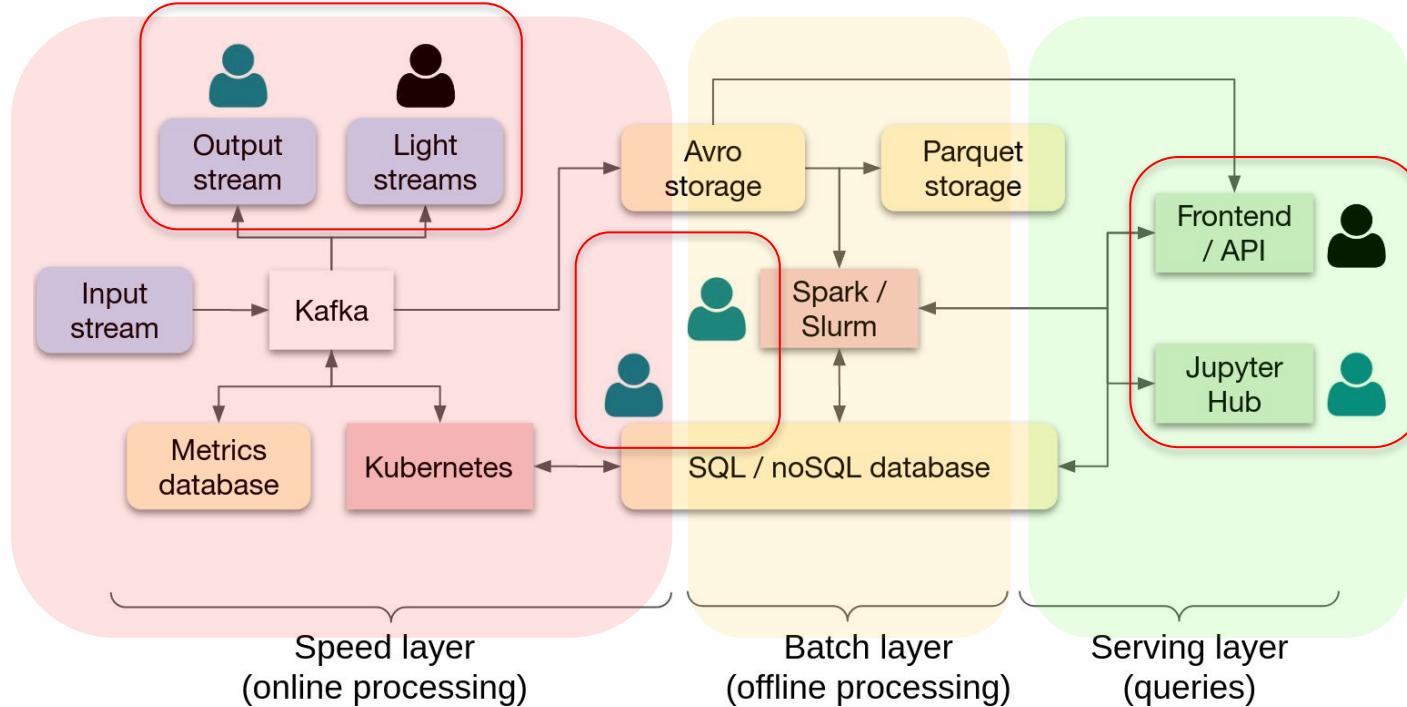
Normalized confusion matrix Acc 0.9223					
	AGN	SN	VS	asteroid	bogus
True label	0.90	0.02	0.08	0.00	0.00
AGN	0.90	0.02	0.08	0.00	0.00
SN	0.03	0.94	0.01	0.02	0.00
VS	0.09	0.00	0.90	0.00	0.00
asteroid	0.00	0.02	0.00	0.96	0.01
bogus	0.00	0.00	0.02	0.00	0.97

	SNIA	SNIbc	SNII	SLSN	QSO	AGN	Blazar	YSO	CV/Nova	LPV	E	DSCT	RRL	CEP	Periodic-Other	SNIA	SNIbc	SNII	SLSN	QSO	AGN	Blazar	YSO	CV/Nova	LPV	E	DSCT	RRL	CEP	Periodic-Other
SNIA	76 ⁺¹ ₋₆	18 ⁺¹ ₋₆	5 ⁺² ₋₂	1 ⁺¹ ₋₁	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	76 ⁺¹ ₋₆	18 ⁺¹ ₋₆	5 ⁺² ₋₂	1 ⁺¹ ₋₁	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀
SNIbc	33 ⁺¹¹ ₋₁₁	50 ⁺⁶ ₋₆	11 ⁺¹ ₋₁	6 ⁺⁴ ₋₄	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	33 ⁺¹¹ ₋₁₁	50 ⁺⁶ ₋₆	11 ⁺¹ ₋₁	6 ⁺⁴ ₋₄	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀
SNII	15 ⁺² ₋₂	16 ⁺³ ₋₃	53 ⁺³ ₋₃	17 ⁺² ₋₂	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	15 ⁺² ₋₂	16 ⁺³ ₋₃	53 ⁺³ ₋₃	17 ⁺² ₋₂	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀
SLSN	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	100 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀				
QSO	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	87 ⁺¹ ₋₁	8 ⁺¹ ₋₁	5 ⁺¹ ₋₁	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀			
AGN	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	9 ⁺¹ ₋₁	85 ⁺³ ₋₃	5 ⁺¹ ₋₁	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀			
Blazar	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	17 ⁺² ₋₂	7 ⁺¹ ₋₁	74 ⁺³ ₋₃	1 ⁺¹ ₋₁	1 ⁺¹ ₋₁	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	17 ⁺² ₋₂	7 ⁺¹ ₋₁	74 ⁺³ ₋₃	1 ⁺¹ ₋₁	1 ⁺¹ ₋₁	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀
YSO	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	1 ⁺⁰ ₋₀	1 ⁺⁰ ₋₀	1 ⁺⁰ ₋₀	78 ⁺³ ₋₃	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	4 ⁺¹ ₋₁	1 ⁺¹ ₋₁	0 ⁺⁰ ₋₀	1 ⁺¹ ₋₁	1 ⁺¹ ₋₁	68 ⁺² ₋₂	1 ⁺¹ ₋₁	3 ⁺² ₋₂	4 ⁺² ₋₂	10 ⁺³ ₋₃	2 ⁺² ₋₂	11 ⁺² ₋₂			
CV/Nova	4 ⁺³ ₋₃	2 ⁺¹ ₋₁	1 ⁺¹ ₋₁	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	1 ⁺¹ ₋₁	1 ⁺¹ ₋₁	1 ⁺¹ ₋₁	68 ⁺² ₋₂	1 ⁺¹ ₋₁	3 ⁺² ₋₂	4 ⁺² ₋₂	10 ⁺³ ₋₃	1 ⁺¹ ₋₁	3 ⁺² ₋₂	4 ⁺² ₋₂	10 ⁺³ ₋₃	2 ⁺² ₋₂	11 ⁺² ₋₂	3 ⁺² ₋₂	4 ⁺² ₋₂	10 ⁺³ ₋₃	2 ⁺² ₋₂	11 ⁺² ₋₂				
LPV	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	1 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	98 ⁺⁶ ₋₆	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀					
E	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	74 ⁺⁵ ₋₅	7 ⁺¹ ₋₁	3 ⁺² ₋₂	4 ⁺² ₋₂	4 ⁺² ₋₂	12 ⁺² ₋₂					
DSCT	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	5 ⁺² ₋₂	89 ⁺³ ₋₃	2 ⁺¹ ₋₁	1 ⁺¹ ₋₁	1 ⁺¹ ₋₁	3 ⁺² ₋₂	3 ⁺² ₋₂	73 ⁺² ₋₂			
RRL	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀				
CEP	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀				
Periodic-Other	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	0 ⁺⁰ ₋₀	2 ⁺¹ ₋₁	11 ⁺² ₋₂	3 ⁺² ₋₂	1 ⁺¹ ₋₁	11 ⁺² ₋₂	7 ⁺¹ ₋₁	76 ⁺³ ₋₃	9 ⁺¹ ₋₁	73 ⁺² ₋₂						

Confusion matrices of the ALeRCE classifiers



Vera C. Rubin architecture



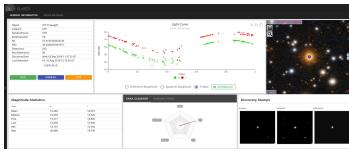
All users
Power users



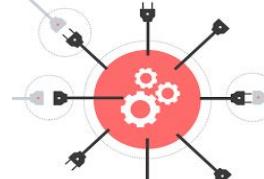


ALeRCE tools and services

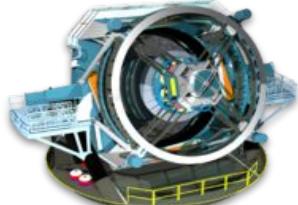
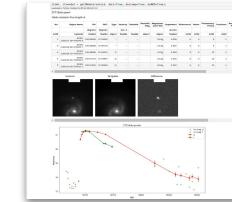
Web Interfaces



API / Python client



Jupyter Notebooks



ALeRCE
Automatic Learning for the
Rapid Classification of Events

<http://alerce.science>

Output
stream
(real-time follow-up)



TOMs



ALeRCE Explorer



<https://alerce.online/>



ALeRCE SN Hunter

The screenshot shows the ATLAS Early Detection interface. At the top, there's a navigation bar with tabs for "ATLAS", "SN Hosts", "SN Images", and "Data". Below the navigation bar, a message box says "16 Candidate Pdcs Detected in past week". The main content area features a large image of a galaxy with a bright central region, identified as "ZTF21acpoujw". Below this image are several buttons: "Discover", "View", "Edit", and "Details". To the right of the image is a "Discovery Stamp" section with three panels: "Discovery", "Composite", and "Difference". A "Details" button is located below these panels. On the far left, there's a circular inset image of a spiral galaxy. At the bottom, there's a table titled "Top 100 SN Early Classified Candidates" with columns for "Rank", "Name", "Discovery Date", and "Host". The table lists several entries, with the first one highlighted in grey.

Rank	Name	Discovery Date	Host
1	ZTF21acpoujw	2021-08-10T00:00:00Z	NGC 1097
2	ZTF21abvqkz	2021-08-09T00:00:00Z	UGC 00000
3	ZTF21ajyqjw	2021-08-08T00:00:00Z	UGC 00000
4	ZTF21ajyqjw	2021-08-08T00:00:00Z	UGC 00000
5	ZTF21ajyqjw	2021-08-08T00:00:00Z	UGC 00000
6	ZTF21ajyqjw	2021-08-08T00:00:00Z	UGC 00000
7	ZTF21ajyqjw	2021-08-08T00:00:00Z	UGC 00000
8	ZTF21ajyqjw	2021-08-08T00:00:00Z	UGC 00000
9	ZTF21ajyqjw	2021-08-08T00:00:00Z	UGC 00000
10	ZTF21ajyqjw	2021-08-08T00:00:00Z	UGC 00000



New features

The screenshot shows the Alerce Watchlist interface. At the top, there's a header with the Alerce logo, user information, and navigation links for 'WATCHLIST', 'OVERVIEW', and 'SETTINGS'. Below this is a section titled 'My Watchlists' with a dropdown menu. The main area is titled 'Targets' and lists three entries:

Name	RA	Dec	Filter	Period	Action
ZTF1/soodit	123.023098	44.774897	r	1.5	<input type="checkbox"/> <input checked="" type="checkbox"/>
ZTF1/soogit	168.211754	16.241882	r	1.5	<input type="checkbox"/> <input checked="" type="checkbox"/>
ZTF1/sooda	1.886763	-19.793493	r	1.5	<input type="checkbox"/> <input checked="" type="checkbox"/>

At the bottom right of the targets table is a blue button labeled 'NEW TARGETS'.

Simple **watchlist** interface. Submit list of targets, explore and wait for notifications.

<https://watchlist.alerce.online>



Integration with ZTF Data Releases.

Enables **outlier** exploration: **changing state AGN as outliers** (Sánchez-Sáez+2021b) and study of **outlier detection algorithms** (Pérez-Carrasco, *in preparation*). 11



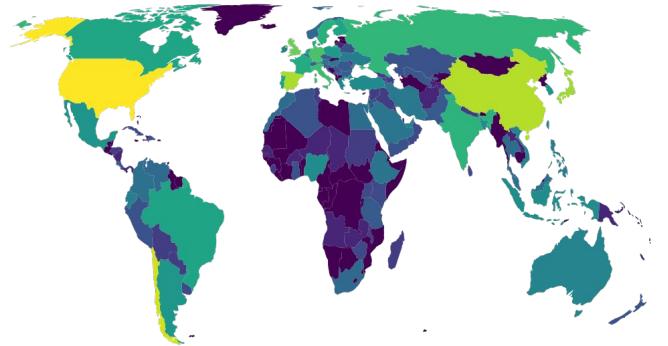
ALeRCE user community

ALeRCE tutorial workshop and LSST Enabling Science Broker Workshops (with ).

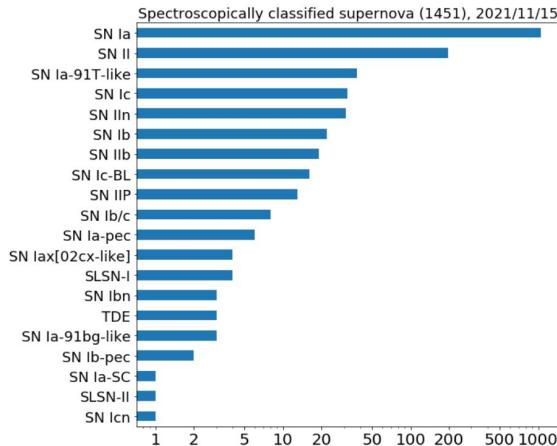
Feedback from science collaborations, notebooks focused on science cases, 76 recordings available!

<http://workshops.alerce.online/>

Services	globe@mpia	SMWLV	SSSC	DESC	AGN	TNS	SLSQ	ISSC
Crossmatch	✓	✓	✓	✓	✓	✓	✓	
Follow up marshall	✓	✓	✓	✓	✓	✓	✓	
Watchlists	✓	✓	✓		✓	✓	✓	
Classification	✓	✓		✓	✓	✓	✓	
Features	✓		✓	✓	✓	✓		
Outliers, anomalies		✓	✓	✓			✓	
Data releases	✓			✓		✓		
Reproducibility				✓			✓	
Multimessenger streams				✓				



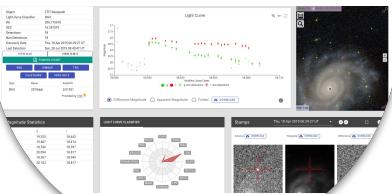
User community from 125 countries!



Enabling spectroscopic follow-up of more than 1620 SNe via SN Hunter and TNS reports. More than 12700 early SNe candidates reported to TNS

Explorer

Search and visualize
<https://alerce.online/>



Notebooks

SNe, Variable stars, AGN



Watchlists

ALeRCE Watchlist

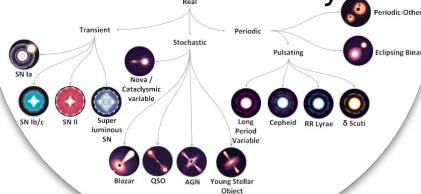
Targets		Matches		
Name	Ra	Dec	Object	Date
Mkn590	2.2426667	-0.7666667		
NGC1068	2.7113056	-0.0133333		
Mkn609	3.4236667	6.1438889		
NGC1365	3.5601111	-36.1402778		
1H0419-577	4.4335278	-57.2002778		

LC Classifier

15 class taxonomy

Stamp classifier

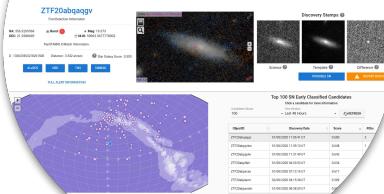
5 class taxonomy



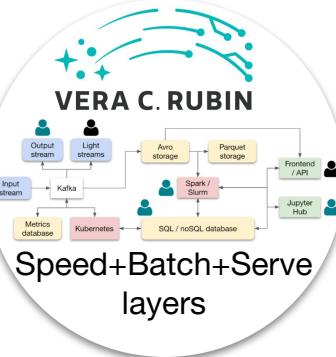
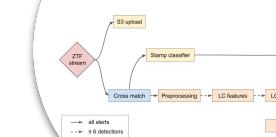
SN Hunter

Find recent SNe

<https://snhunter.alerce.online/>



Pipeline Modular design



<http://alerce.science/>

