

# The Zwicky Transient Facility: Third Public Data Release & Science Opportunities

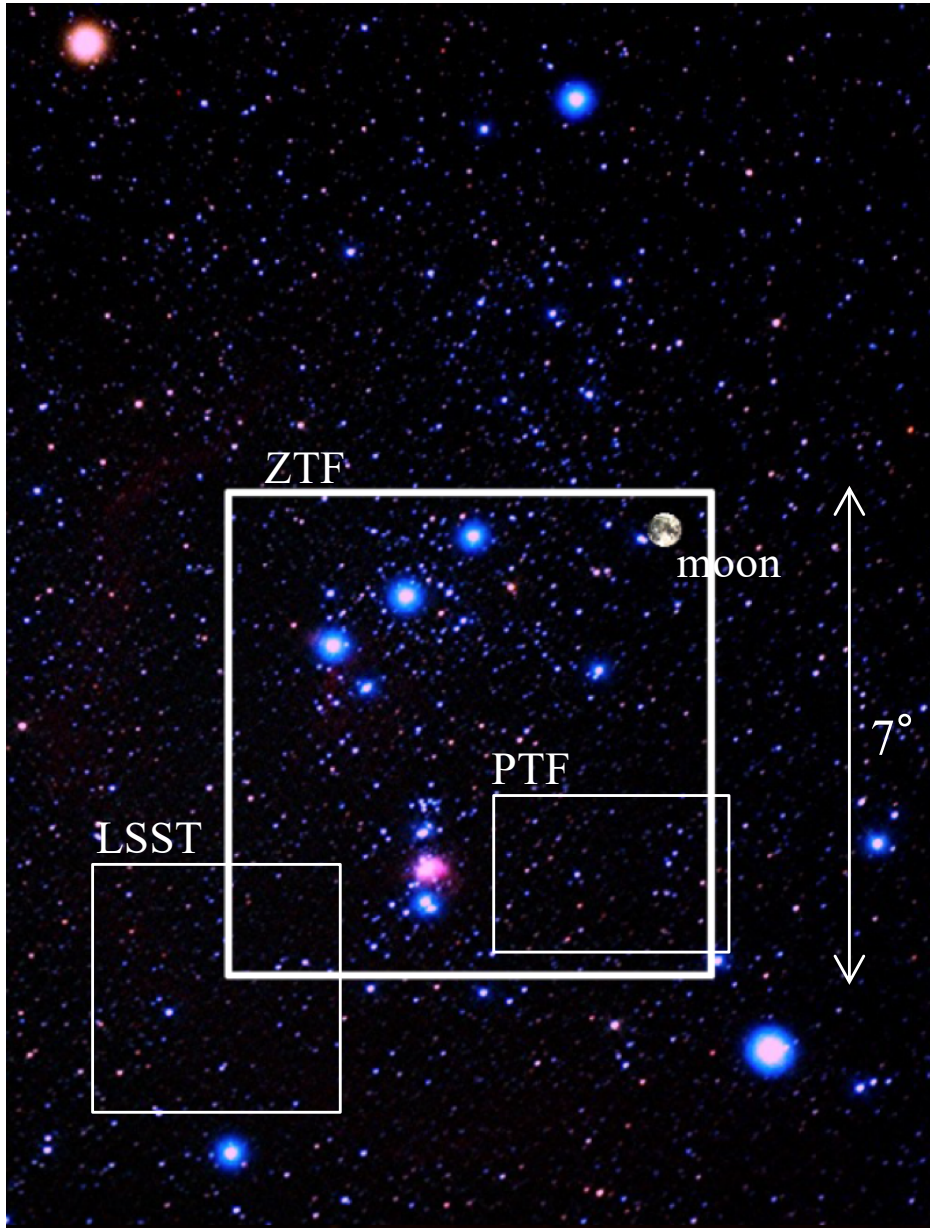
Frank Masci & the IPAC/Caltech ZTF Team

August 24, 2020



HEISING-SIMONS  
FOUNDATION

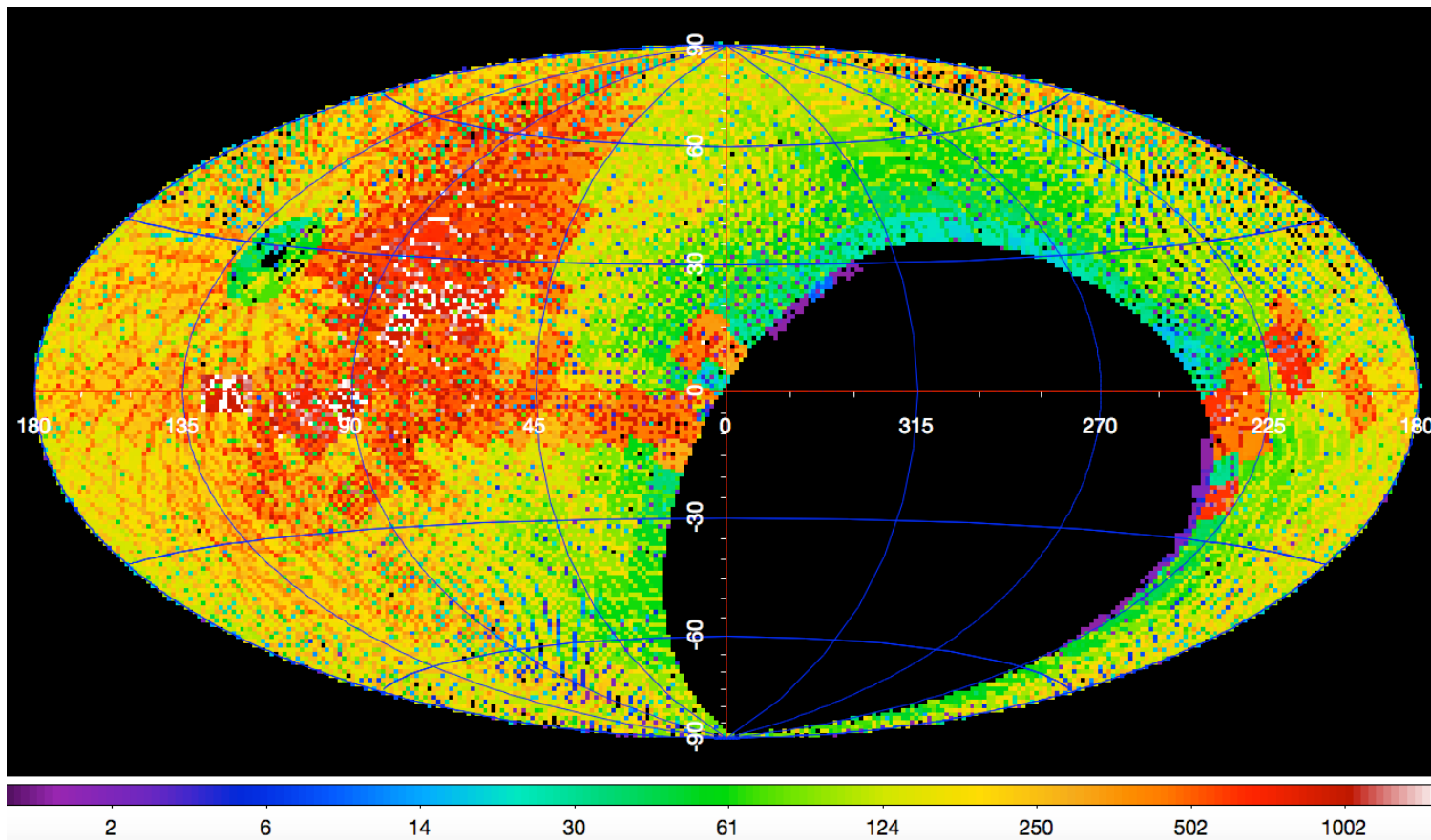
# ZTF at a glance



- A fast, wide-area time-domain survey using the Palomar 48-inch Schmidt telescope
  - Active detector area:  $\sim 47 \text{ deg}^2$  (576M pixels)
  - Areal survey rate:  $3760 \text{ deg}^2 / \text{hour}$
  - Single exposure depth ( $5\sigma$ ):  $r \sim 20.5 \text{ mag.}$
  - Median image quality ( $r$ ):  $\sim 2.1''$  (FWHM)
  - Number of filters: 3 (  $g, r, i$  )
  - Survey of Northern visible sky:  $\text{Dec} > \sim -28^\circ$
  - Consists of private and public surveys (60/40%)
  - Public survey:  $\sim 15\text{k deg}^2$  repeated every 3 nights
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- Data processing and archiving occurs at IPAC
  - Operations managed by COO/Caltech and UW
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- **ZTF Phase-I:** Mar 2018 – Nov 2020
  - **ZTF Phase-II:** Dec 2020 – Sep 2023

# Data Release 3 Definition

- Observation span included: **March 17, 2018 – December 31, 2019.**
  - ~ 21 months of public survey and ~ first 9 months of private (partnership) surveys.
- Public surveys have 3-night cadence with 1-night cadence in Galactic plane  $|b| < \sim 7^\circ$  (seasonal)
- Private surveys have a mixed cadence down to  $< \sim 1$  minute.



Depth-of-coverage  
centered on  $l, b = 0, 0$   
( $r$ -filter)

# Data Release 3 Products

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- Instrumentally calibrated epochal images with ancillary products; including difference images
- Source catalog table files corresponding to epochal images; both PSF-fitting & aperture photometry
- Co-adds of epochal images (reference images) with source catalog files
- Objects (Database) Table storing sources extracted from co-added images
  - Facilitates object position searches to support lightcurve retrieval
- Lightcurves from matching PSF-fit photometry measurements across all epochs per object
  - Tarballs of lightcurves are also available for bulk download

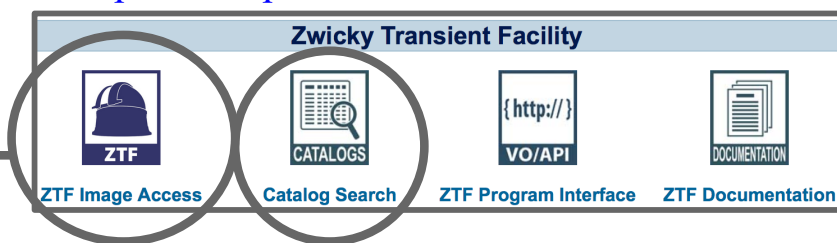
## **DR3 Statistics**

- ~ 12.6 million “good” (usable) single-epoch calibrated images
- ~ 138,000 co-adds (reference images)
- ~ 5.6 billion sources extracted from all co-adds (Objects DB Table)
- ~ 2.6 billion lightcurves with  $\geq 2$  epochs (~ 1.4 billion with  $\geq 20$  epochs)

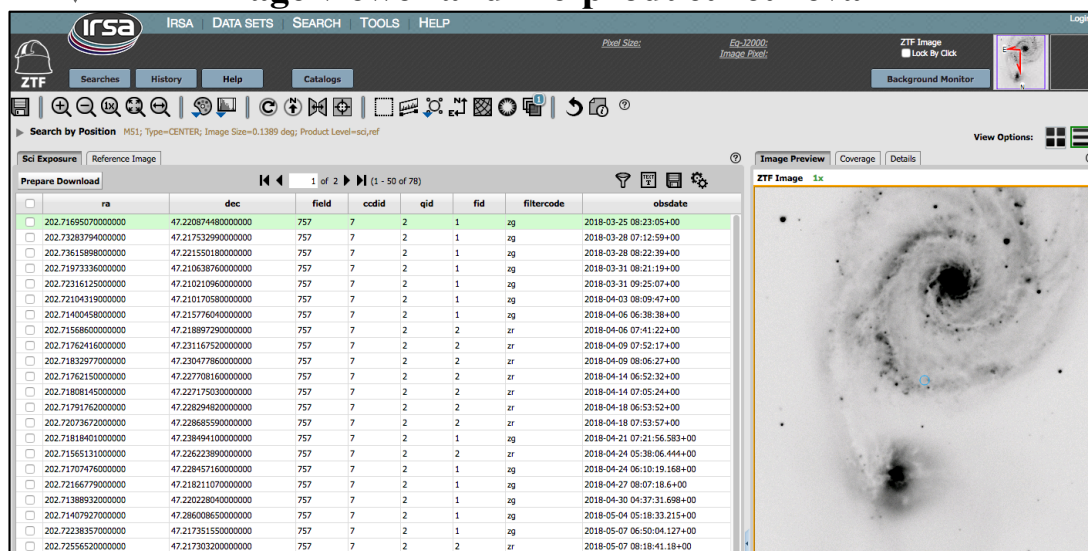
# Data Access and Visualization Tools

- Access is through IRSA at IPAC.
- Search for images and source catalog files by position or object name (including SSOs), sources extracted from co-adds with full lightcurves; overlays, time series viewer, interactive manipulation
- Accompanying APIs (command-line driven retrieval) are also available.

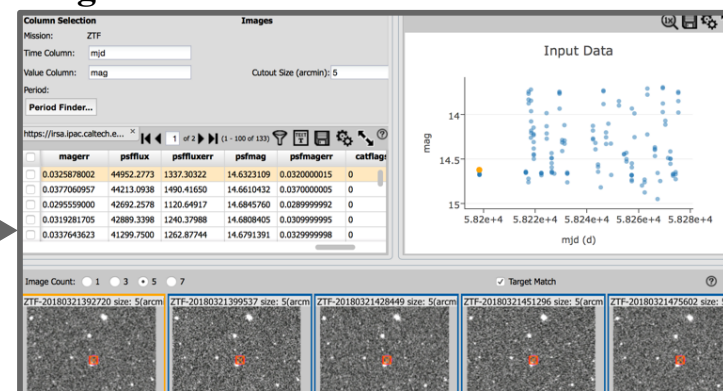
<https://irsa.ipac.caltech.edu/Missions/ztf.html>



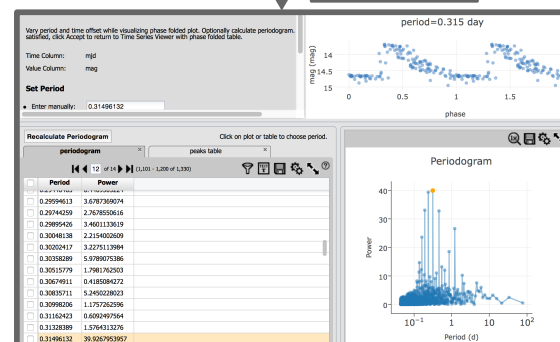
**Image viewer and file-product retrieval**



**Lightcurve retrieval / Time Series Tool**



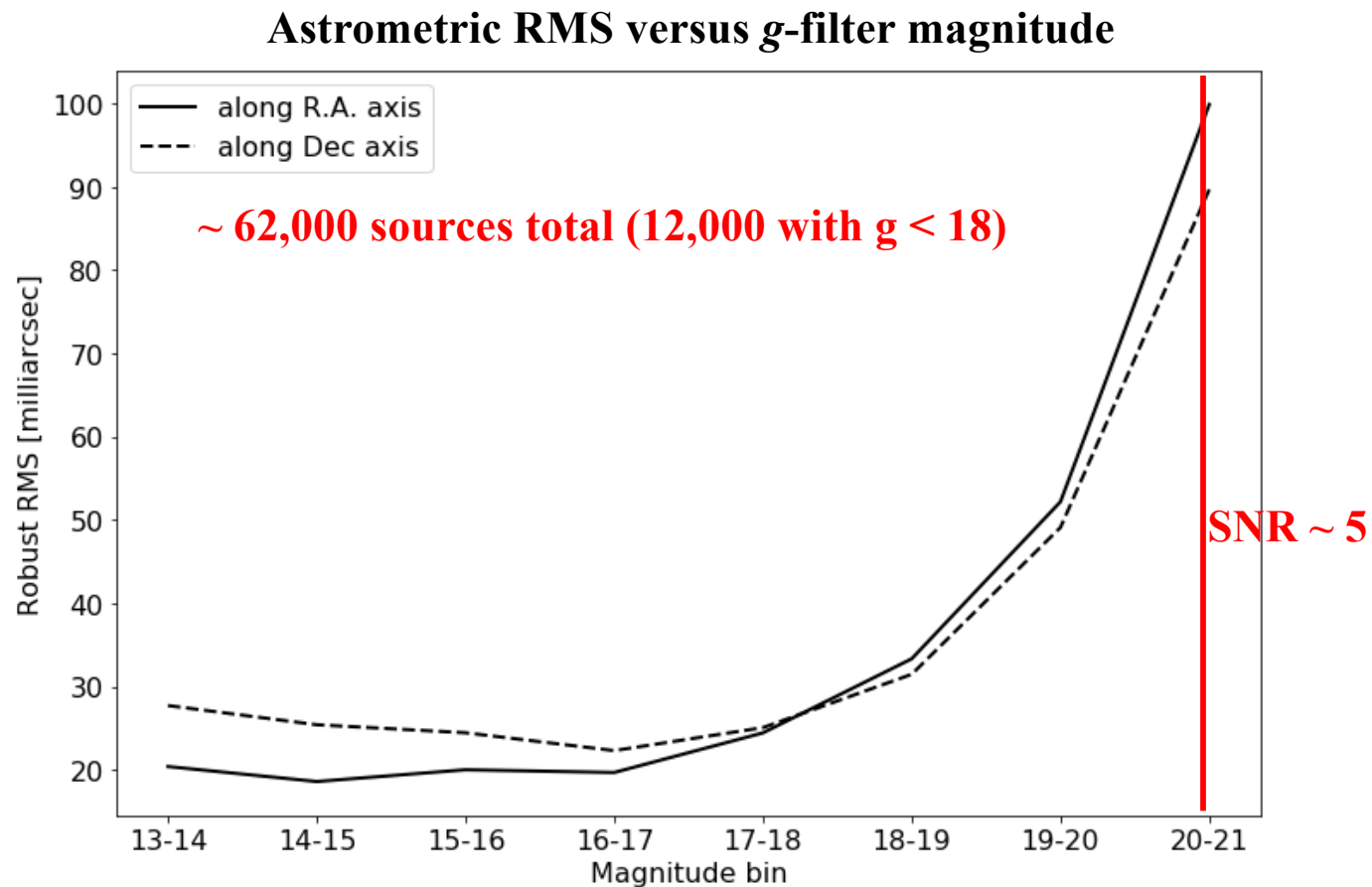
**Period finding**





# Astrometric performance relative to Gaia

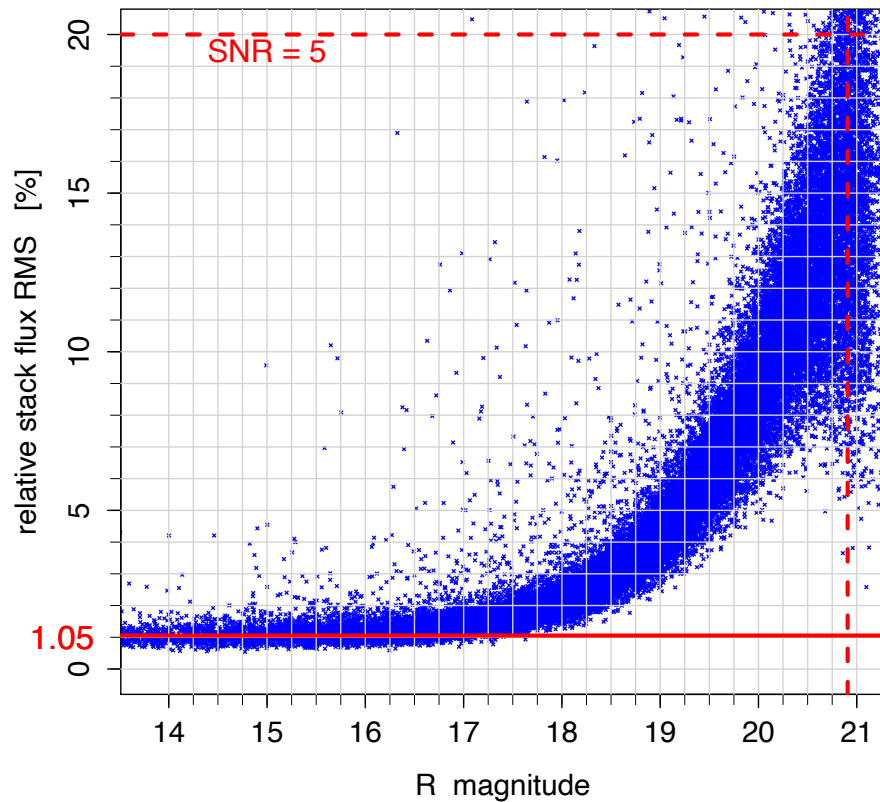
Astrometric precision of bright stars with  $r, g < 18$  mag at airmass  $< 1.2$  is  $< \sim 30$  milliarcsec (RMS per axis).



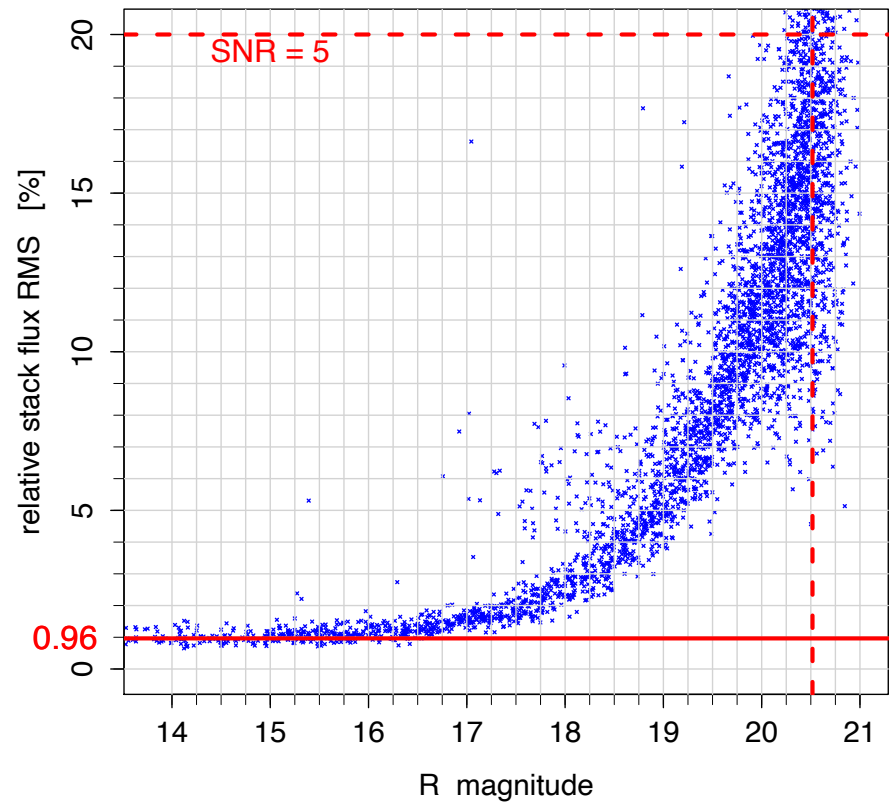
# Photometric precision (repeatability)

From matching epochal PSF-fit source catalogs: typical range is  $\sim 8$  to 20 millimag; depends on airmass/field.

*galactic plane field*

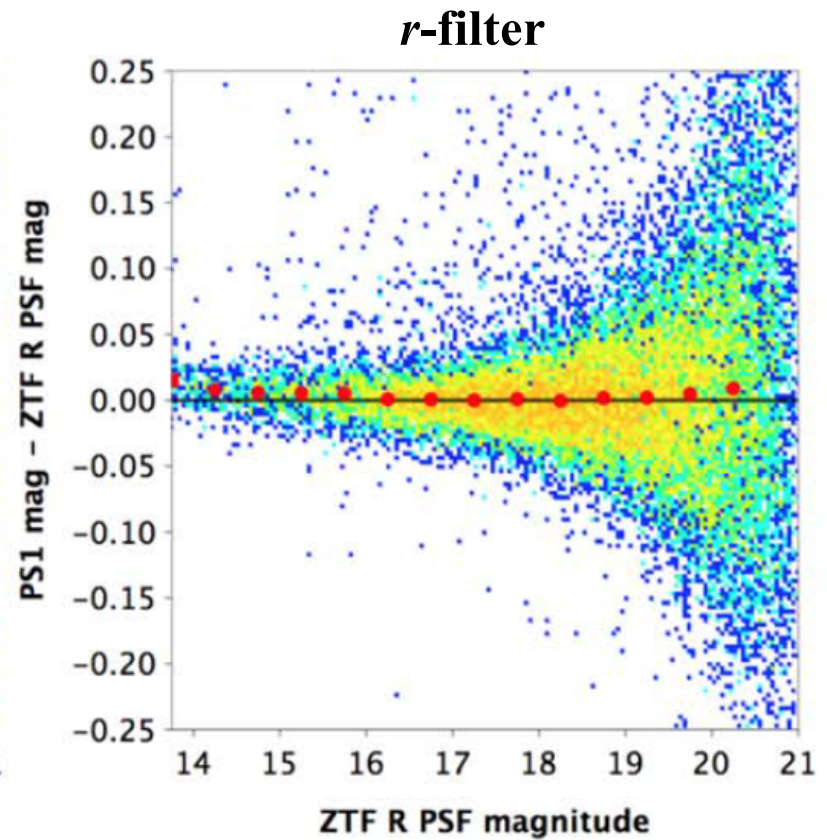
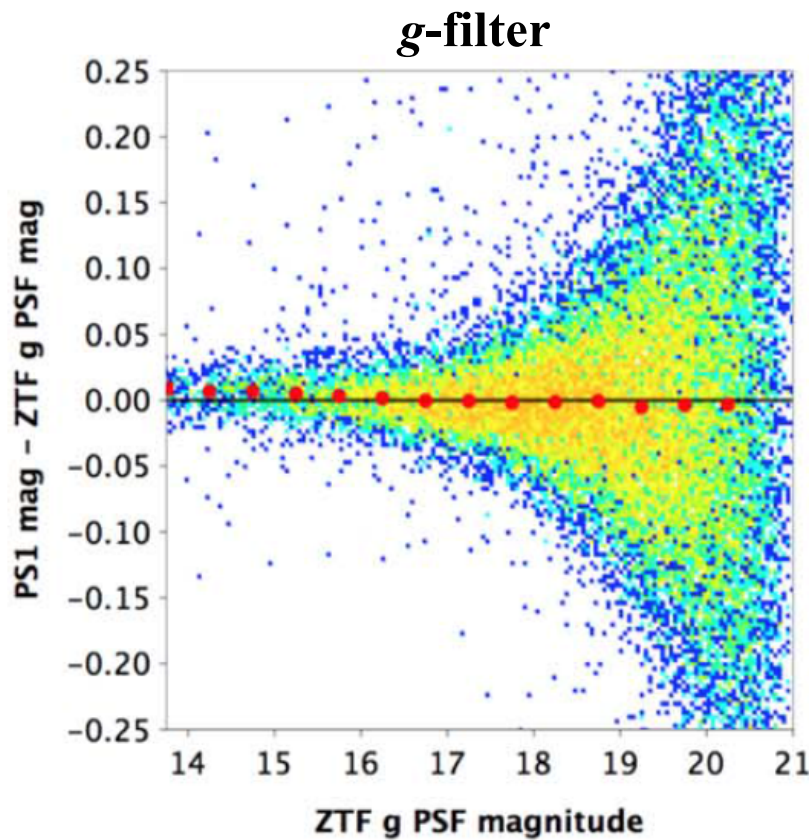


*high galactic latitude field*



# Photometric calibration accuracy

Calibration is performed with respect to *Pan STARRS1*; RMS in residuals *with respect to PS1* is  $< \sim 0.03$  mag.





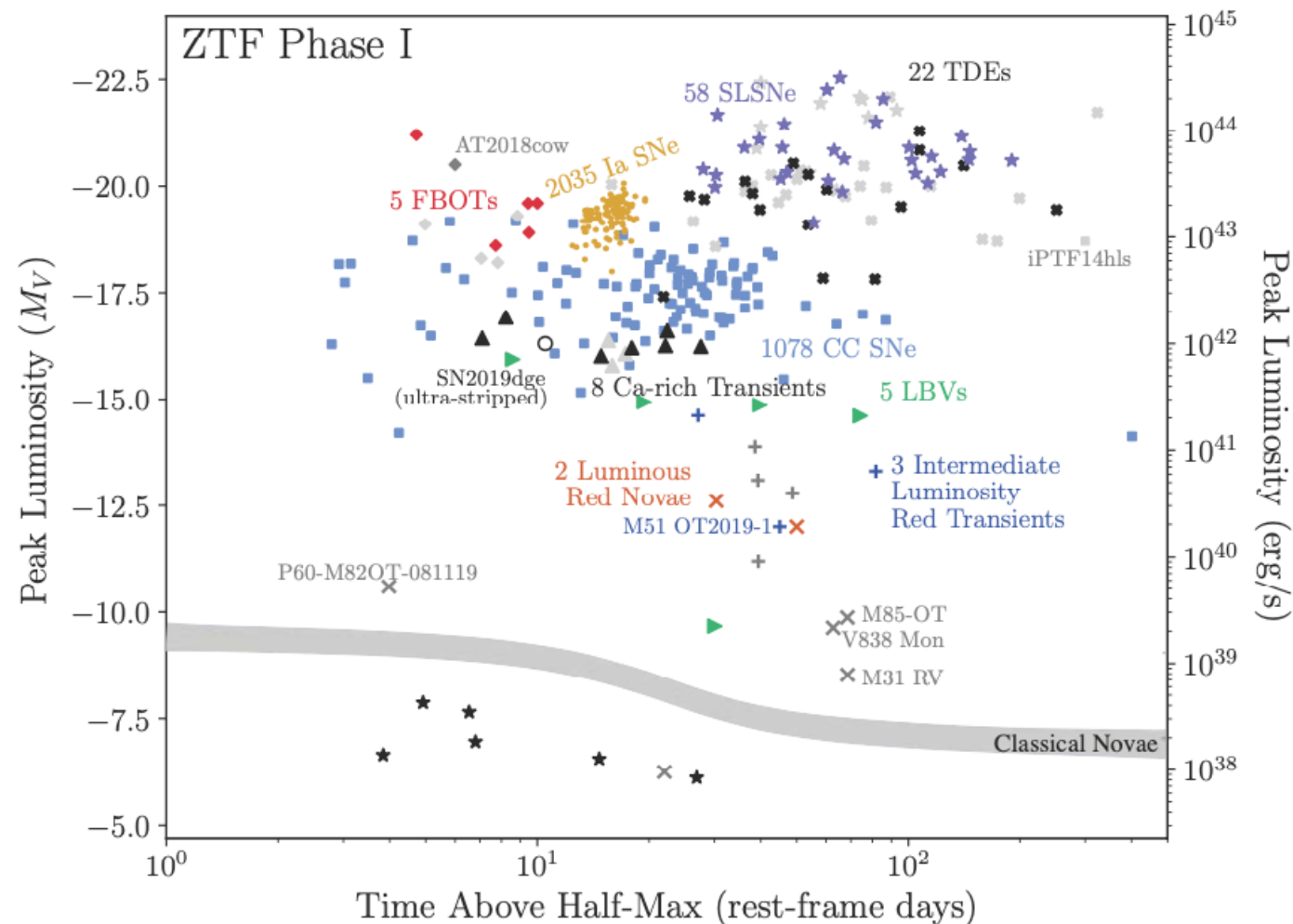
# Ongoing ZTF Science

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- **Supernovae:** Early detection and rapid follow-up of young SNe; rare and superluminous SNe
- **Follow-up of rare events:** Gravitational wave triggers from LIGO; neutrino triggers from IceCube; Fermi triggers
- **Active Galactic Nuclei:** Long term variability and Tidal Disruption Events
- **Stellar variability:** Rare classes of pulsators; cataclysmic variables; ultra-compact eclipsing binary systems
- **Solar System Objects:** Searching for NEAs and PHAs; comet outbursts

# Transients are a hot topic

- Synergy with other facilities: follow-up and classification of one-off transient events in near-realtime.
- Once a transient has faded, it's gone for good.
- Can classify transients using archival lightcurves alone, but limited by photometric accuracy/sampling

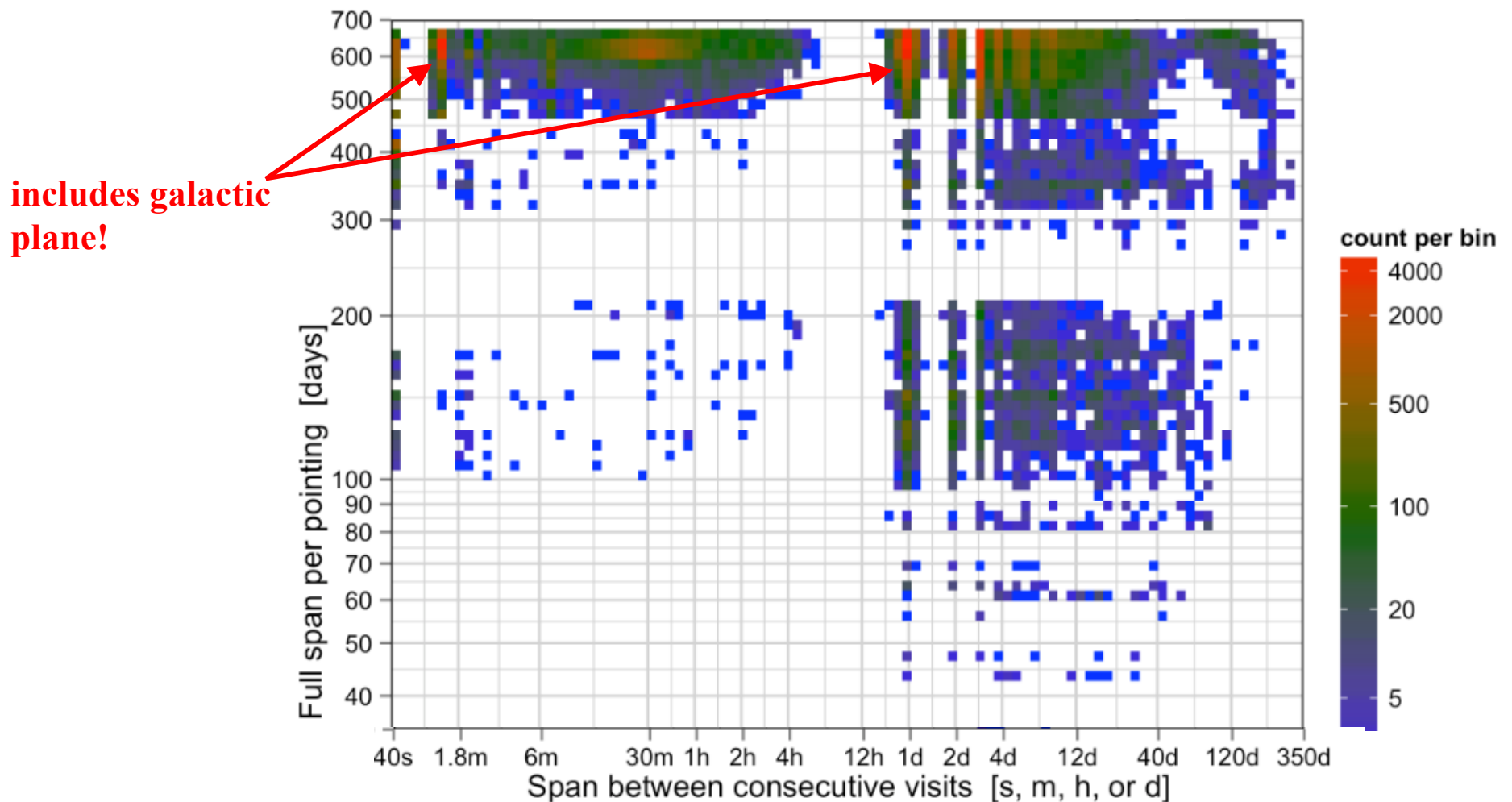


Courtesy  
Shri Kulkarni

# What can DR3 provide?

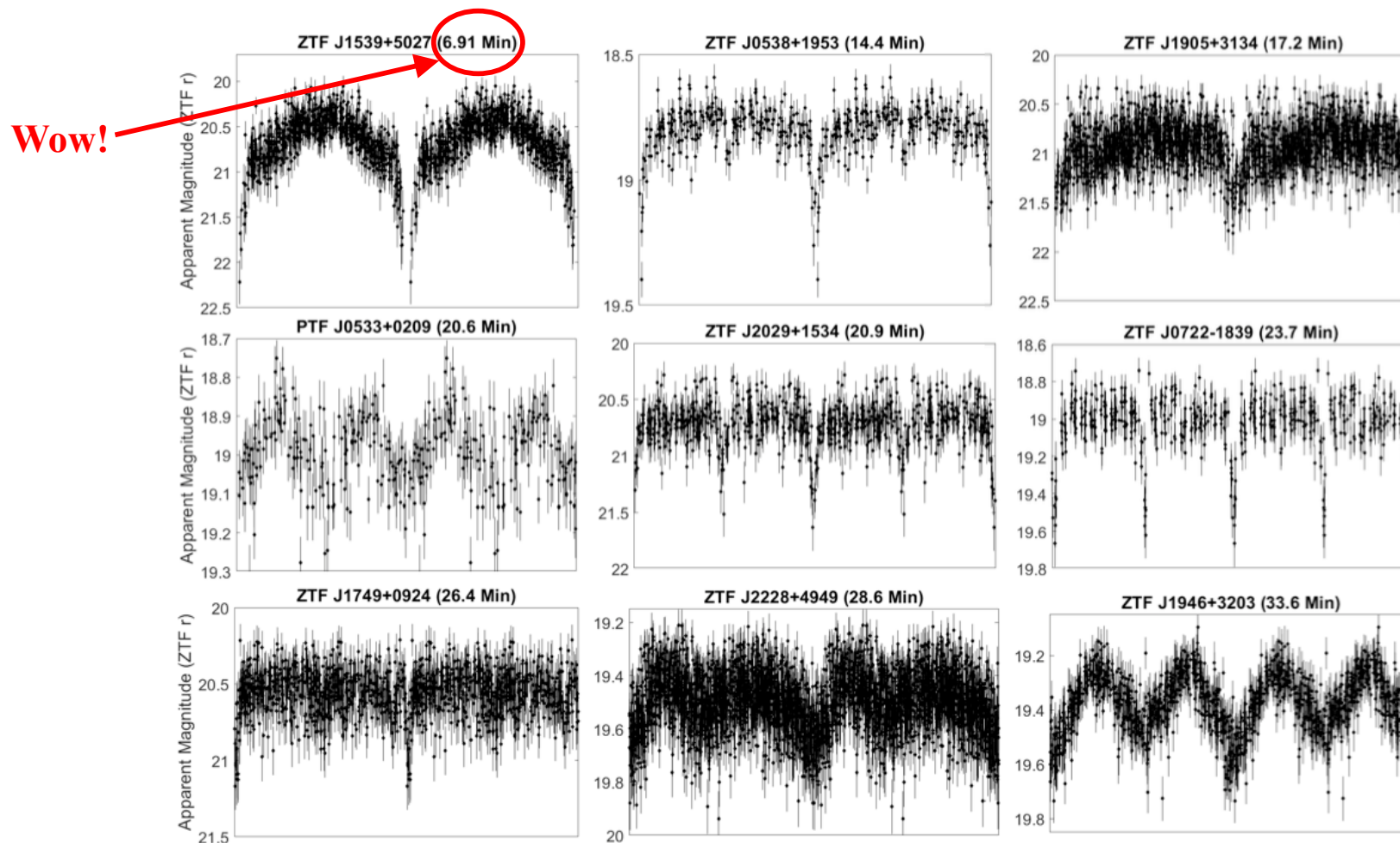
## *Lightcurve Timespans and Cadences*

- Counts per bin are *#visits per 47 square degree field*.
- Sampling is non-uniform and irregular due to seasonal variation in field visibility from P48.
- Constrains the variability-related archival science projects possible with DR3.



# DR3 archive is waiting to be mined for new classes of variable stars & ultracompact binaries

- Demographics for various classes: short period white dwarf binaries; fast rotators; exotic pulsators.
- ZTF depth is complementary to *Gaia* and SDSS-V: *Gaia* provides distances and absolute luminosities while SDSS-V spectroscopy provides high precision radial velocities.
- Candidates for gravitational-wave sources detectable by *Laser Interferometer Space Antenna* (LISA)



Burdge et al.  
2019

## In closing

- Grab the DR3 data and let us know what you find!
- Stay tuned for DR4 in Dec 2020: 6 months more data covering obs span: Mar 2018 – Jun 2020
- **DR3 product access, recipes, and documentation:**  
<https://irsa.ipac.caltech.edu/Missions/ztf.html>  
<https://www.ztf.caltech.edu/page/dr3>

