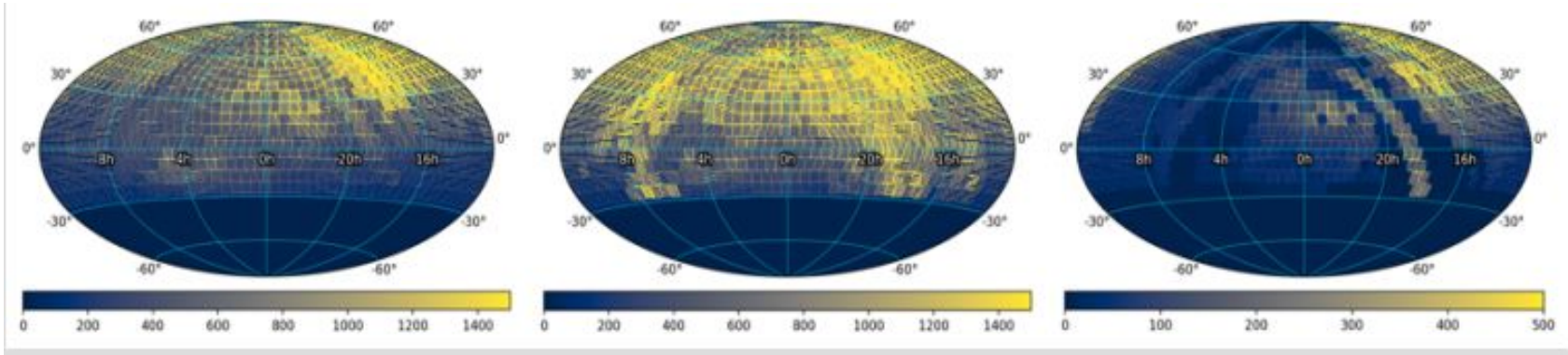


# Zwicky Transient Facility

From exciting transients to their populations



Ashish Mahabal  
Caltech

Small Telescopes Workshop, AAS, 2023-06-03

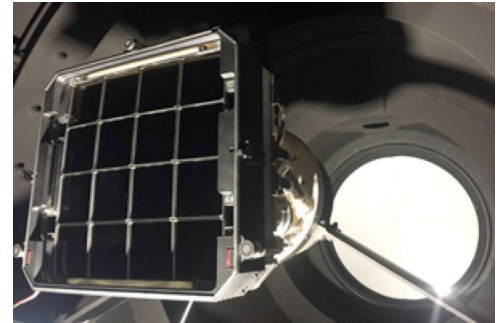
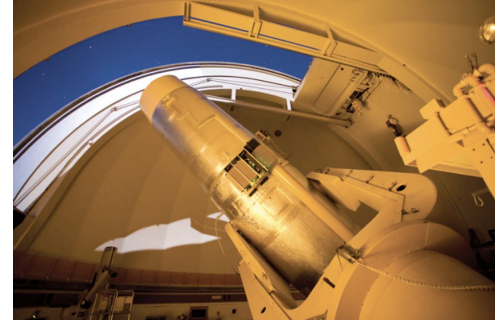


# **ZTF** Zwicky Transient Facility

Systematic Exploration of the Dynamic Sky

- 1.2m automated Telescope @ Palomar, CA
- 47 deg<sup>2</sup> FOV
- $m_{lim} \sim 20.5$  in 30 sec exposures
- g, r, i filters
- 1.4 TB data nightly
- $\sim 20000$  sq deg every 2 nights in g and r

**Plans beyond Sep 2023**





PI:	Shri Kulkarni
Co-PI:	Thomas Prince, Mansi Kasliwal, Matthew Graham, Richard Dekany
Project Scientist:	Matthew Graham
Survey Scientist:	Eric Bellm
Project Manager:	Richard Dekany
Lead Camera Engineer:	Roger Smith
P48 Operations:	Tom Barlow
Data Archive Director:	George Helou
Science Data System Lead:	Ben Rusholme
→ Machine Learning Lead:	Ashish Mahabal
Data Quality Scientist:	Andrew Drake

+ real stars



## DR16:

[https://irsa.ipac.caltech.edu/data/ZTF/docs/releases/ztf\\_release\\_notes\\_latest](https://irsa.ipac.caltech.edu/data/ZTF/docs/releases/ztf_release_notes_latest)

Filter(s)	#PSFcat- <i>sci</i> sources	#Aperturecat- <i>sci</i> sources	#PSFcat- <i>ref</i> sources	#Aperturecat- <i>ref</i> sources
<i>g</i>	179,661,606,131	114,144,715,027	2,527,614,585	794,988,671
<i>r</i>	506,885,000,022	315,778,300,845	3,393,409,691	1,153,239,938
<i>i</i>	58,976,476,111	33,687,367,330	1,414,109,235	455,279,857
<i>g+r+i</i>	745,523,082,264	463,610,383,202	7,335,133,511	2,403,508,466

Table 3: Number of sources in CCD-quadrant-based catalog files in DR16, according to extraction and image type



# Zwicky Transient Facility

Systematic Exploration of the Dynamic Sky

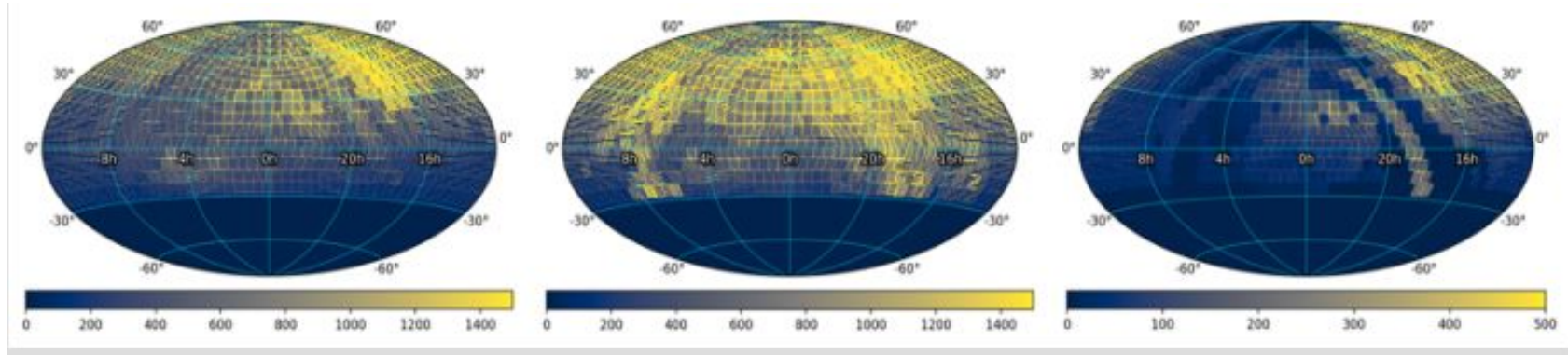


Figure 1 - Sky coverage and number of observation epochs in DR16 in g, r, i filters.

Example Query  
using the APIs

```
wget "https://irsa.ipac.caltech.edu/ibe/search/ztf/products/sci?  
POS=255.9302,11.8654&WHERE=obsjd>2458219.9678+AND+obsjd<2458228.8155+  
AND+infobits<33554432" -O out.tbl
```

Ashish Mahabal

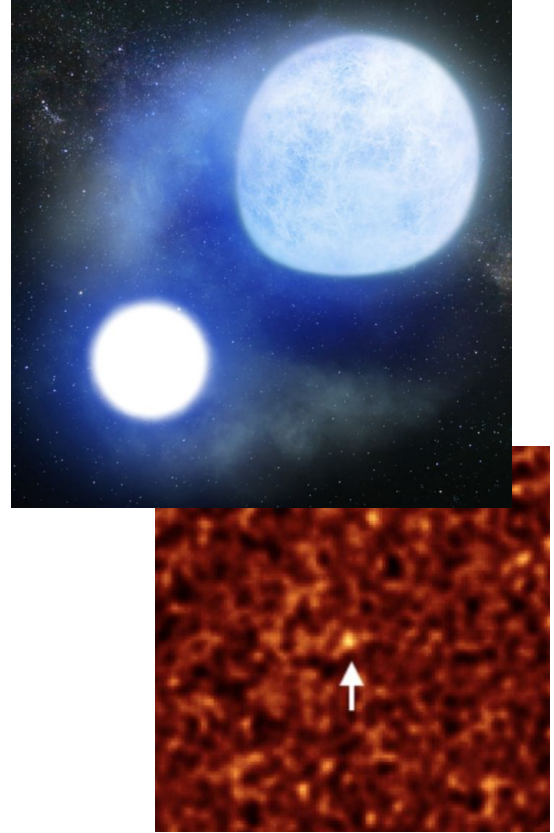


# Main science drivers of ZTF

A fast, wide-area time-domain survey:

- Fast, young, and rare flux transients
- Counterparts to gravitational wave sources
- Low-z Type Ia SNe for cosmology
- Variable stars & eclipsing binaries
- Solar System objects

<https://www.ztf.caltech.edu>

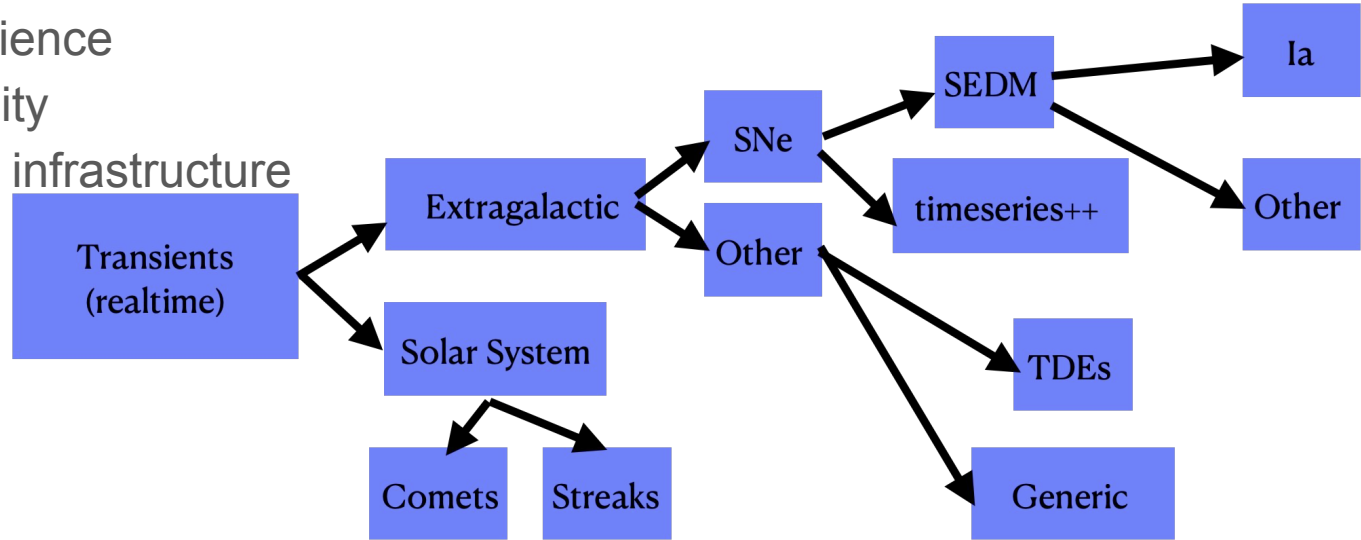


# Highlights - exemplars rather than exhaustive

Also likely biased towards areas I work in, or am better versed in

- Solar System
- Extragalactic science
- Galactic variability
- Technology and infrastructure

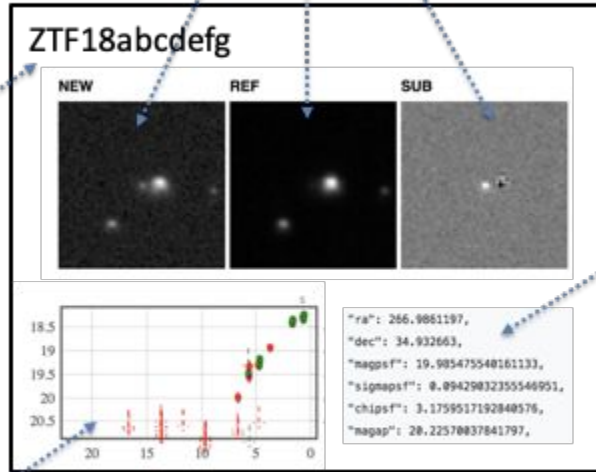
O4 follow-up



# ZTF transient alerts



63 x 63 pixel 32-bit images



Unique spatially  
matched alert name  
(1.5" radius)

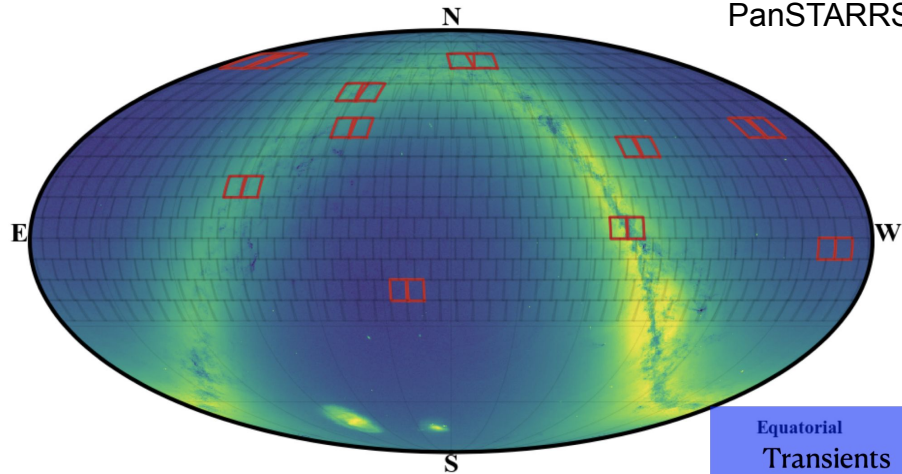
Rolling 30-day window  
light curve

- ZOGY parameters
- Real-bogus scores
- Star/galaxy score
- 3 nearest PS1 sources
- Nearest SS object
- Alert history

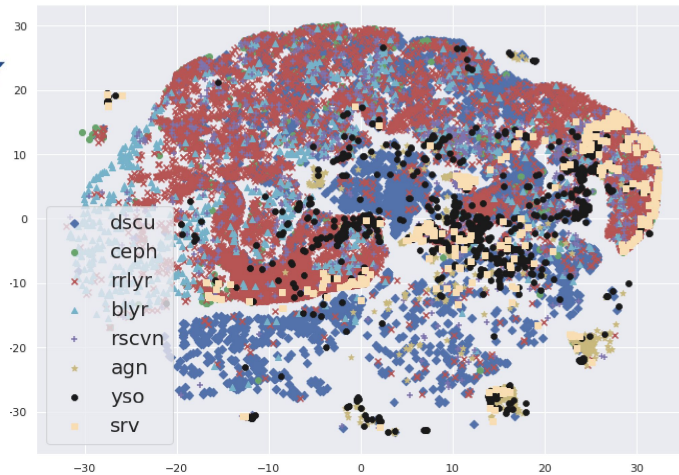
Packet size: ~80kB  
Evolving schema!



# SCoPe and ML with ZTF



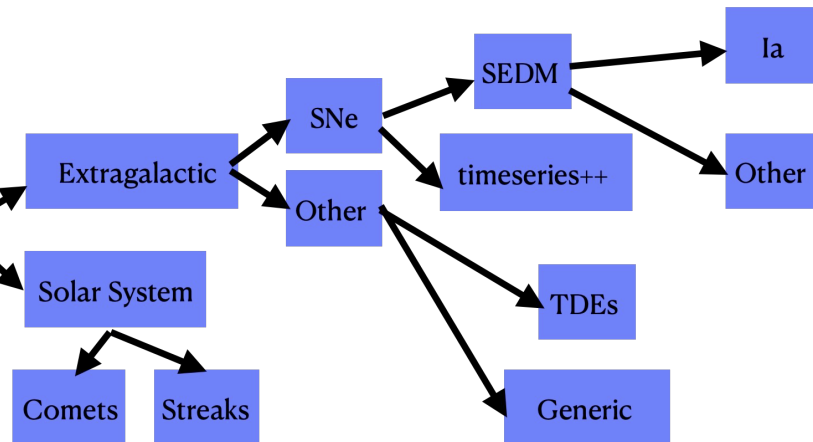
Combined with Gaia, PanSTARRS, WISE



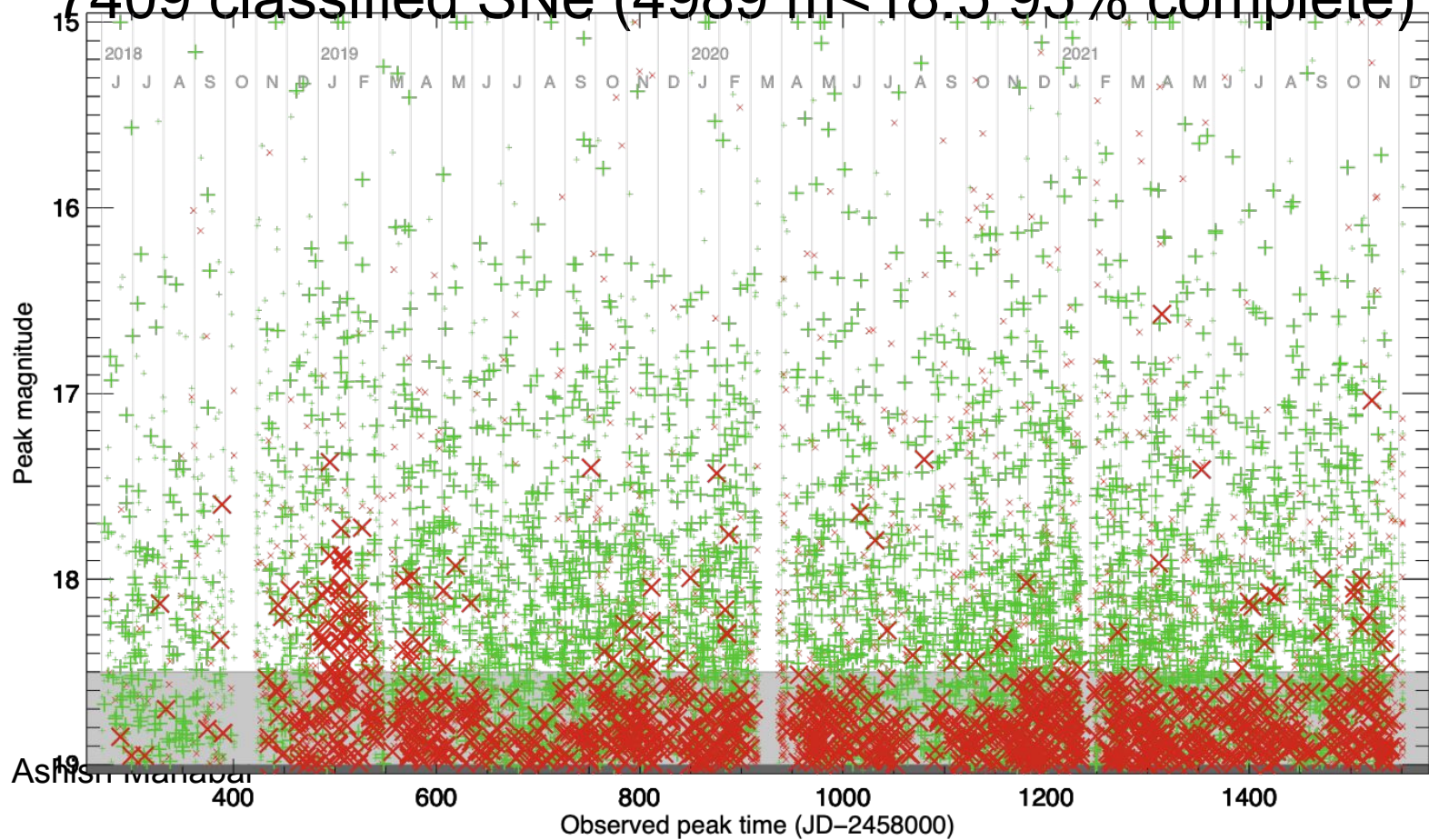
Van Roestel, Duev, Mahabal et al. 2020

More coming: Healy, Coghlin, ...

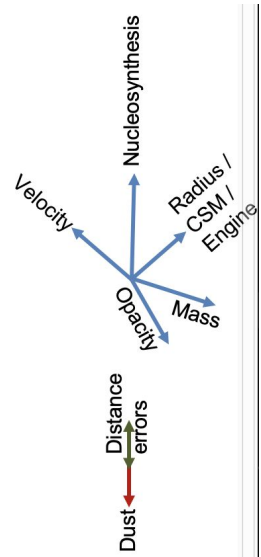
Fritz, SkyPortal



# 7409 classified SNe (4989 $m < 18.5$ 95% complete)



Perley,  
Fremling, ...  
(the ZTF  
SNe team)

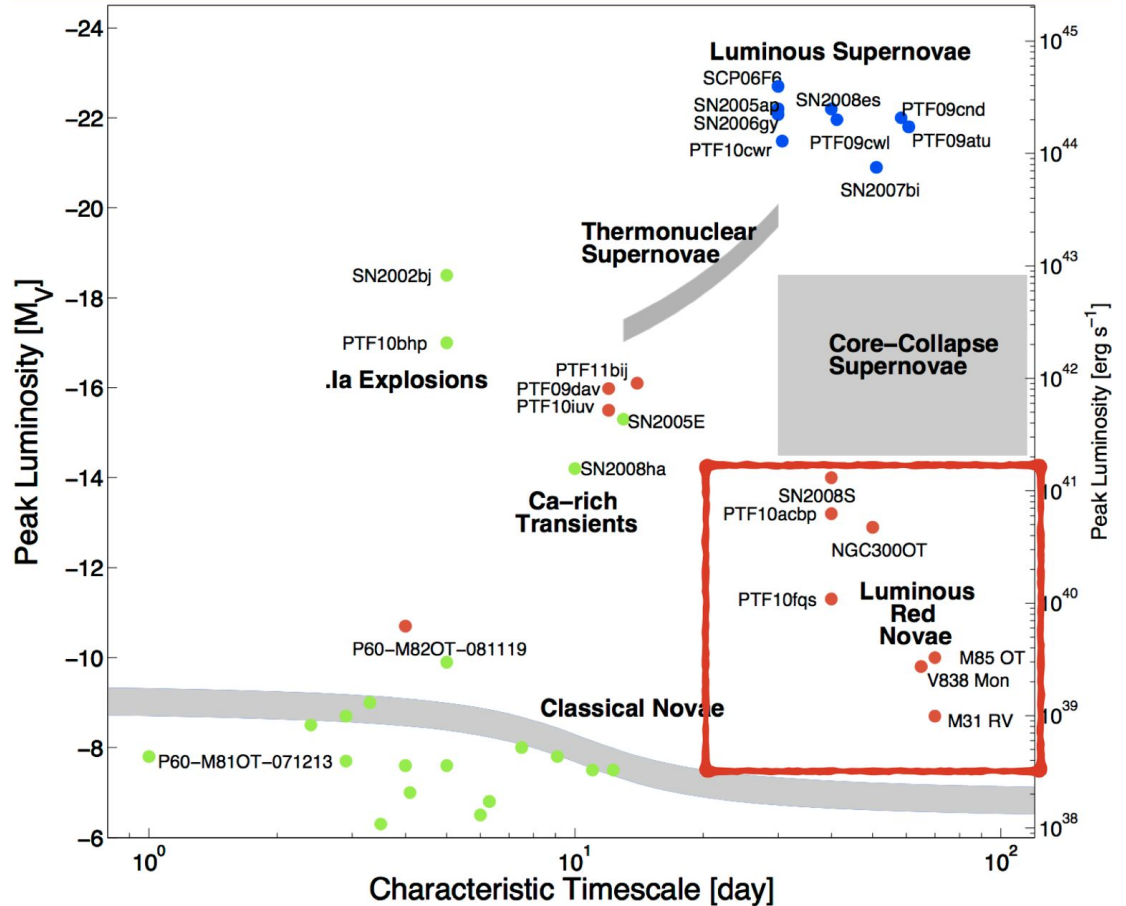


Perley+2020

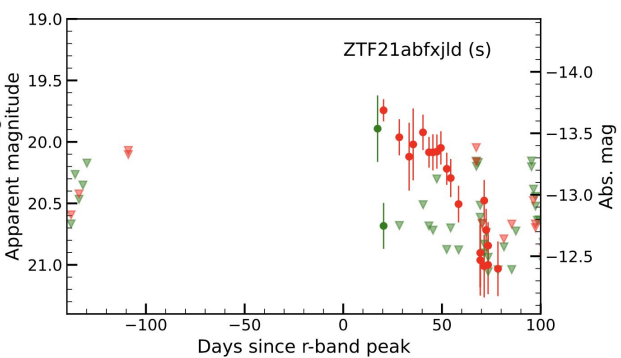
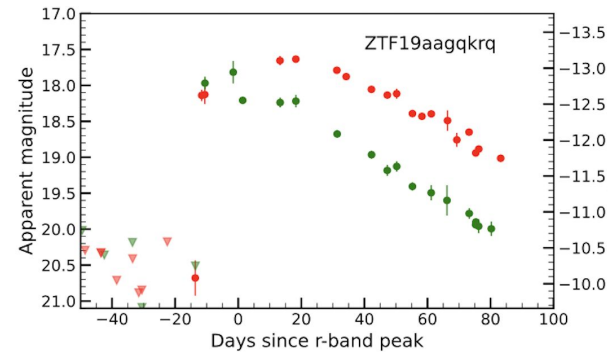
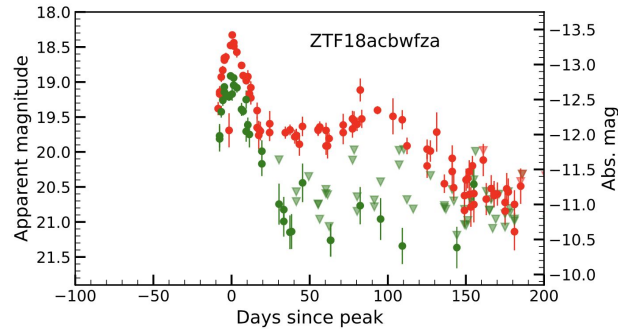
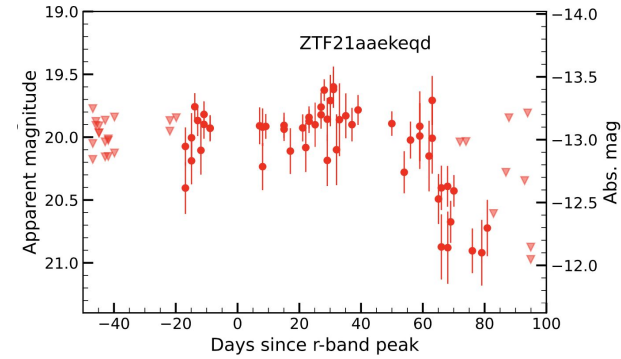
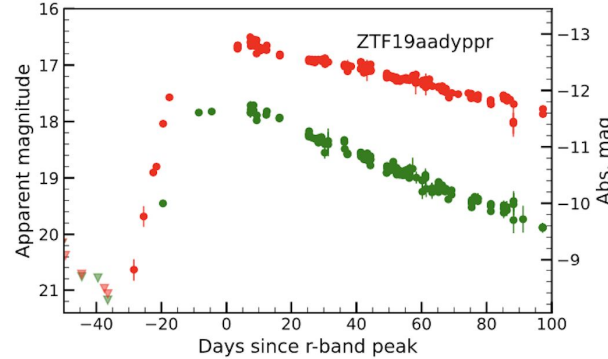
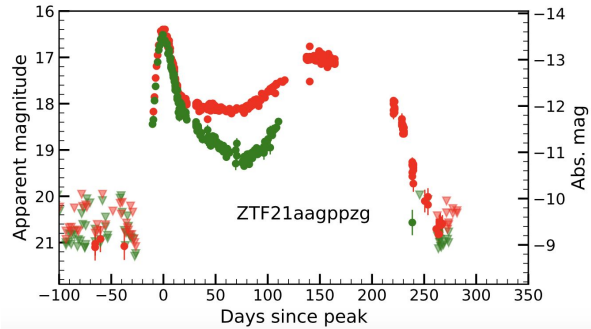
# Non-SNe in ZTF

- ZTF has been observing several rare “gap-transients” that occupy the luminosity space between supernovae and classical novae.

Kasliwal 2010



# Gap transient variety in ZTF



**Luminous red novae**  
(Stellar mergers)

**Intermediate luminosity red transients**  
(e-capture explosions?)

**Possible Luminous Blue**  
**Variable outbursts**

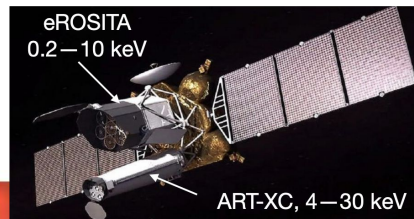


# TDE strides

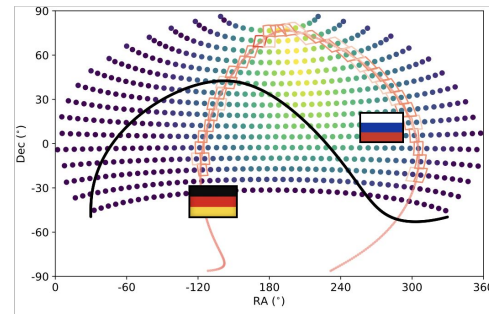
## Entering the Era of Population Studies

van Velzen + 2019  
van Velzen + 2021

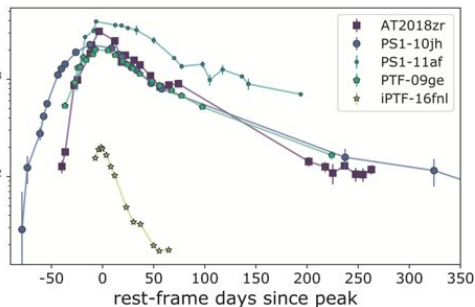
Gezari + 2021



- 2020–2023
- 8 all sky surveys
- 6 months cadence
- >1  $\mu$ Crab in each epoch

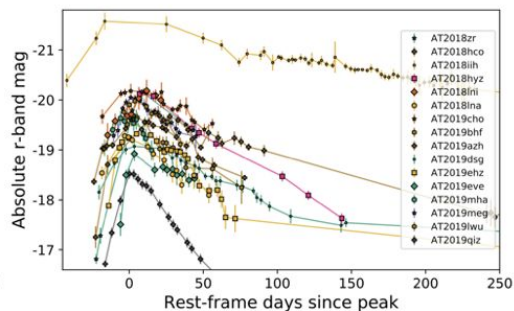


### Before ZTF

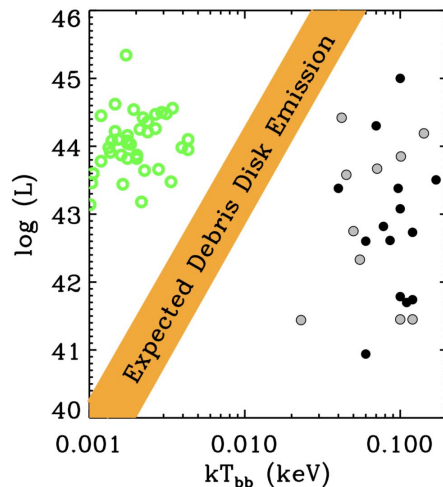


*AT2018zr, the first TDE detected by ZTF, was one of only 5 TDEs discovered before peak!*

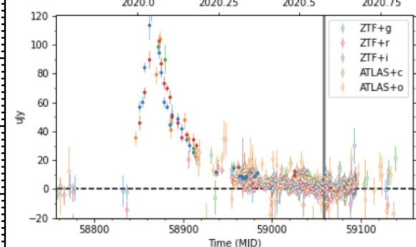
### After ZTF



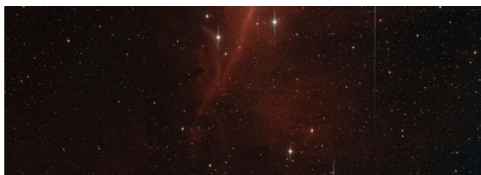
*In the first 1.5yr of ZTF survey operations, we have detected 16 more!*



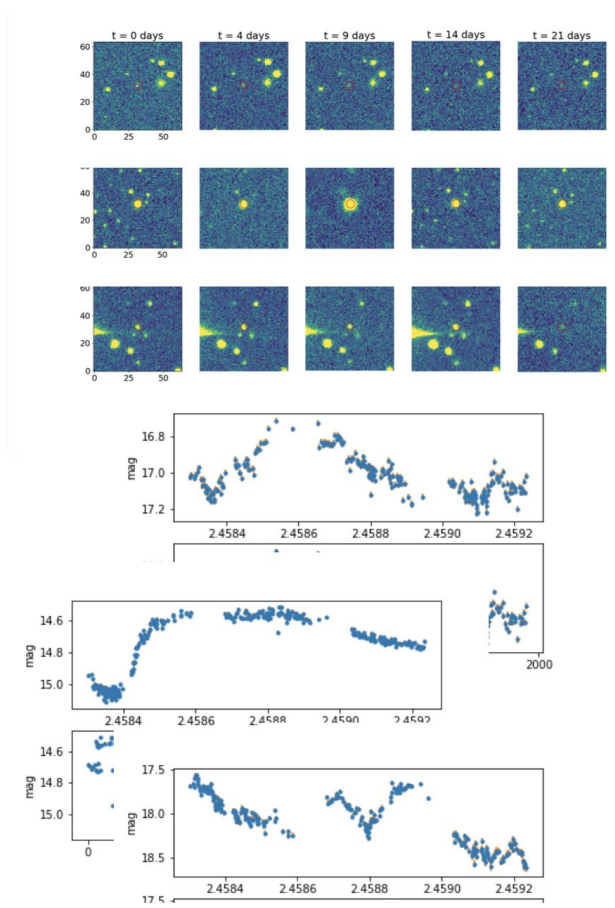
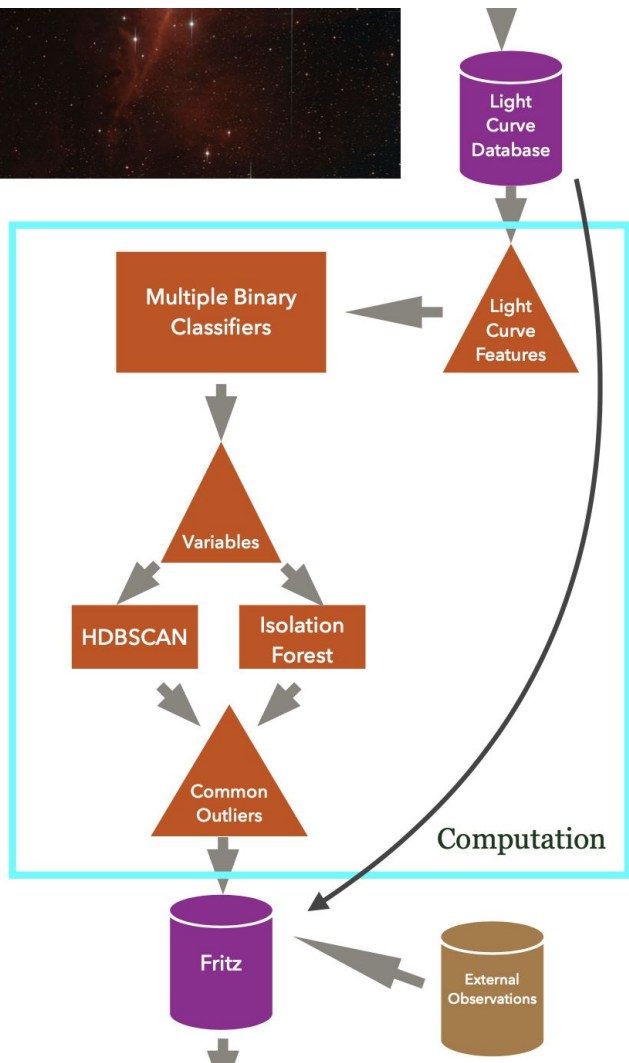
## Optically Discovered X-ray Discovered



Yuhan Yao  
arXiv:2206.12713

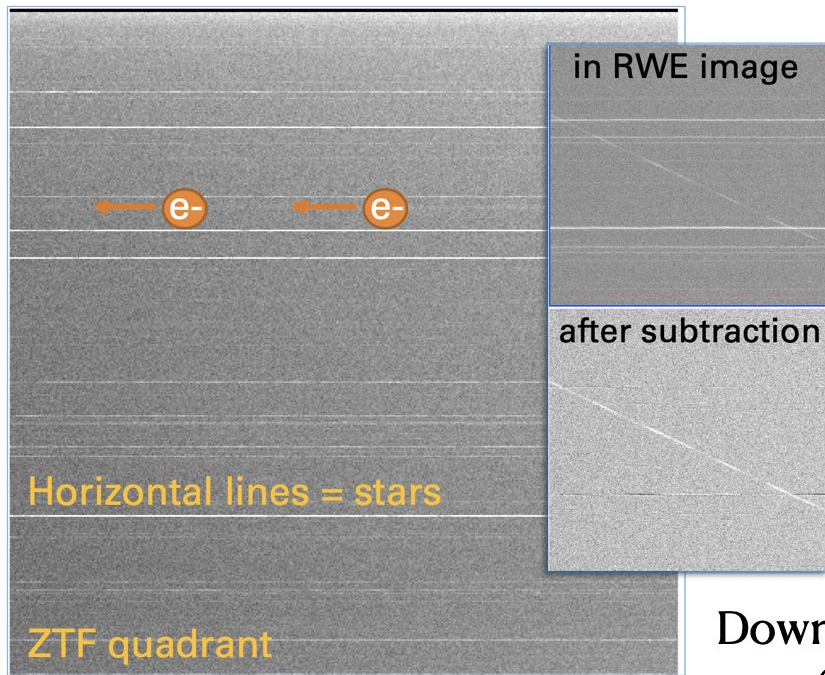


# No Anomaly Left Behind



With  
 PPurohit,  
 SParikh,  
 YHassan,  
 TJegou Du  
 Laz, ...





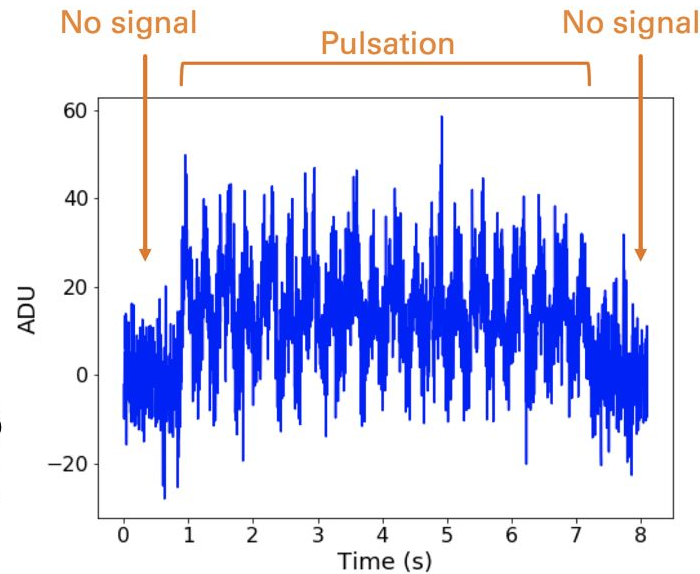
Down to  $\sim 12.6$  mag (SNR=10)

**Read While Expose**

Testing a new ZTF observing mode

few ms time resolution

Finding counterparts to Fast Radio Bursts



Rapidly spinning space debris

The pulsating object was bright for  $\sim 6$ s

With Igor Andreoni, Roger Smith, ...

# ZARTH - Pokemon GO for ZTF transients

Coming this month to androids

With D Pindawala,  
A Arora, D  
Thummar, A  
Bhavsar, I  
Kostadinova, ...



Made with midjourney



Ashish Mahabal

