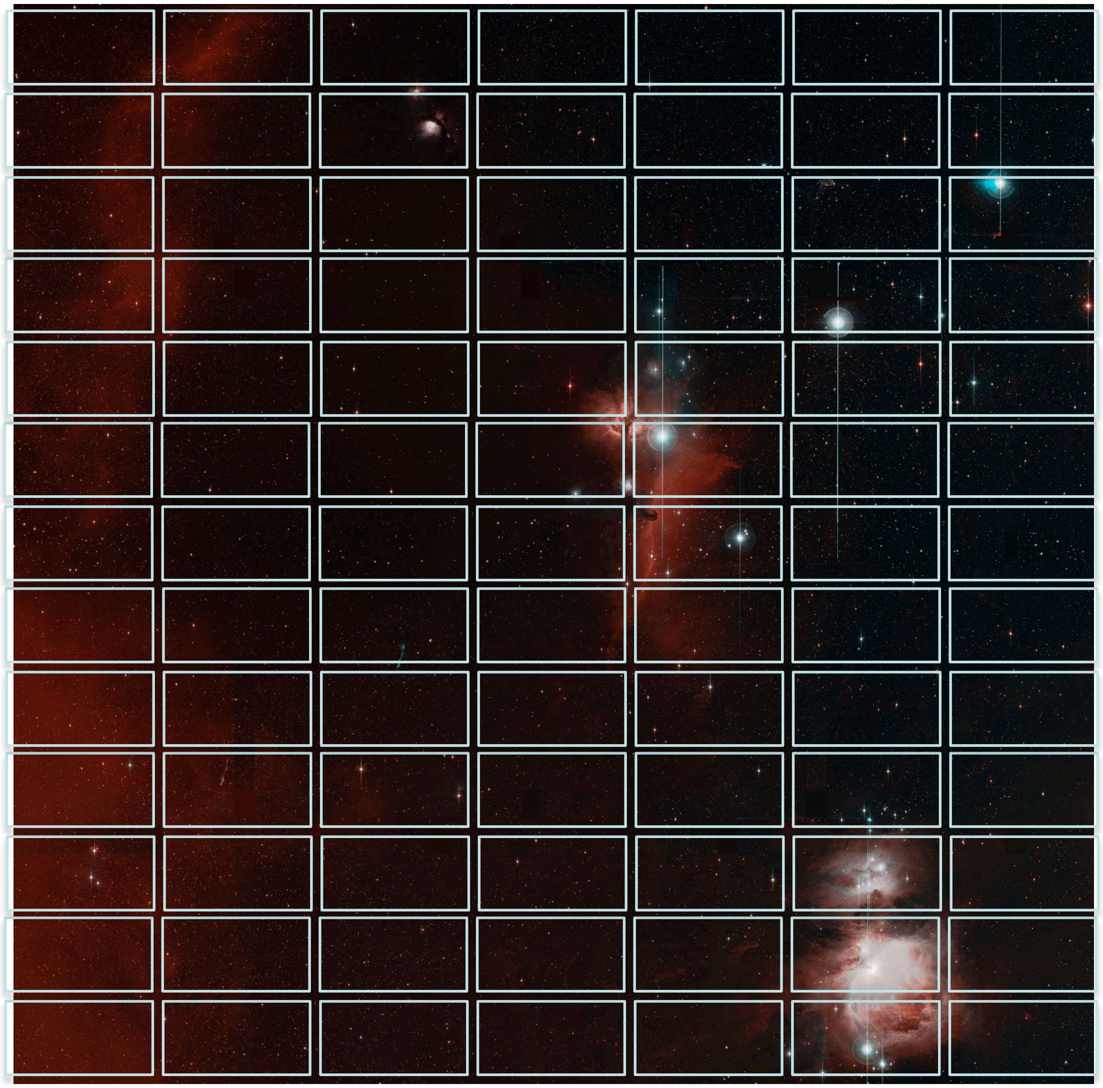
# ZTF and Gaia synergy for classification of sources



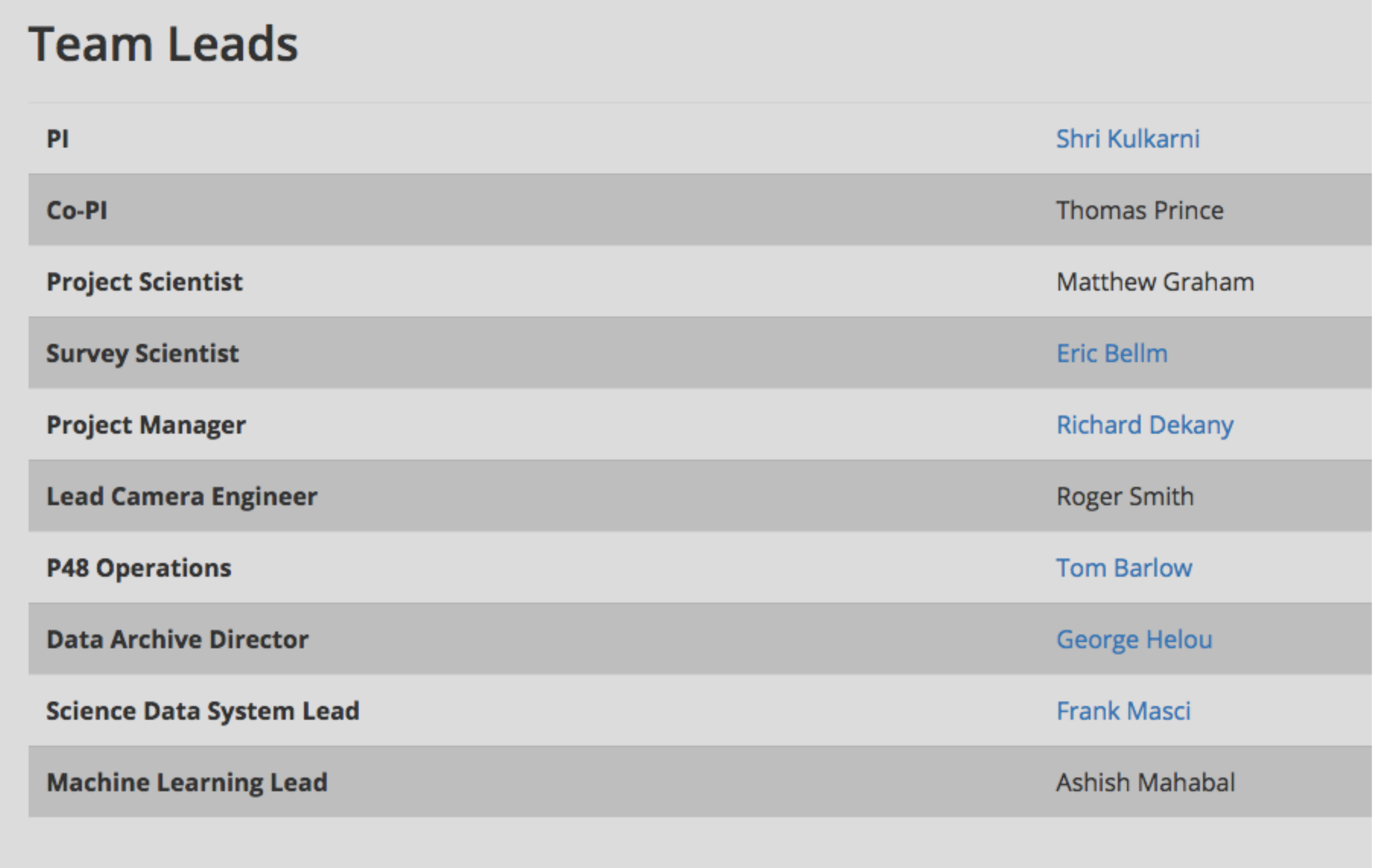
**Ashish Mahabal, aam at astro.caltech.edu**
**ZTF ML lead, astronomy**
**Center for Data-Driven Discovery**

**9th Gaia Science Alerts Workshop**
**Vipava, Slovenia, 2018-10-08**

# Outline

- **Intro to Zwicky Transient Facility (ZTF)**
- **Data processing and science**
- **Connection to Gaia**
- **Possibilities**

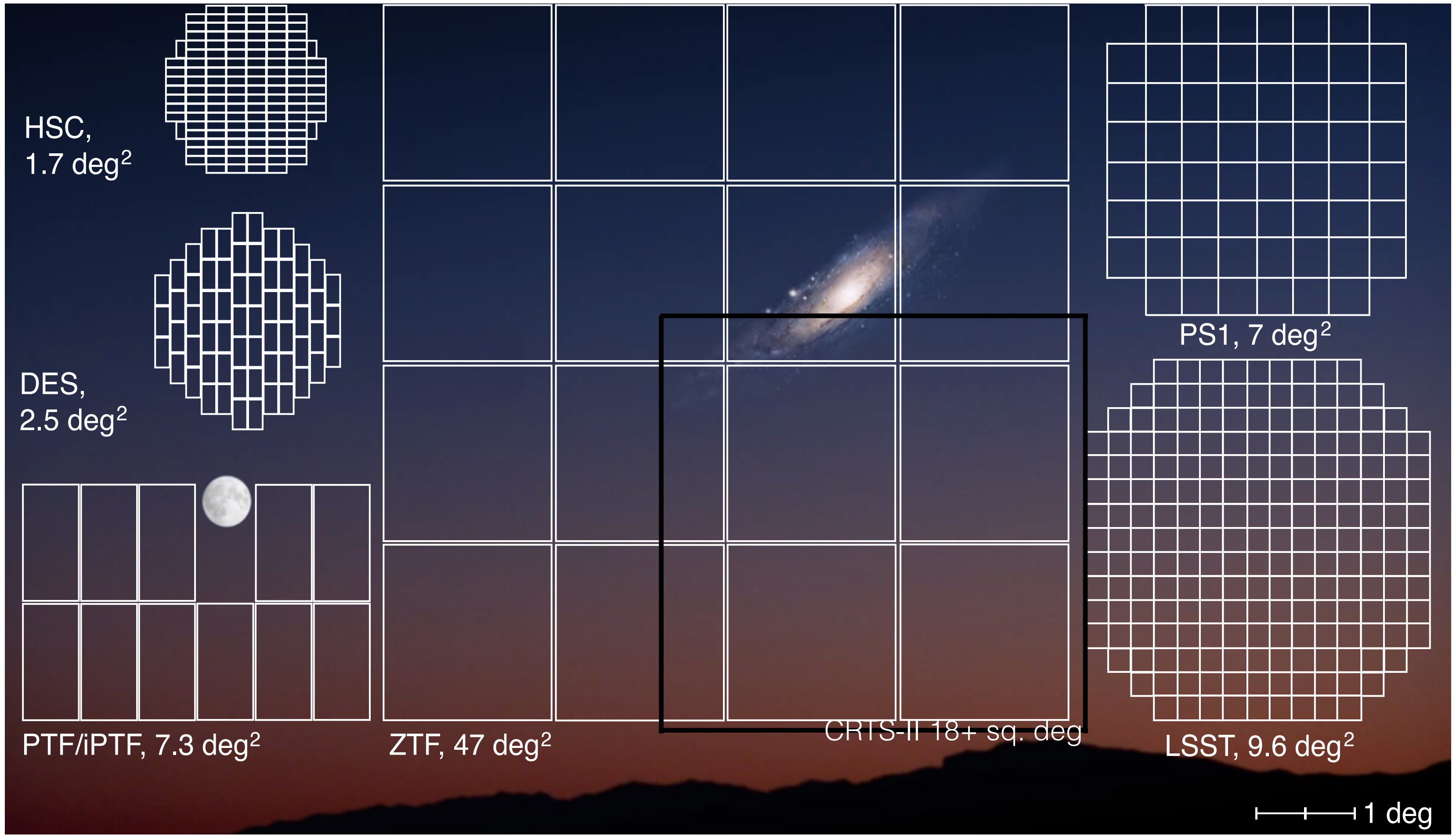
PEOPLE CLOSEST TO INSTRUMENTS AND DATA
ARE BEST TO WORK WITH EVEN IF THE DATA ARE PUBLIC



## Team Leads

| | |
|---|---|
| **PI** | Shri Kulkarni |
| **Co-PI** | Thomas Prince |
| **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** | Frank Masci |
| **Machine Learning Lead** | Ashish Mahabal |

# ZTF has a large FOV and fast cadence



**300K - 1M alerts/night**

**1000 observations over 3 years**
**1 billion sources**
**First trillion row survey**

**ZTF has bigger FOV (47 sq. deg.),**
**new camera (600 M pixels),**
**new CCDs,**
**Nightly data: 1.4 TB**
**more science use-cases**

# Different observing programs

- **MSIP - Public (g/r 40%) - 3 nights (|b| < 7, every night)**
- **Partnership (g/r/i 40%)**
- **Caltech (20% mostly g/r)**

**MSIP - alerts public in real time**
**Data to be made public**
**Like with Gaia data we do not see/use non-public MSIP data for science**

March 17, 2018 – start of survey operations
June 4, 2018 – start of public alert stream

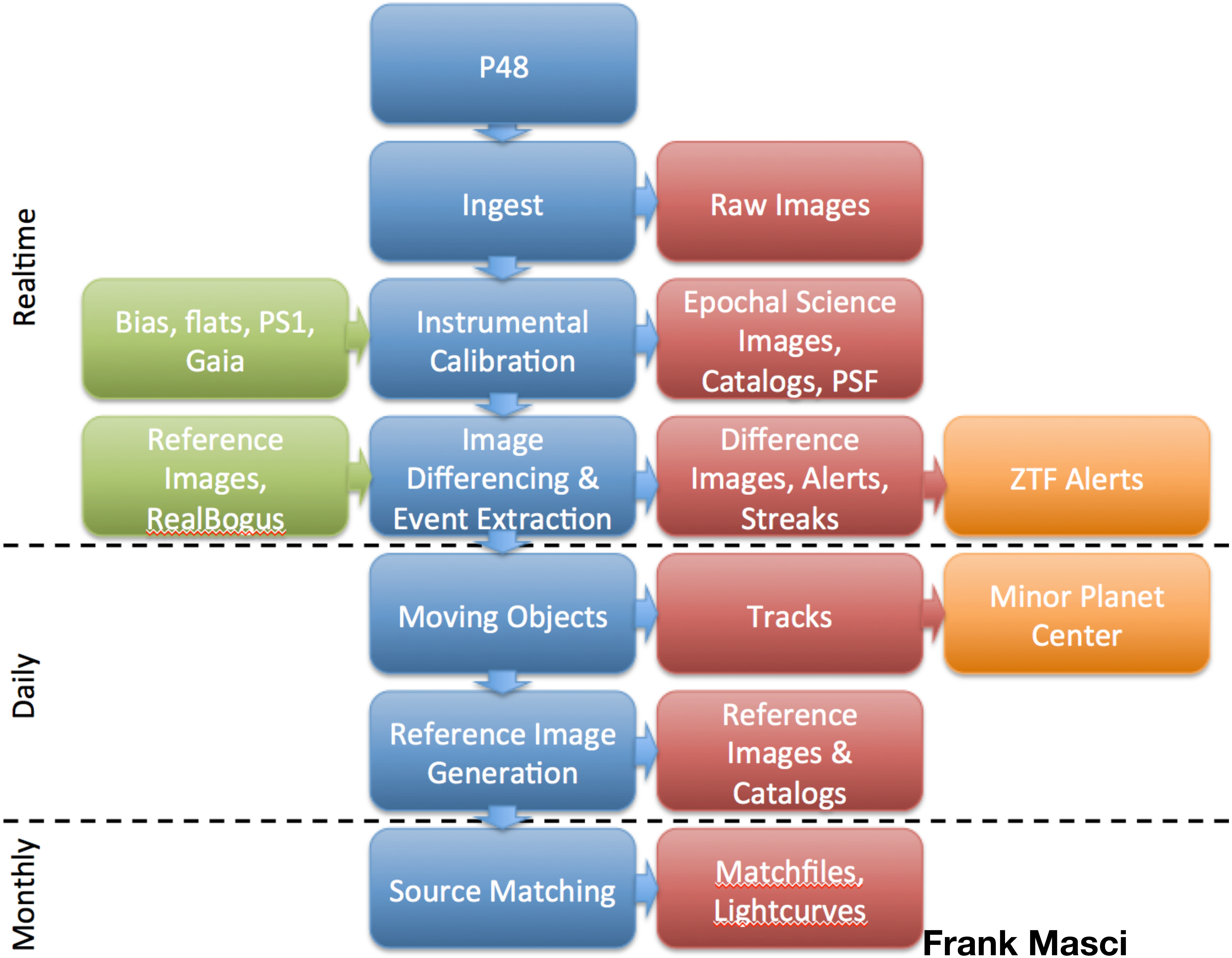
# Caltech cadence

**One of the programs (high cadence):**

- **-14 < GB < 14**
- **90 minutes continuous**
- **repeated thrice (over few nights)**

**This is an area where we could do more together**

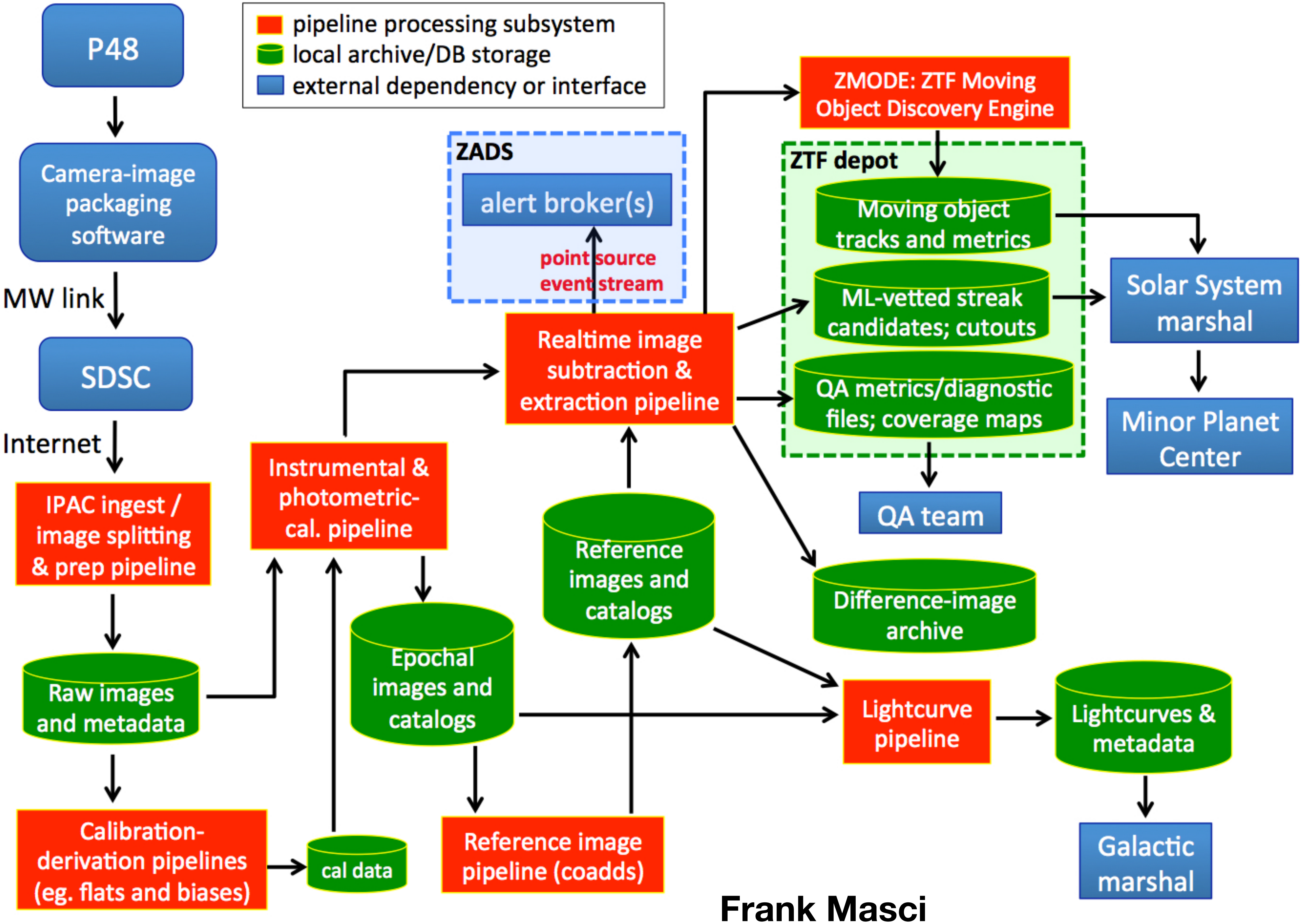
# All data uniformly processed - end points differ



**Frank Masci**

Ashish Mahabal

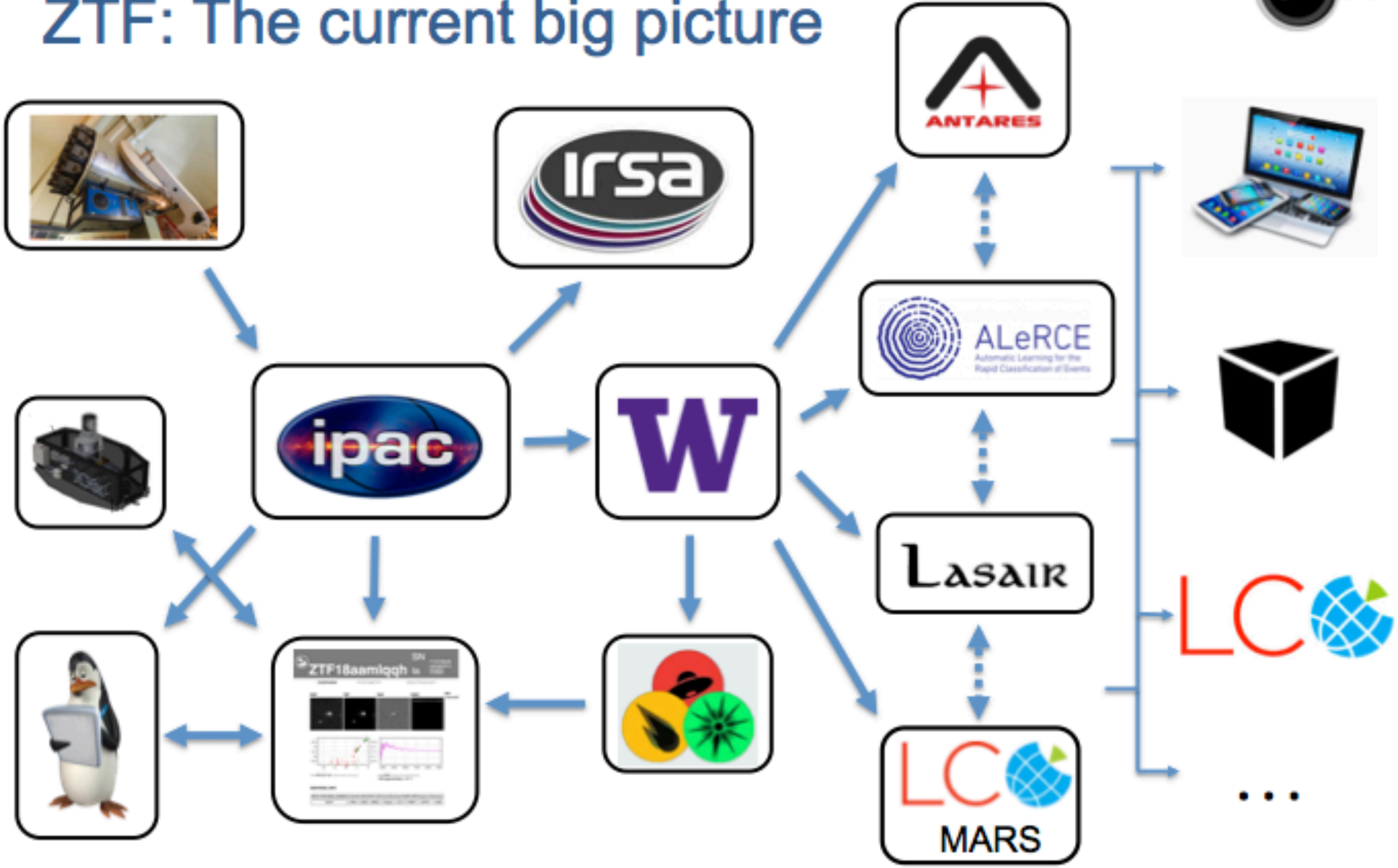
# For partnership data we have marshals



**Frank Masci**

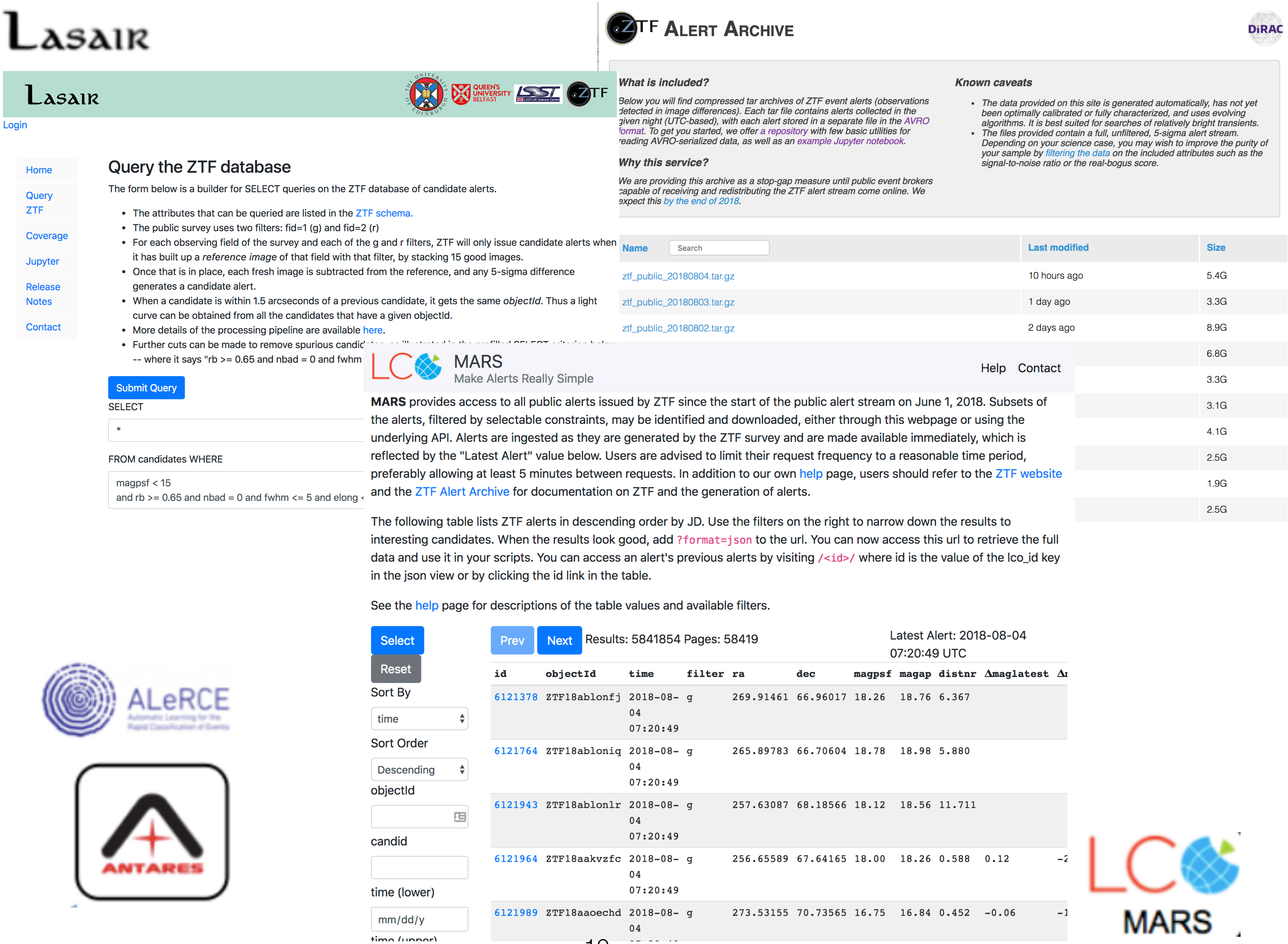
Ashish Mahabal

# ZTF: The current big picture



**Graham**

# Lasair



Lasair

Login

- Home
- Query ZTF
- Coverage
- Jupyter
- Release Notes
- Contact

## Query the ZTF database

The form below is a builder for SELECT queries on the ZTF database of candidate alerts.

- The attributes that can be queried are listed in the ZTF schema.
- The public survey uses two filters: fid=1 (g) and fid=2 (r)
- For each observing field of the survey and each of the g and r filters, ZTF will only issue candidate alerts when it has built up a *reference image* of that field with that filter, by stacking 15 good images.
- Once that is in place, each fresh image is subtracted from the reference, and any 5-sigma difference generates a candidate alert.
- When a candidate is within 1.5 arcseconds of a previous candidate, it gets the same *objectId*. Thus a light curve can be obtained from all the candidates that have a given objectId.
- More details of the processing pipeline are available here.
- Further cuts can be made to remove spurious candid
-- where it says "rb >= 0.65 and nbad = 0 and fwhm

Submit Query

SELECT

*

FROM candidates WHERE

magpsf < 15
and rb >= 0.65 and nbad = 0 and fwhm <= 5 and elong

## ZTF Alert Archive

DiRAC

**What is included?**

*Below you will find compressed tar archives of ZTF event alerts (observations detected in image differences). Each tar file contains alerts collected in the given night (UTC-based), with each alert stored in a separate file in the AVRO format. To get you started, we offer a repository with few basic utilities for reading AVRO-serialized data, as well as an example Jupyter notebook.*

**Why this service?**

*We are providing this archive as a stop-gap measure until public event brokers capable of receiving and redistributing the ZTF alert stream come online. We expect this by the end of 2018.*

**Known caveats**

- *The data provided on this site is generated automatically, has not yet been optimally calibrated or fully characterized, and uses evolving algorithms. It is best suited for searches of relatively bright transients.*
- *The files provided contain a full, unfiltered, 5-sigma alert stream. Depending on your science case, you may wish to improve the purity of your sample by filtering the data on the included attributes such as the signal-to-noise ratio or the real-bogus score.*

| Name | Last modified | Size |
|---|---|---|
| ztf_public_20180804.tar.gz | 10 hours ago | 5.4G |
| ztf_public_20180803.tar.gz | 1 day ago | 3.3G |
| ztf_public_20180802.tar.gz | 2 days ago | 8.9G |
|  |  | 6.8G |
|  |  | 3.3G |
|  |  | 3.1G |
|  |  | 4.1G |
|  |  | 2.5G |
|  |  | 1.9G |
|  |  | 2.5G |

## MARS
Make Alerts Really Simple

Help Contact

**MARS** provides access to all public alerts issued by ZTF since the start of the public alert stream on June 1, 2018. Subsets of the alerts, filtered by selectable constraints, may be identified and downloaded, either through this webpage or using the underlying API. Alerts are ingested as they are generated by the ZTF survey and are made available immediately, which is reflected by the "Latest Alert" value below. Users are advised to limit their request frequency to a reasonable time period, preferably allowing at least 5 minutes between requests. In addition to our own help page, users should refer to the ZTF website and the ZTF Alert Archive for documentation on ZTF and the generation of alerts.

The following table lists ZTF alerts in descending order by JD. Use the filters on the right to narrow down the results to interesting candidates. When the results look good, add `?format=json` to the url. You can now access this url to retrieve the full data and use it in your scripts. You can access an alert's previous alerts by visiting `/<id>/` where id is the value of the lco_id key in the json view or by clicking the id link in the table.

See the help page for descriptions of the table values and available filters.

Select
Reset
Sort By: time
Sort Order: Descending
objectId:
candid:
time (lower): mm/dd/y
time (upper)

Prev Next Results: 5841854 Pages: 58419

Latest Alert: 2018-08-04 07:20:49 UTC

| id | objectId | time | filter | ra | dec | magpsf | magap | distnr | Δmaglatest | Δ |
|---|---|---|---|---|---|---|---|---|---|---|
| 6121378 | ZTF18ablonfj | 2018-08-04 07:20:49 | g | 269.91461 | 66.96017 | 18.26 | 18.76 | 6.367 |  |  |
| 6121764 | ZTF18abloniq | 2018-08-04 07:20:49 | g | 265.89783 | 66.70604 | 18.78 | 18.98 | 5.880 |  |  |
| 6121943 | ZTF18ablonlr | 2018-08-04 07:20:49 | g | 257.63087 | 68.18566 | 18.12 | 18.56 | 11.711 |  |  |
| 6121964 | ZTF18aakvzfc | 2018-08-04 07:20:49 | g | 256.65589 | 67.64165 | 18.00 | 18.26 | 0.588 | 0.12 | -2 |
| 6121989 | ZTF18aaoechd | 2018-08-04 | g | 273.53155 | 70.73565 | 16.75 | 16.84 | 0.452 | -0.06 | -1 |

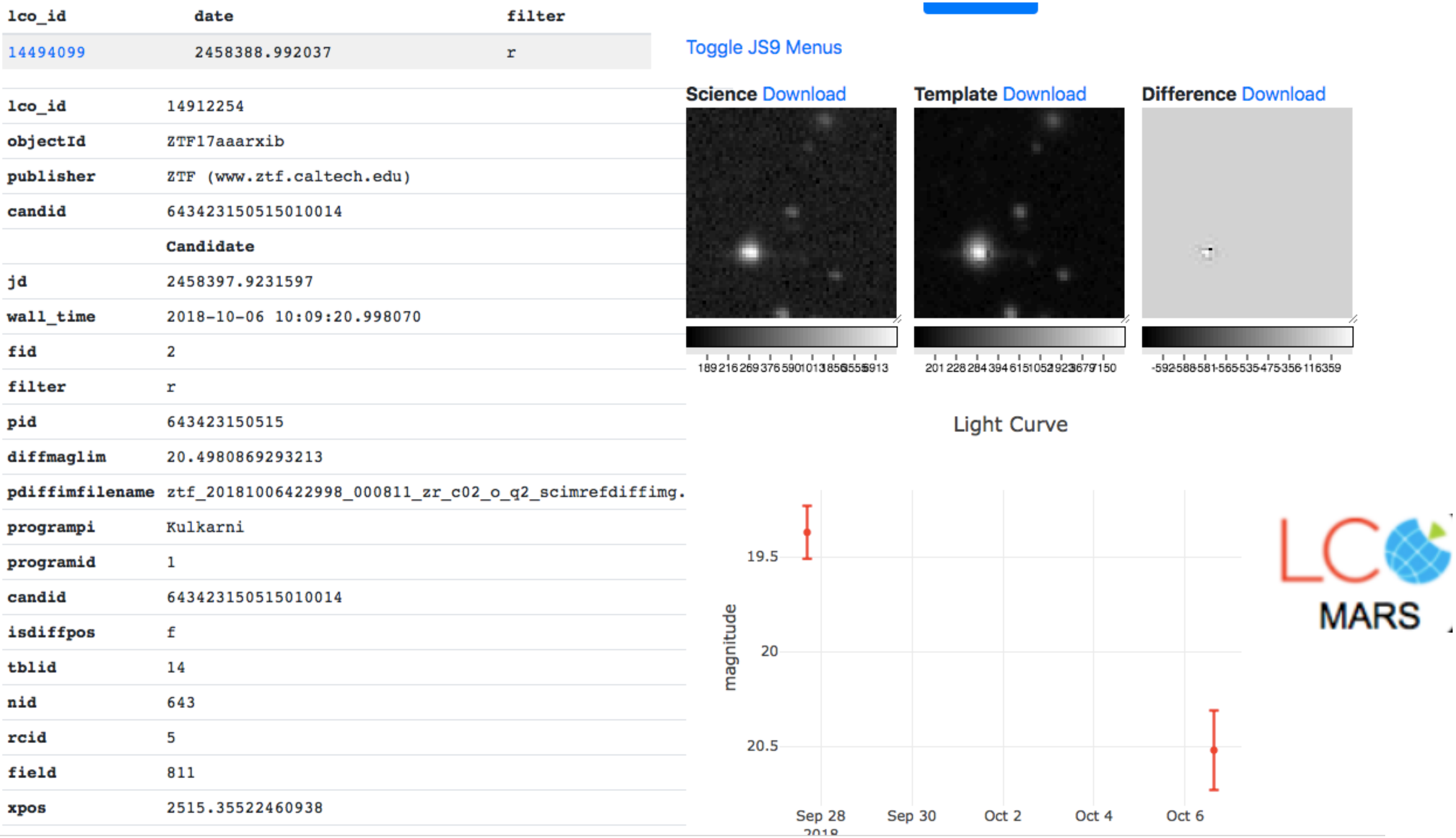
ALeRCE

ANTARES

MARS

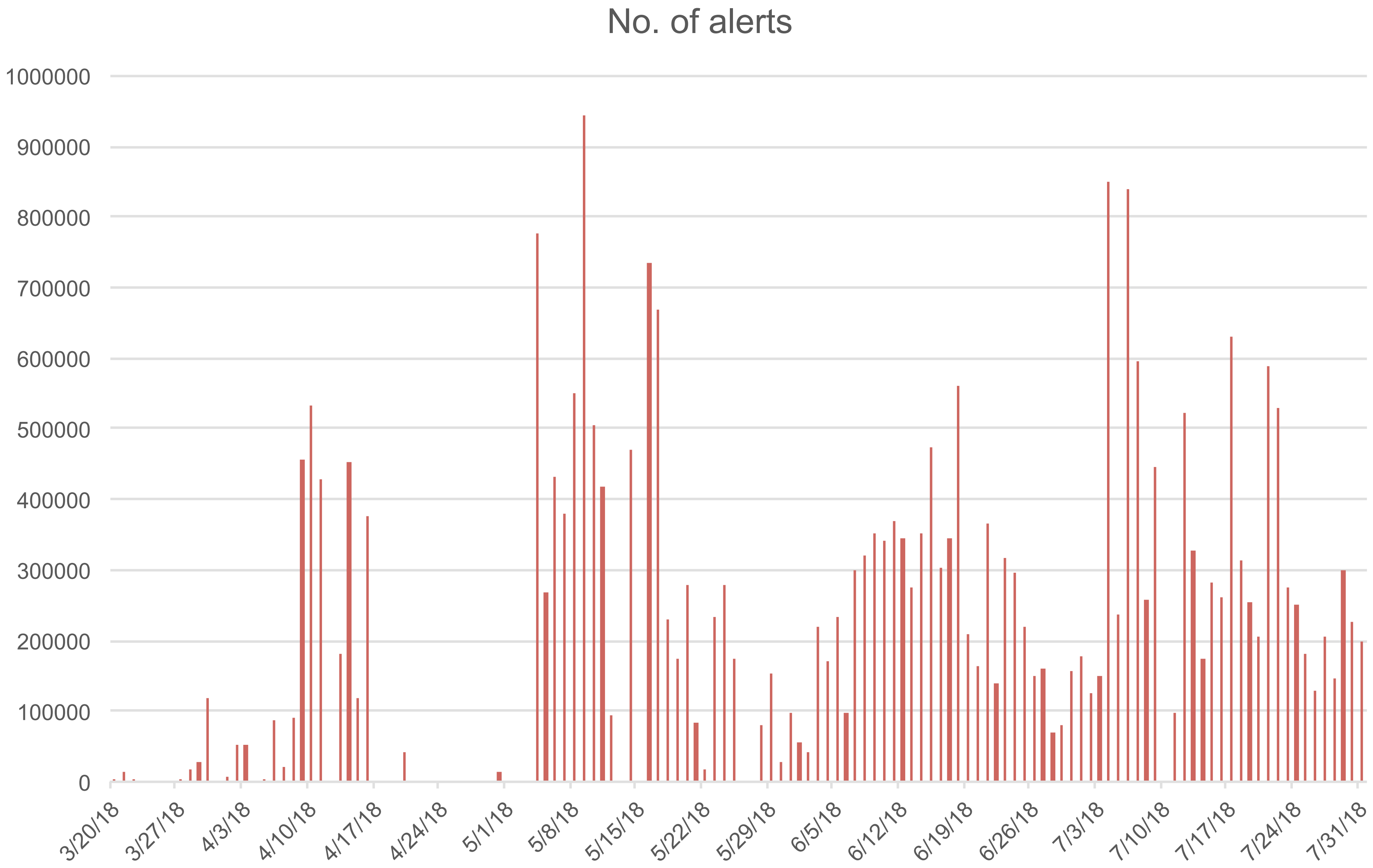
Ashish Mahabal

# MARS drilldown



| lco_id | date | filter |
|---|---|---|
| 14494099 | 2458388.992037 | r |

| | |
|---|---|
| lco_id | 14912254 |
| objectId | ZTF17aaarxib |
| publisher | ZTF (www.ztf.caltech.edu) |
| candid | 643423150515010014 |
| | **Candidate** |
| jd | 2458397.9231597 |
| wall_time | 2018-10-06 10:09:20.998070 |
| fid | 2 |
| filter | r |
| pid | 643423150515 |
| diffmaglim | 20.4980869293213 |
| pdiffimfilename | ztf_20181006422998_000811_zr_c02_o_q2_scimrefdiffimg. |
| programpi | Kulkarni |
| programid | 1 |
| candid | 643423150515010014 |
| isdiffpos | f |
| tblid | 14 |
| nid | 643 |
| rcid | 5 |
| field | 811 |
| xpos | 2515.35522460938 |

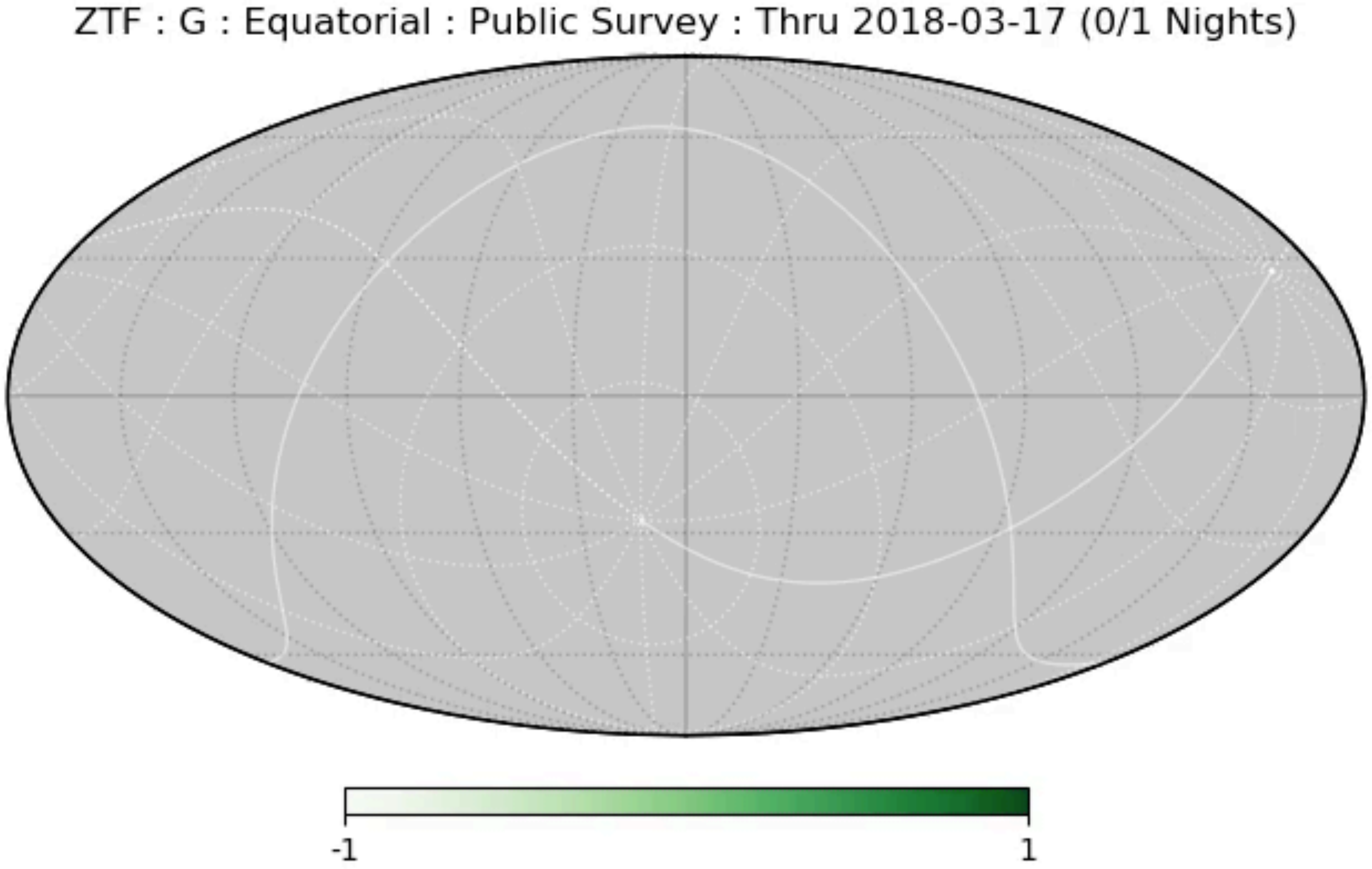


Astrometric reference sources from Gaia DR1 already in use for calibration. DR2 soon.

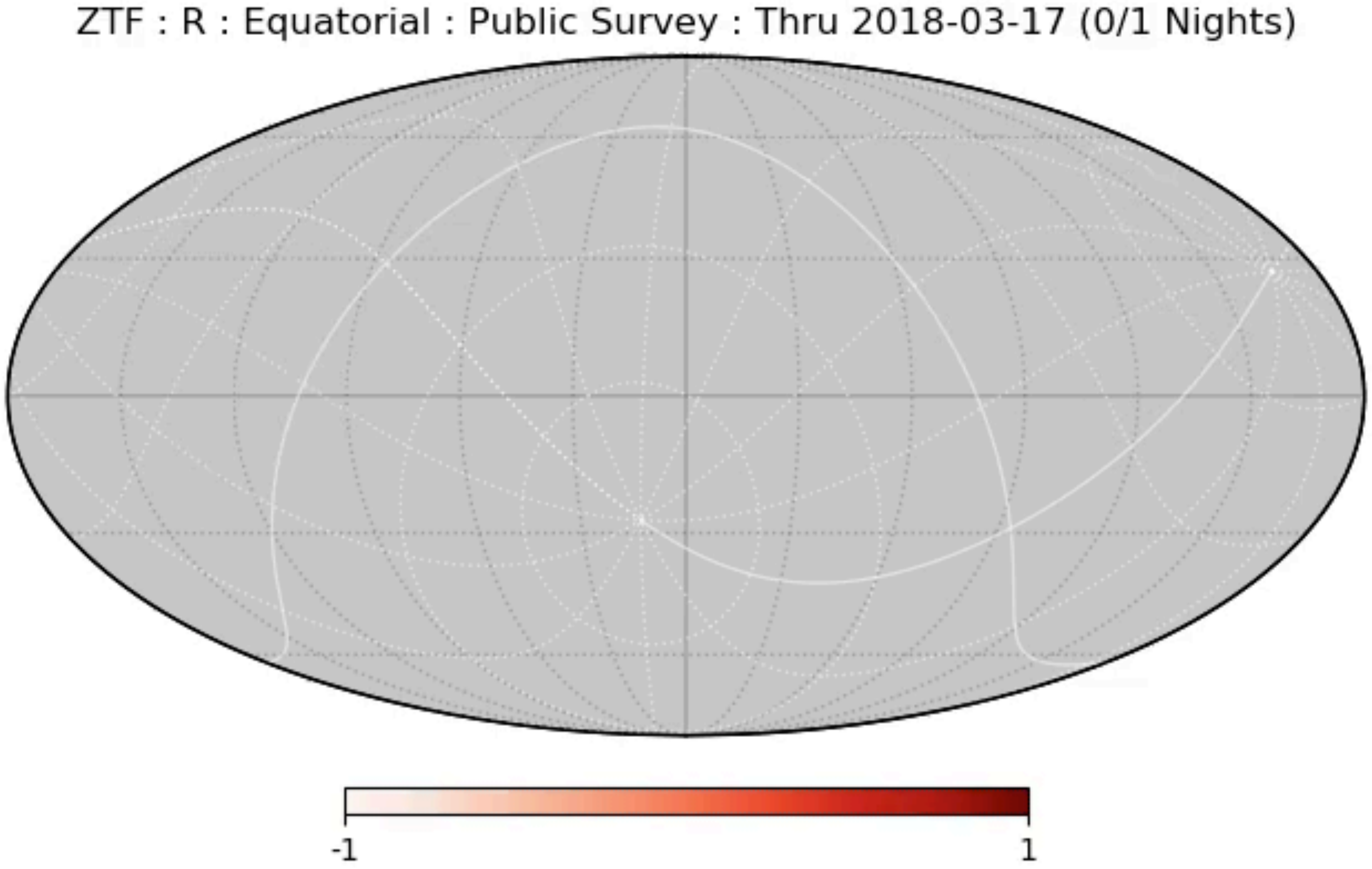
Gaia allows quantification of astrometric biases due to Differential Chromatic Refraction (DCR). DCR dominates above airmass of 1.8

Nearest Gaia DR1 source is reported in alert packets

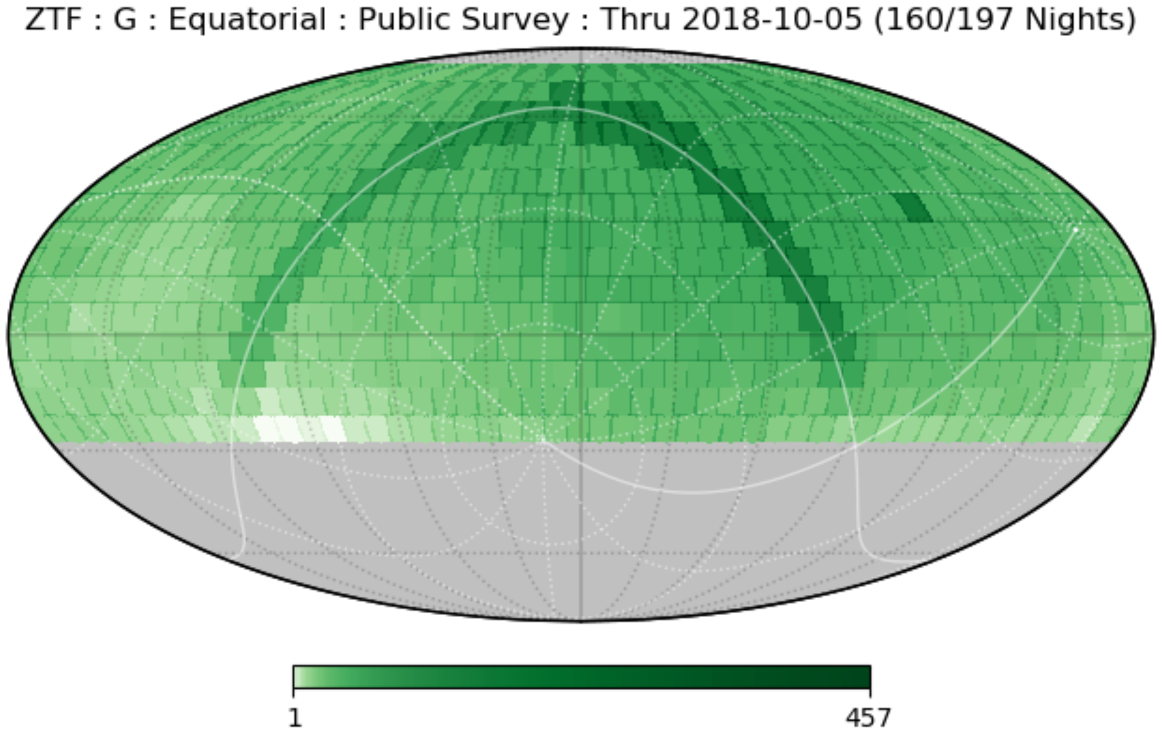
# MSIP g band coverage

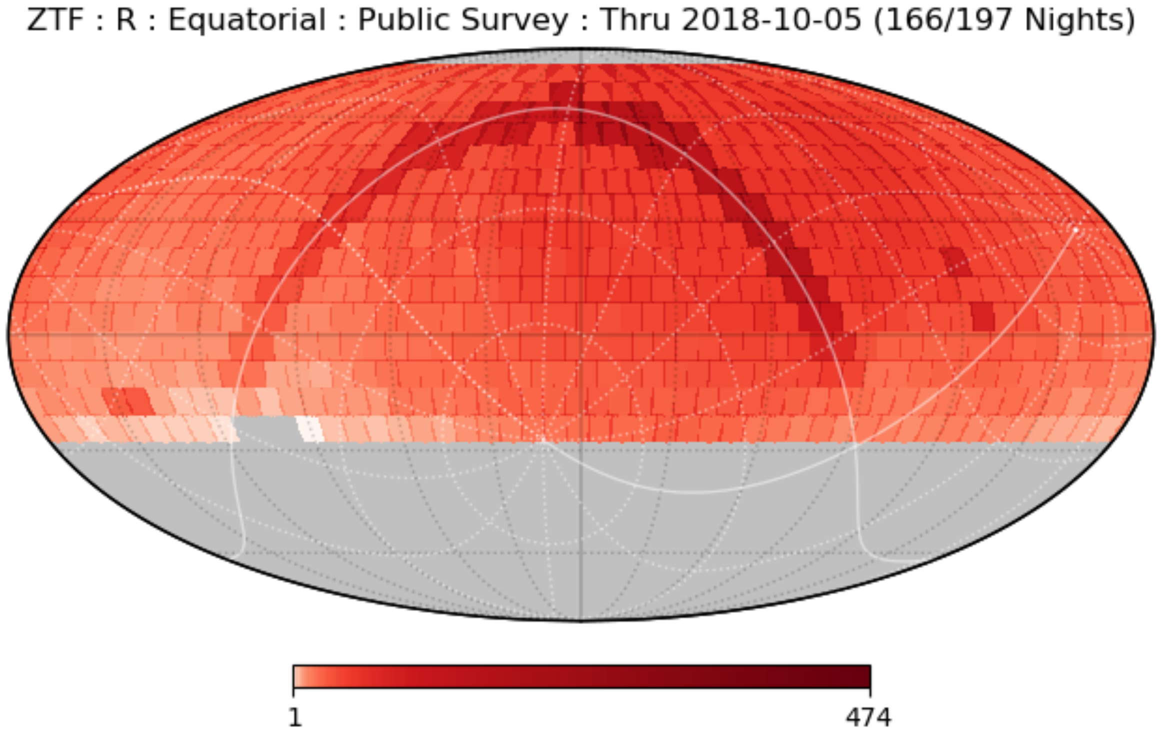


# MSIP r band coverage

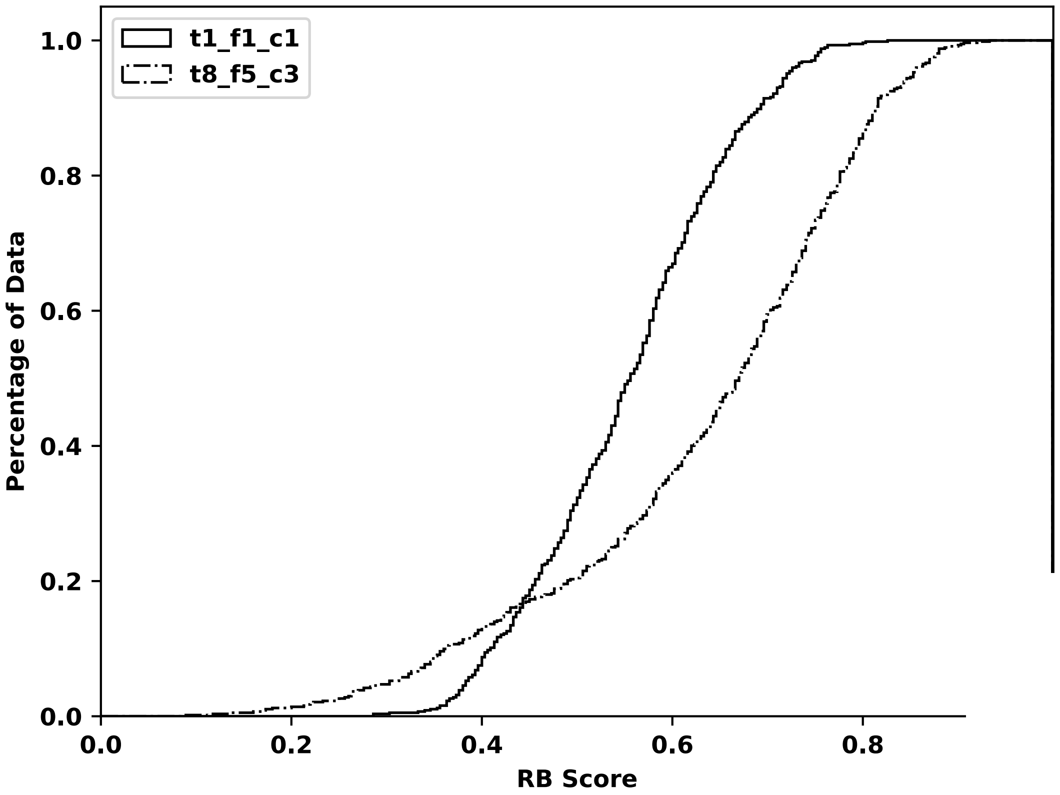


# MSIP g and r band coverage


ZTF : G : Equatorial : Public Survey : Thru 2018-10-05 (160/197 Nights)


ZTF : R : Equatorial : Public Survey : Thru 2018-10-05 (166/197 Nights)

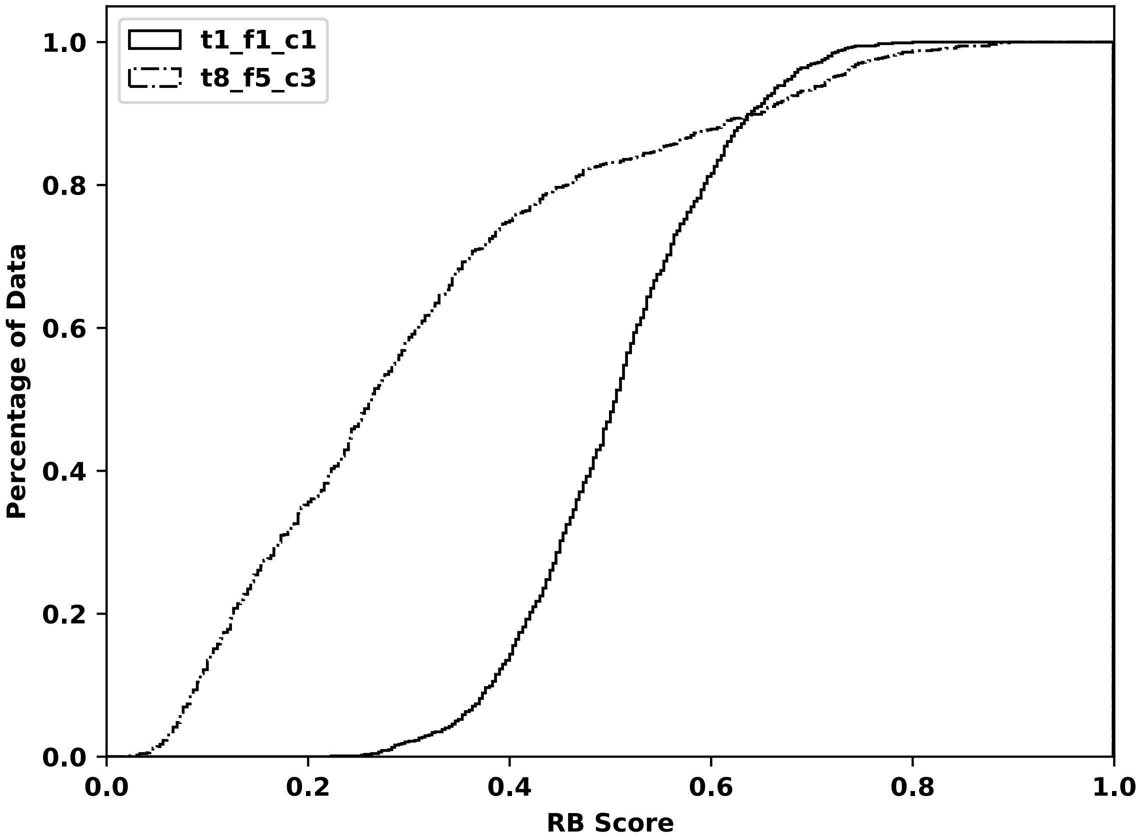
# Real-Bogus separation



**improvement of performance over time**

**bogus**

**reals**



# ZTF Science working groups

- **Cosmology with Supernovae and Gravitational Lensing**
  - Uli Feindt and Jakob Nordin
- **AGNs and TDEs**
  - Suvi Gezari and Matthew Graham
- **EM/GW and Neutrino Counterparts**
  - Mansi Kasliwal and Anna Franckowiak
- **Physics of Supernovae and Relativistic Explosions**
  - Ragnhild Lunna, Christoffer Fremling, and Steve Schulze
- **Galactic and M31 Science**
  - Thomas Kupfer and Po-Chieh Yu
- **Solar System Bodies**
  - Quan-Zhi Ye, Dennis Bodewits, and Rex Chang

# Supernovae

**> 400 Ia**

**> 100 II**

**~20 SLSNe**

**>10 Ib**

**>10 Ic**

**Lensed supernovae, catching all types on the rise, …**

# First ZTF TDE

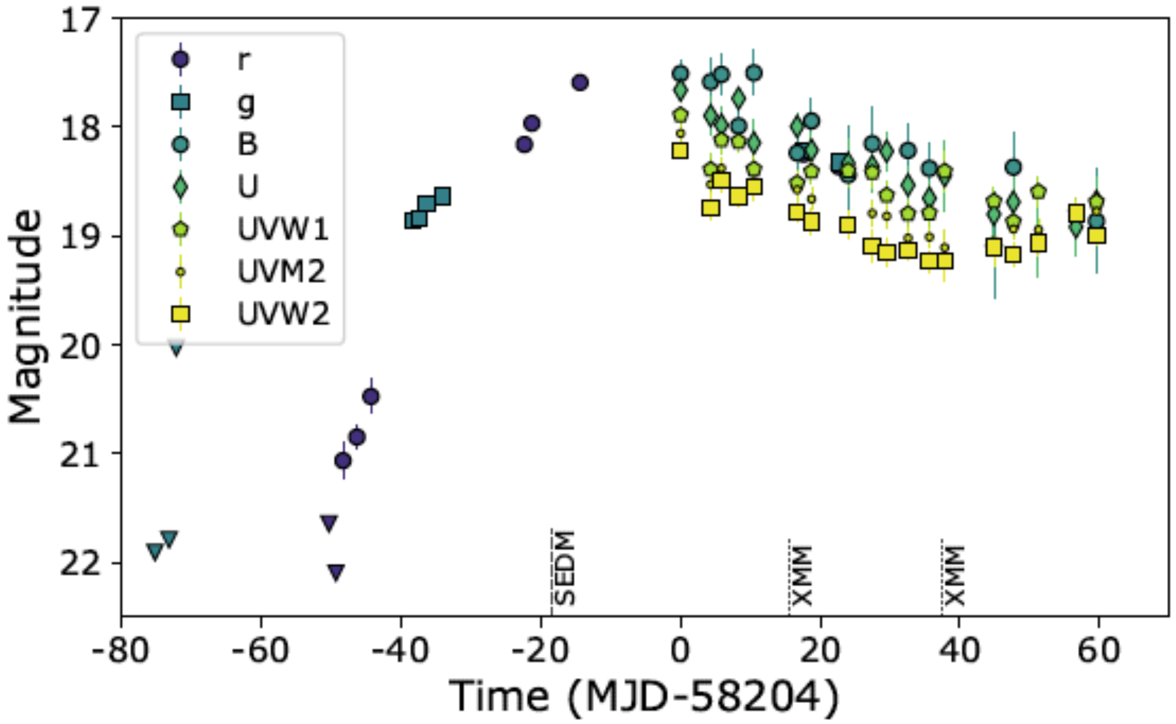


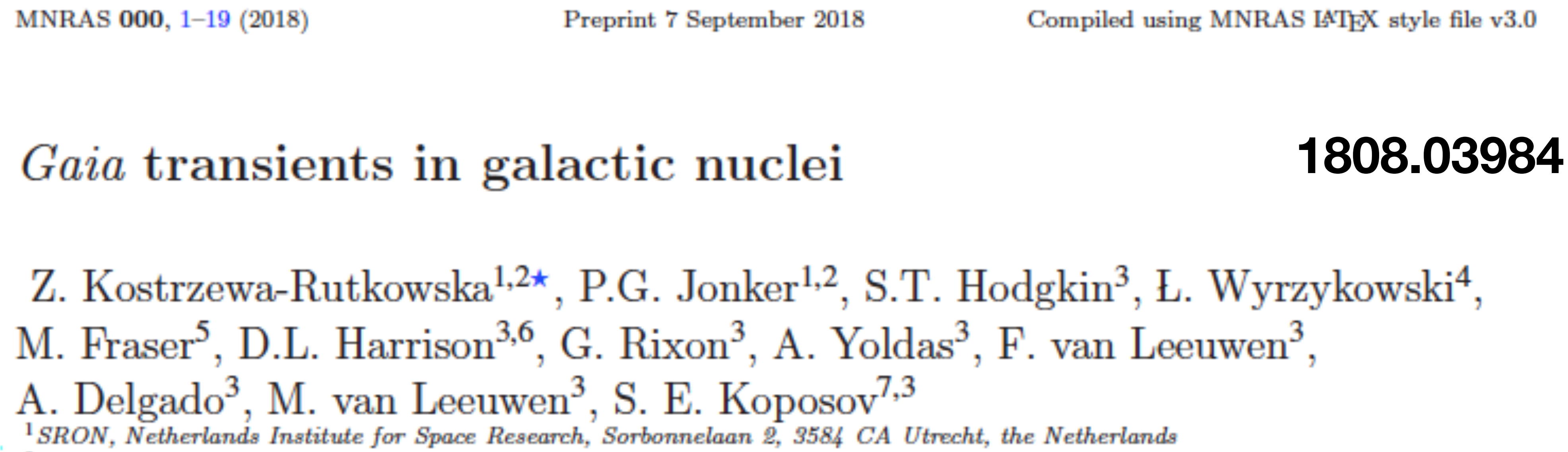
**Figure 1.** ZTF and *Swift*/UVOT light curve. The dashed line indicates the time of the first SEDM spectrum, while the dotted lines label the time of XMM X-ray observations. Triangles denote $5\sigma$ upper limits to the flux.

**Van Velzen et al.**
**1809.02608**

**AT2018zr**
**ZTF18aabtxvd**
**ZTF-NedStark**

**z=0.071**

**x-ray detection**
**but no radio**



MNRAS **000**, 1–19 (2018) Preprint 7 September 2018 Compiled using MNRAS LaTeX style file v3.0

# *Gaia* transients in galactic nuclei

**1808.03984**

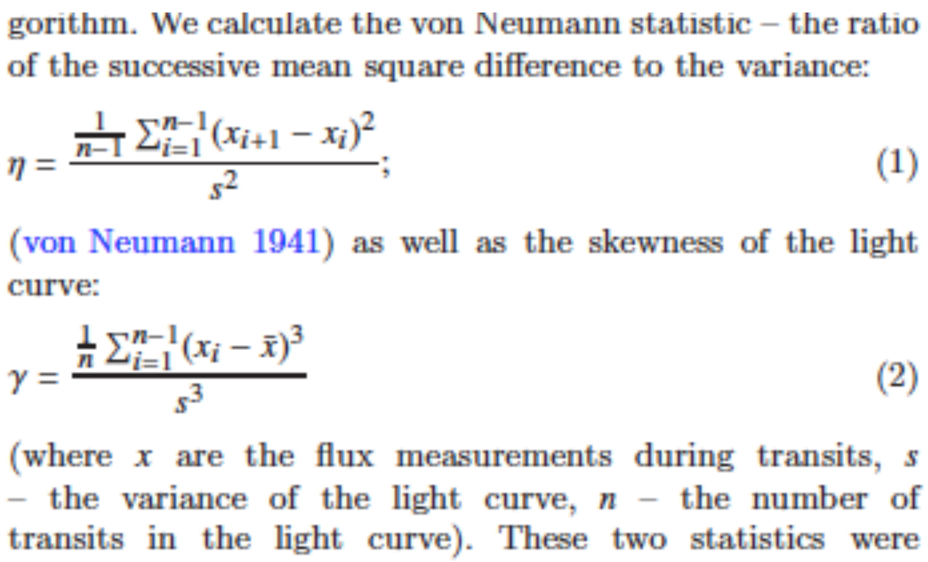
Z. Kostrzewa-Rutkowska[1,2★], P.G. Jonker[1,2], S.T. Hodgkin[3], Ł. Wyrzykowski[4], M. Fraser[5], D.L. Harrison[3,6], G. Rixon[3], A. Yoldas[3], F. van Leeuwen[3], A. Delgado[3], M. van Leeuwen[3], S. E. Koposov[7,3]

[1] *SRON, Netherlands Institute for Space Research, Sorbonnelaan 2, 3584 CA Utrecht, the Netherlands*

[2] *Department of Astrophysics/IMAPP, Radboud University, P.O. Box 9010, 6500 GL Nijmegen, the Netherlands*

**iPTF source**

## von Neumann and skewness



gorithm. We calculate the von Neumann statistic – the ratio of the successive mean square difference to the variance:

$$\eta = \frac{\frac{1}{n-1}\sum_{i=1}^{n-1}(x_{i+1}-x_i)^2}{s^2}; \qquad (1)$$

(von Neumann 1941) as well as the skewness of the light curve:

$$\gamma = \frac{\frac{1}{n}\sum_{i=1}^{n-1}(x_i-\bar{x})^3}{s^3} \qquad (2)$$

(where $x$ are the flux measurements during transits, $s$ – the variance of the light curve, $n$ – the number of transits in the light curve). These two statistics were

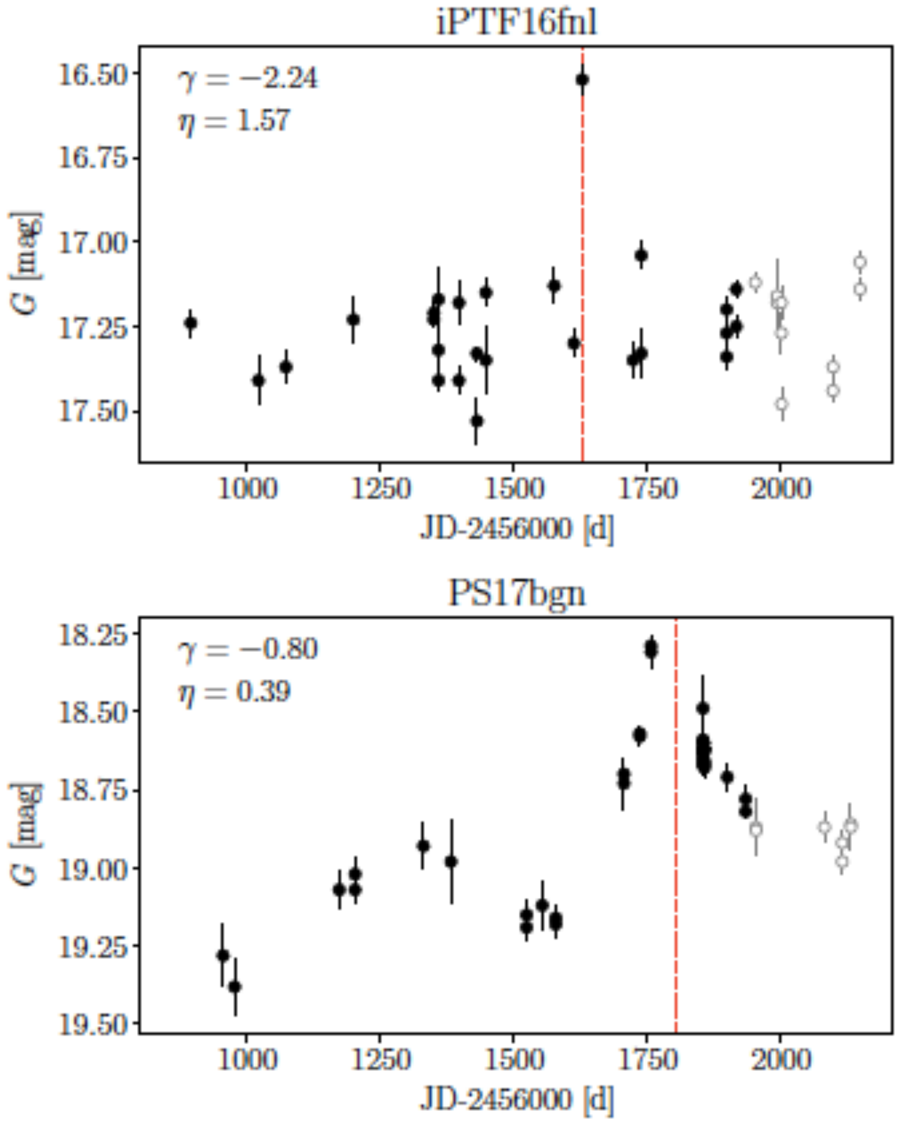


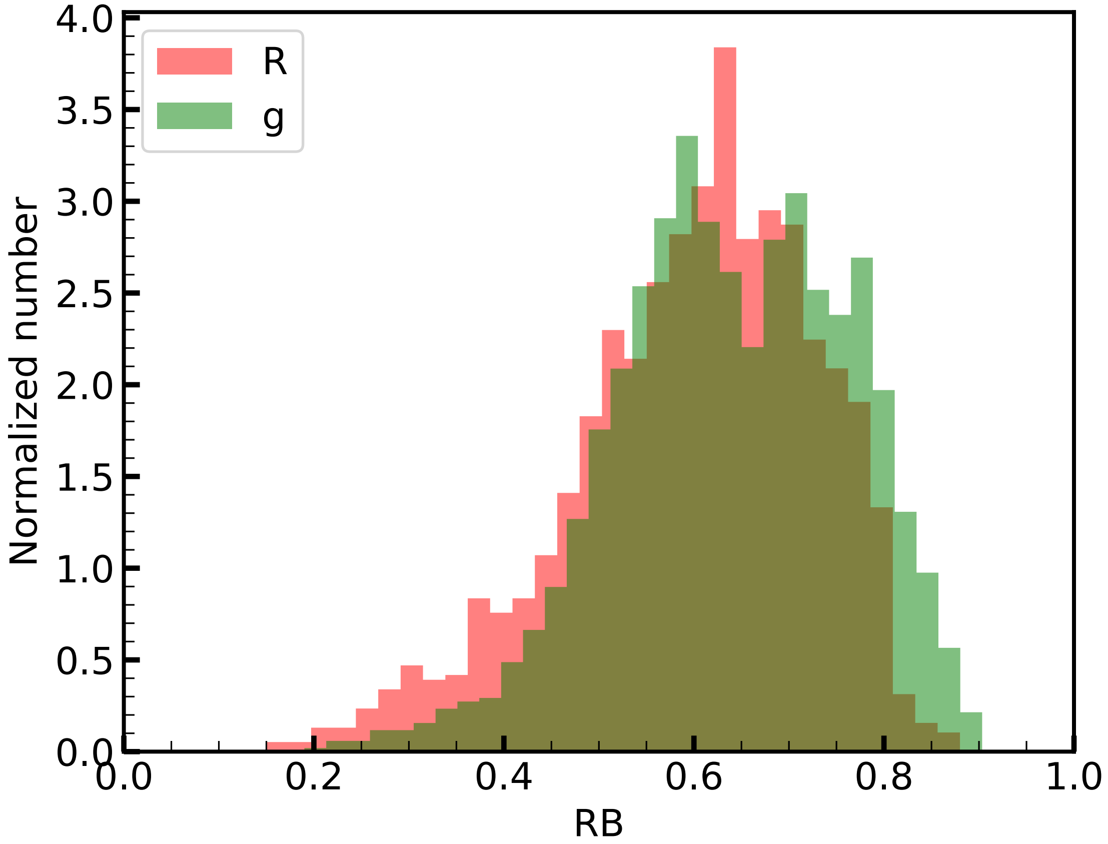
**Figure 9.** Examples of light curves of transient sources discovered by other surveys but not by *Gaia* even though the sources were detected. The dashed red line indicates the discovery time. *Top:*

**AlertPipe**
**OldSource**
**NewSource**

**Sources missed**

Ashish Mahabal

# Comparison of ZTF sources with TNS



**Mahabal et al 2018**
**Blagorodnova**

**Also validation through detection of known asteroids**

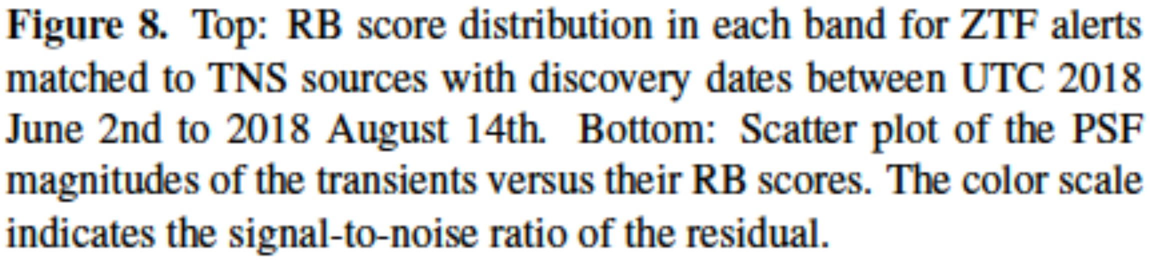
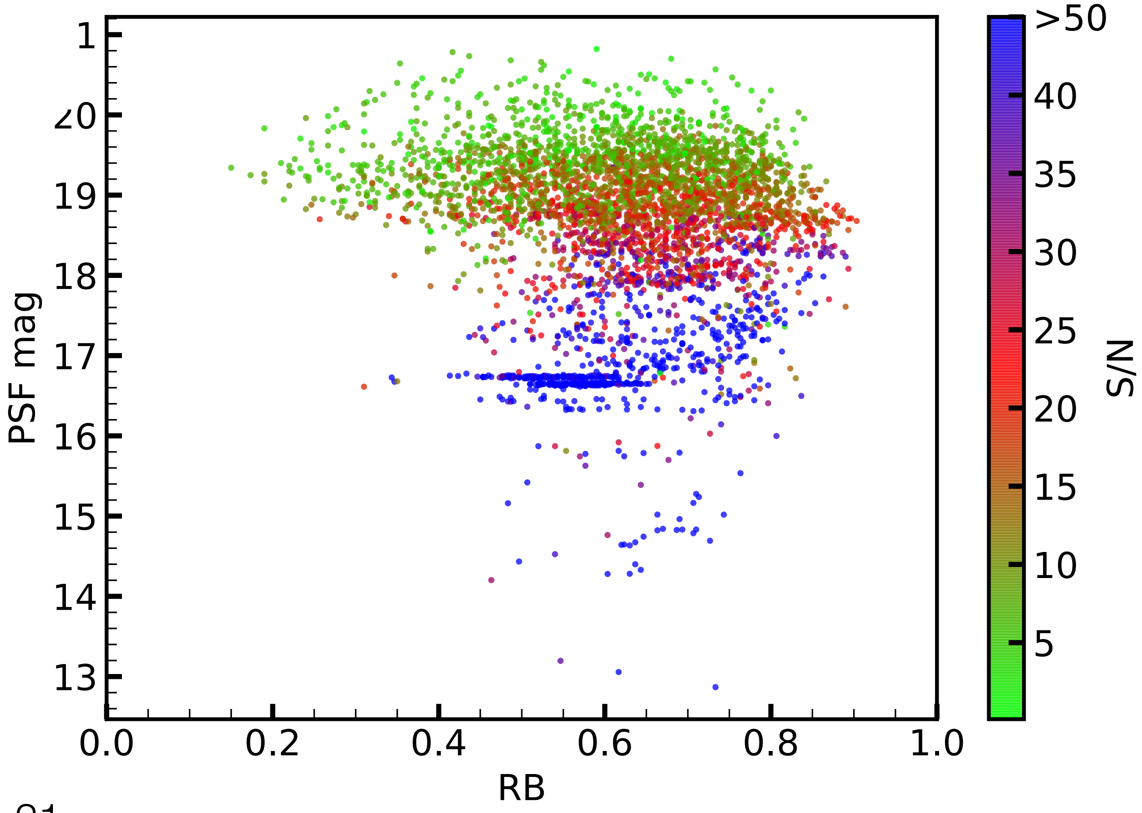


**Figure 8.** Top: RB score distribution in each band for ZTF alerts matched to TNS sources with discovery dates between UTC 2018 June 2nd to 2018 August 14th. Bottom: Scatter plot of the PSF magnitudes of the transients versus their RB scores. The color scale indicates the signal-to-noise ratio of the residual.



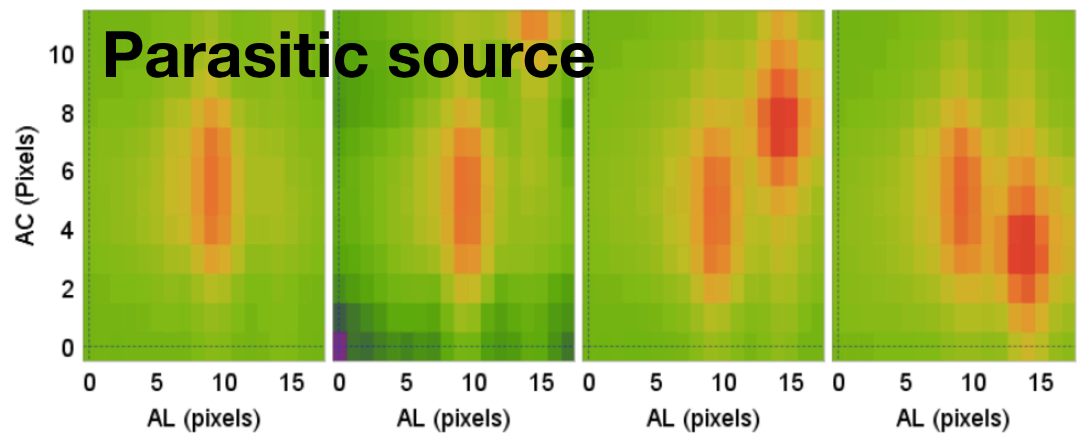
MNRAS **000**, 1–10 (2017) Preprint 13 August 2018 Compiled using MNRAS LATEX style file v3.0

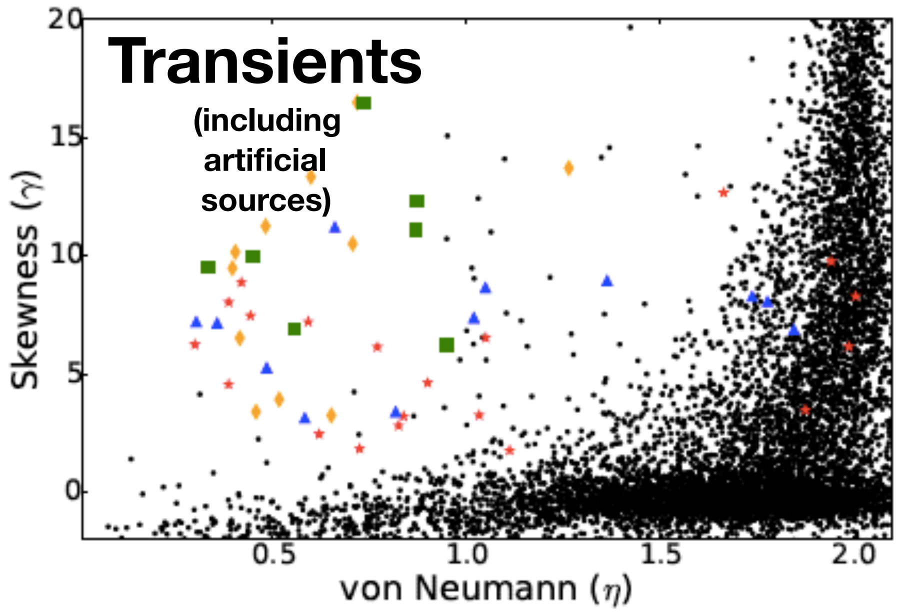
# The fast transient sky with *Gaia*

**1710.08924**

Thomas Wevers[1]*, Peter G. Jonker[2,1], Simon T. Hodgkin[3],
Zuzanna Kostrzewa-Rutkowska[2,1], Diana L. Harrison[3,4], Guy Rixon[3], Gijs Nelemans[1,5],
Maroussia Roelens[6], Laurent Eyer[6], Floor van Leeuwen[3] and Abdullah Yoldas[3]

[1] *Department of Astrophysics/IMAPP, Radboud University, P.O. Box 9010, NL-6500GL Nijmegen, The Netherlands*





om above and passes
ightening lasts for 3
effect can be visually
es.

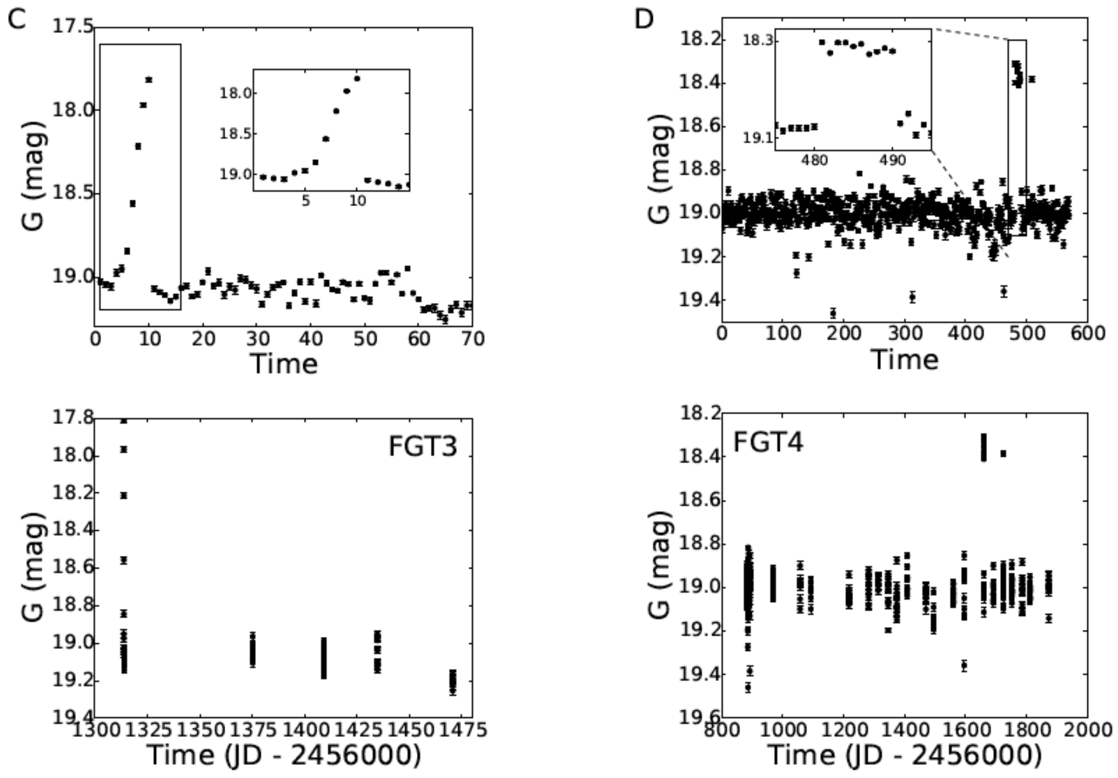
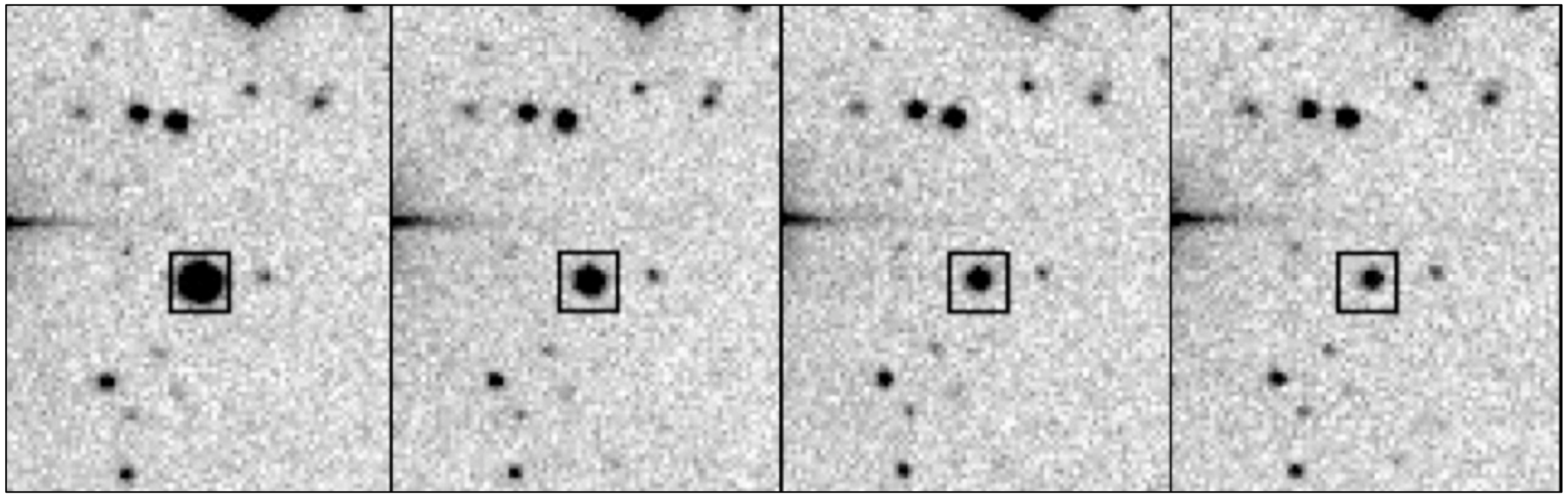


**Figure 5.** Lightcurves of FGT1 (panel A) through FGT4 (panel D). Each panel consists of 2 figures: the top figure shows the concatenated lightcurve for display purposes, with a running number per CCD crossing (i.e. time increases with running number). 10 measurements constitute 1 transit. The inset shows a zoom-in to the transient event. The bottom panel shows the actual time spacing of the observations, in Julian days. The data of the outlying transits is presented in tabular form in the Appendix.

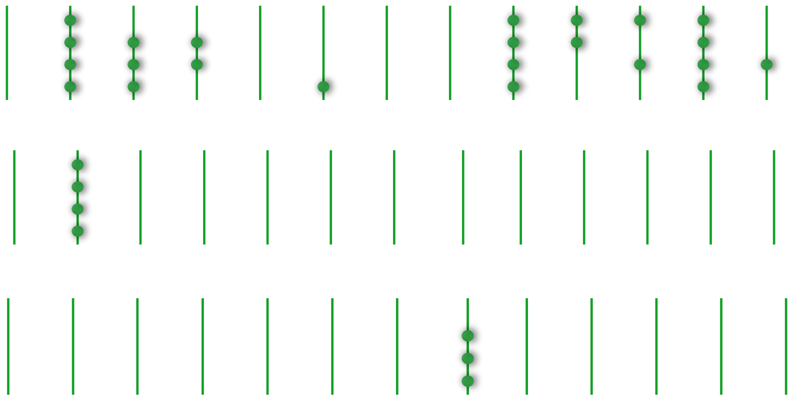
## A couple of the sources found

# orphancat vetting through Gaia

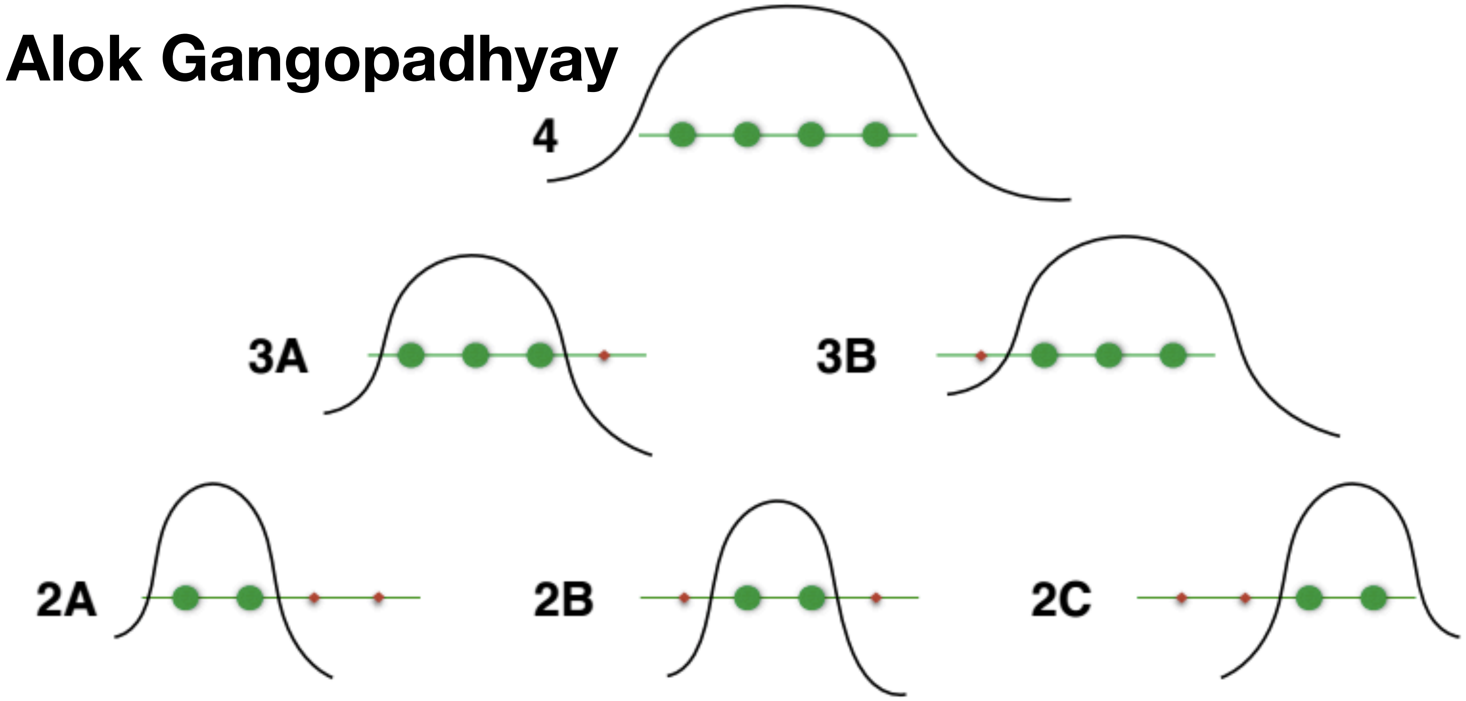


Photcat Orphancat **CRTS**

**nK transients 1.87B**



**Alok Gangopadhyay**

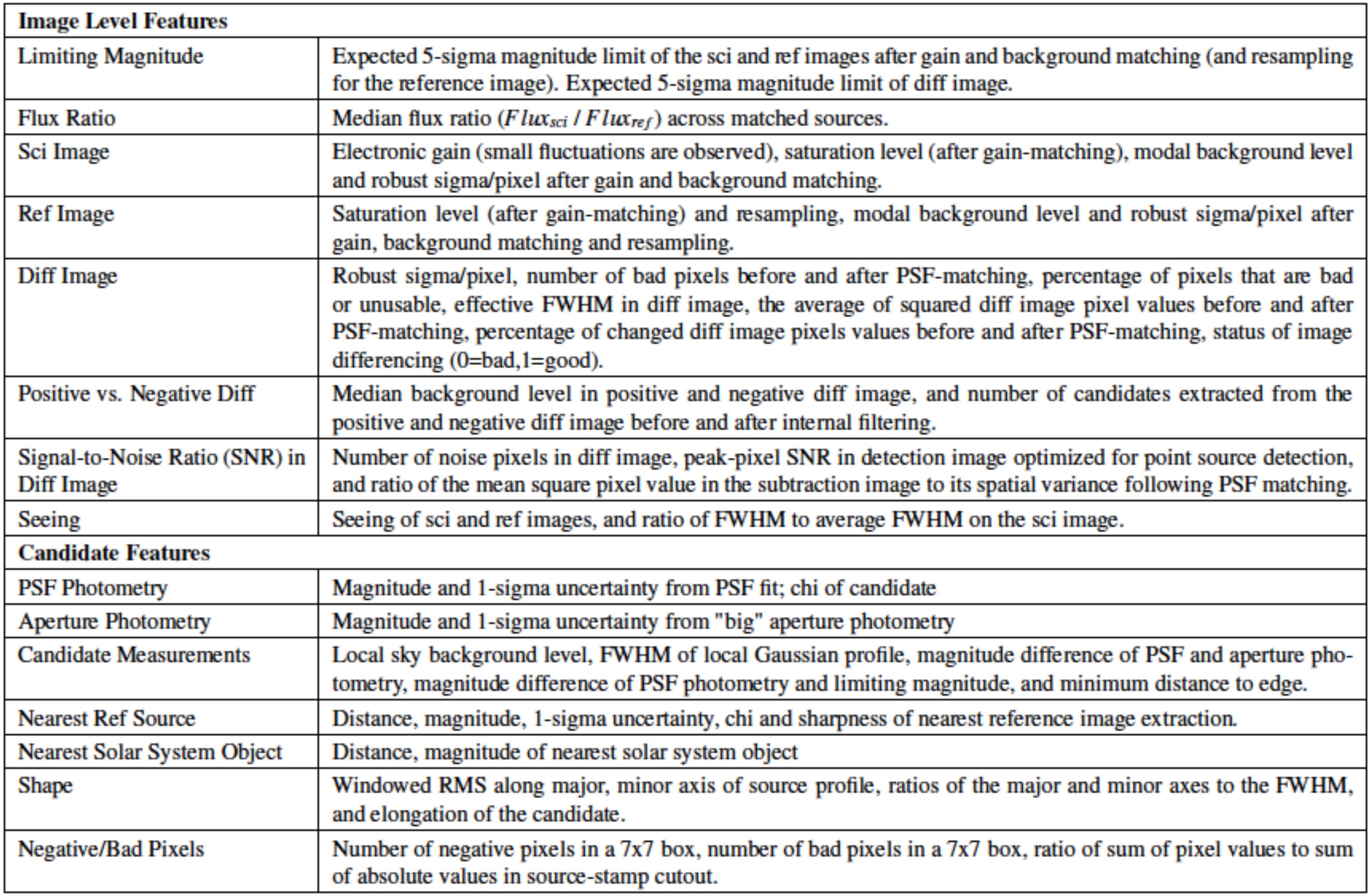


**Will be vetting with Gaia**
**Will start to repeat with ZTF**

| | unfiltered | filtered |
|---|---|---|
| 4-4 | 1.86 M | 0.96 M |
| 4 | 172 K | 64 K |
| 3A | 198 K | 78 K |
| 3B | 77 K | 18 K |
| 2A | 735 K | 75 K |
| 2B | 486 K | 62 K |
| 2C | 643 K | 79 K |

**Igor Anderoni**

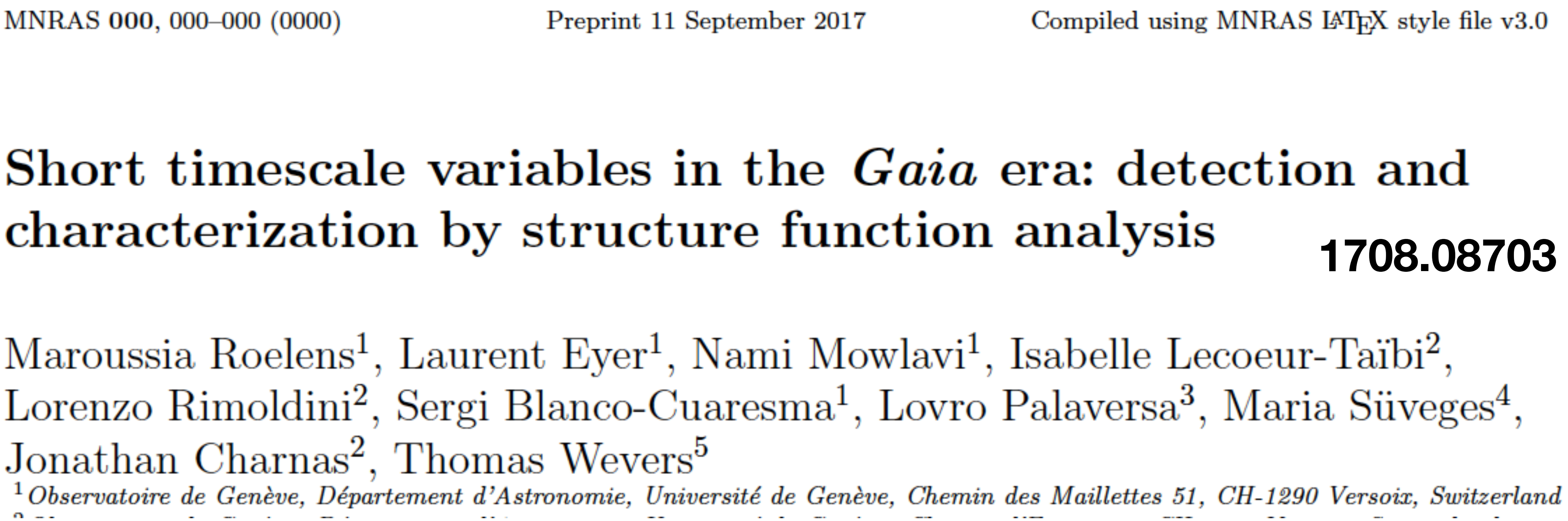
# Real-Bogus separation with large number of features



| **Image Level Features** | |
|---|---|
| Limiting Magnitude | Expected 5-sigma magnitude limit of the sci and ref images after gain and background matching (and resampling for the reference image). Expected 5-sigma magnitude limit of diff image. |
| Flux Ratio | Median flux ratio ($Flux_{sci}$ / $Flux_{ref}$) across matched sources. |
| Sci Image | Electronic gain (small fluctuations are observed), saturation level (after gain-matching), modal background level and robust sigma/pixel after gain and background matching. |
| Ref Image | Saturation level (after gain-matching) and resampling, modal background level and robust sigma/pixel after gain, background matching and resampling. |
| Diff Image | Robust sigma/pixel, number of bad pixels before and after PSF-matching, percentage of pixels that are bad or unusable, effective FWHM in diff image, the average of squared diff image pixel values before and after PSF-matching, percentage of changed diff image pixels values before and after PSF-matching, status of image differencing (0=bad,1=good). |
| Positive vs. Negative Diff | Median background level in positive and negative diff image, and number of candidates extracted from the positive and negative diff image before and after internal filtering. |
| Signal-to-Noise Ratio (SNR) in Diff Image | Number of noise pixels in diff image, peak-pixel SNR in detection image optimized for point source detection, and ratio of the mean square pixel value in the subtraction image to its spatial variance following PSF matching. |
| Seeing | Seeing of sci and ref images, and ratio of FWHM to average FWHM on the sci image. |
| **Candidate Features** | |
| PSF Photometry | Magnitude and 1-sigma uncertainty from PSF fit; chi of candidate |
| Aperture Photometry | Magnitude and 1-sigma uncertainty from "big" aperture photometry |
| Candidate Measurements | Local sky background level, FWHM of local Gaussian profile, magnitude difference of PSF and aperture photometry, magnitude difference of PSF photometry and limiting magnitude, and minimum distance to edge. |
| Nearest Ref Source | Distance, magnitude, 1-sigma uncertainty, chi and sharpness of nearest reference image extraction. |
| Nearest Solar System Object | Distance, magnitude of nearest solar system object |
| Shape | Windowed RMS along major, minor axis of source profile, ratios of the major and minor axes to the FWHM, and elongation of the candidate. |
| Negative/Bad Pixels | Number of negative pixels in a 7x7 box, number of bad pixels in a 7x7 box, ratio of sum of pixel values to sum of absolute values in source-stamp cutout. |

**Random Forest**

**Larger number of features helps.**
**Also exploring deep learning**



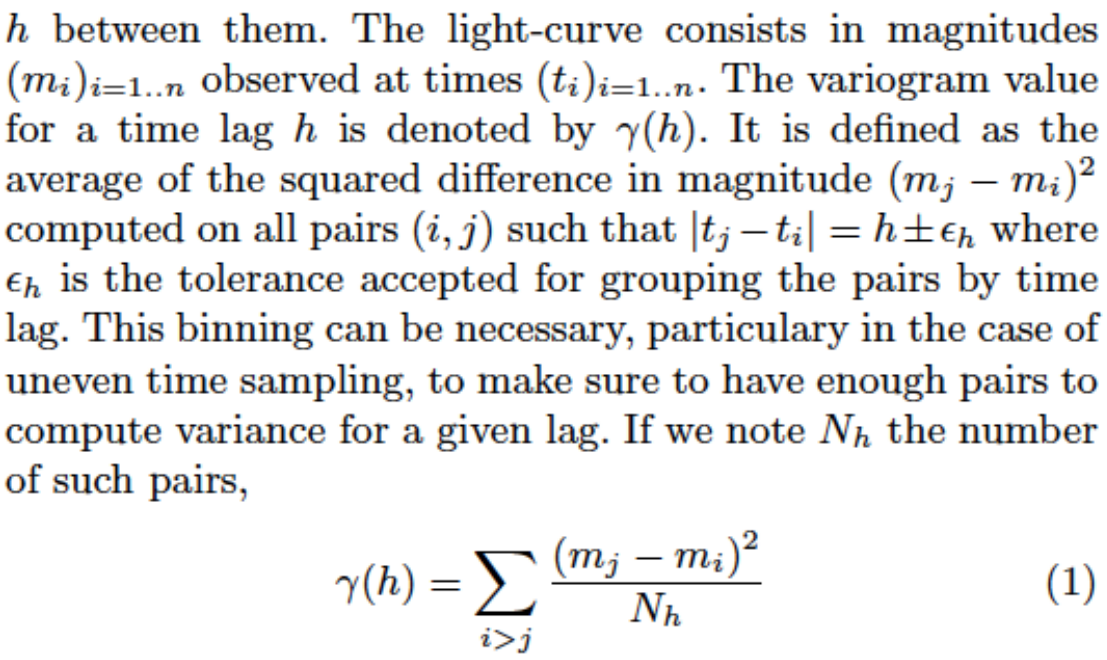
MNRAS **000**, 000–000 (0000) Preprint 11 September 2017 Compiled using MNRAS LaTeX style file v3.0

# Short timescale variables in the *Gaia* era: detection and characterization by structure function analysis

**1708.08703**

Maroussia Roelens[1], Laurent Eyer[1], Nami Mowlavi[1], Isabelle Lecoeur-Taïbi[2], Lorenzo Rimoldini[2], Sergi Blanco-Cuaresma[1], Lovro Palaversa[3], Maria Süveges[4], Jonathan Charnas[2], Thomas Wevers[5]

[1] *Observatoire de Genève, Département d'Astronomie, Université de Genève, Chemin des Maillettes 51, CH-1290 Versoix, Switzerland*



$h$ between them. The light-curve consists in magnitudes $(m_i)_{i=1..n}$ observed at times $(t_i)_{i=1..n}$. The variogram value for a time lag $h$ is denoted by $\gamma(h)$. It is defined as the average of the squared difference in magnitude $(m_j - m_i)^2$ computed on all pairs $(i,j)$ such that $|t_j - t_i| = h \pm \epsilon_h$ where $\epsilon_h$ is the tolerance accepted for grouping the pairs by time lag. This binning can be necessary, particulary in the case of uneven time sampling, to make sure to have enough pairs to compute variance for a given lag. If we note $N_h$ the number of such pairs,

$$\gamma(h) = \sum_{i>j} \frac{(m_j - m_i)^2}{N_h} \qquad (1)$$

**Variogram**

**M-dwarf**

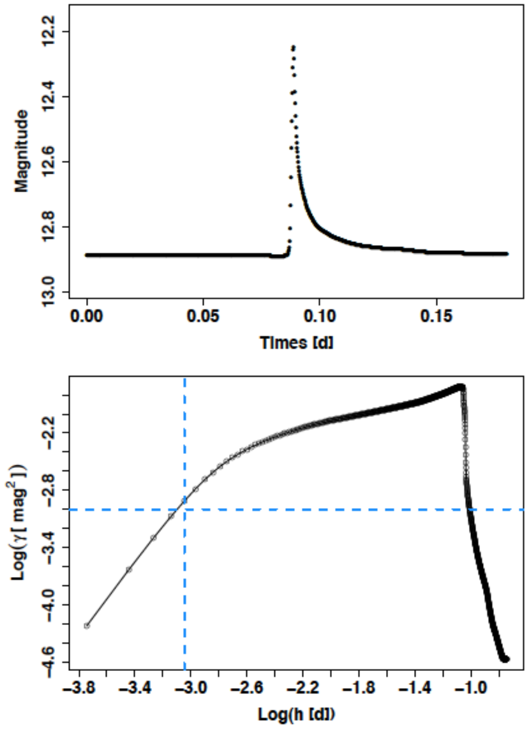


**Figure 6.** Example of M flare continuous light-curve (top), and corresponding theoretical variogram (bottom). The blue dashed lines indicate the detection threshold ($\gamma_{det} = 10^{-3}$ mag$^2$) and the associated detection timescale $\tau_{det}$.

**Supernova**

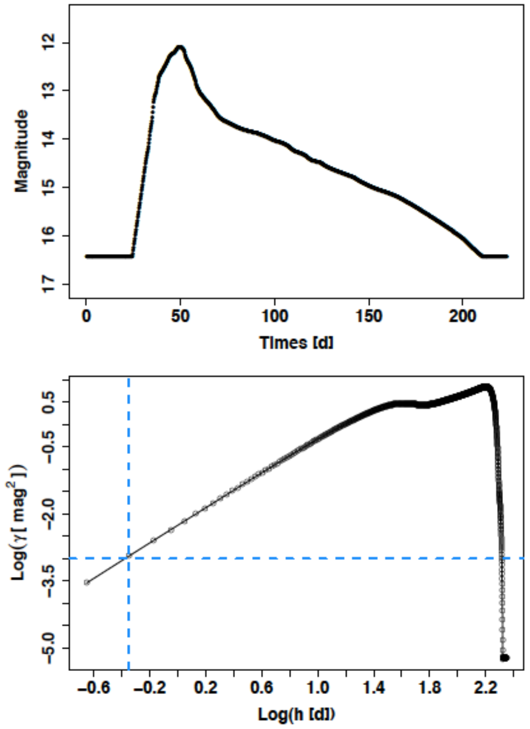
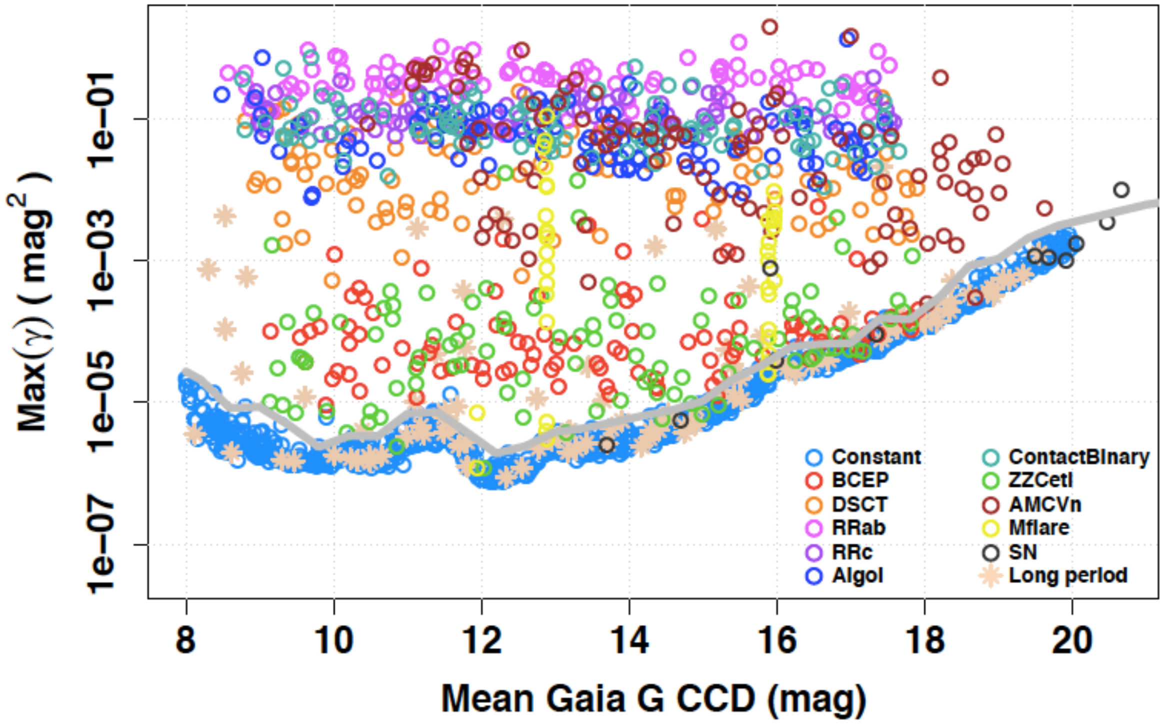


**Figure 7.** Example of SN continuous light-curve (top), and corresponding theoretical variogram (bottom). The blue dashed lines indicate the detection threshold ($\gamma_{det} = 10^{-3}$ mag$^2$) and the associated detection timescale $\tau_{det}$.

**x-axis extents differ**



**Short timescale variability can be recovered**

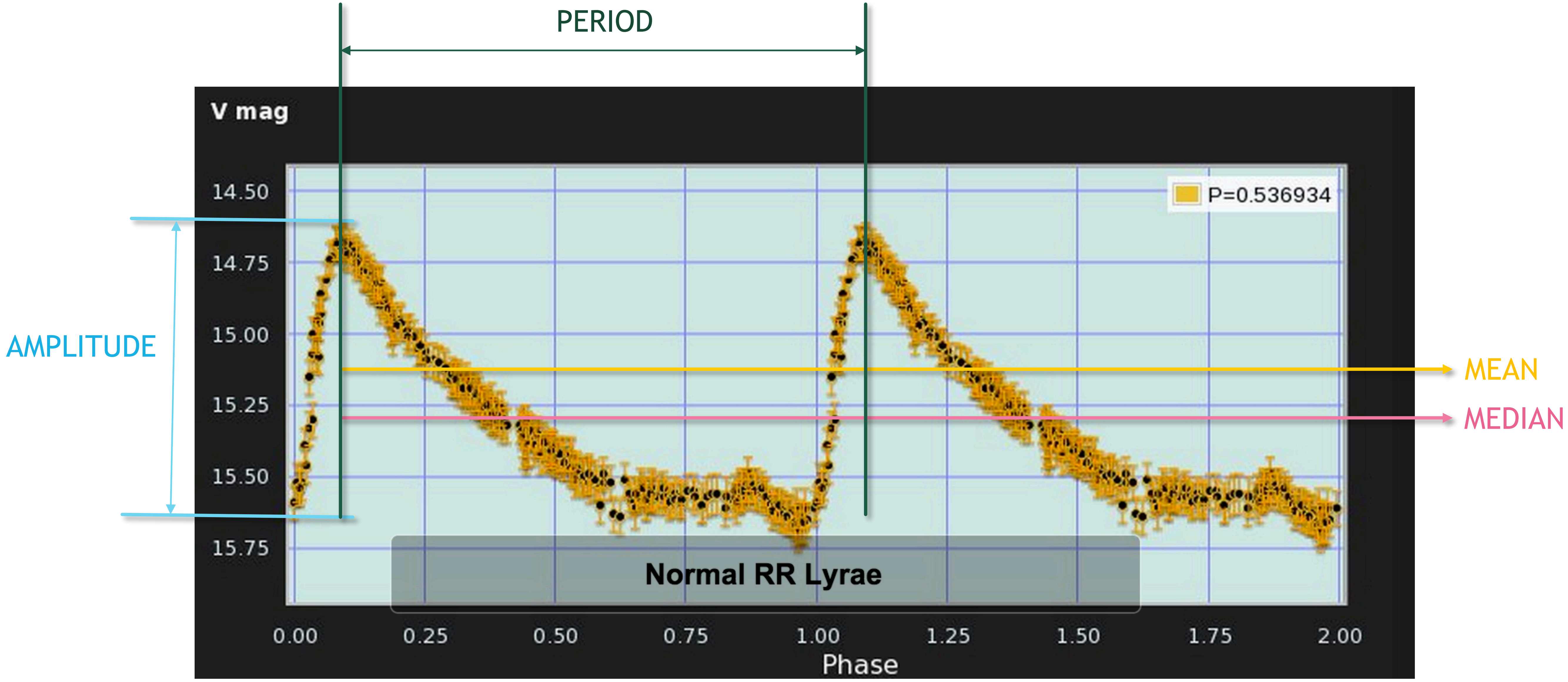
**Figure 17.** Maximum weighted variogram value as function of the mean magnitude, for the short timescale periodic variables, the transients, the longer period variables and the constant sources of the *Gaia*-like data set. The grey line shows the refined detection threshold depending on the mean magnitude of the source ($\gamma_{det} = \Gamma(\bar{G}_{CCD})$).

## 6 CONCLUSION

In this work, by mean of extensive light-curve simulations, we showed that, with a specifically tailored detection criterion, the variogram method should enable a good recovery of short timescale variability, periodic or transient, from *Gaia* per-CCD photometry, with a reduced fraction of observed constant sources resulting in false positives. Contamination for longer period variables is significant, and is essentially due to amplitude variations greater than 0.25 mag typically. It should be efficiently eliminated by post-processing involving both periodogram investigation and comparison with the other variability studies performed in the *Gaia* DPAC con-

**Contamination from longer term variability (removable through postprocessing)**

# Light-curve features



# Many features
# - not all are independent

Adam Miller

flux_%_mid20
flux_%_mid35
flux_%_mid50
flux_%_mid65
flux_%_mid80

scatter_res_raw

fold_2p_slope_10%
fold_2p_slope_90%

medperc90_p2_p

QSO
non_QSO

p2p_scatter_pfold_over_mad

p2p_scatter_2praw

pair_slope_trend

percent_difference_flux_percentile

freq_signif

freq_n_alias

freq_varrat

$A_{1,1}$
$A_{1,2}$
$A_{1,3}$
$A_{1,4}$
$A_{2,1}/A_{1,1}$
$A_{3,1}/A_{1,1}$

freq_y_offset

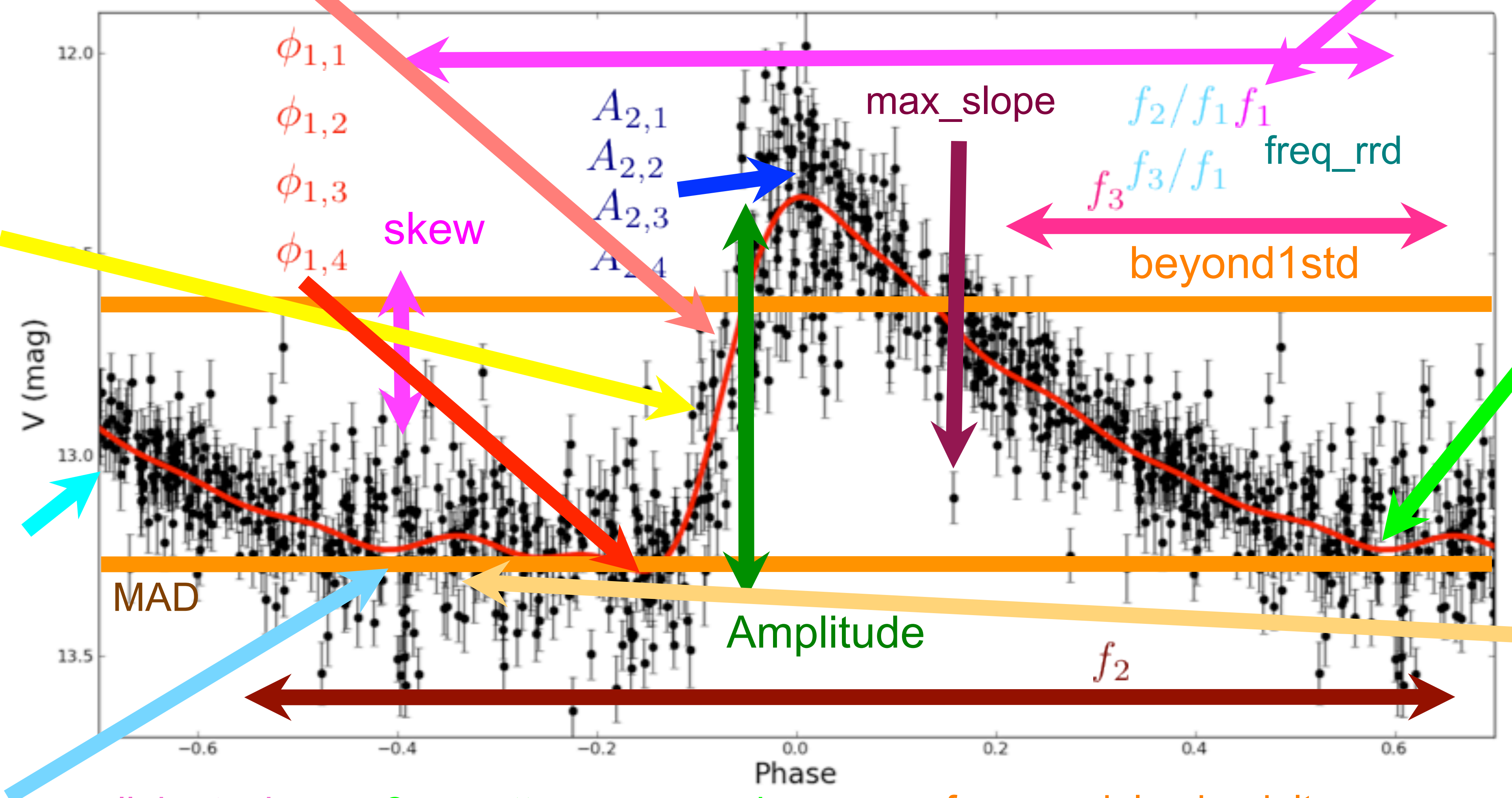
stetson_j
stetson_k

$\phi_{3,1}$
$\phi_{3,2}$
$\phi_{3,3}$
$\phi_{3,4}$

$\phi_{2,1}$
$\phi_{2,2}$
$\phi_{2,3}$
$\phi_{2,4}$

std

$A_{3,1}$
$A_{3,2}$
$A_{3,3}$
$A_{3,4}$



small_kurtosis

percent_amplitude

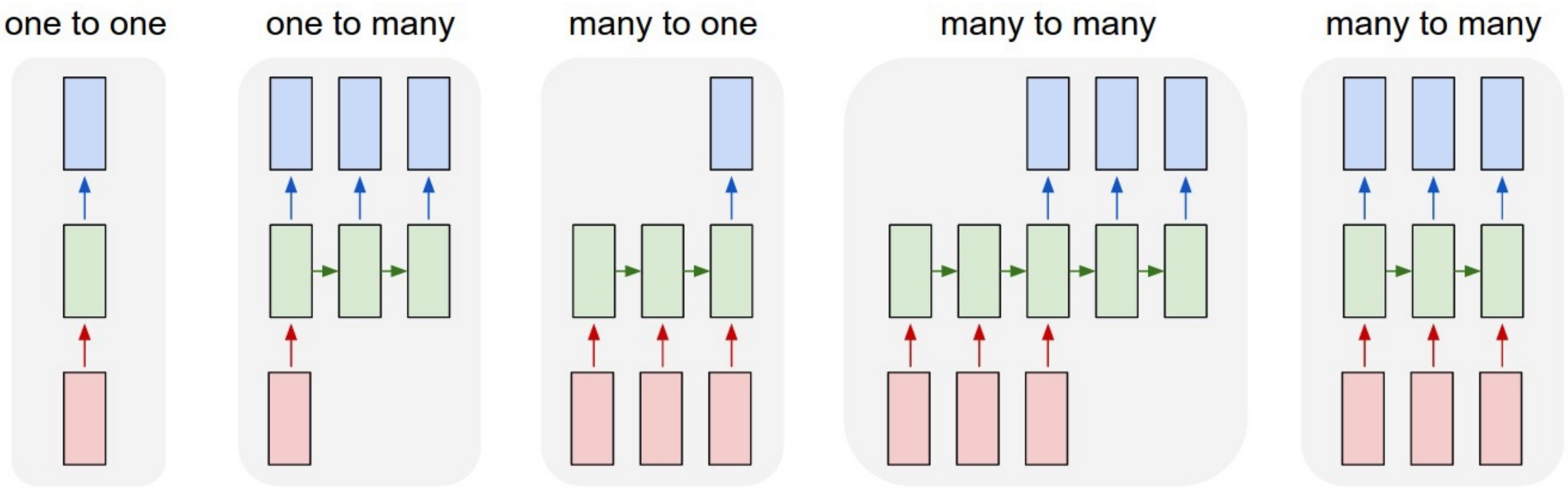
median_buffer_range_percentage

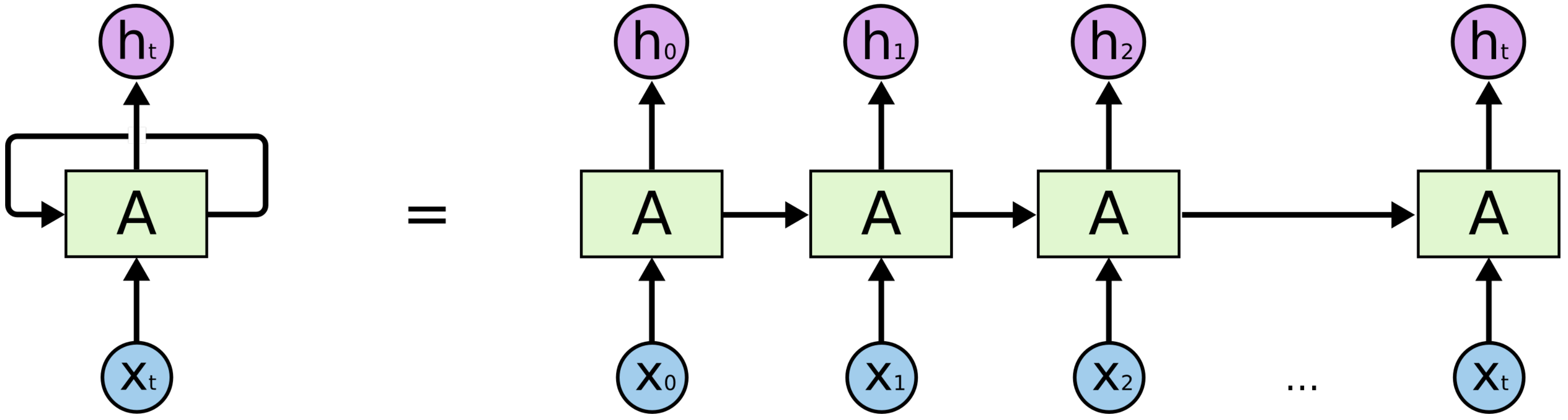
p2p_scatter_over_mad

linear_trend

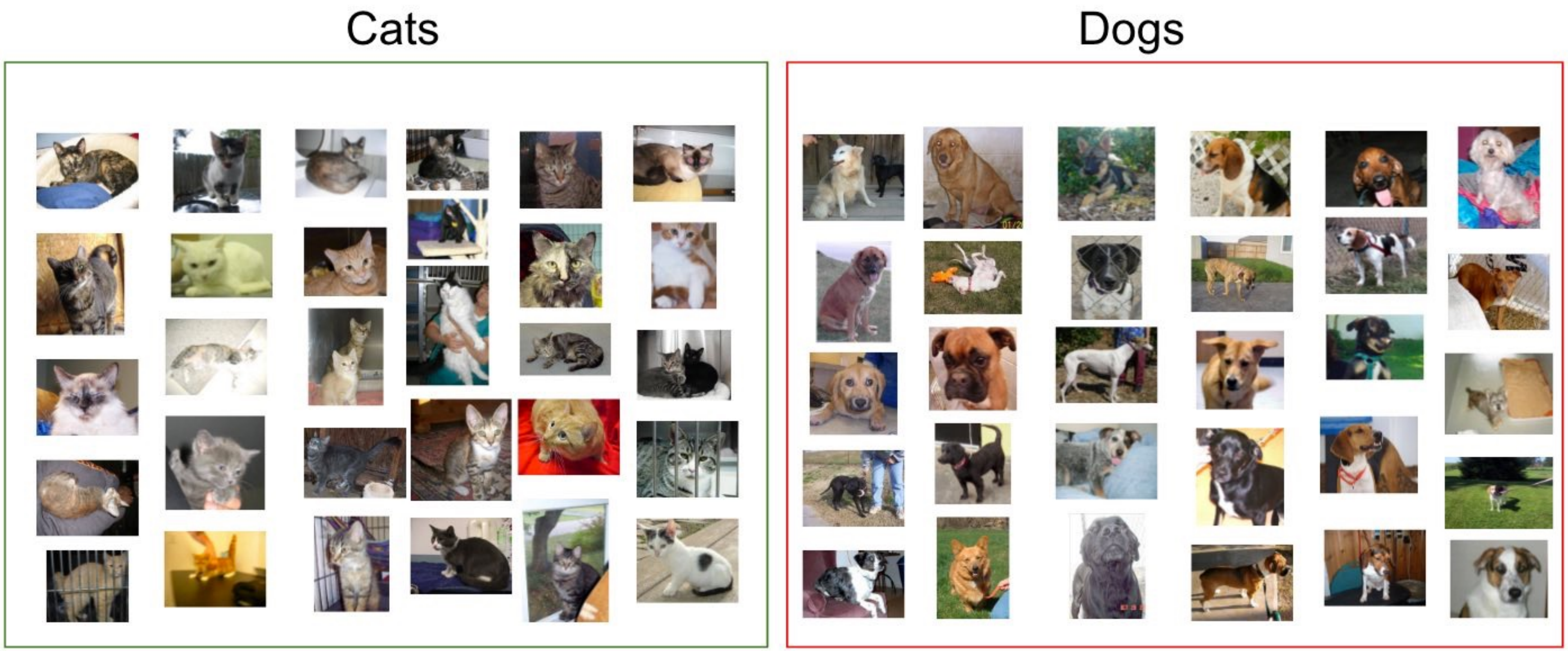
freq_model_min_delta_mag
freq_model_max_delta_mag
freq_model_phi1_phi2
p2p_ssqr_diff_over_var

# Recurrent Neural Networks





http://colah.github.io/posts/2015-08-Understanding-LSTMs/



**Sample of cats & dogs images from Kaggle Dataset**


Input → Feature Extractor → Features → Traditional ML Algorithm → Output

Traditional Machine Learning Flow


Input → Deep Learning Algorithm → Output

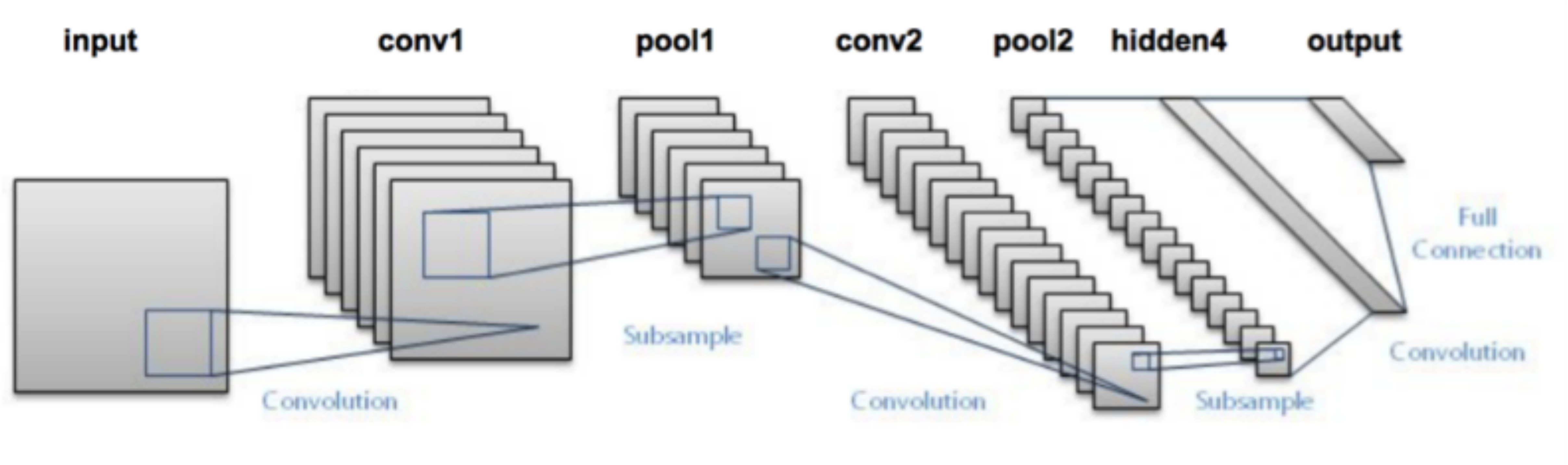
Deep Learning Flow

Adil Moujahid

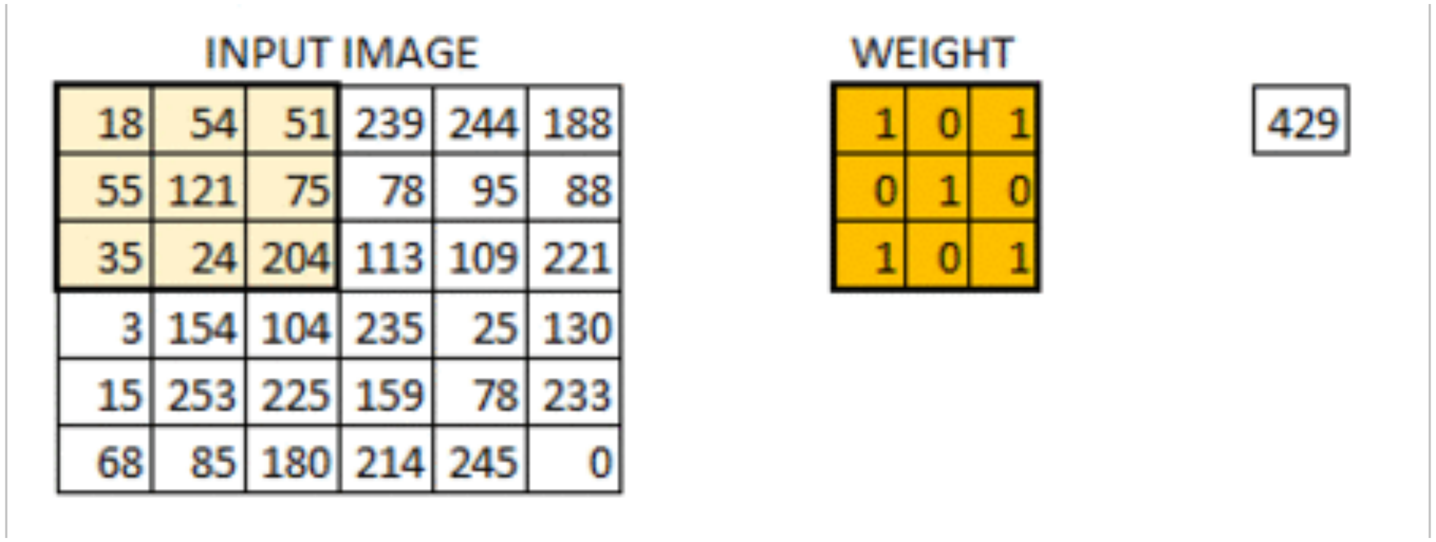
Promise:
Works better

Pitfall:
Blacker box

# Convolutional network (single slide) primer



analyticsvidhya.com



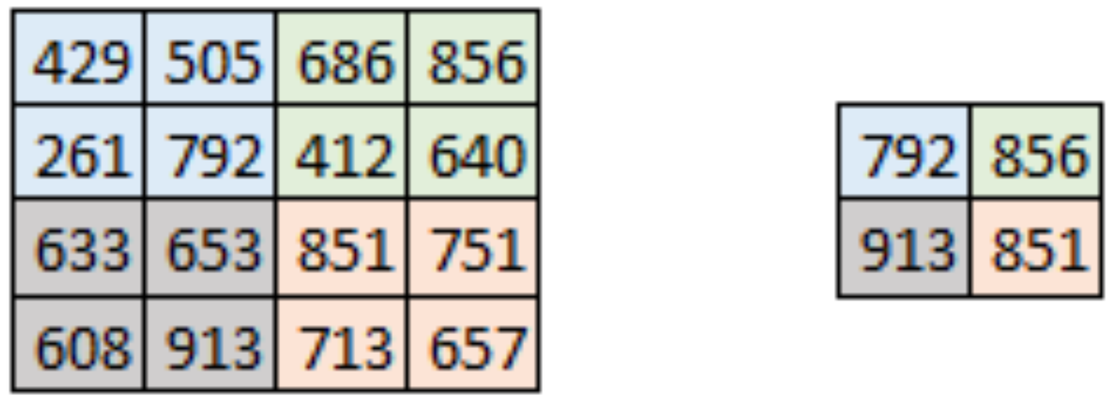
INPUT IMAGE

| | | | | | |
|---|---|---|---|---|---|
| 18 | 54 | 51 | 239 | 244 | 188 |
| 55 | 121 | 75 | 78 | 95 | 88 |
| 35 | 24 | 204 | 113 | 109 | 221 |
| 3 | 154 | 104 | 235 | 25 | 130 |
| 15 | 253 | 225 | 159 | 78 | 233 |
| 68 | 85 | 180 | 214 | 245 | 0 |

WEIGHT

| | | |
|---|---|---|
| 1 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 1 |

| |
|---|
| 429 |



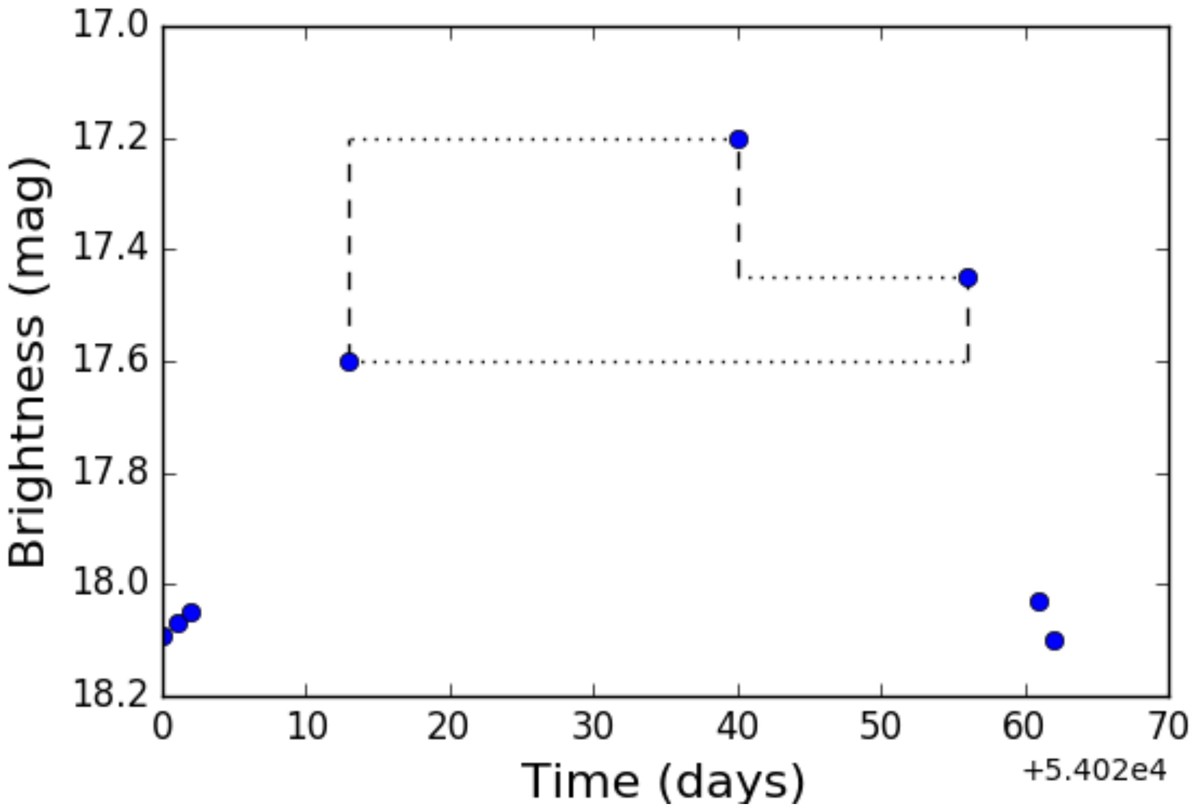
| | | | |
|---|---|---|---|
| 429 | 505 | 686 | 856 |
| 261 | 792 | 412 | 640 |
| 633 | 653 | 851 | 751 |
| 608 | 913 | 713 | 657 |

| | |
|---|---|
| 792 | 856 |
| 913 | 851 |

# (dmdt) Image representation

Mahabal et al., 2017

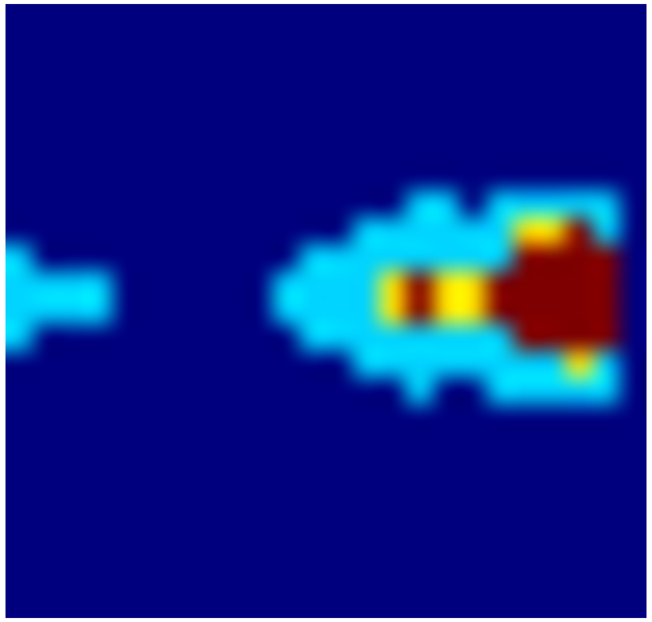
**arXiv:1709.06257**

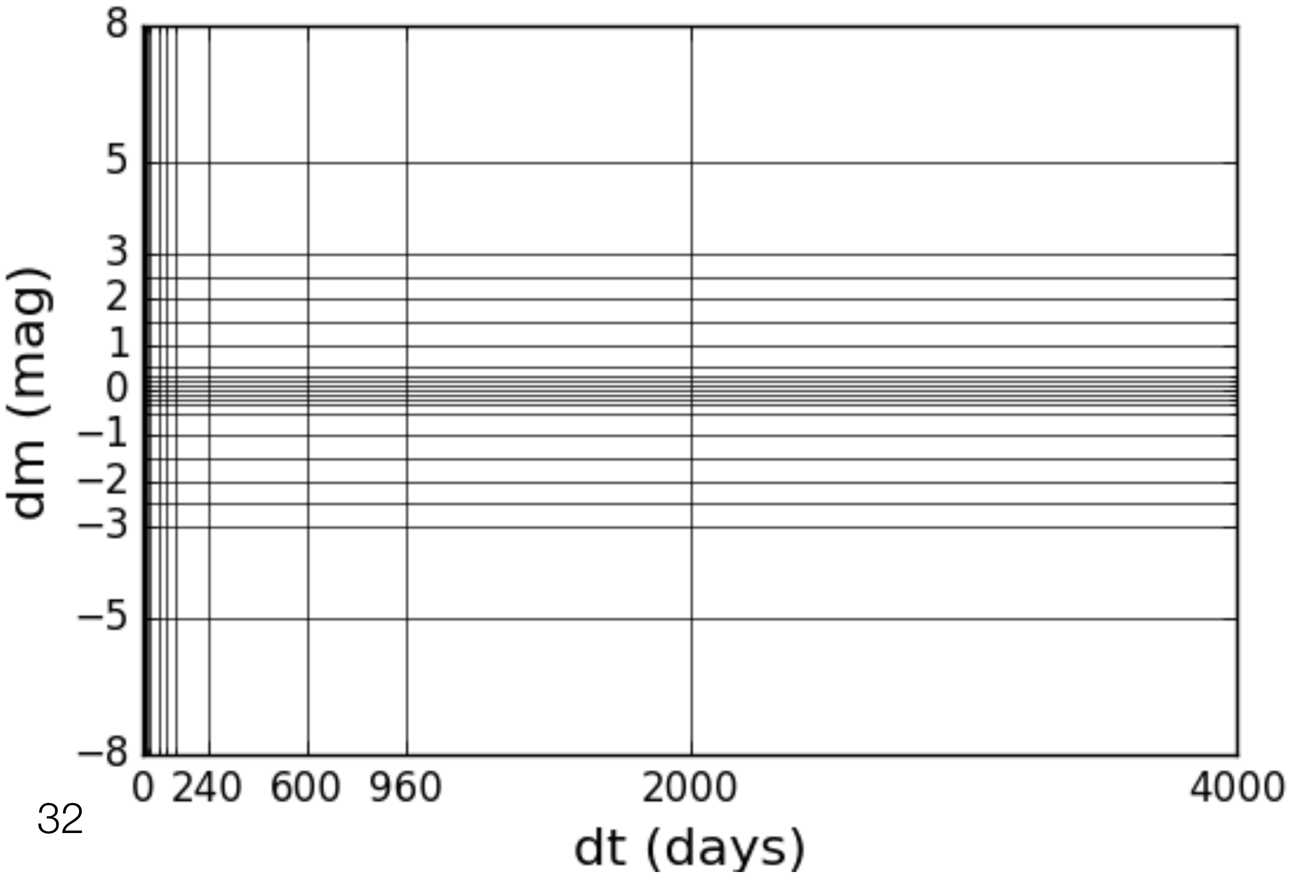


light curve with n points

**23 x 24 output grid**

n * (n-1)/2 points





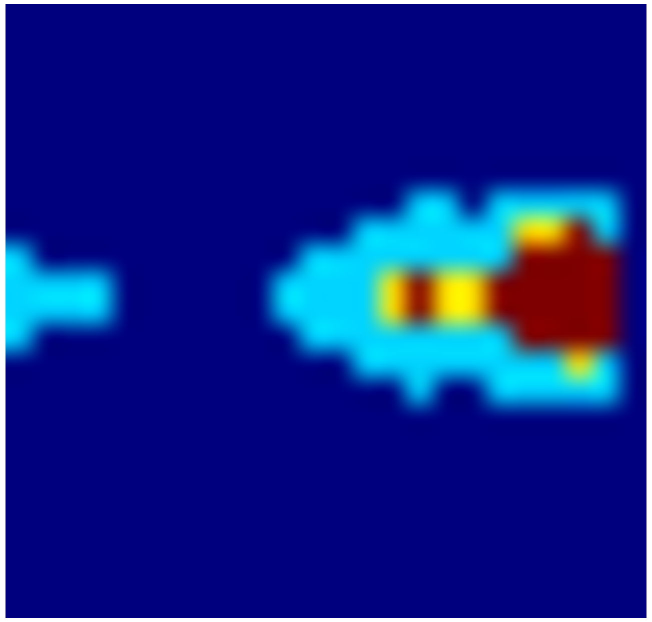
Area equalized pixels

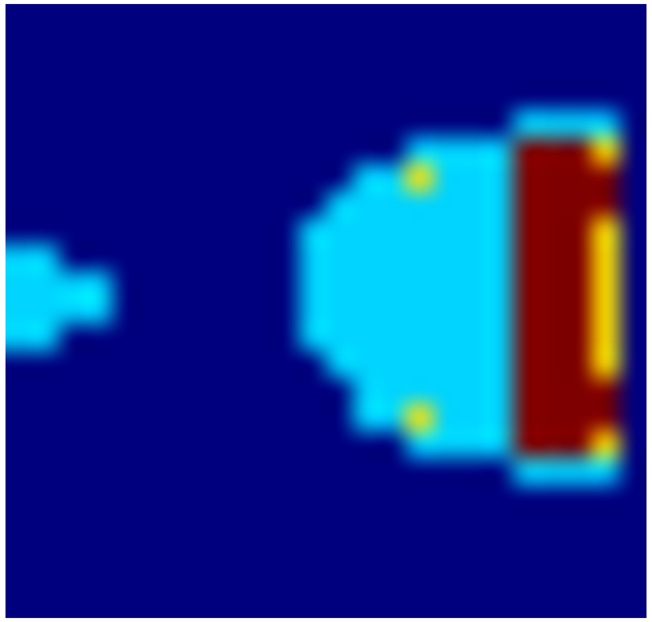
EW

EA

RR

RS CVn

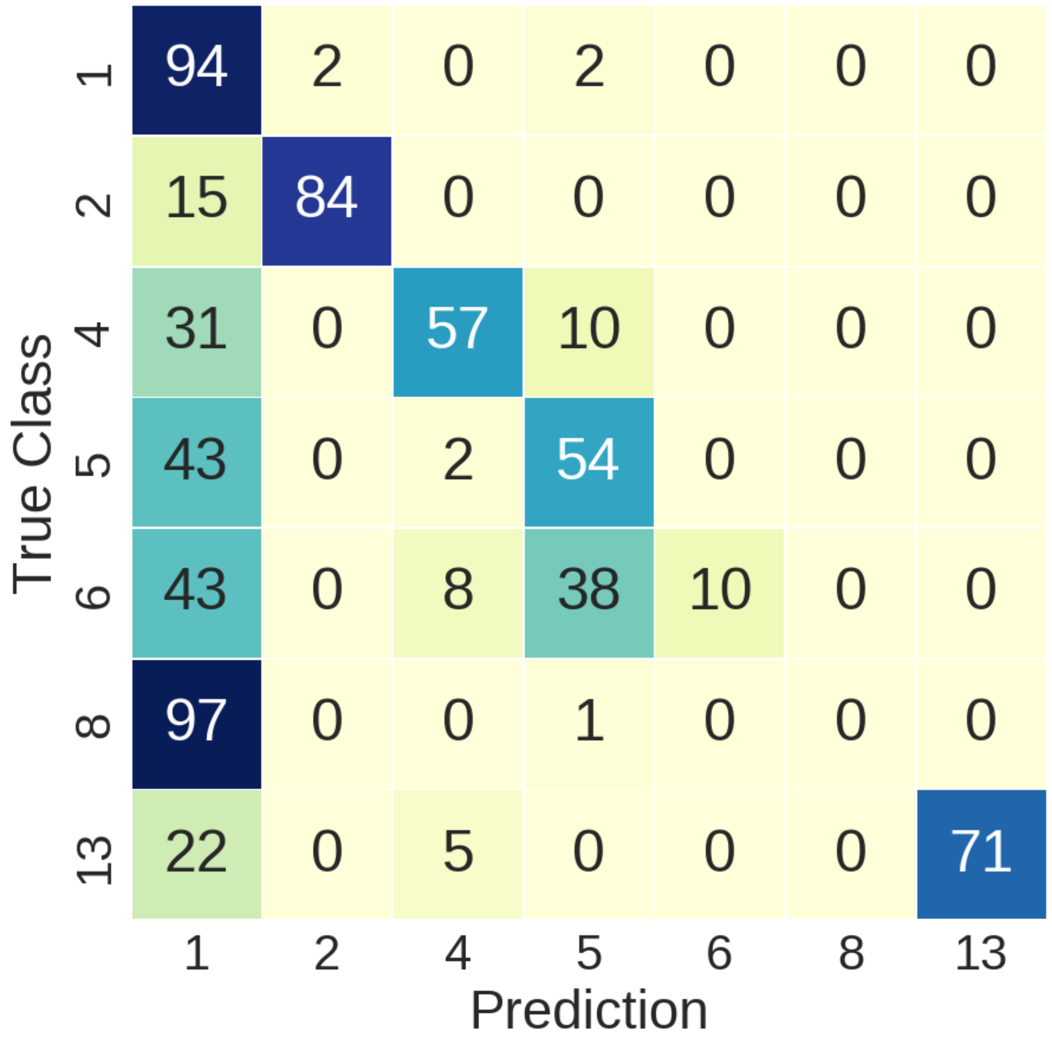




LPV

with Kshiteej Sheth

**medians**

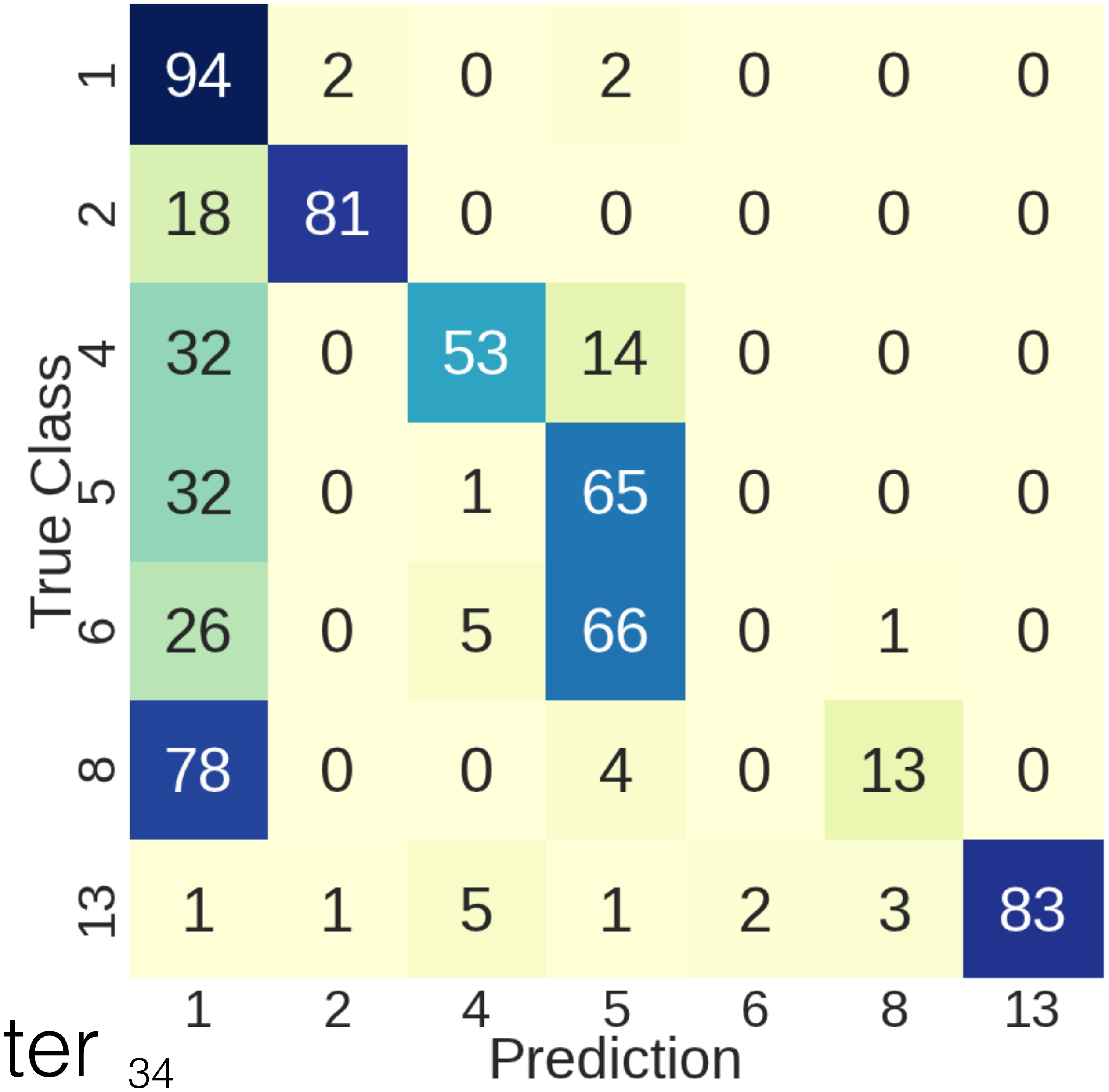


| | 1 | 2 | 4 | 5 | 6 | 8 | 13 |
|---|---|---|---|---|---|---|---|
| 1 | 94 | 2 | 0 | 2 | 0 | 0 | 0 |
| 2 | 15 | 84 | 0 | 0 | 0 | 0 | 0 |
| 4 | 31 | 0 | 57 | 10 | 0 | 0 | 0 |
| 5 | 43 | 0 | 2 | 54 | 0 | 0 | 0 |
| 6 | 43 | 0 | 8 | 38 | 10 | 0 | 0 |
| 8 | 97 | 0 | 0 | 1 | 0 | 0 | 0 |
| 13 | 22 | 0 | 5 | 0 | 0 | 0 | 71 |

# Random Forest using standard features

**no features**
**no dimensionality reduction**
**comparable results**

# Convolutional Network



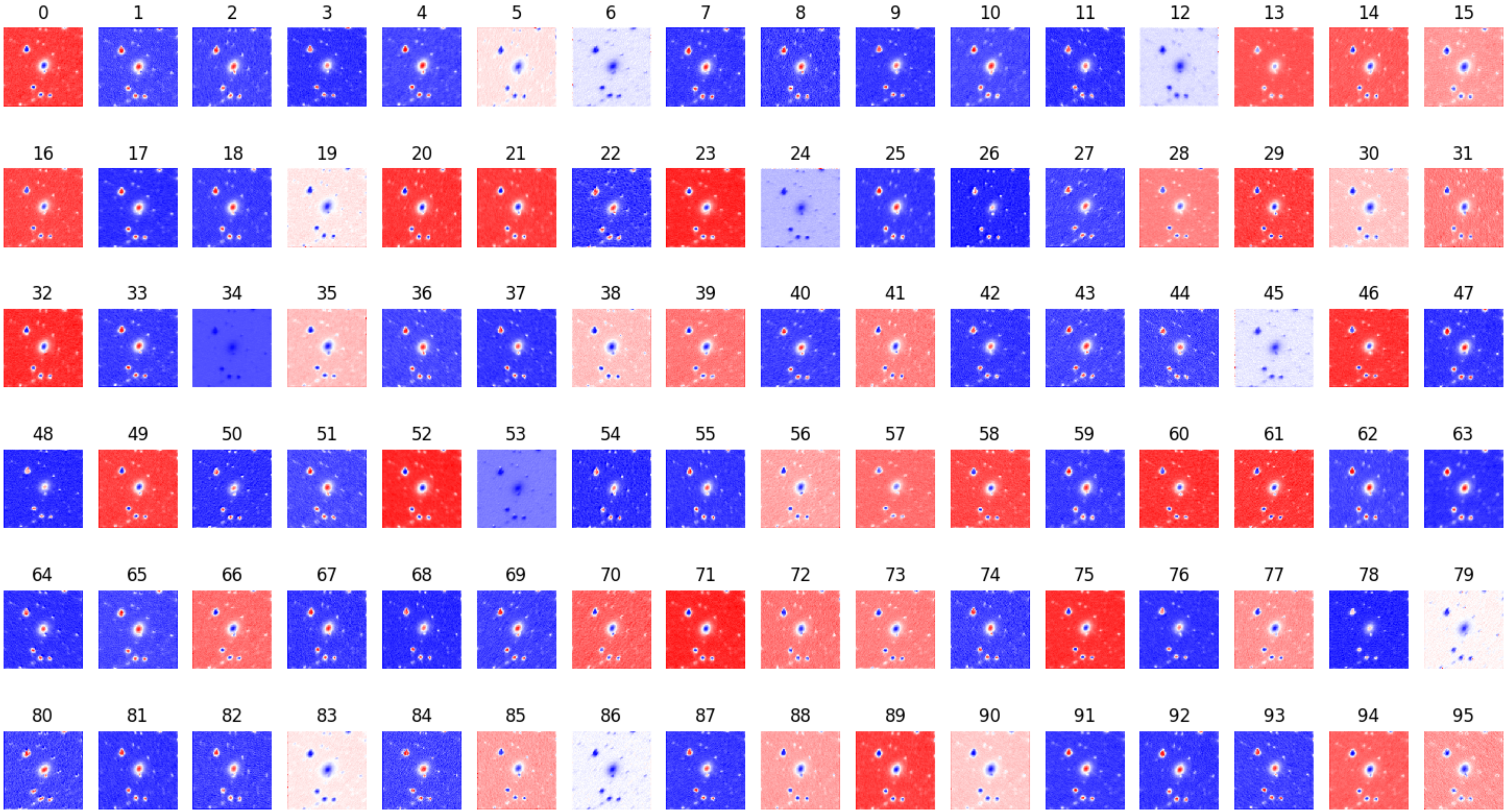
| | 1 | 2 | 4 | 5 | 6 | 8 | 13 |
|---|---|---|---|---|---|---|---|
| 1 | 94 | 2 | 0 | 2 | 0 | 0 | 0 |
| 2 | 18 | 81 | 0 | 0 | 0 | 0 | 0 |
| 4 | 32 | 0 | 53 | 14 | 0 | 0 | 0 |
| 5 | 32 | 0 | 1 | 65 | 0 | 0 | 0 |
| 6 | 26 | 0 | 5 | 66 | 0 | 1 | 0 |
| 8 | 78 | 0 | 0 | 4 | 0 | 13 | 0 |
| 13 | 1 | 1 | 5 | 1 | 2 | 3 | 83 |

| | |
|---|---|
| **1** | EW/EB |
| **2** | EA |
| **4** | RRab |
| **5** | RRc |
| **6** | RRd |
| **8** | RS CVn |
| **13** | LPV |

Binary probabilities are better

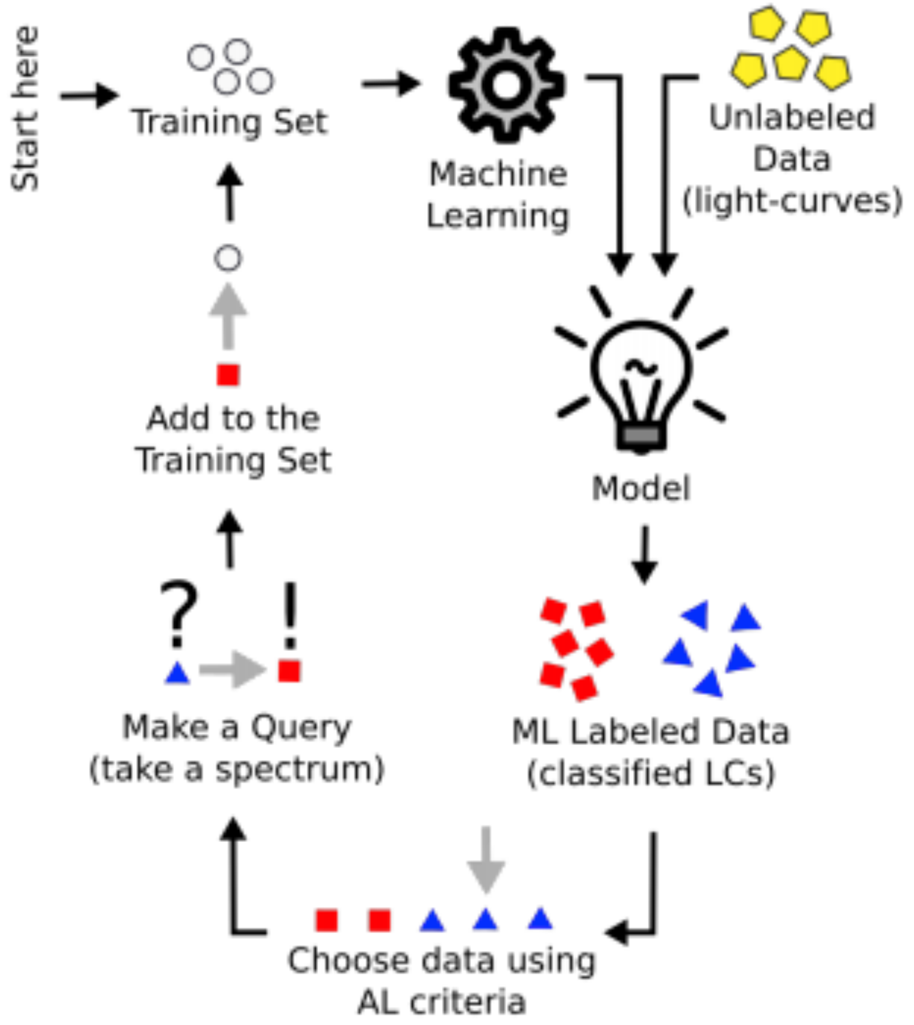
# Visualizations (astronomy)

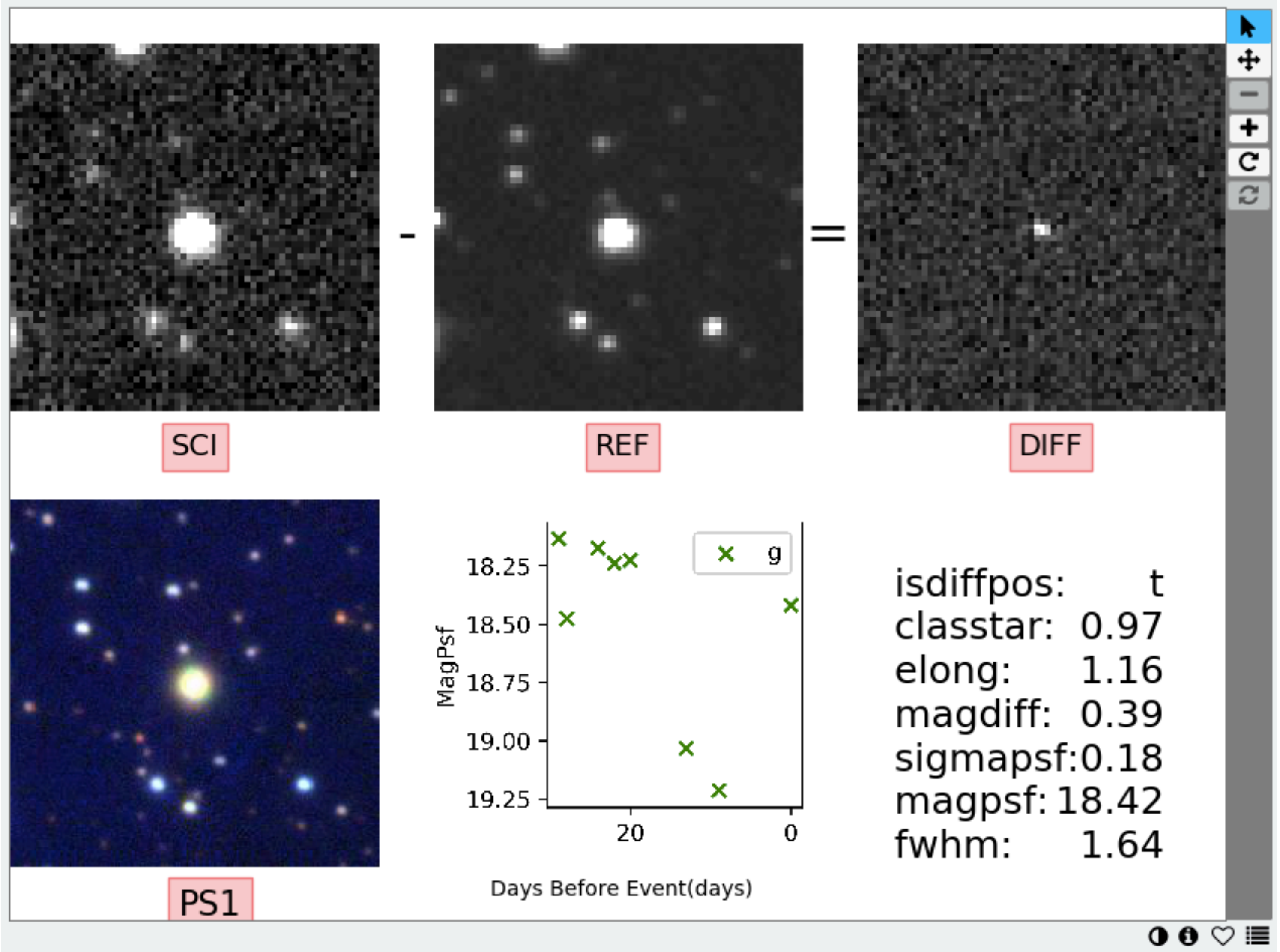
# Interpretability



**TransiNet with N Sedaghat**

# Active learning to minimize follow-up





isdiffpos: t
classtar: 0.97
elong: 1.16
magdiff: 0.39
sigmapsf: 0.18
magpsf: 18.42
fwhm: 1.64

Images, light curves, metadata

Ishida et al. 2018, arXiv:1804.03765

**Accuracy of 80% reached in 100 days of observations, far above the canonical rate**

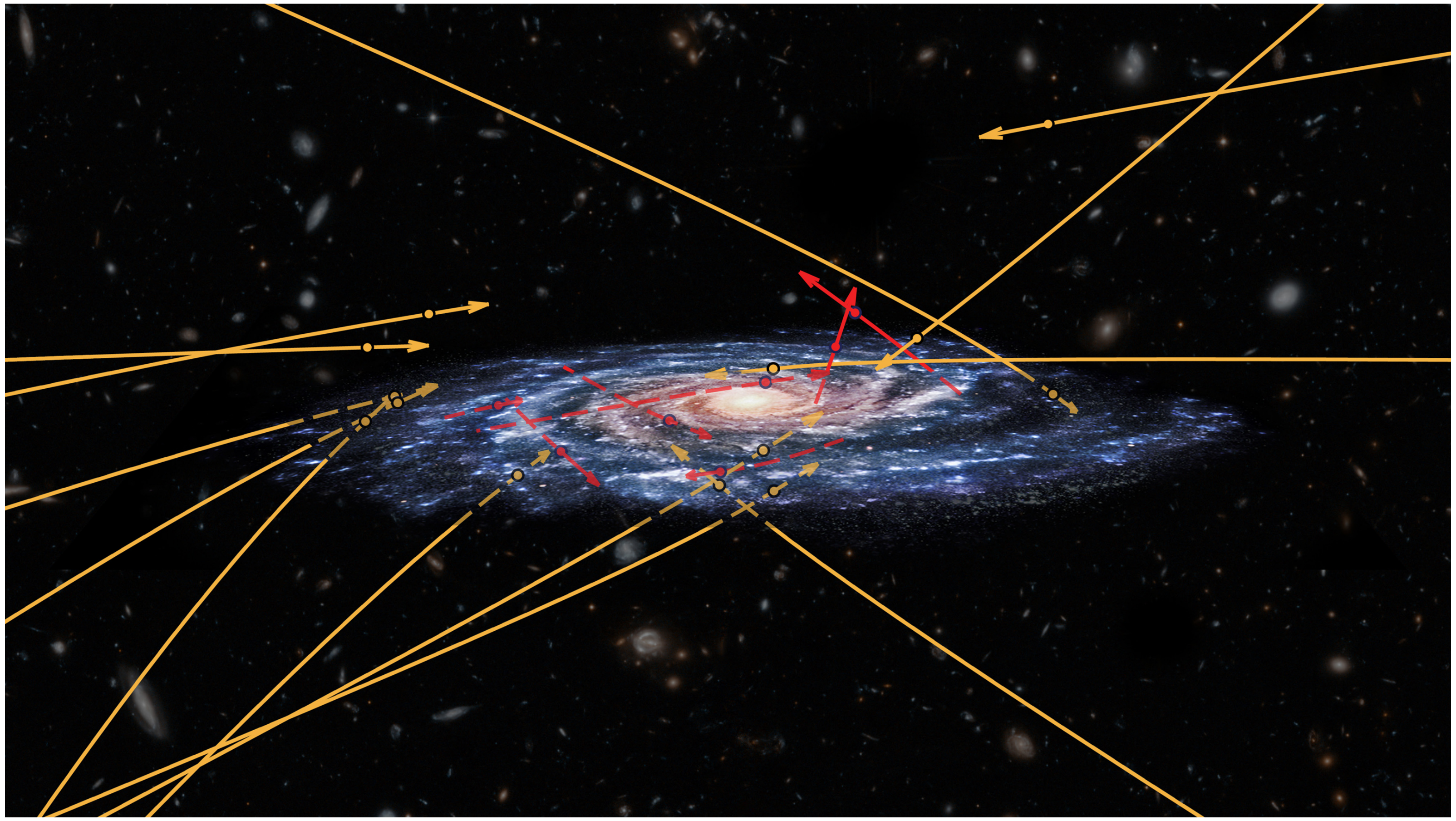
**Connecting to Brokers**

ALeRCE.science

**AMPEL**
**Antares**
**Lasair**

**LSST data challenges**
**(check on Kaggle to win 25K USD)**
**1810.00001**

# Hypervelocity stars and high cadence data

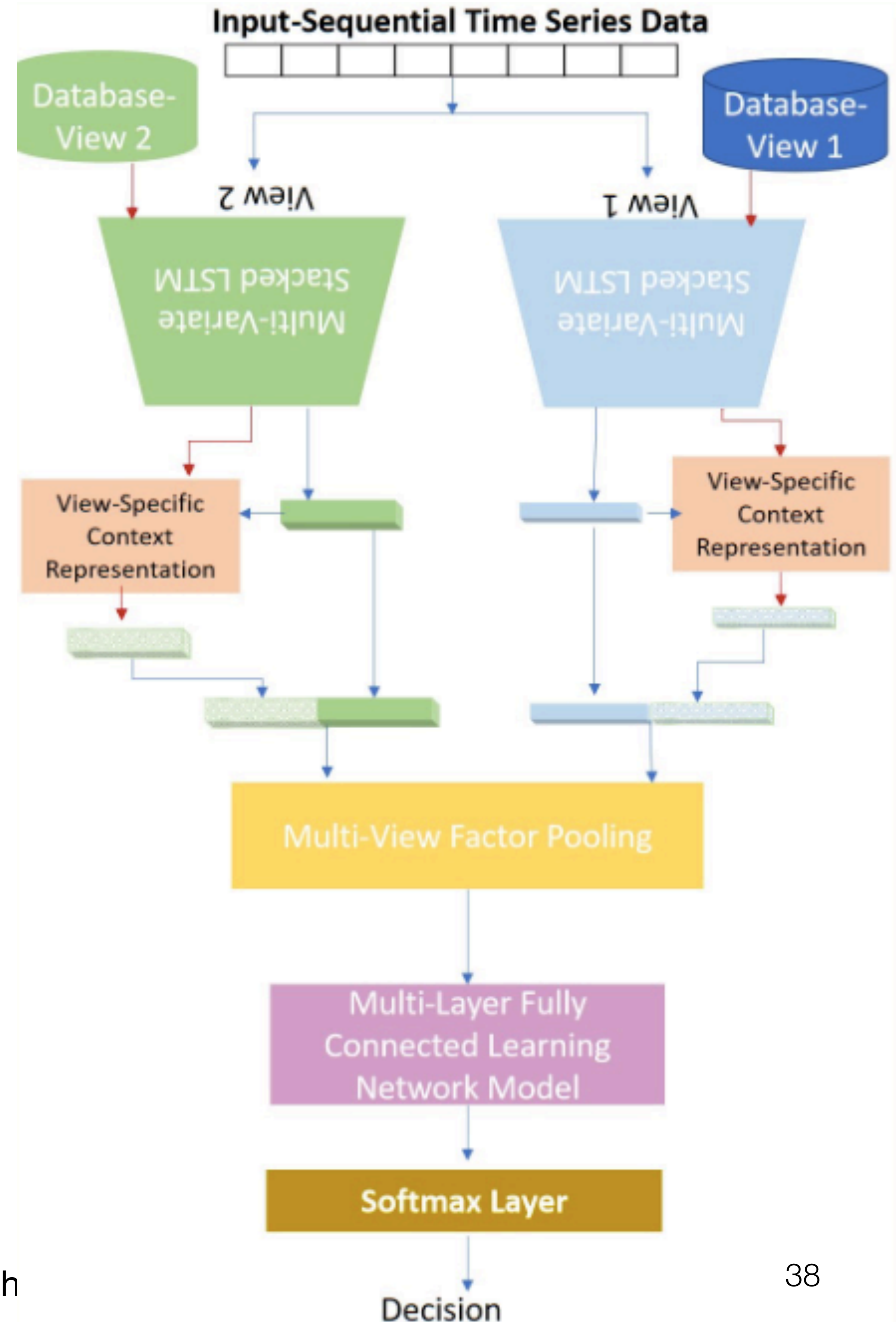


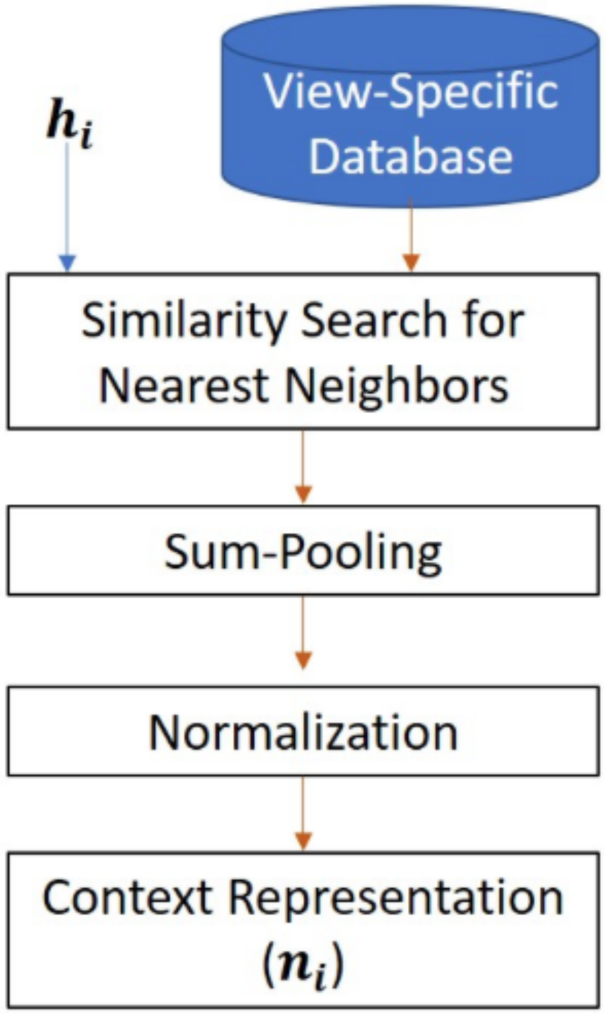
**Tomasso Marchetti's talk last week (Caltech)**

**Possibly extra-Galactic stars**

**Many more epochs could help here as well (over a much longer time)**

# VIFI and CRTS/PTF/Gaia/ZTF

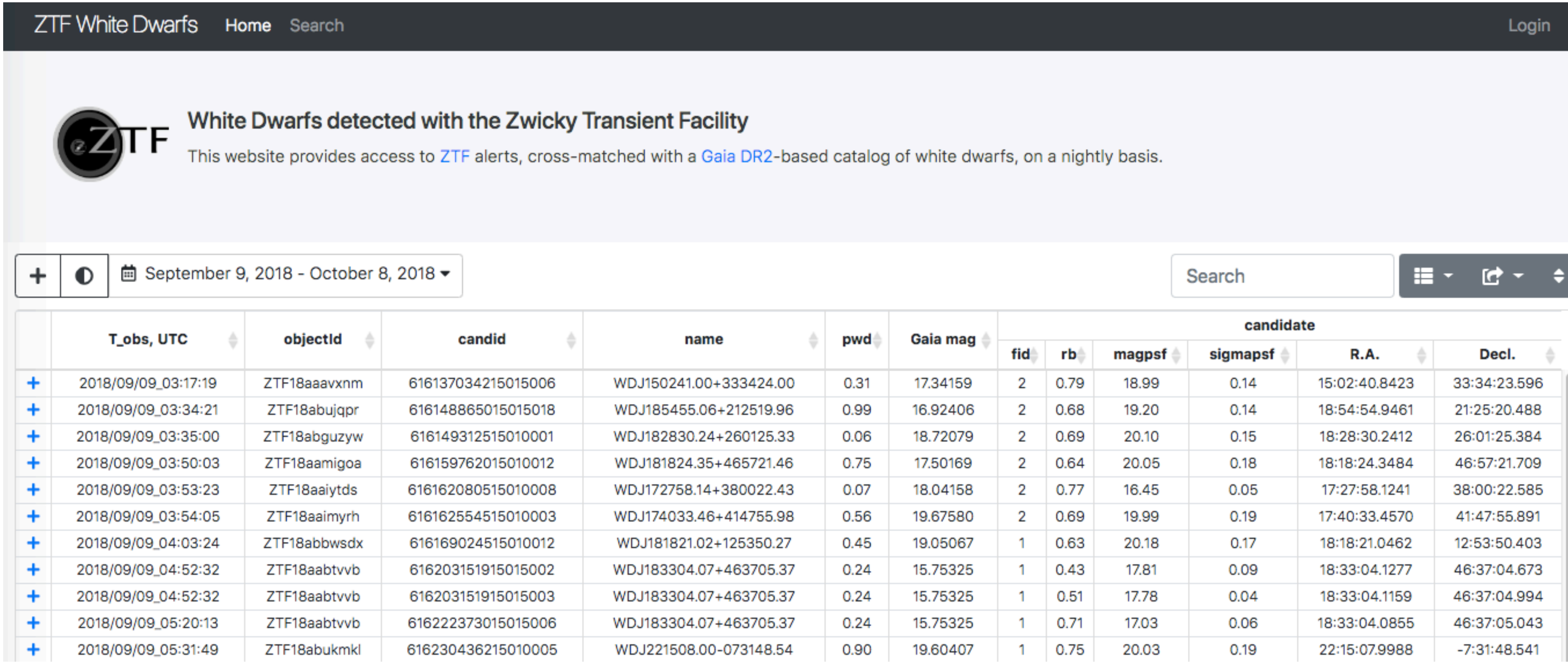




**Multi-view transfer learning**

**S Das et al. 2018**

# White dwarf sentinel service



**White Dwarfs detected with the Zwicky Transient Facility**

This website provides access to ZTF alerts, cross-matched with a Gaia DR2-based catalog of white dwarfs, on a nightly basis.

| | T_obs, UTC | objectId | candid | name | pwd | Gaia mag | candidate | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | fid | rb | magpsf | sigmapsf | R.A. | Decl. |
| + | 2018/09/09_03:17:19 | ZTF18aaavxnm | 616137034215015006 | WDJ150241.00+333424.00 | 0.31 | 17.34159 | 2 | 0.79 | 18.99 | 0.14 | 15:02:40.8423 | 33:34:23.596 |
| + | 2018/09/09_03:34:21 | ZTF18abujqpr | 616148865015015018 | WDJ185455.06+212519.96 | 0.99 | 16.92406 | 2 | 0.68 | 19.20 | 0.14 | 18:54:54.9461 | 21:25:20.488 |
| + | 2018/09/09_03:35:00 | ZTF18abguzyw | 616149312515010001 | WDJ182830.24+260125.33 | 0.06 | 18.72079 | 2 | 0.69 | 20.10 | 0.15 | 18:28:30.2412 | 26:01:25.384 |
| + | 2018/09/09_03:50:03 | ZTF18aamigoa | 616159762015010012 | WDJ181824.35+465721.46 | 0.75 | 17.50169 | 2 | 0.64 | 20.05 | 0.18 | 18:18:24.3484 | 46:57:21.709 |
| + | 2018/09/09_03:53:23 | ZTF18aaiytds | 616162080515010008 | WDJ172758.14+380022.43 | 0.07 | 18.04158 | 2 | 0.77 | 16.45 | 0.05 | 17:27:58.1241 | 38:00:22.585 |
| + | 2018/09/09_03:54:05 | ZTF18aaimyrh | 616162554515010003 | WDJ174033.46+414755.98 | 0.56 | 19.67580 | 2 | 0.69 | 19.99 | 0.19 | 17:40:33.4570 | 41:47:55.891 |
| + | 2018/09/09_04:03:24 | ZTF18abbwsdx | 616169024515010012 | WDJ181821.02+125350.27 | 0.45 | 19.05067 | 1 | 0.63 | 20.18 | 0.17 | 18:18:21.0462 | 12:53:50.403 |
| + | 2018/09/09_04:52:32 | ZTF18aabtvvb | 616203151915015002 | WDJ183304.07+463705.37 | 0.24 | 15.75325 | 1 | 0.43 | 17.81 | 0.09 | 18:33:04.1277 | 46:37:04.673 |
| + | 2018/09/09_04:52:32 | ZTF18aabtvvb | 616203151915015003 | WDJ183304.07+463705.37 | 0.24 | 15.75325 | 1 | 0.51 | 17.78 | 0.04 | 18:33:04.1159 | 46:37:04.994 |
| + | 2018/09/09_05:20:13 | ZTF18aabtvvb | 616222373015015006 | WDJ183304.07+463705.37 | 0.24 | 15.75325 | 1 | 0.71 | 17.03 | 0.06 | 18:33:04.0855 | 46:37:05.043 |
| + | 2018/09/09_05:31:49 | ZTF18abukmkl | 616230436215010005 | WDJ221508.00-073148.54 | 0.90 | 19.60407 | 1 | 0.75 | 20.03 | 0.19 | 22:15:07.9988 | -7:31:48.541 |

**ZTF alerts, matched to Gaia DR2**

**https://rico.caltech.edu**

# Take away message

- There are areas where working together will benefit Gaia and ZTF science
- In particular to check iffy and/or strange transients in the other survey
- Combining ZTF cadence and Gaia's multi-epoch positional accuracy can be rewardi
- I am sure I have left out many things (that I do not know enough about)
- Lets talk …

aam at astro.caltech.edu