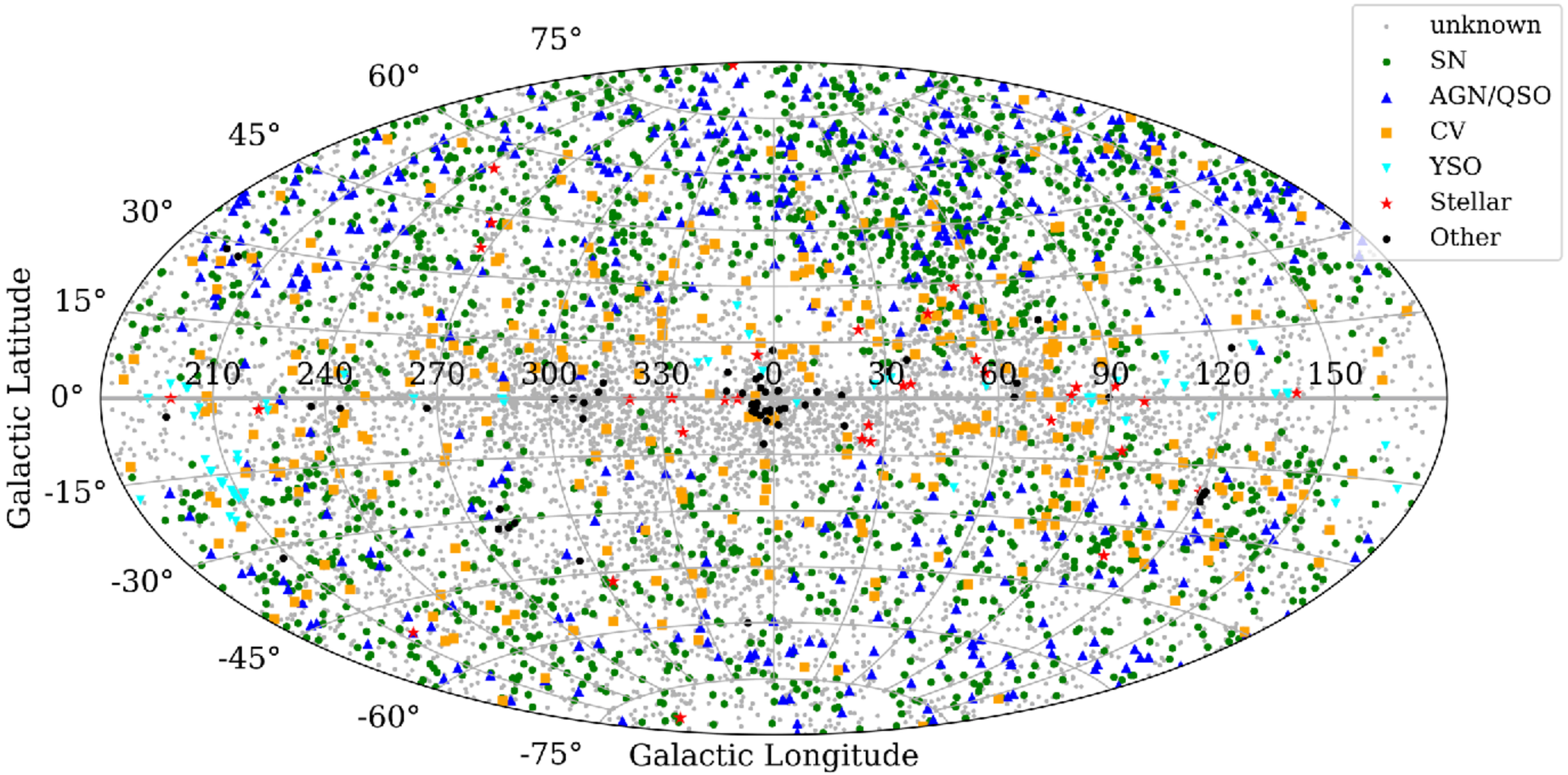
Gaia Science Alerts: Status



Simon Hodgkin

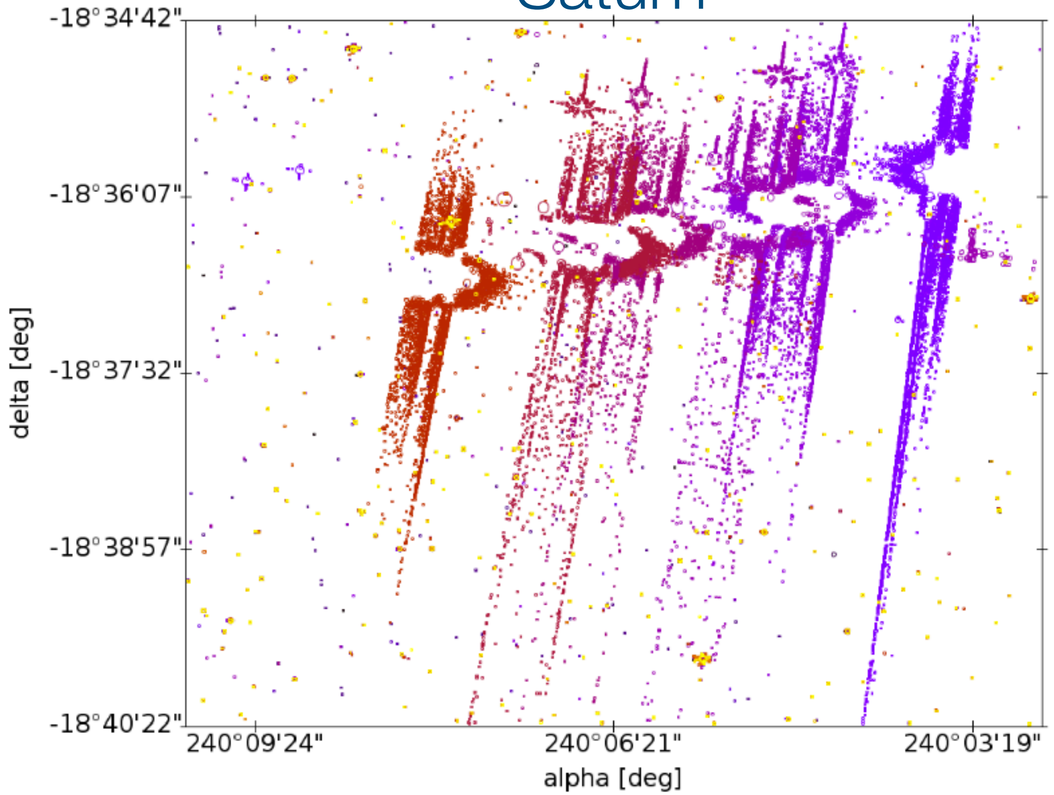
E. Breedt, A. Delgado, D.L. Harrison, M. van Leeuwen, G.Rixon, T. Wevers, A. Yoldas, N. Blagorodnova, S. Koposov (IoA Cambridge),
N. Ihanec, K. Kruszyńska, K.A. Rybicki, Ł. Wyrzykowski (Warsaw UniversityAstronomical Observatory),
Z. Kostrzewa-Rutkowska (Leiden Observatory), D. Eappachen (SRON/RU),
G. Marton (Konkoly Observatory)

@SpacemanSimon
@gaia_alerts

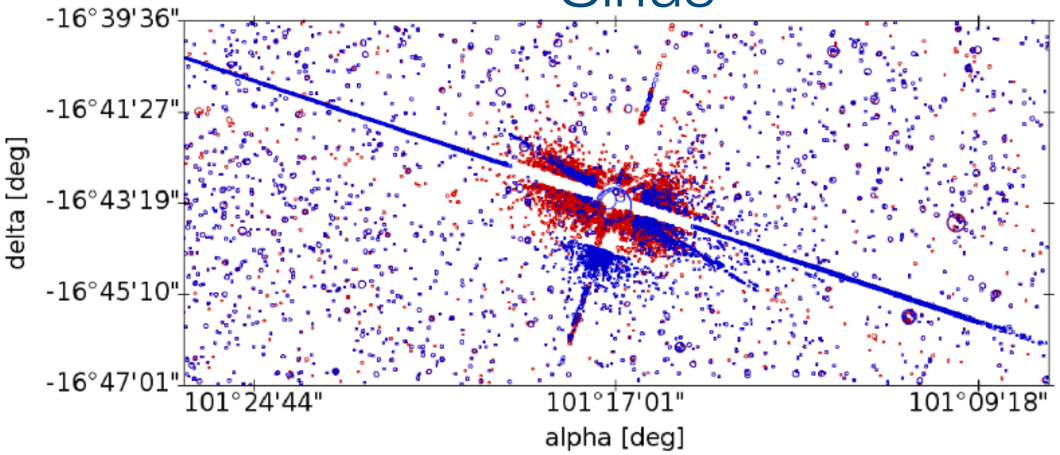
http://gsaweb.ast.cam.ac.uk/alerts

Initial Data Treatment

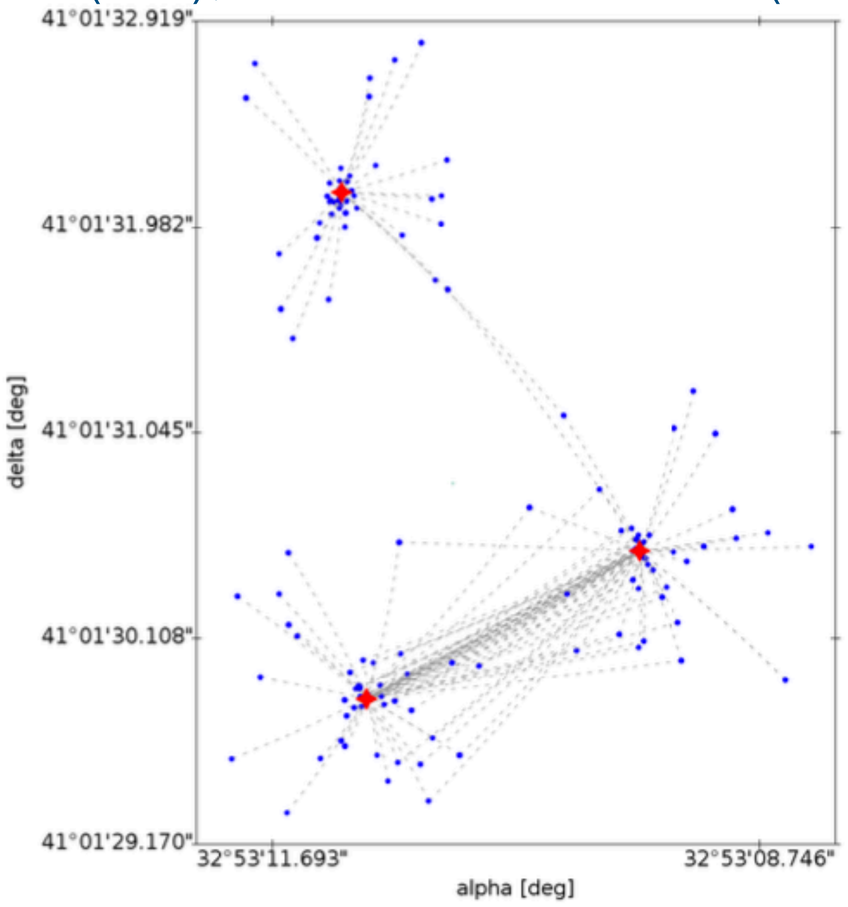
Saturn



Sirius

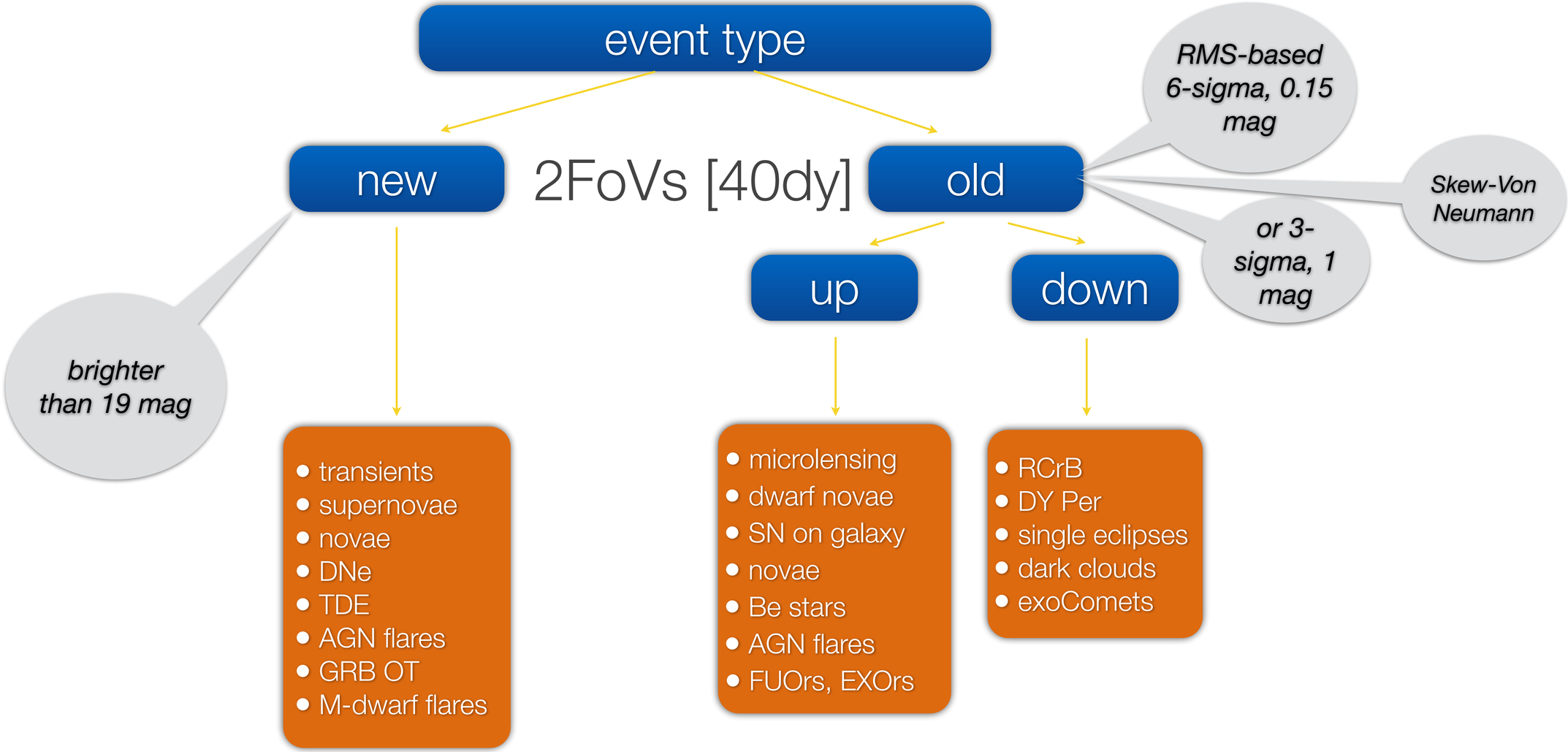


Candidate matching: 3 sources (red), 180 observations (blue)



Fabricius et al. 2016

Alert Detection: Daily



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detection, filtering, eyeballing

Transits

~10^8

Mitigation

Detection

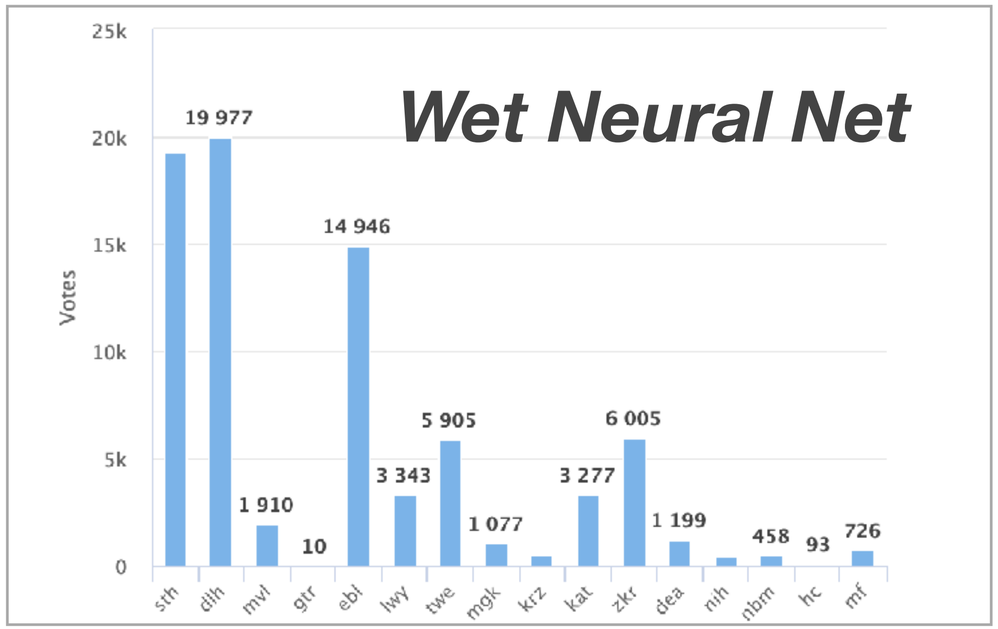
Classification

candidates ~10^3

Filtering

Eyeball ~20-30

Alert ~12



guy

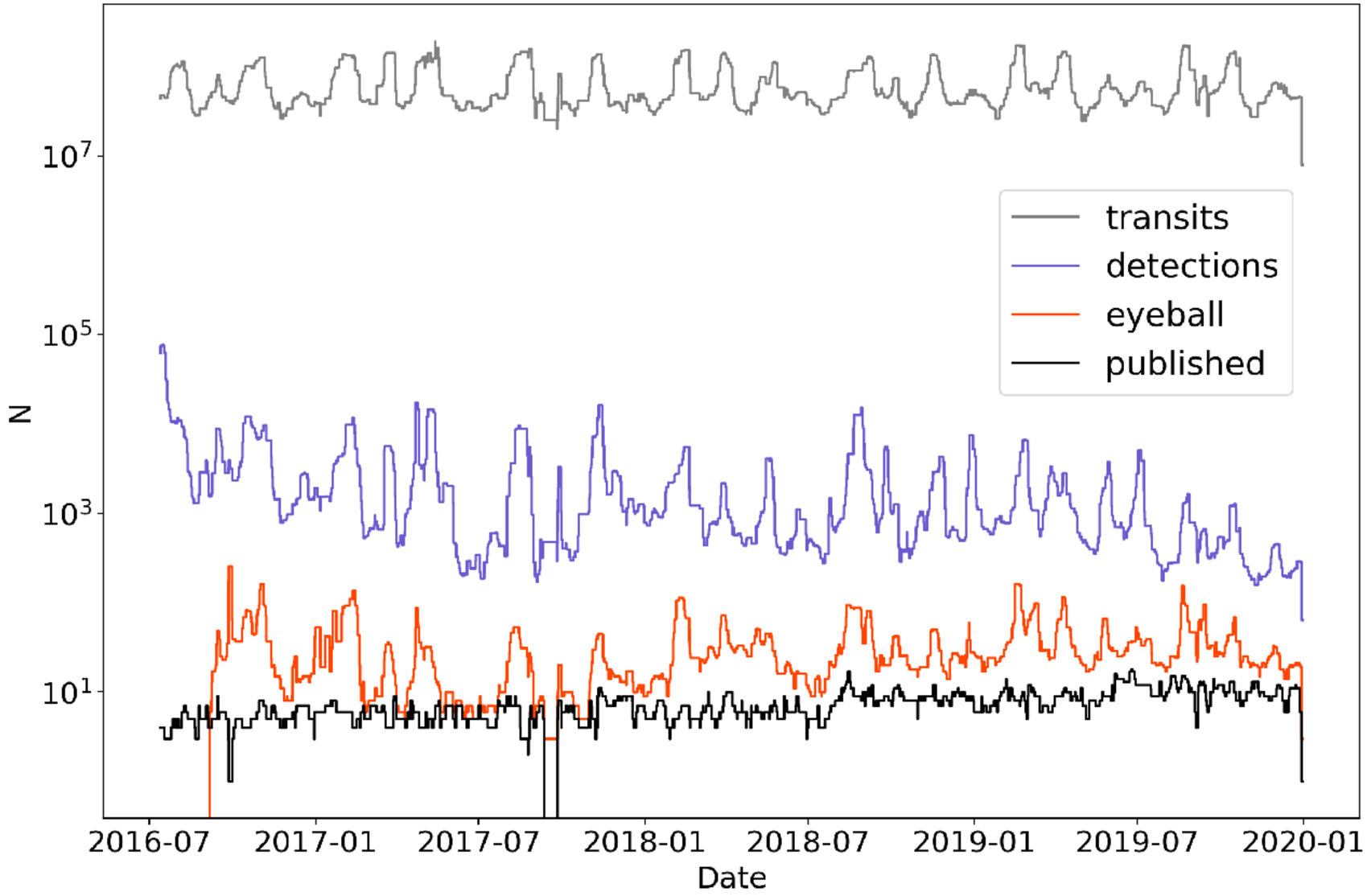
abdullah

diana

arancha

Data Rates

1. numbers of transits processed by AlertPipe
2. numbers of alert detections
3. numbers of alerts presented to eyeballers after additional (mostly environmental filtering)
4. numbers of alerts published from each run.



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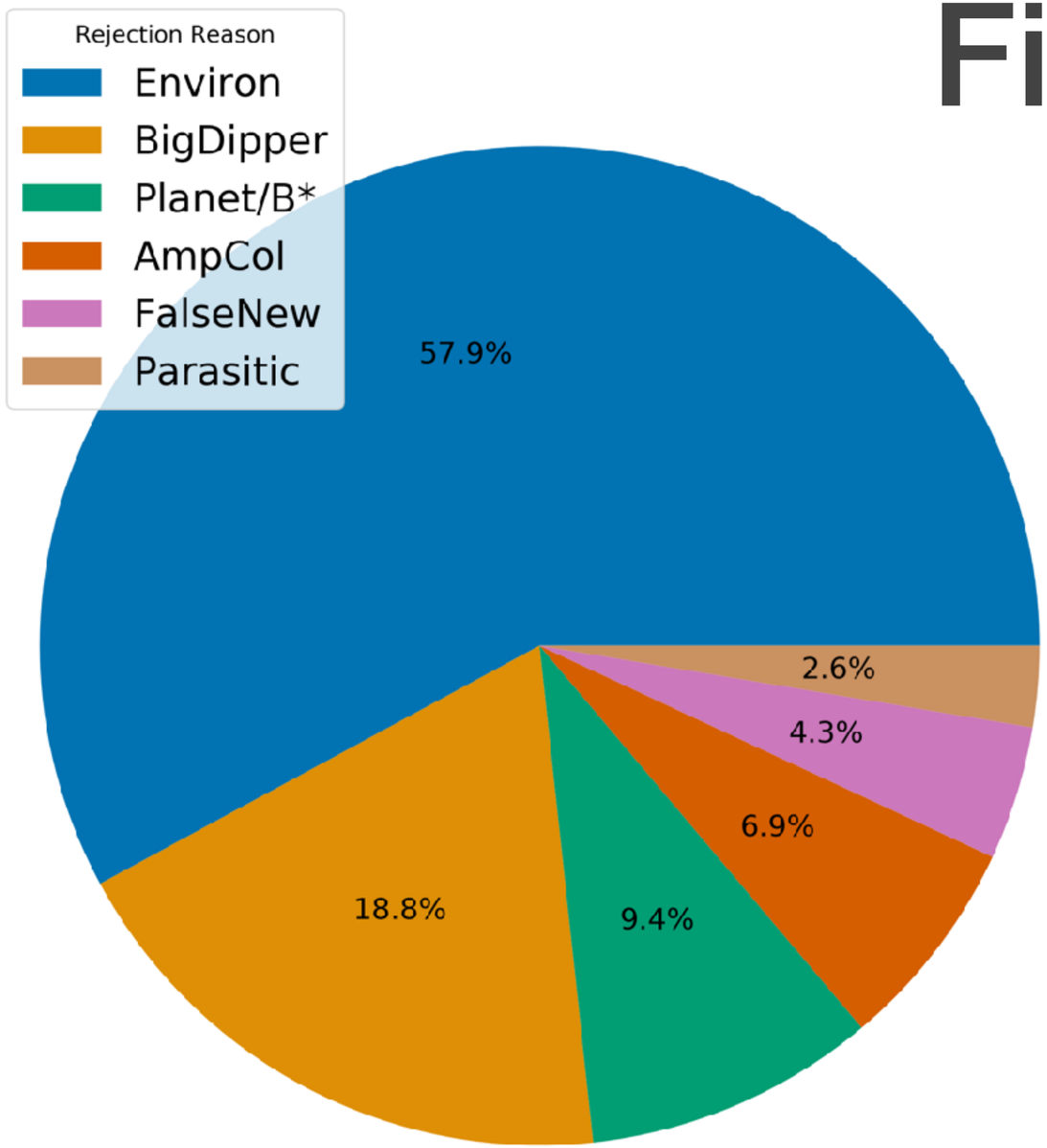
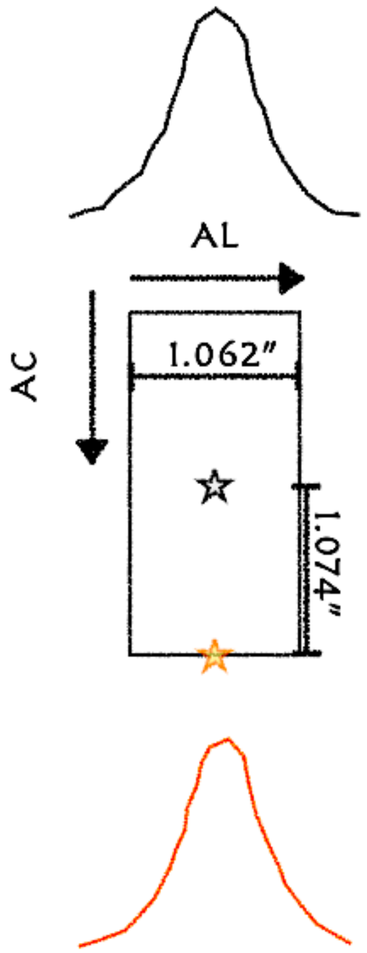
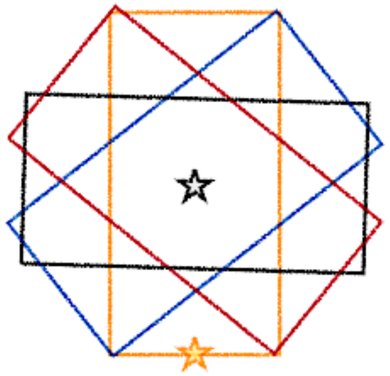
Filters

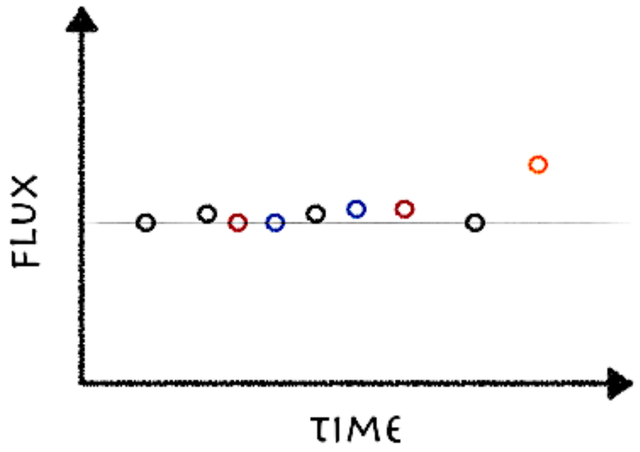


1. Most false positives are environmental in origin, examples:
    1. In wings of bright star
    2. planet or bright star close to pointing
    3. Near neighbour
2. But we also classify/reject:
    1. Known SSOs
    2. Known DR2 variable stars
    3. High amplitude red variables

Filters







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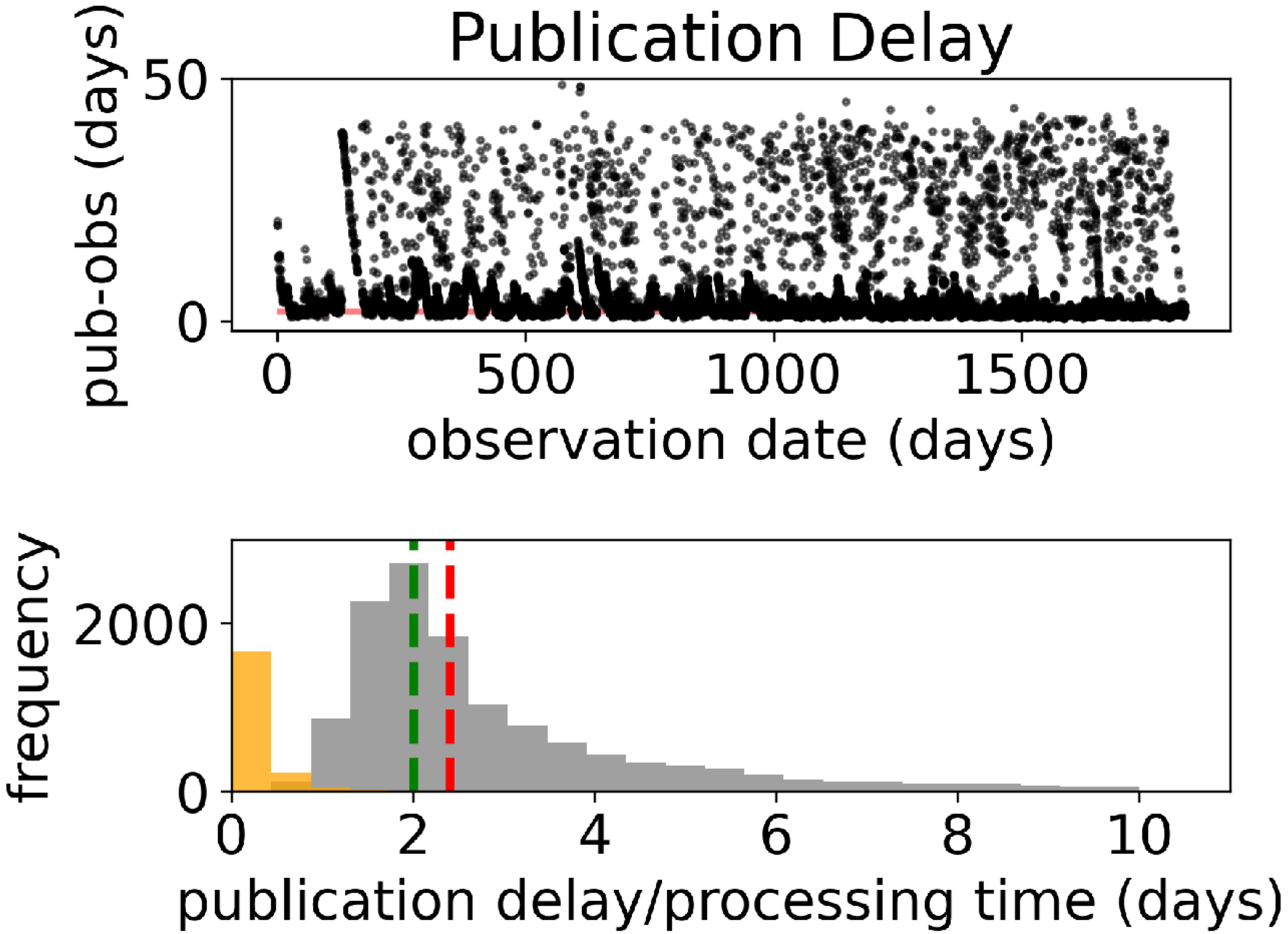

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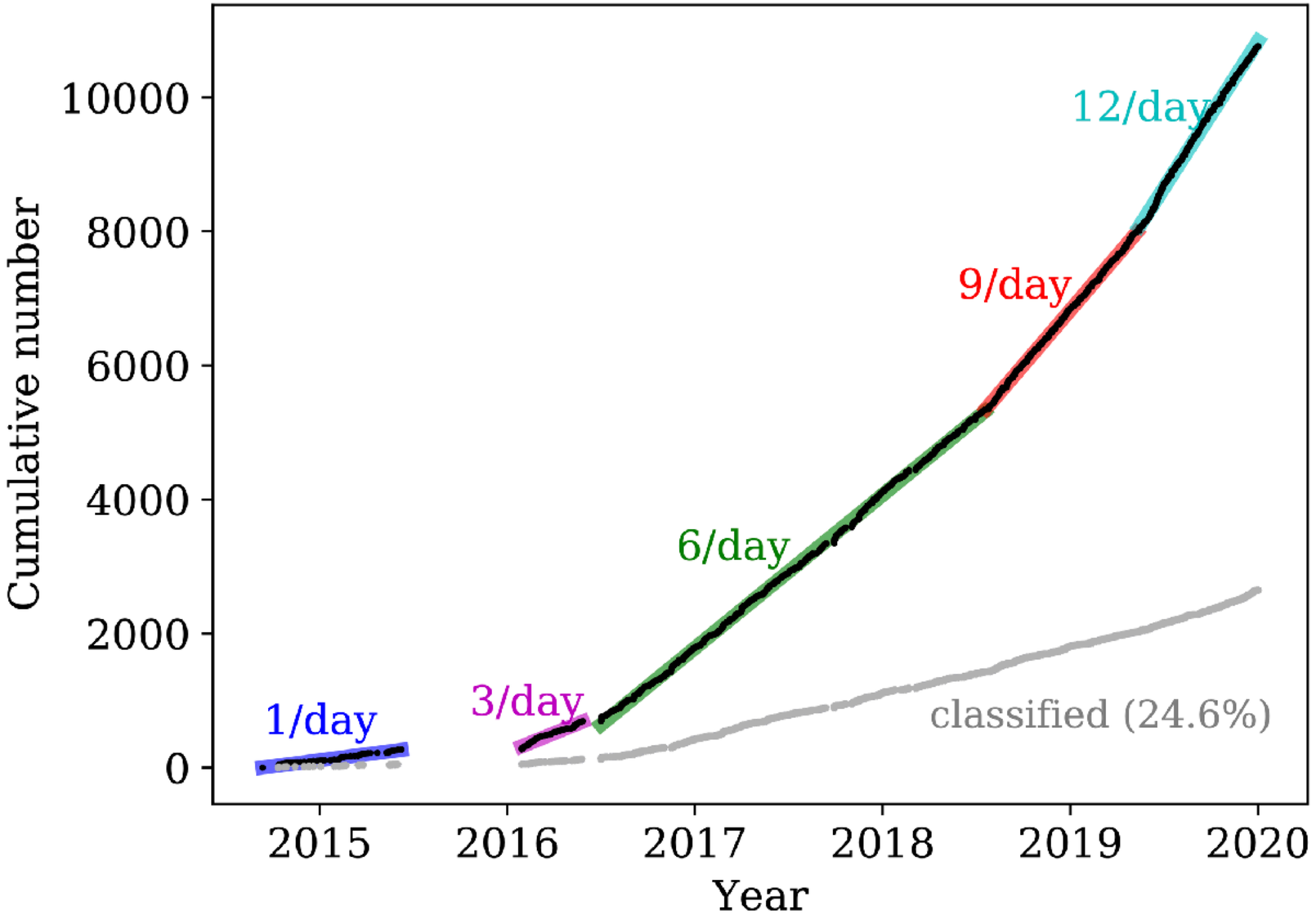
14,961 Alerts since Nov 2014

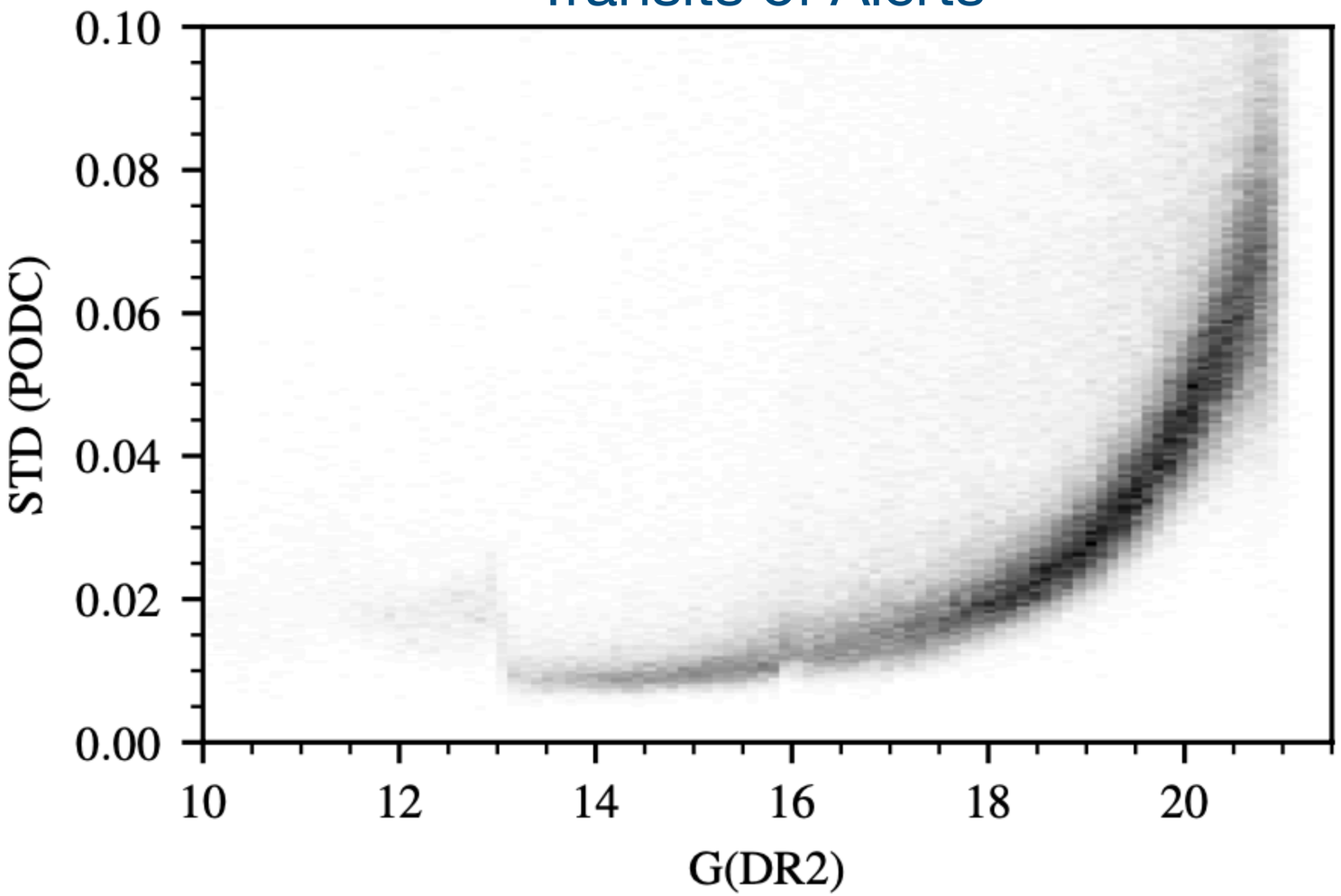


- Initial commissioning phase, spanning almost 300 days
- Density map avoiding crowded regions used for few months
- Environment Filters and Eyeballing App.
- Rock and GDR2 variables
- Skew-VonNewumann detector introduced

Precise Photometry

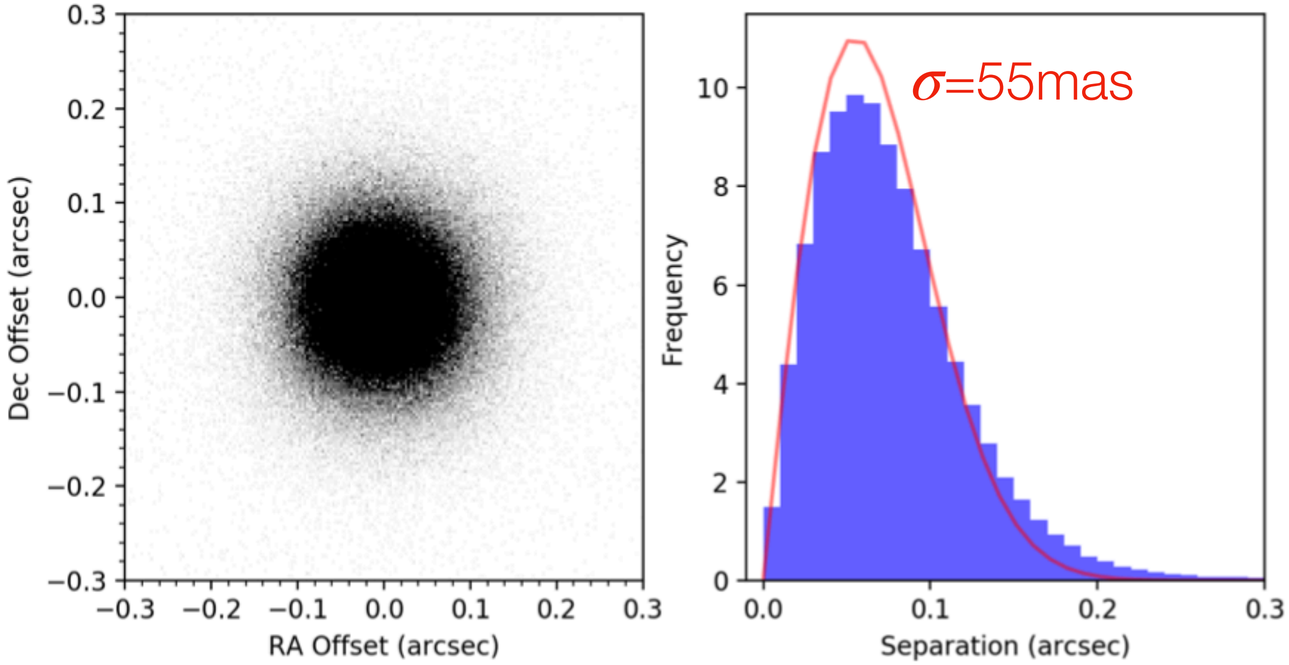
- Photometric One-Day Calibration
- Precision per-transit
- σ ~1% at G=15
- σ ~3% at G=19
- Updated ~monthly
- DPCI (Paul Osborne)

Transits of Alerts



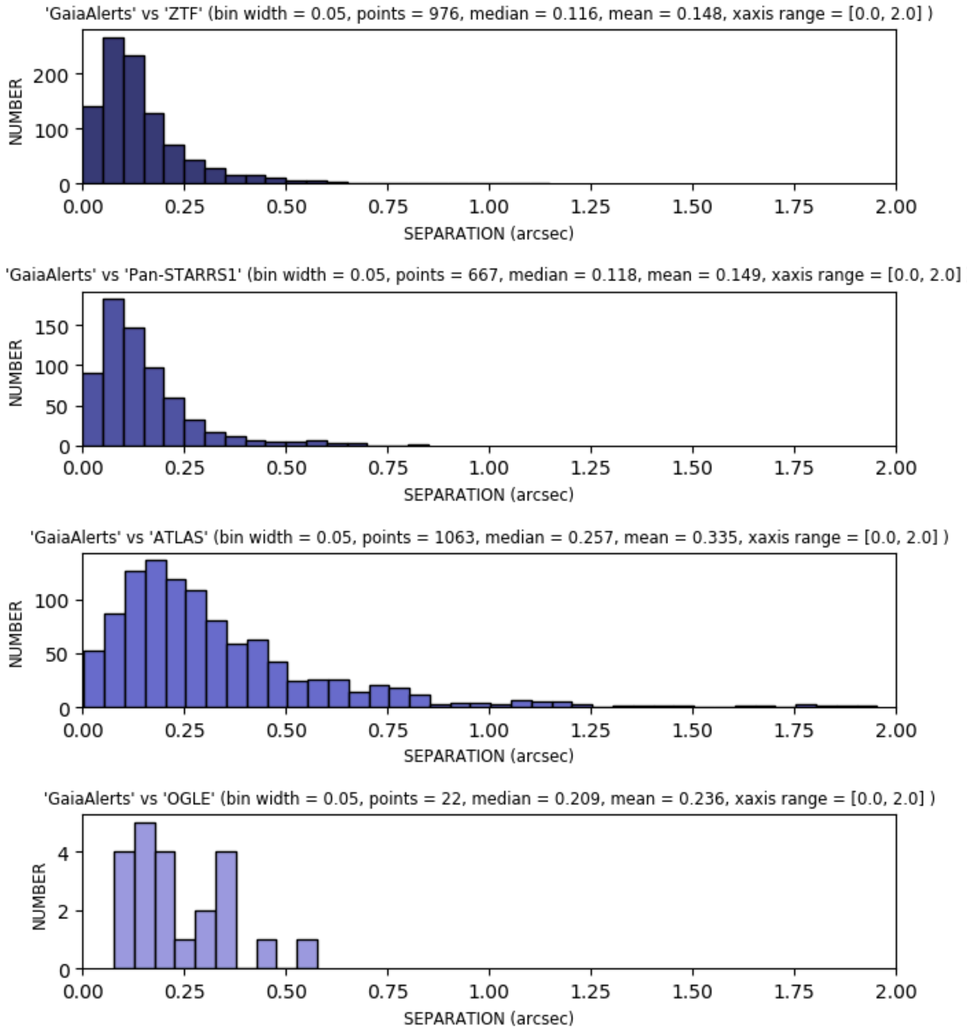
Accurate Astrometry

GSA vs GDR2

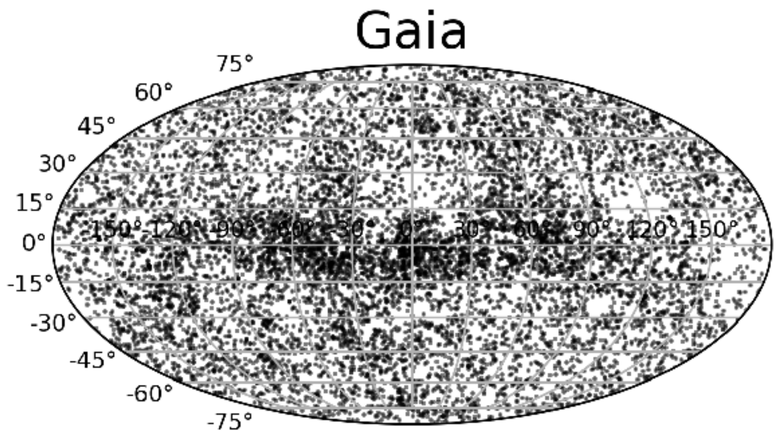


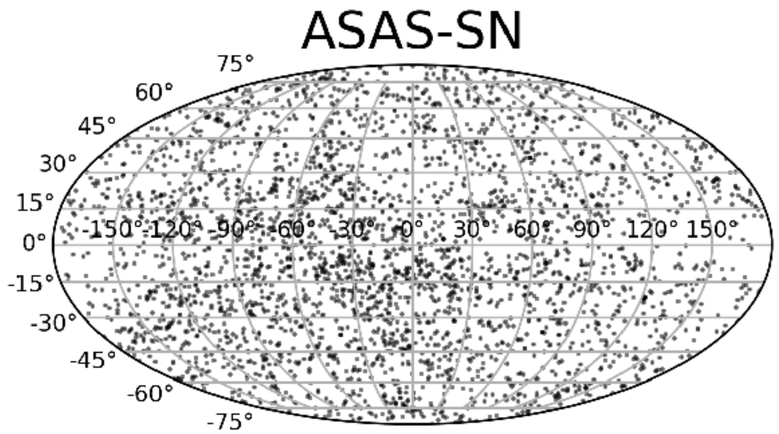
- TNS AstroNote 2019-15
- …we used the transient reports by Gaia as "ground truth”

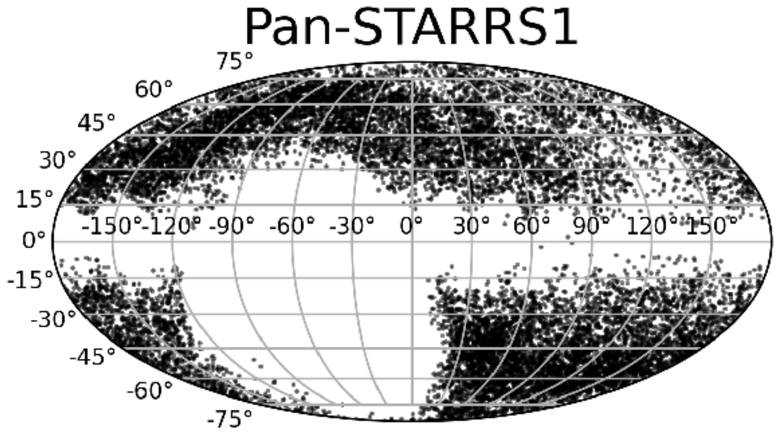
GSA vs ZTF/PS1/ATLAS/OGLE

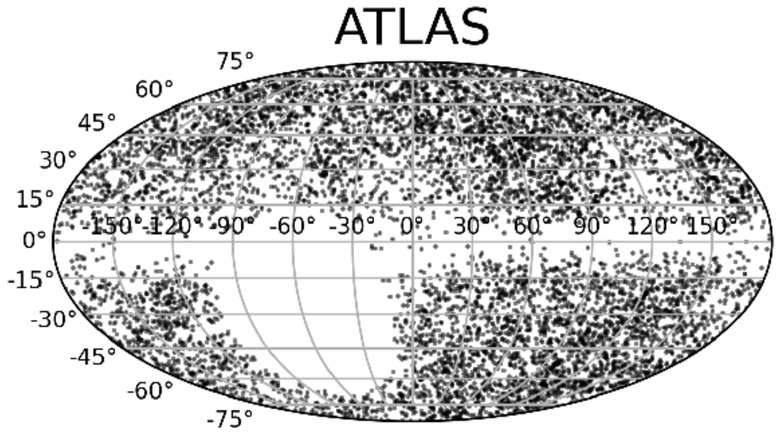


All-Sky









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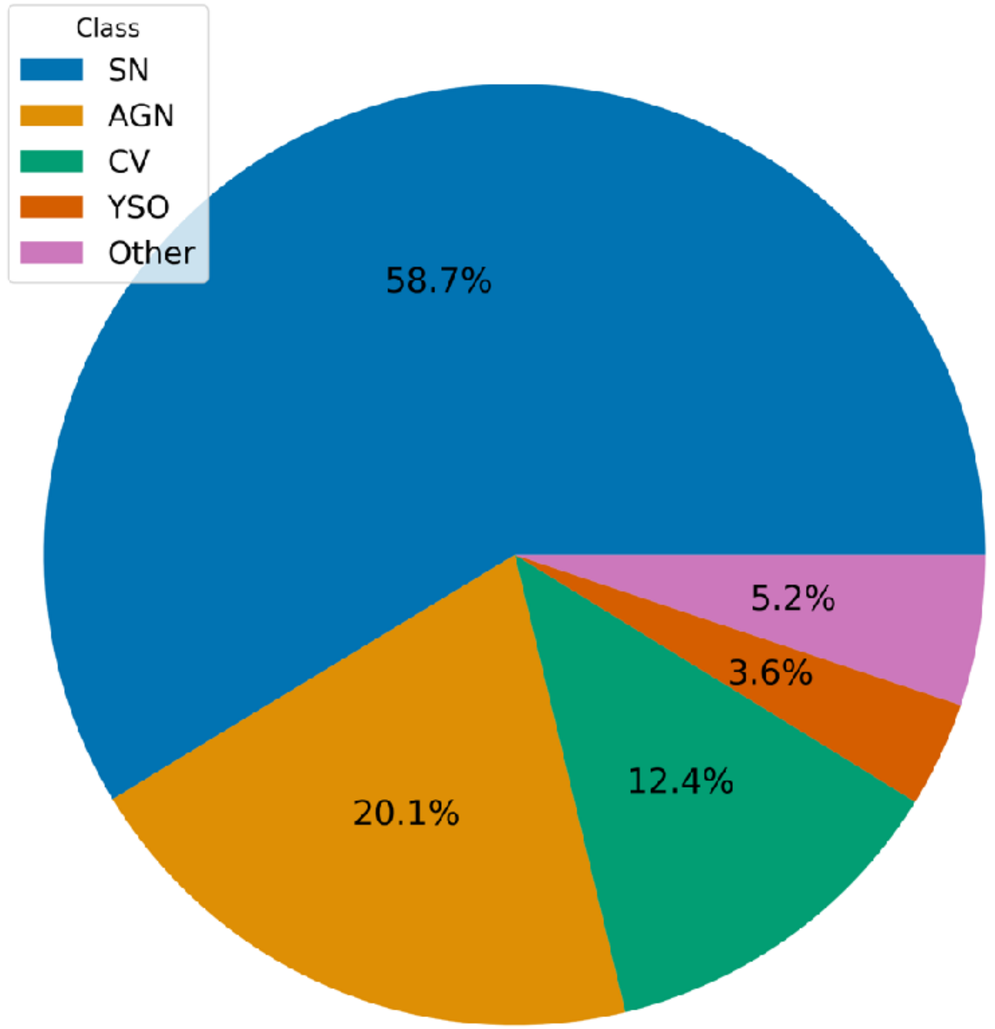
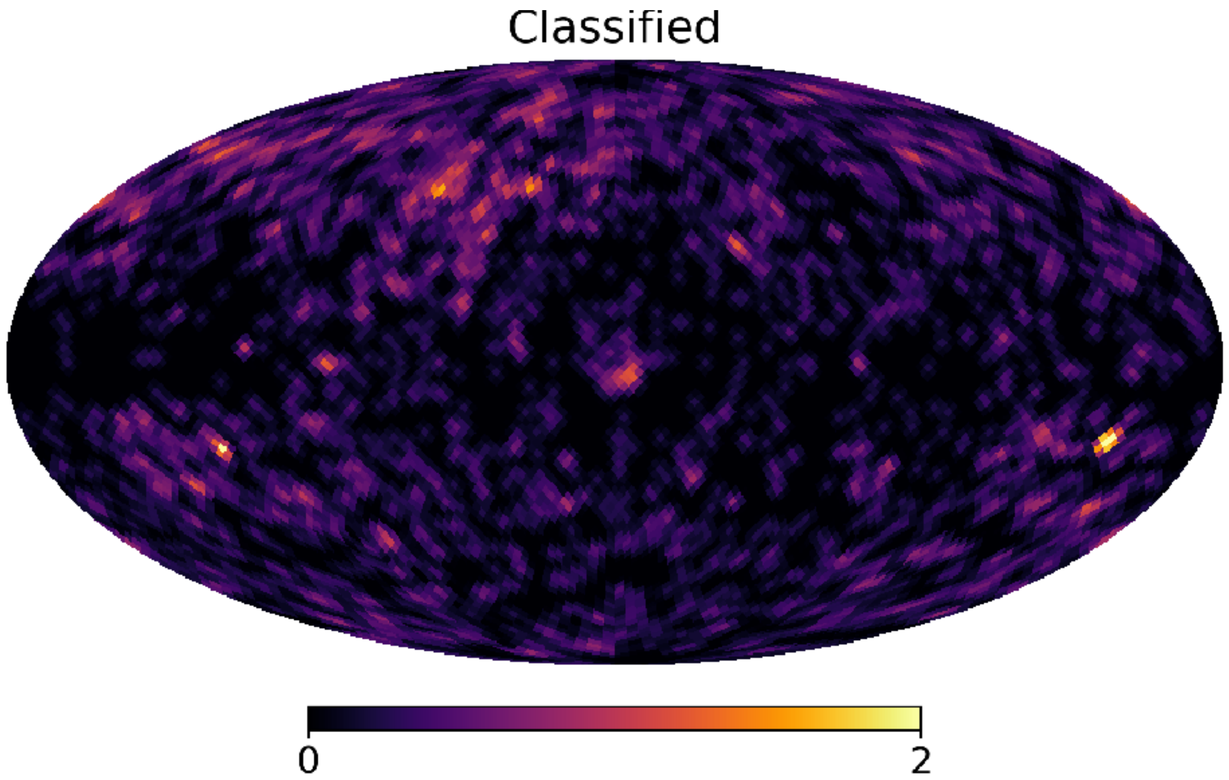
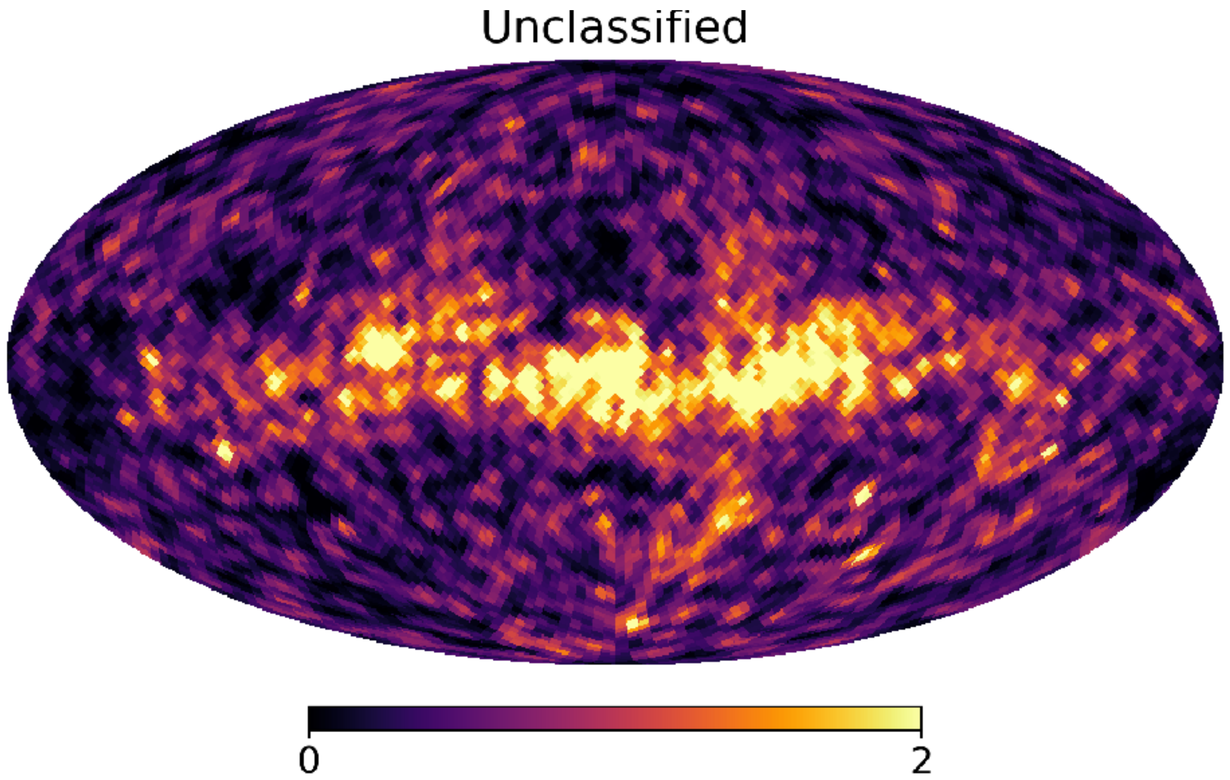
Classification

- almost 25 per cent of alerts classified.
- These classifications were obtained from numerous sources (including Simbad, ADS, TNS, ATels)
- SN dominate: due to dedicated spectroscopic follow-up programmes (PESSTO, NUTS, SED Machine, ZTF BTS)
- Thus the classification fractions should not be extended to the entire sample of GSA events.



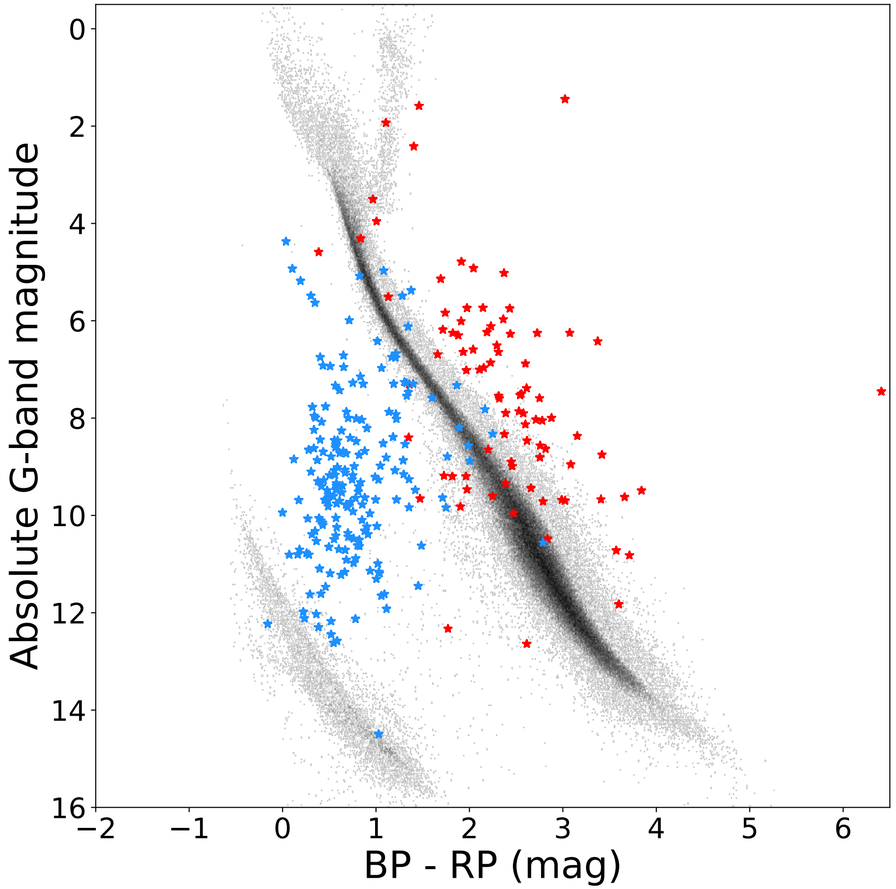
Classification

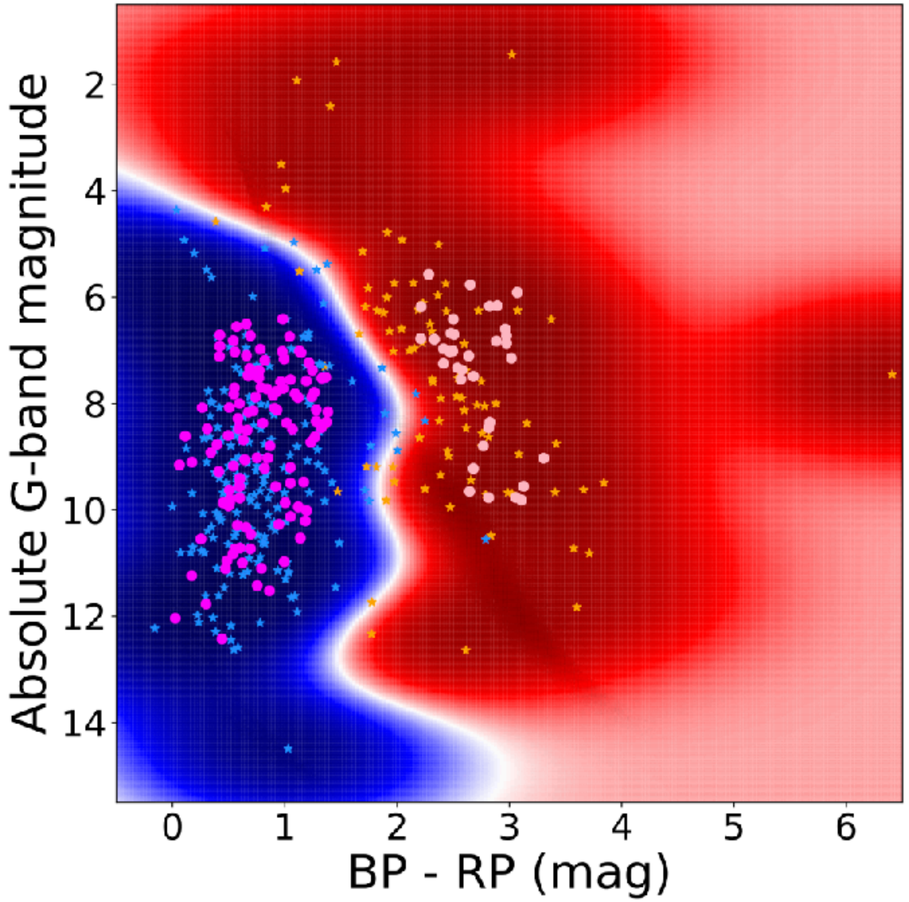




Majority of unclassified alerts are Galactic in origin, and thus the statistics presented in previous figure are not reflective of the true breakdown of the GSA transient classes.

Classification





Left: CMD of GDR2 counterparts to Gaia Alerts (stars), overlaid on a clean 100pc sample (grey background). Classified CVs are blue and YSOs are red. **Right**: probability map of a binary SVM classifier for 1815 unknown alerts in GDR2. Blue regions indicate CV parameter space, red regions YSOs. The white line is the decision boundary; training samples are shown as coloured stars, while new classifications (with P>0.95) are shown as magenta/pink circles. 727 (838) sources as CVs for P>0.95 (P>0.90), while 198 (410) new YSOs are classified.

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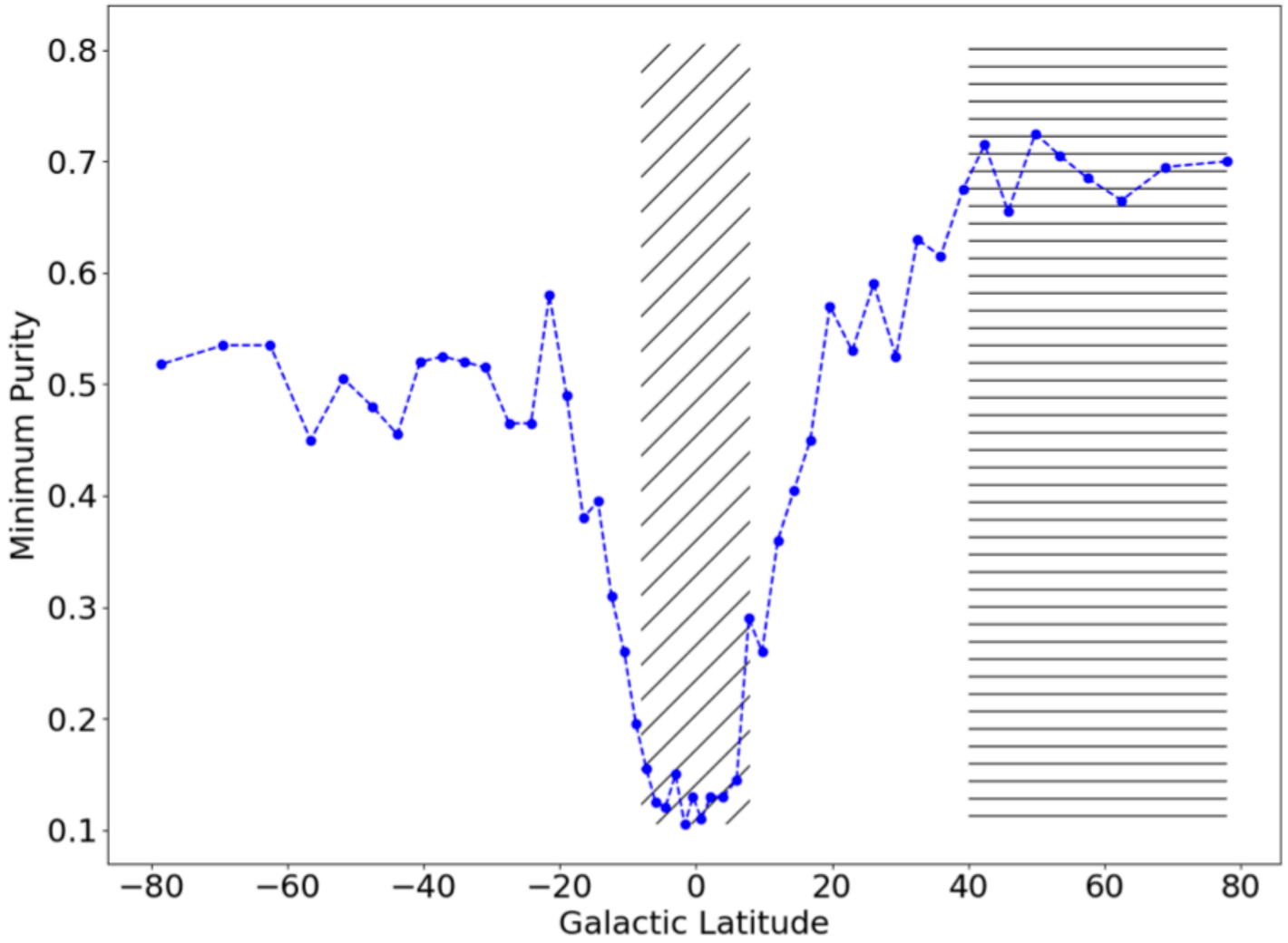
Purity

- Minimum purity of the published alerts as a function of Galactic latitude.
- An alert considered real if there exists some ancillary information concerning it, such as a classification, or an ATEL, or if it was reported by another survey either before or after the Gaia detection.
- We conclude that these alerts must be astrophysically real and not due to some known or unknown systematic of the Gaia data.
- For G<17, the fraction of our alerts confirmed by ancillary data is 0.93



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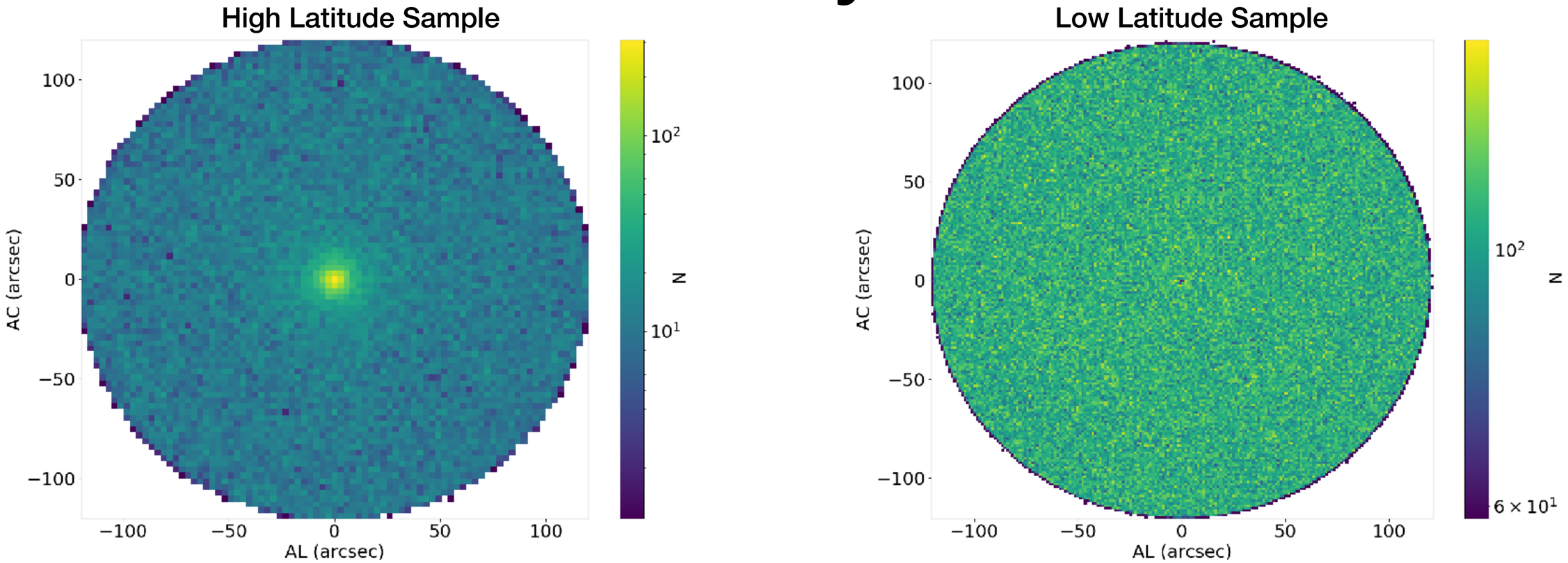
Purity



neighbouring sources within 2′, but outside of 0.2′′, of each published alert in the AL and AC directions at the time of the alert, for b ≥ 40◦ (Left), and for |b| < 8◦ (Right). Much larger proportion of SN detected at high latitudes (hence excess near alert position), and a lack of perturbing/contaminating neighbour sources for alerts at low Galactic latitude.

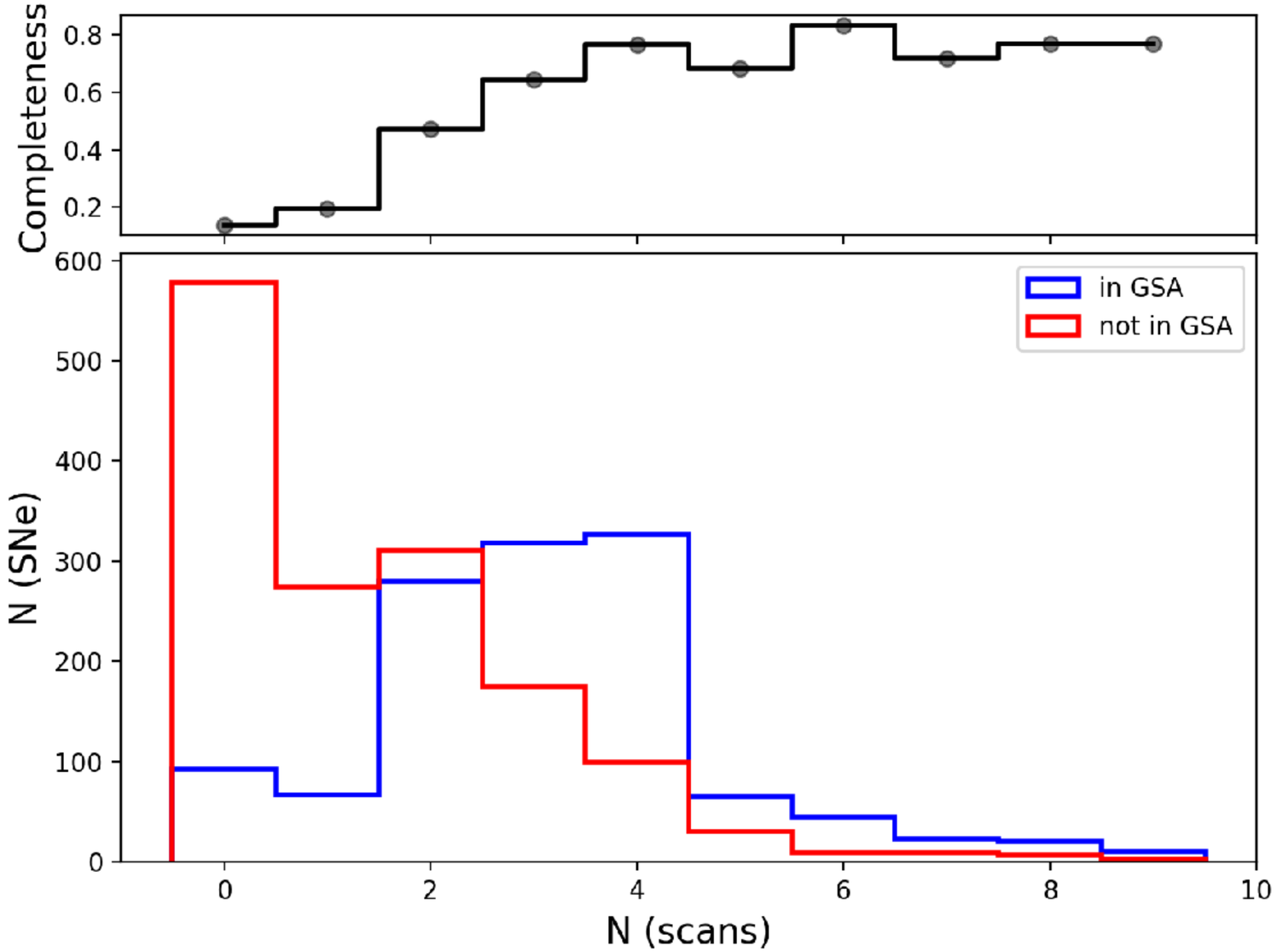
No evidence that alerts in the Galactic plane are less reliable than those at higher latitudes, nor that fainter alerts are any less reliable than brighter ones. Thus the overall purity of our published alerts is no worse than that of the subset where b ≥ 40◦ and Gmag < 17 and the fraction of our alerts confirmed by ancillary data is 0.93.

Completeness for SNe

- We have tested the completeness of GSA
- Using SNe: classified, numerous, long-lived
- TNS is the IAU-approved host of discoveries and classifications for SNe

Completeness: scanning law

- TNS recorded 2826 SNe, mag<=19 (7/16-1/20)
- GSA requires detection in both FoVs within 40 dy
- This dominates GSA recovery of SNe.
- External completeness, C_E=0.46



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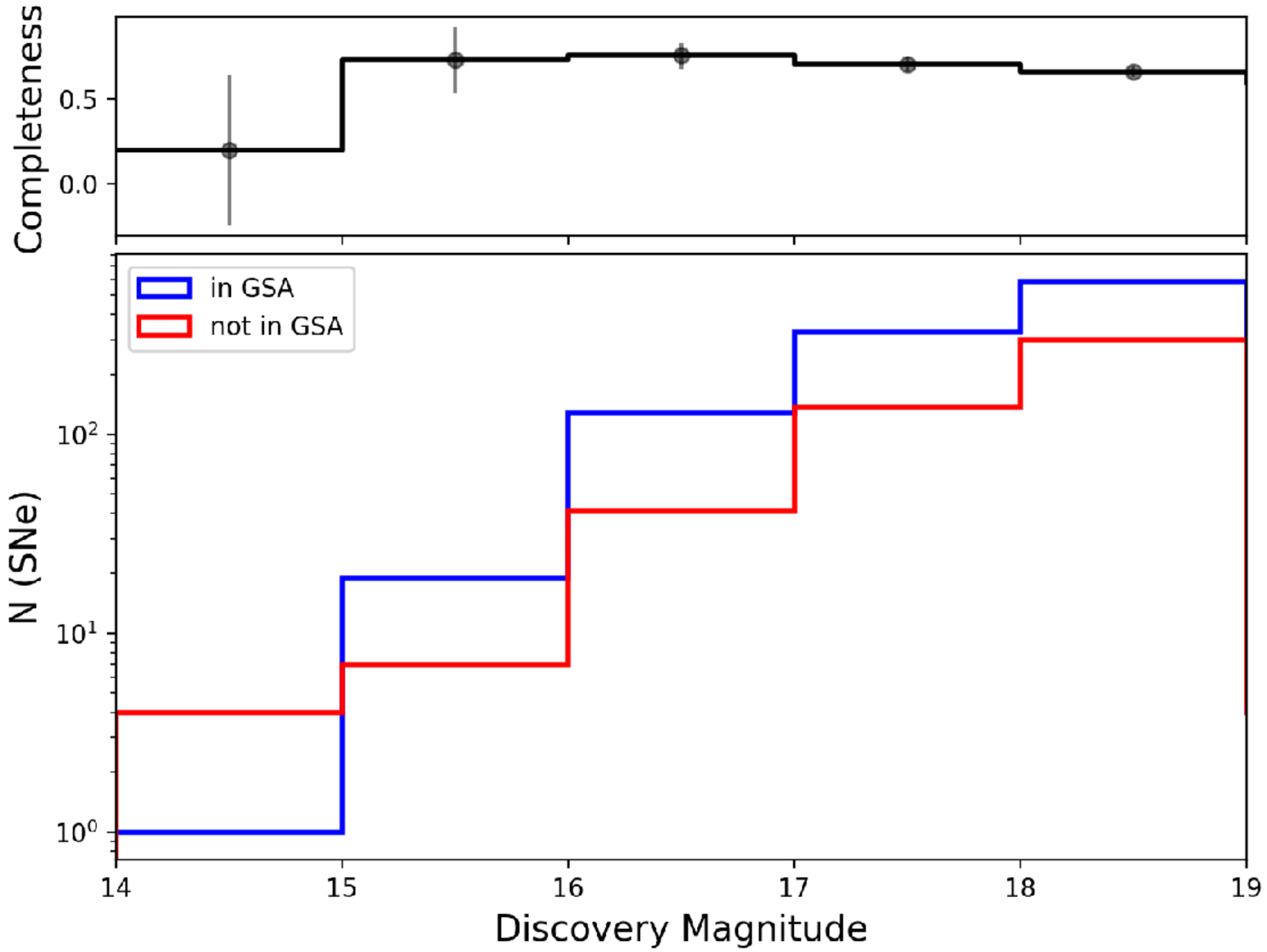
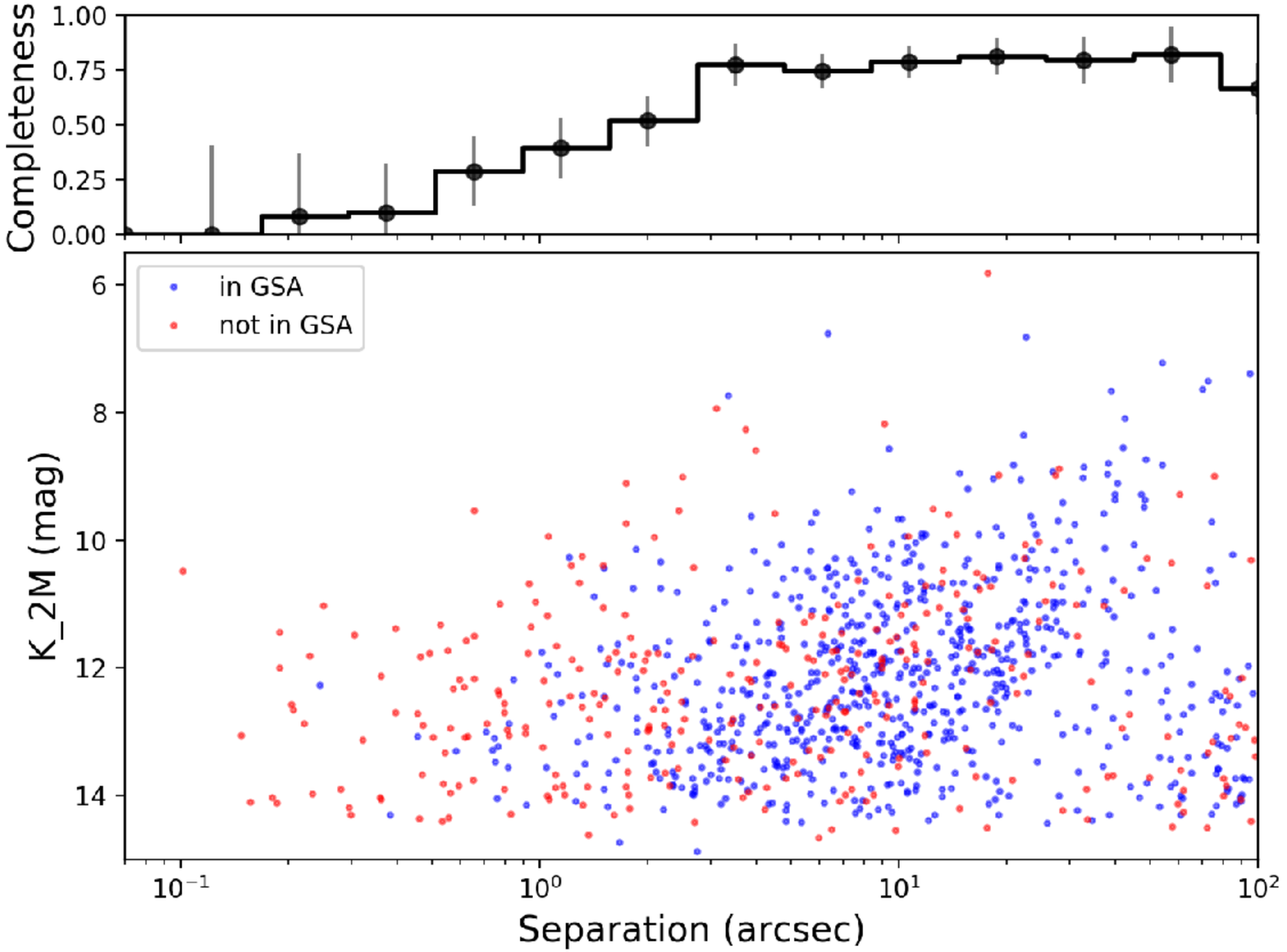
Completeness: magnitude

- Now use sample with >=2 scans (1564 SNe)
- 1073 detected, 491 not: thus overall internal completeness $C_I = 0.69$
- Fairly uniform with mag
- Roll-off to fainter magnitudes:
  - different survey photometry?
  - fading at time of discovery?



Completeness: separation

- SN with >=2 scans
- xmatch vs. 2MASS Extended Sources
- likely mismatches for sep>~20 arcsec
- Significant drop at sep<~3 arcsec
- Indicative of a reduction in the sensitivity of the NewSource detector to complex environments



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Coming Soon

- Single Transit Alerts (Kostrzewa-Rutkowska+20, Tue talk)
- Full Automation (Marton, Wed talk)
- GSA paper: it has been shown to DPACE, and we are addressing (mostly minor) comments. We are about to circulate to all authors to secure their consent.
- DR3 includes alerts in Cycle 03 (25-07-2014 to 28-05-2017)

Summary

- We handle upwards of 60 million measurements per-day, searching for new sources, and sources which change significantly in brightness. Detectors work with lightcurves, and thus are also sensitive to slowly varying sources.
- A series of (mostly environmental) filters reduces the detection rate from a few thousand provisional candidates to a shortlist of several tens of events per day which are eyeballed.
- Astrometry is accurate to 55 mas, photometry to better than 0.031 mag (at G=19).
- We currently publish alerts at a rate of approximately 12 events/day, ~25 per cent of them receive classifications.
- Published classifications are dominated by SNe, but this is biased by the extensive follow-up campaigns. The bulk of our unclassified alerts reside in the Galactic plane, and are therefore likely to be Galactic in origin.
- GSA suffers very low levels of contamination from false positives. We showed that the minimum purity of the survey in uncrowded regions for sources with G<17 is 93 per cent. We find no evidence of additional sources of contamination at faint magnitudes, or in crowded regions.
- Overall completeness to SNe is 46 per cent. The Gaia scanning law, combined with requirement for two detections, dominates ability to detect SNe. Completeness for SNe with>=2 scans is 79 per cent, unless within 3 arcsec of the nucleus.
- For those alerting sources which were included in Gaia DR2, we have shown that a simple classifier is able to distinguish between YSOs, and CVs with high reliability, resulting in 838 new candidate CVs, and 410 new candidate YSOs.

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- *Michel Dennefeld*
- *Andrew Drake*
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- *Morgan Fraser*
- *Gerry Gilmore*
- *GREAT*
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- *Peter Jonker*
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- *Thomas Wevers*
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- *Roy Williams*
- *Lukasz Wyrzykowski*
- *all co-I's on our numerous proposals.*