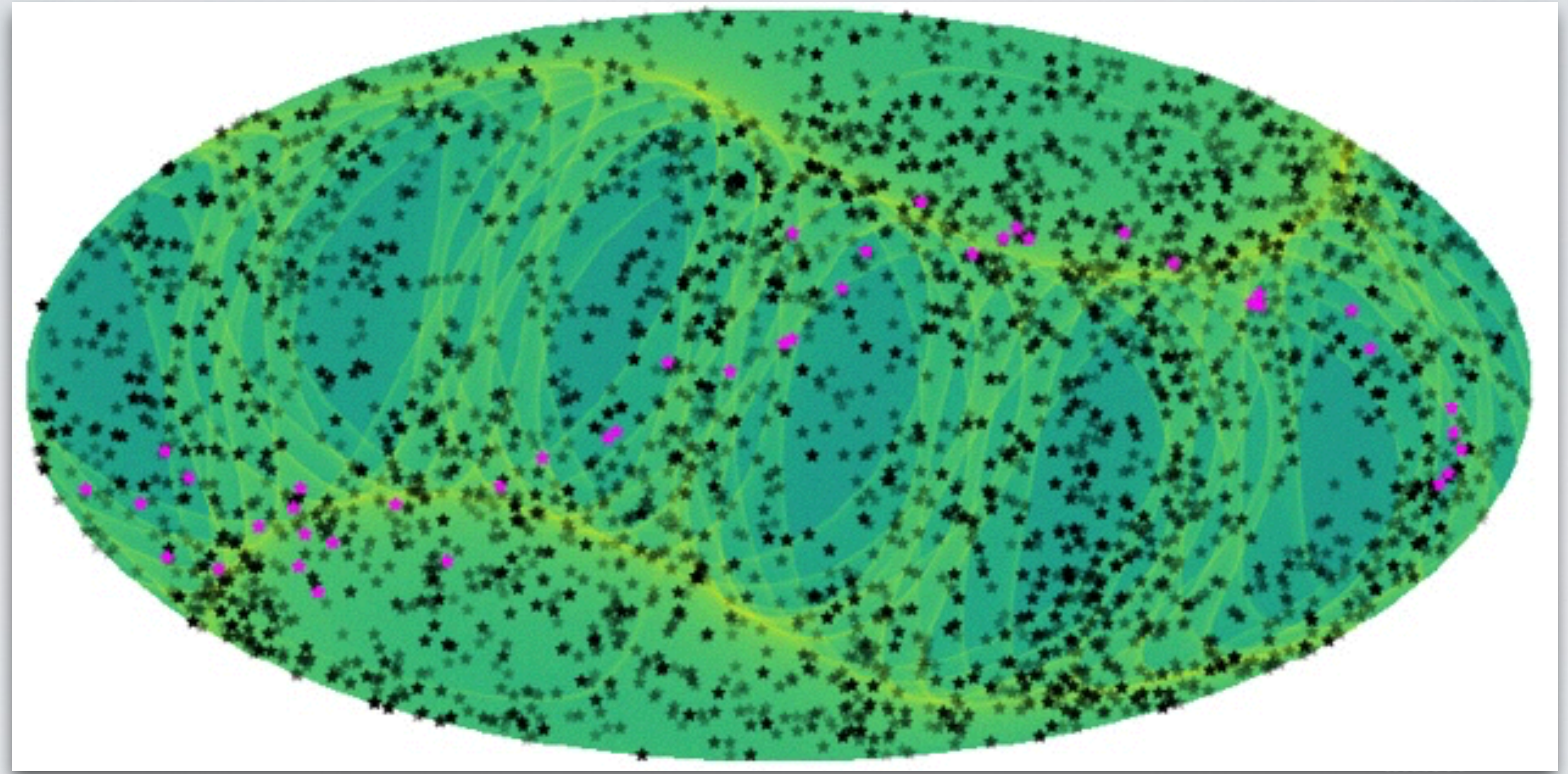
Gaia and Alerts: Status

Simon Hodgkin



Nadia Blagorodnova
Arancha Delgado
Diana Harrison
Sergey Koposov

Zuzanna Kostrzewa-Rutkowska
Elme Breedt Lategan
Guy Rixon
Goska van Leeuwen

Floor van Leeuwen
Thomas Wevers
Lukasz Wyrzykowski
Abdullah Yoldas

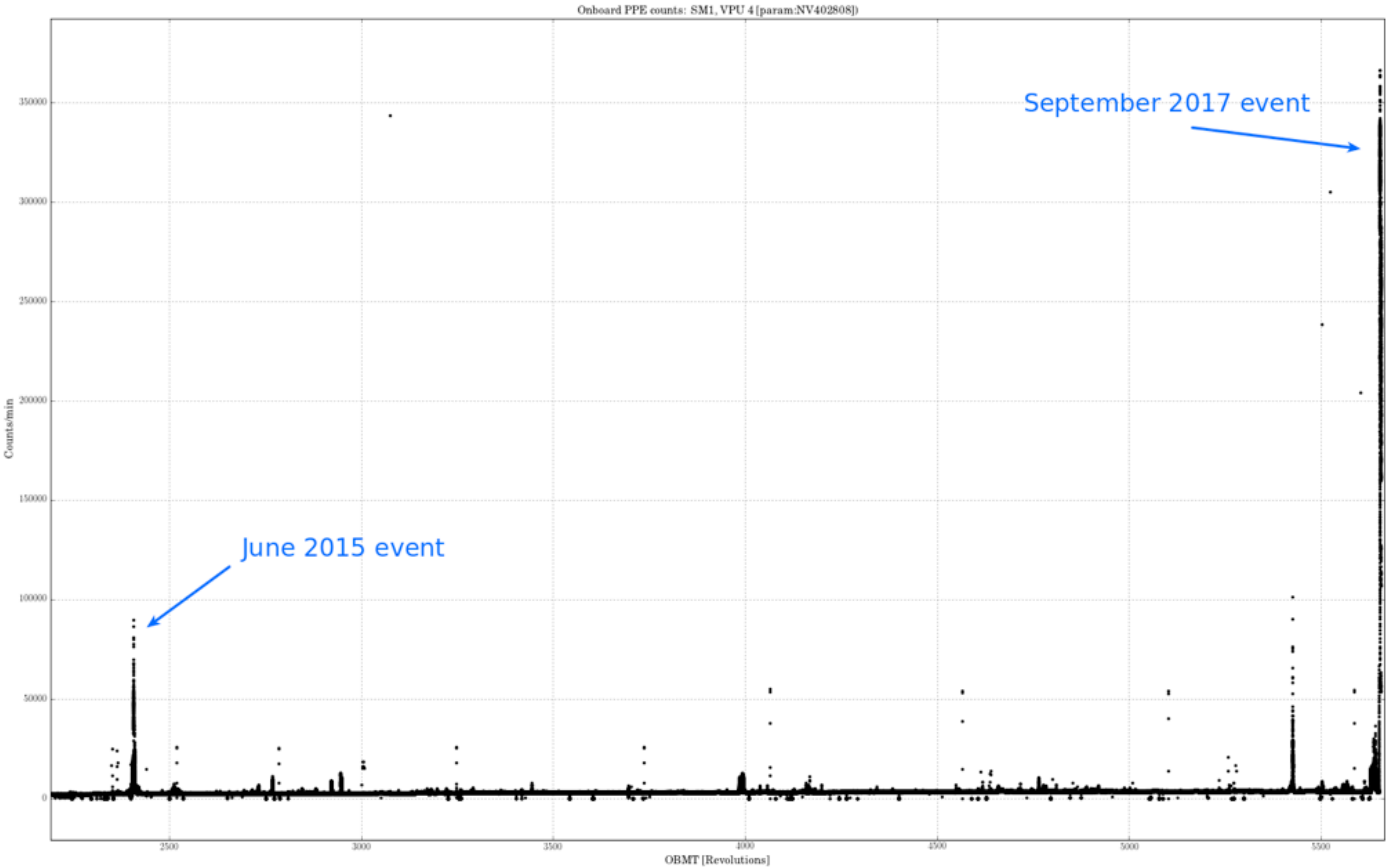
@SpacemanSimon
@gaia_alerts

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

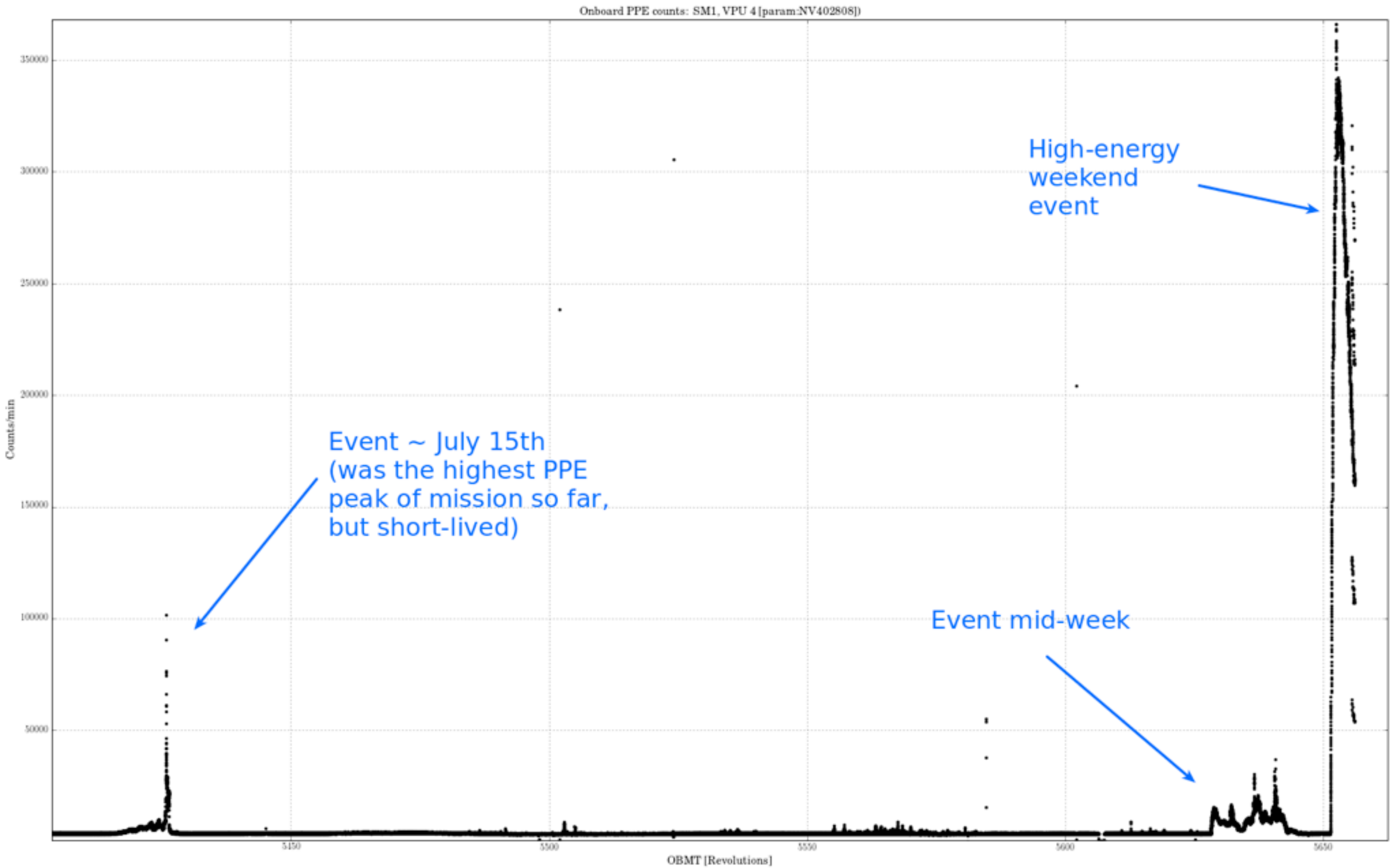
7th Gaia Science Alerts Workshop
7-9 December 2016 * SRON Utrecht NL
SRON
8th OPTICON
Gaia Science Alerts
Workshop
6-8 December 2017
Warsaw, Poland
Details and registration: https://tinyurl.com/gaiaworkshop
Gaia Science Alerts Verification
and Follow-up Workshop
Wednesday 29 June - Friday 1 July 2011, at the
Institute of Astronomy, University of Cambridge
DETAILS AND REGISTRATION
THE 3RD
GAIA SCIENCE ALERTS WORKSHOP
BOLOGNA 6-7 SEPTEMBER 2012
FIFTH GAIA SCIENCE ALERTS WORKSHOP
UNIVERSITY OF WARSAW 9-12 SEPTEMBER 2014
Status of Gaia
Workshop Organising Committee:
Gaia Science Alerts Workshop 201
Liverpool John Moores University (UK
10-13 November 2015
Follow-up observatio
Automated classificat
Gaia Alerts Publisher
Science cases
Robotic telescopes
Outreach
Transient surveys
Hands-on sessions
GAIA SCIENCE ALERTS WORKSHOP
Institute of Astronomy, Cambridge: 23 - 25 June 2010
Important dates: Registration closes - 30 April 2010, Invitations allocated - 10 May 2010
th Gaia Science Alerts Workshop
1 June 2013, IAP, Paris
Ga!a
cience Alerts

Mission Status

- Spacecraft operations are generally running smoothly
  - Safe mode in Jun-2017
    - Re-focus needed – Astrometry Focus now 'best ever'
    - Root cause in mircopropulsion system has now been cured
  - Sailed very stably through intense solar flare(s) ➔ But memory was filled with false detections and it took a while to empty the memory
    - Procedures in planning to delete such data on-board in a possible future occasion
    - Impact on CCD corresponded 1-1.5 years of radiation damage, but globally still below expected level
  - Loss-of-convergence through micro-meteorites and tank 'bubbles' continue with the usual frequency
  - Significant event on 24-Nov
    - Max AL angle error = ~11 arcssec
    - Max AC angle error = ~45 arcsec
    - Recovered autonomously
  - Ground station equipment moved to new technology
    - Test – Gaia switching to Low Gain Antenna - performed successfully 23-Nov



Onboard PPE counts: SM1, VPU 4 [param:NV402808])
September 2017 event
June 2015 event
Counts/min
OBMT [Revolutions]
350000
300000
250000
200000
150000
100000
50000
0
2500
3000
3500
4000
4500
5000
5500



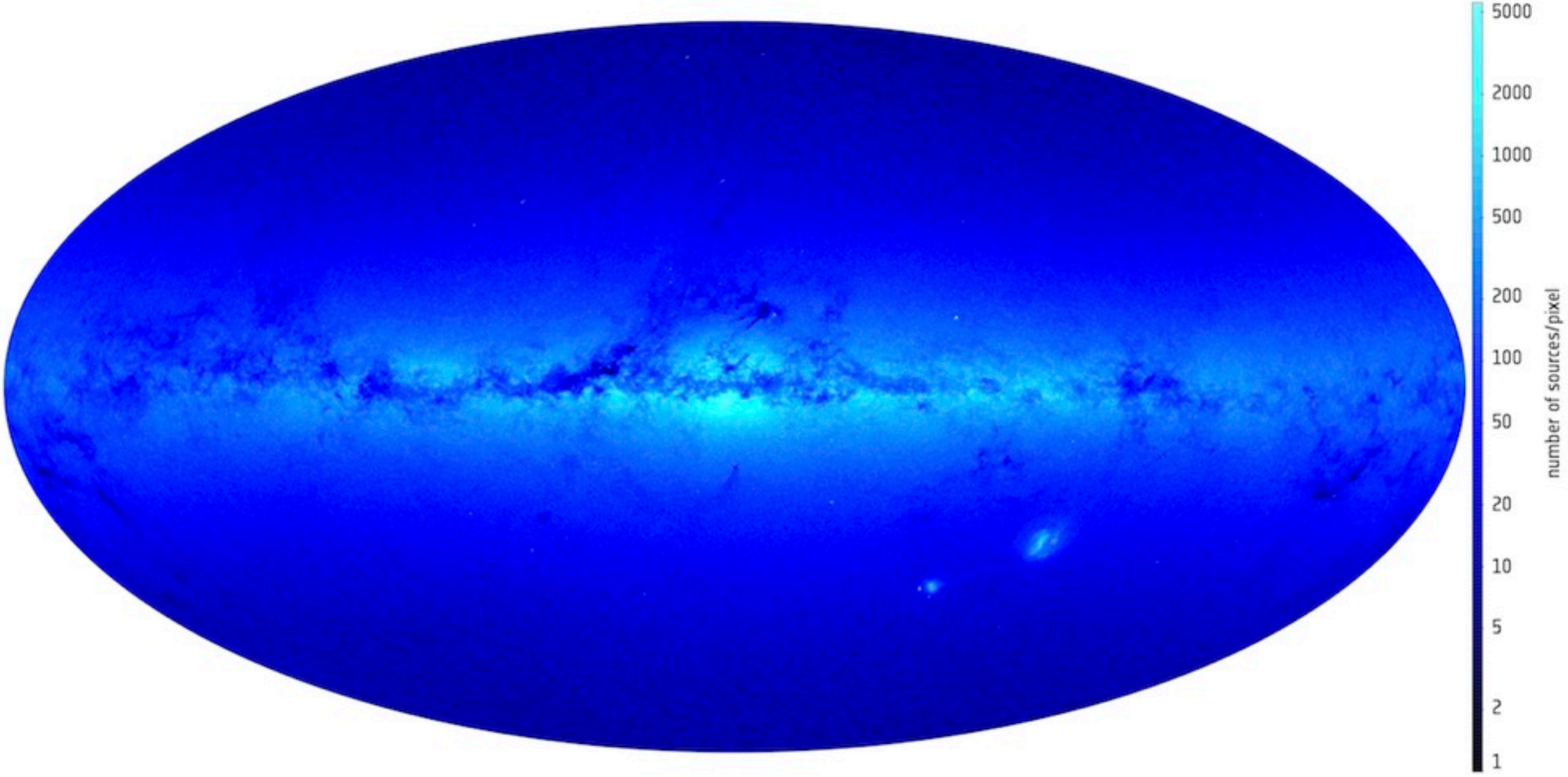
Onboard PPE counts: SM1, VPU 4 [param:NV402808])
Counts/min
OBMT [Revolutions]
High-energy weekend event
Event ~ July 15th (was the highest PPE peak of mission so far, but short-lived)
Event mid-week

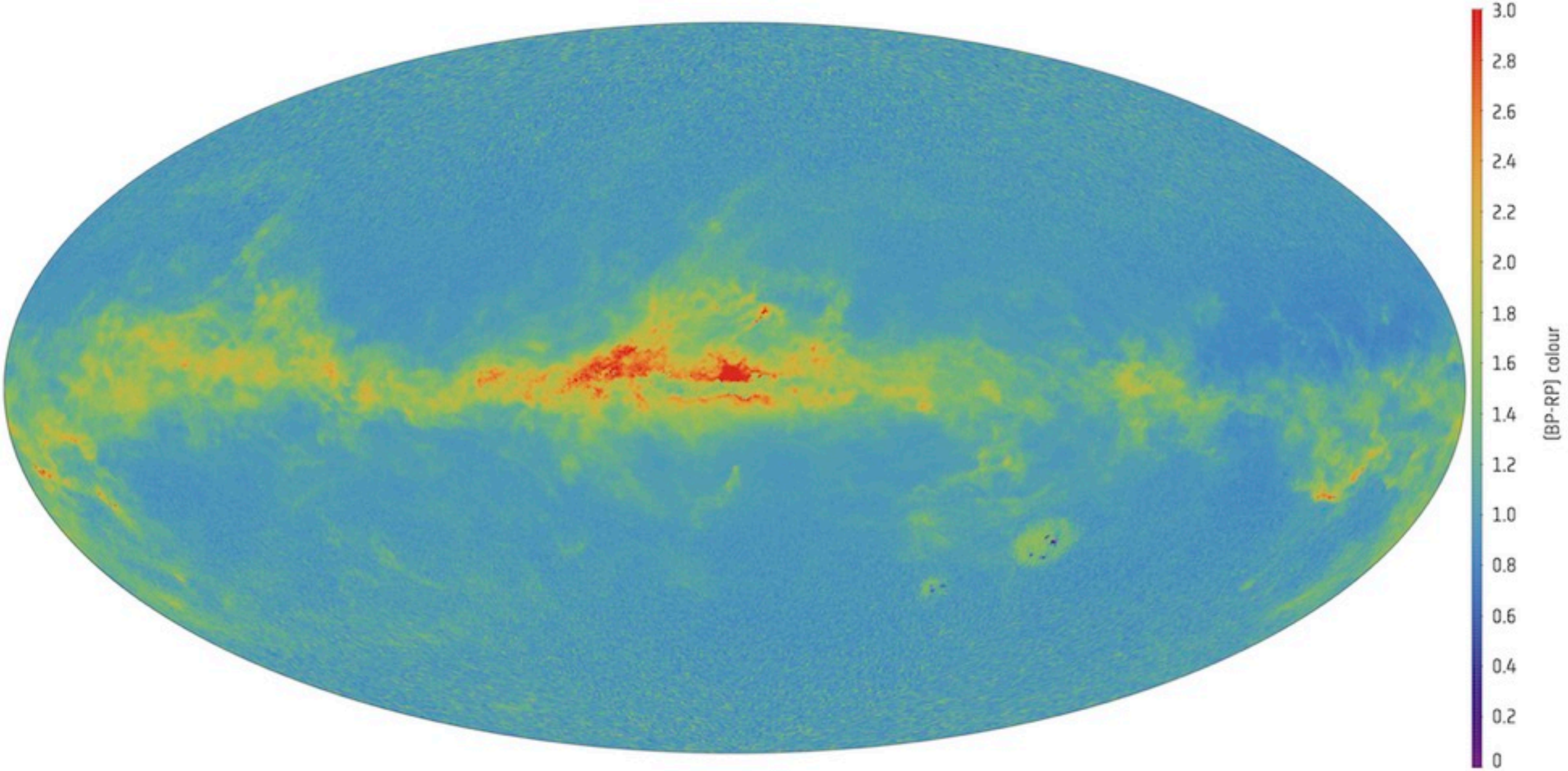
A big step from Gaia DR1 to DR2

Gaia DR1	**Gaia DR2**
14 months input telemetry	22 months input telemetry
Parallaxes and proper motions from Gaia-Hipparcos combination	Stand-alone Gaia astrometric solution
Limited/incomplete calibrations leading to significant systematics	Much improved calibrations, much reduced systematics
G-band only	G, G_{BP}, G_{RP}, pass-bands
Small set of variable star light curves	Much expanded variable star catalogue
	Radial velocities
	Solar system objects

A big step from Gaia DR1 to DR2

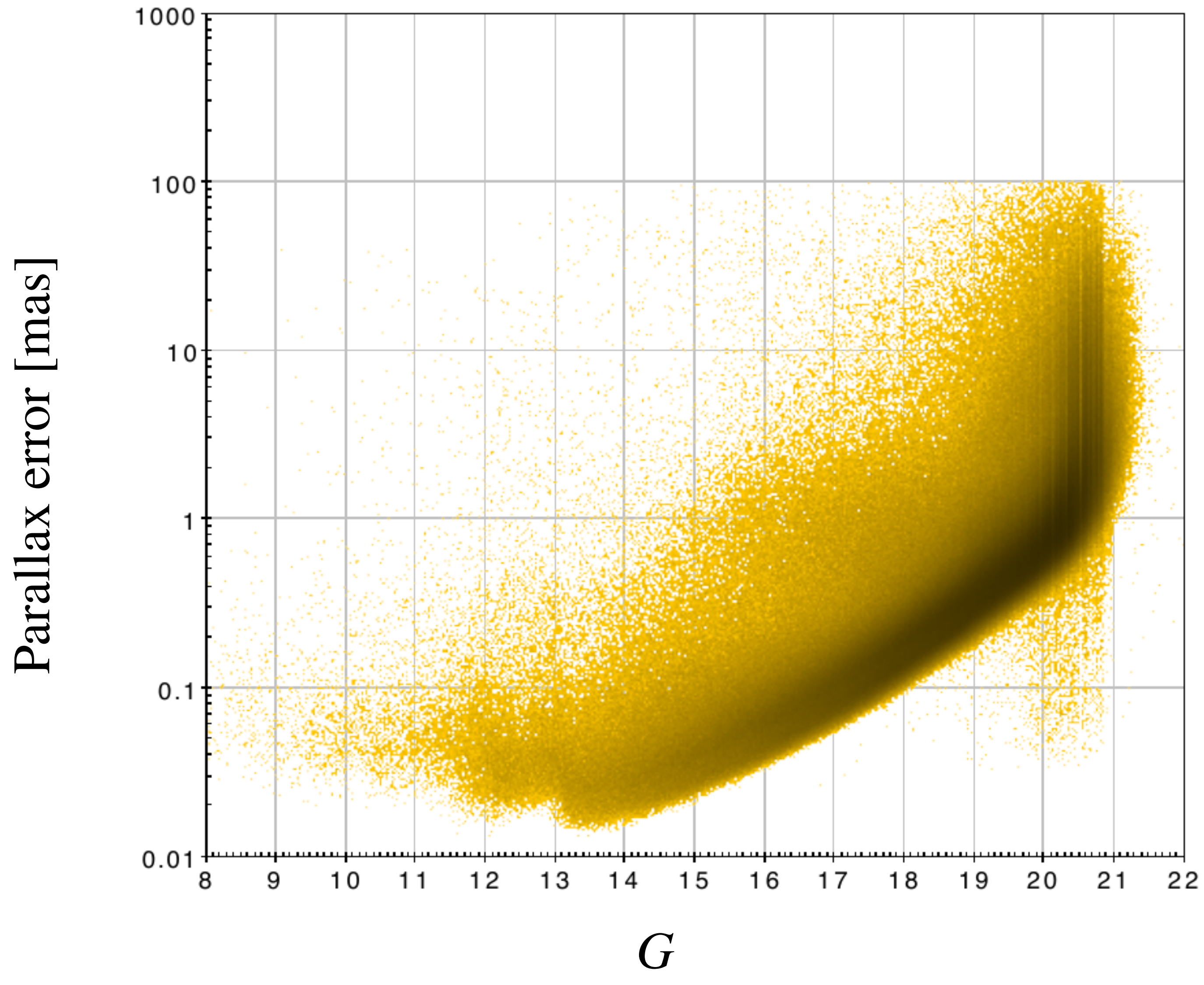
Data product	**Very preliminary source numbers**
(α, δ), G, G_{BP}, G_{RP}	~ 1.5 billion
Parallax, proper motion	~ 1 billion
Median v_{rad} at $G_{\mathrm{RVS}} < 12$	3–5 million
Estimates of T_{eff} and possibly A_V; radii, luminosities for subset	sources at $G < 17$
Photometric data for a variety of variable star types, all-sky RR Lyrae survey	TBD
Epoch astrometry for a pre-selected list of asteroids	$> 10\,000$


5000
2000
1000
500
200
100
50
20
10
5
2
1
number of sources/pixel



3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
(BP-RP) colour

AGIS-2.1: preliminary astrometry solution



- Systematic errors below 100 μas
- Typical parallax precision: $G = 15$, 30 μas; $G = 18$, 150 μas; $G = 20$, 700 μas
- Improvements with respect to Gaia DR1
  - Gaia-only solution (no prior used) for the majority of sources
  - more/better input data
  - improved calibrations (in particular colour terms)
  - improved removal of attitude disturbances

Longer term data release schedule

<u>Gaia DR3</u>

- Targeted for mid to late 2020
- Examples of new data products
  - Source classification and astrophysical parameters
  - BP/RP and RVS spectra for sources with astrophysical parameters
  - Rotational velocities for bright stars
  - Non-single stars: various levels of astrometric binary solutions (where possible), eclipsing binaries
  - Updated and extended variable star catalogue
  - Updated and extended solar system objects catalogue

Longer term data release schedule

Gaia DR4

- Targeted for end 2022
- Final release for the nominal mission
- Foreseen data products
  - Full astrometric, photometric, and radial-velocity catalogues
  - All available variable-star and non-single-star solutions
  - Source classifications (probabilities) plus multiple astrophysical parameters (derived from BP/RP, RVS, and astrometry) for stars, unresolved binaries, galaxies, and quasars
  - An exo-planet list
  - All epoch and transit data for all sources, including all BP/RP/RVS spectra

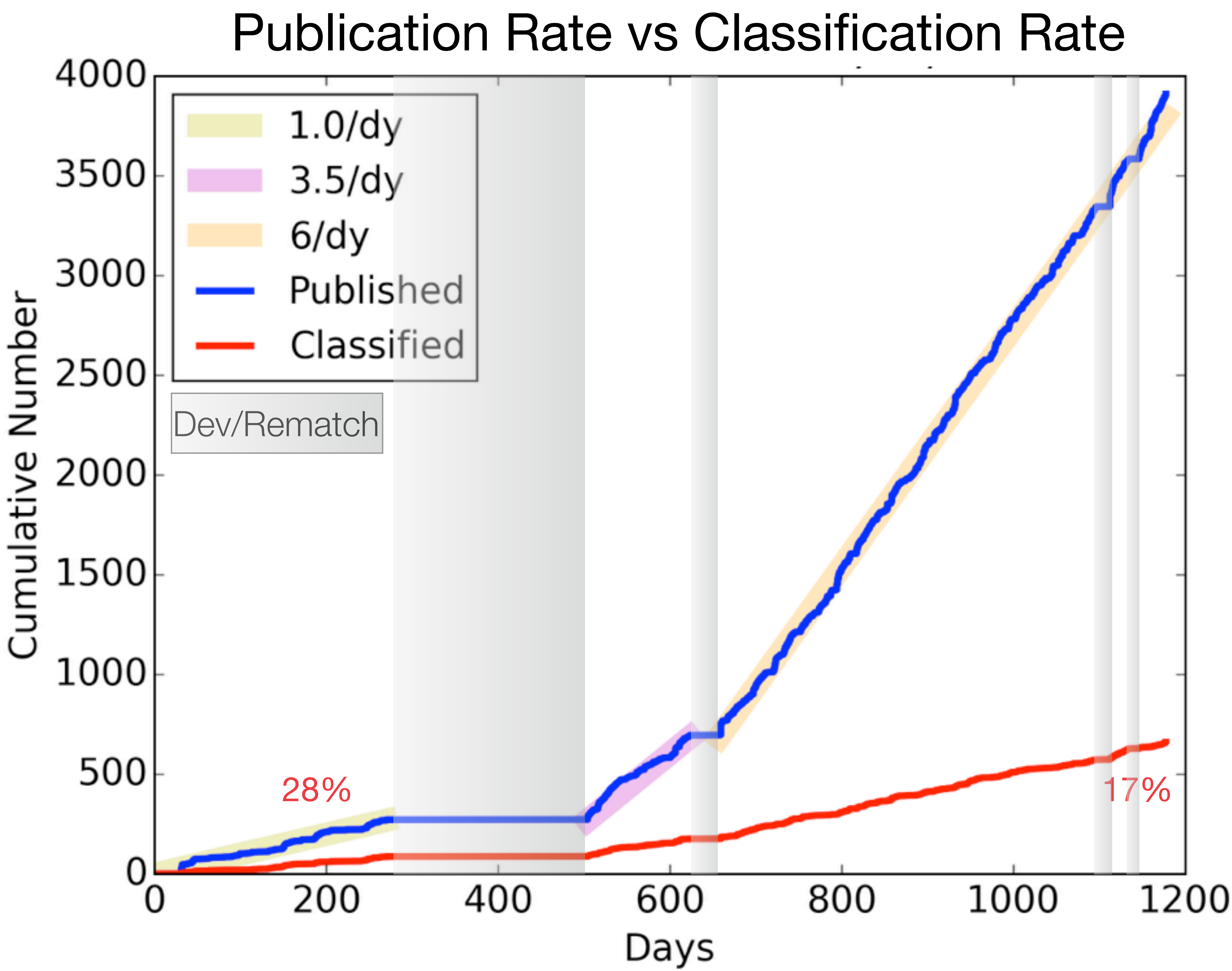
N

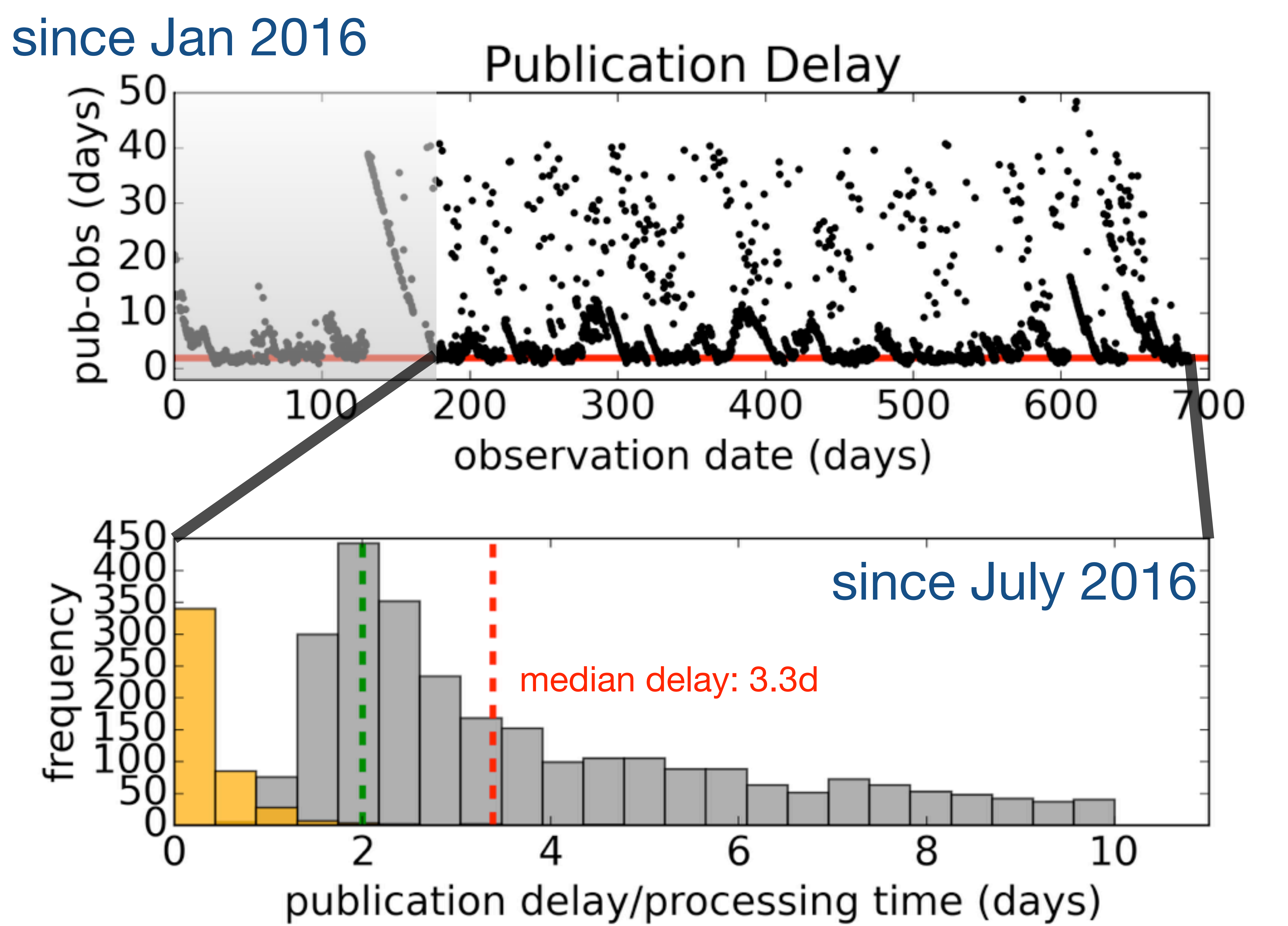
WHE~~RE~~ ARE WE?

	Q1	Q2	Q3	Q4
2013				Launch
2014			Science Operations	Start Alerts
2015			Validation	Development
2016	Restart Alerts			
2017				
2018				
2019		Nominal Mission End		
2020				Actual Mission End?
2021				Actual Mission End?
2022				Actual Mission End?

PROGRESS OVER THE YEAR

- Stable Ops: little downtime, and no major Dev changes (useful for tests: see Zuzanna)
- Retraction of unpublished Alert Candidates - can re-trigger (marginal cases -> more convincing)
- Swap to new hardware: 10 days downtime
- Implement the rematch tables (for the next [DR2] catalogue), 10 days downtime.
- Add RVS spectra

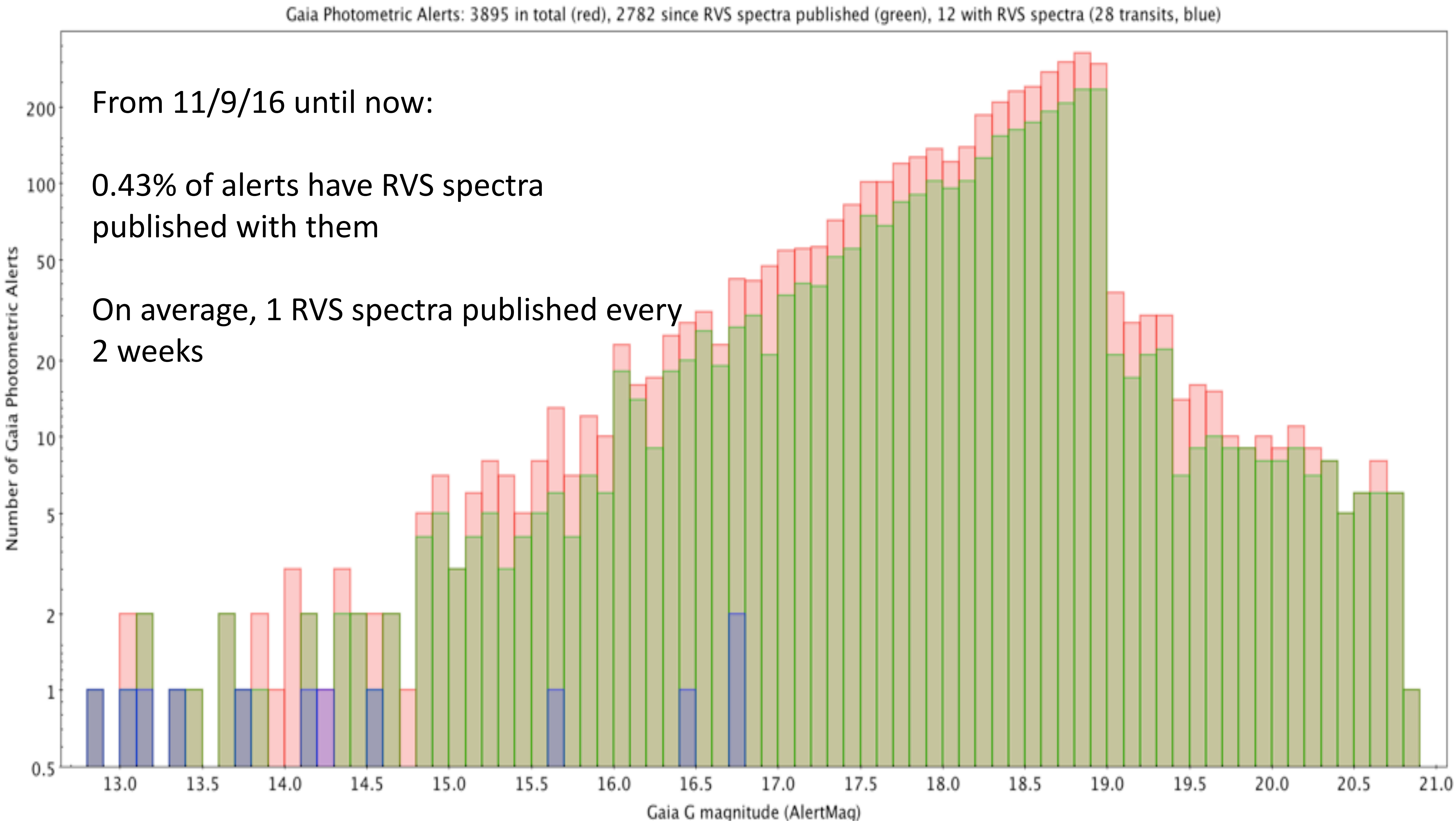

Publication Rate vs Classification Rate
4000
3500
3000
2500
2000
1500
1000
500
0
Cumulative Number
1.0/dy
3.5/dy
6/dy
Published
Classified
Dev/Rematch
28%
17%
0
200
400
600
800
1000
1200
Days


since Jan 2016
Publication Delay
pub-obs (days)
observation date (days)
frequency
since July 2016
median delay: 3.3d
publication delay/processing time (days)

From 11/9/16 until now:

0.43% of alerts have RVS spectra published with them

On average, 1 RVS spectra published every 2 weeks

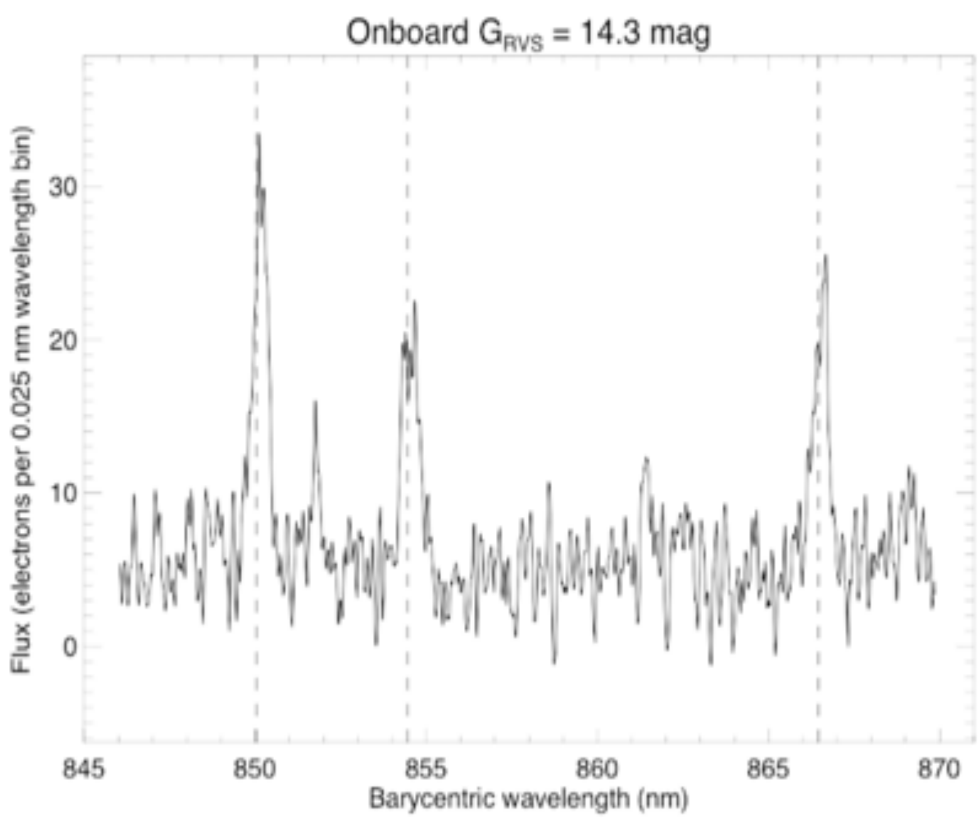


gsaweb.ast.cam.ac.uk

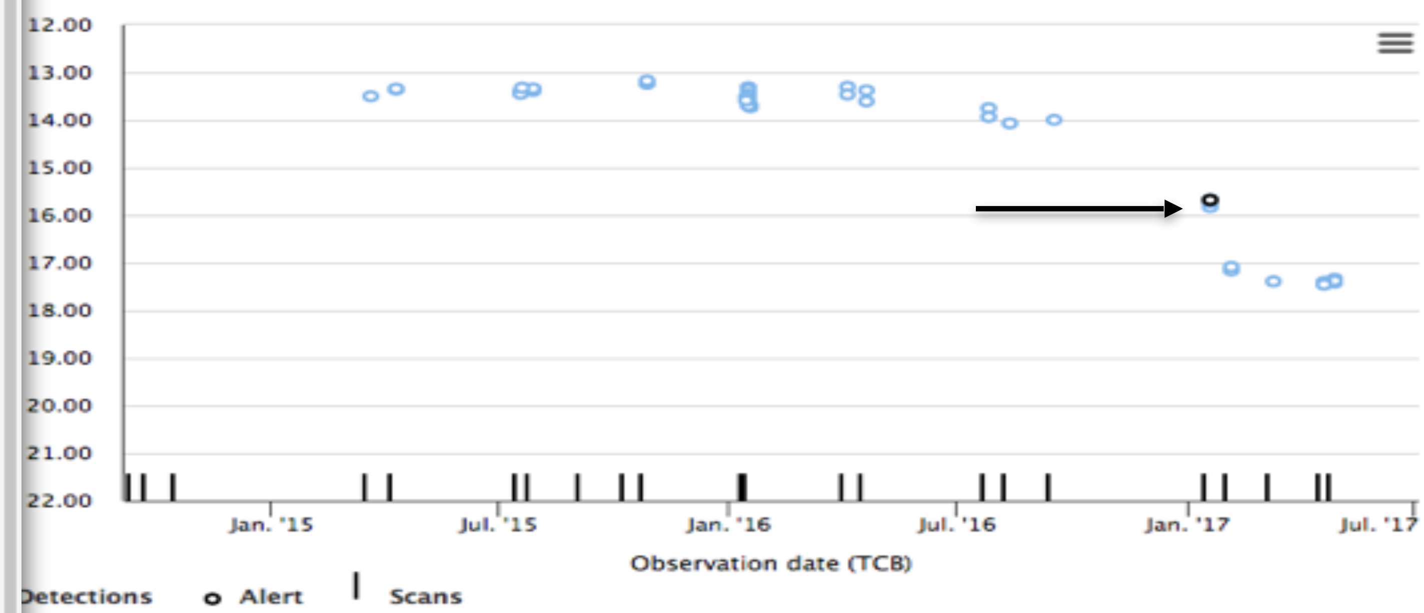
RVS data reduction info >>

<< previous next >>

Gaia17aeq

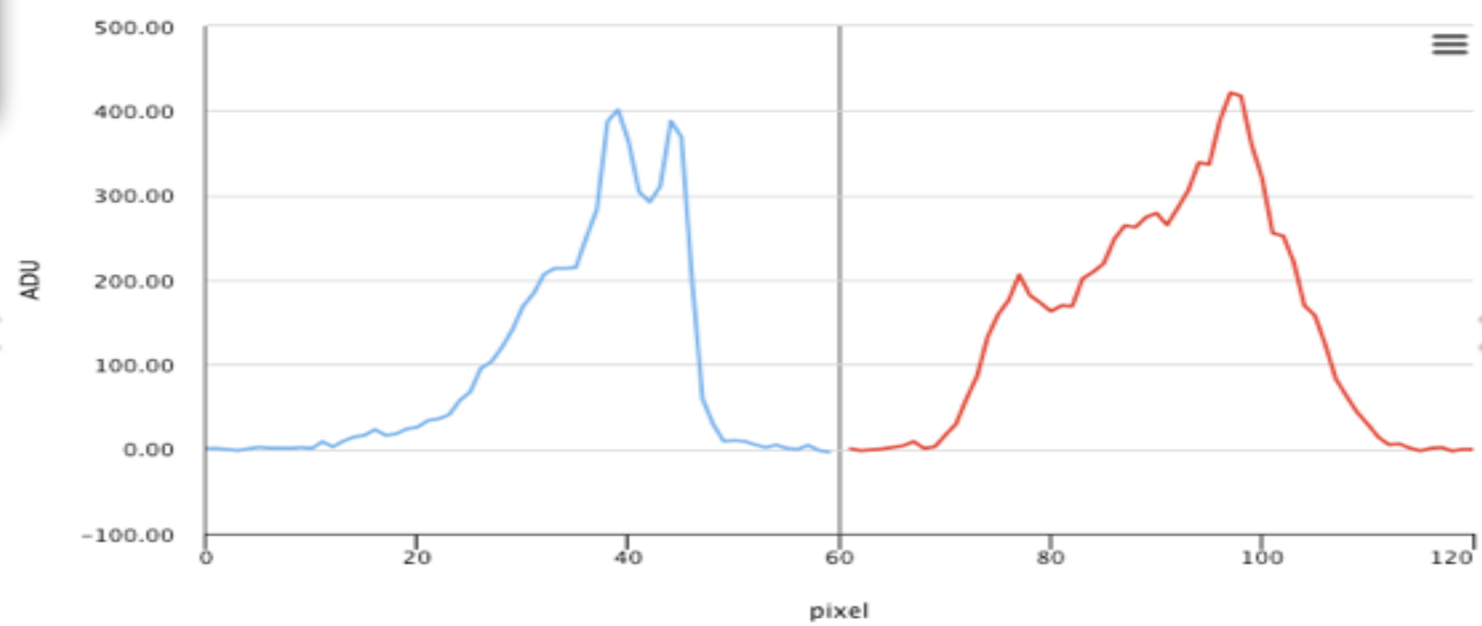


The vertical dashed lines delineate the rest wavelengths in vacuum of the CaII triplet lines: 850.035, 854.444 and 866.452 nm.



Get lightcurve data

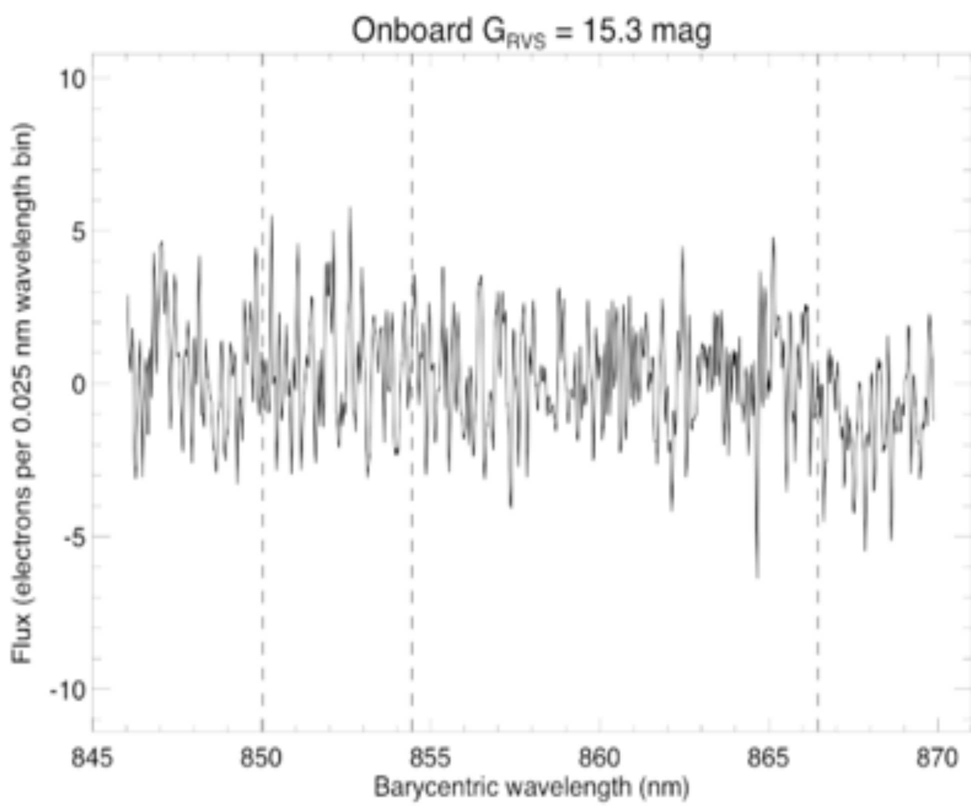
2017-01-19 04:28:44	2457772.69	15.69	spectrum
2017-01-19 08:42:23	2457772.86	15.73	
2017-02-05 08:48:02	2457789.87	17.09	
2017-02-05 10:34:36	2457789.94	17.16	spectrum
2017-03-10 23:26:28	2457823.48	17.39	
2017-04-19 22:30:02	2457863.44	17.46	



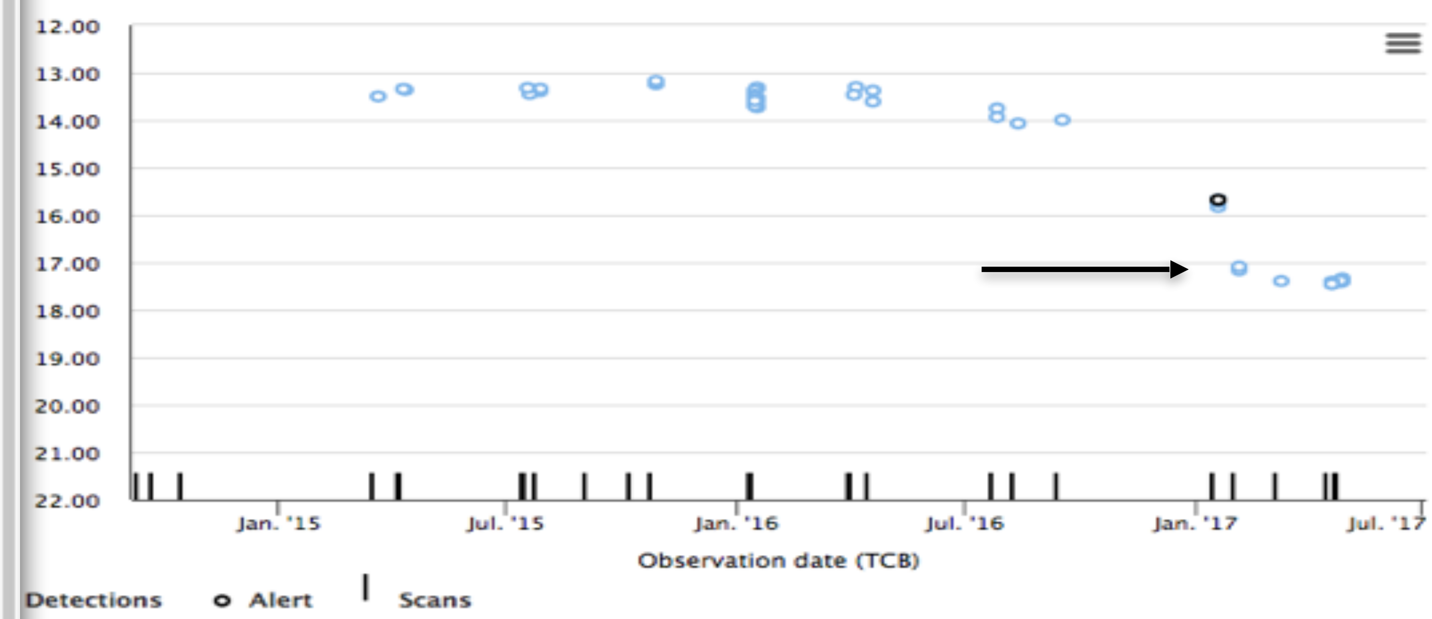
gsaweb.ast.cam.ac.uk

<< previous next >>

Gaia17aeq

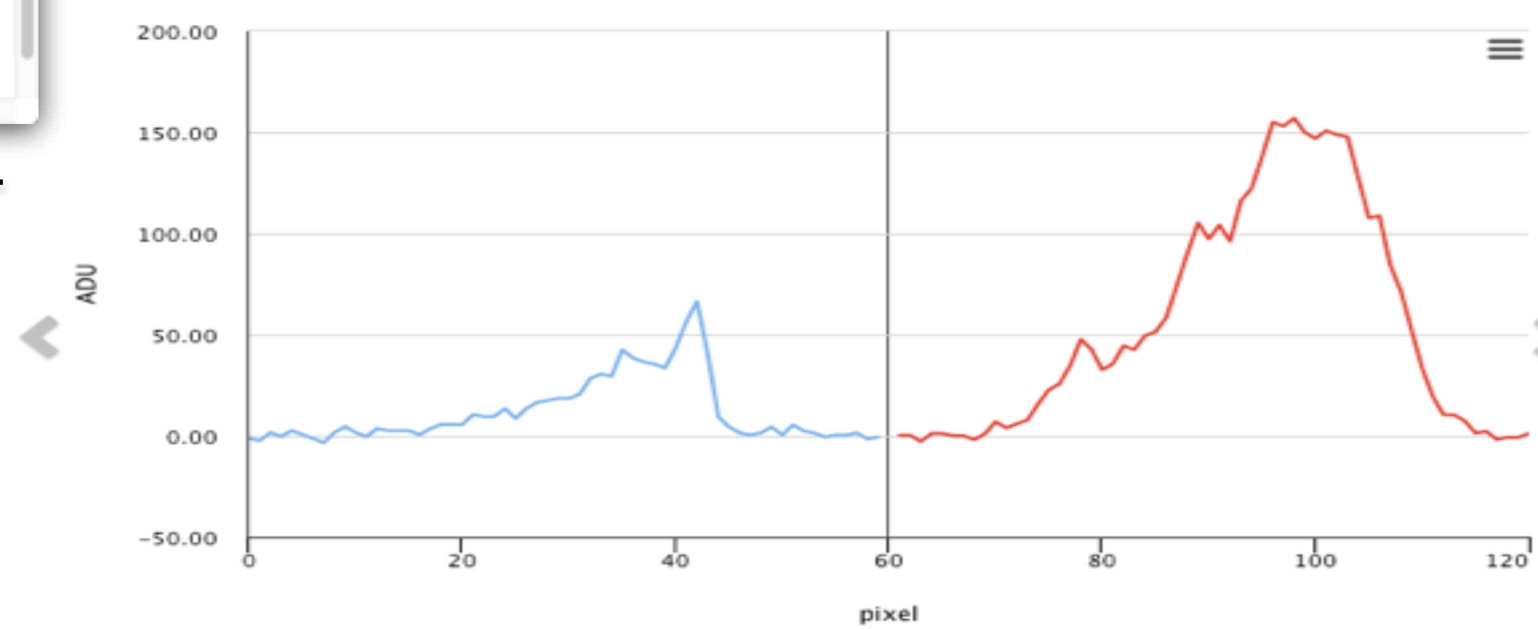


The vertical dashed lines delineate the rest wavelengths in vacuum of the CaII triplet lines: 850.035, 854.444 and 866.452 nm.



Get lightcurve data

2017-02-05 10:34:36	2457789.94	17.16	spectrum
2017-03-10 23:26:28	2457823.48	17.39	
2017-04-19 22:30:02	2457863.44	17.46	
2017-04-20 02:43:41	2457863.61	17.41	
2017-04-20 04:30:14	2457863.69	17.44	
2017-04-20 08:43:53	2457863.86	17.42	



NEXT STEPS FOR GAIA ALERTS

- Addition of GS-TEC classification for **all** Alert Candidates (now, run for filtered candidates)
- Improved astrometry (100 microarcsecond, 1 day later)
- Improved Photometry (PODC: Photometric One-Day Calibration .. good to ~1.5%)

NEXT STEPS FOR GAIA ALERTS

- Calibrate BP/RP spectra
- Predictive classifications for everything (LC and environment classifiers [input from Konkoly])
- Implement the Watch List [replace with external triggers approach]

CLASSIFICATION

- Most transient surveys can only follow-up a fraction of their detections
- Thus the majority are lost
- Follow-up is necessarily biased

MOTIVATION

- To understand biases and completeness
- To measure rates, luminosity functions, feed formation/evolutionary models
- To prepare for dedicated transient surveys (e.g. LSST)
- To pick out the rare and exciting stuff (Gaia14aae: eclipsing AM CVn)
- To ensure optimised follow-up (e.g. Gaia16aye)
- To pick out new kinds of transient
- Step towards automation

TRANSIENT NAME SERVER

TNS Transients Statistics and Skymaps

IAU SUPERNOVA WORKING GROUP

TNS Transients Statistics | Reports Timeline | Skymaps

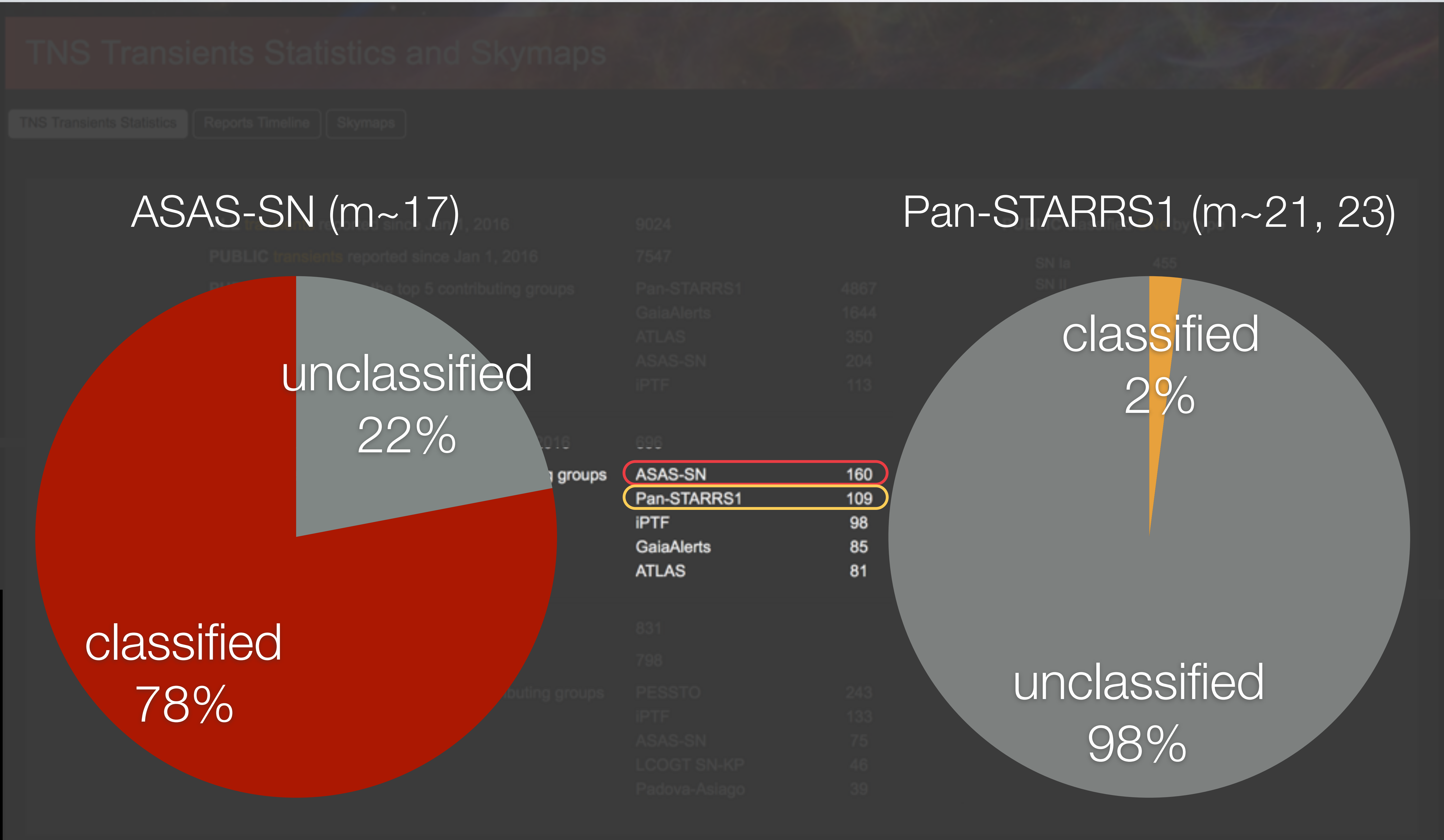
ALL transients reported since Jan 1, 2016	9024	
PUBLIC transients reported since Jan 1, 2016	7547	
PUBLIC transients for the top 5 contributing groups	Pan-STARRS1	4867
	GaiaAlerts	1644
	ATLAS	350
	ASAS-SN	204
	iPTF	113
PUBLIC classified SNe reported since Jan 1, 2016	696	
PUBLIC classified SNe for the top 5 contributing groups	ASAS-SN	160
	Pan-STARRS1	109
	iPTF	98
	GaiaAlerts	85
	ATLAS	81
ALL spectra reported to the TNS	831	
PUBLIC spectra reported to the TNS	798	
PUBLIC classifications for the top 5 contributing groups	PESSTO	243
	iPTF	133
	ASAS-SN	75
	LCOGT SN-KP	46
	Padova-Asiago	39

PUBLIC classified SNe by type

SN Ia	455
SN II	103
SN IIP	33
SN Ia-91T-like	19
SN IIn	17
SN IIb	14
SN Ib	10
SN Ia-91bg-like	10
SN Ic	9
SN Ic-BL	5
SN Ia-pec	5
SLSN-I	4
SN Ia-02cx-like	3
SN Ib/c	2
SN Ic-pec	1
SN Ia-CSM	1
SN IIL	1
SN IIn-pec	1
SLSN-II	1
SN Ibn	1
SN Ib-pec	1

https://wis-tns.weizmann.ac.il

TRANSIENT NAME SERVER

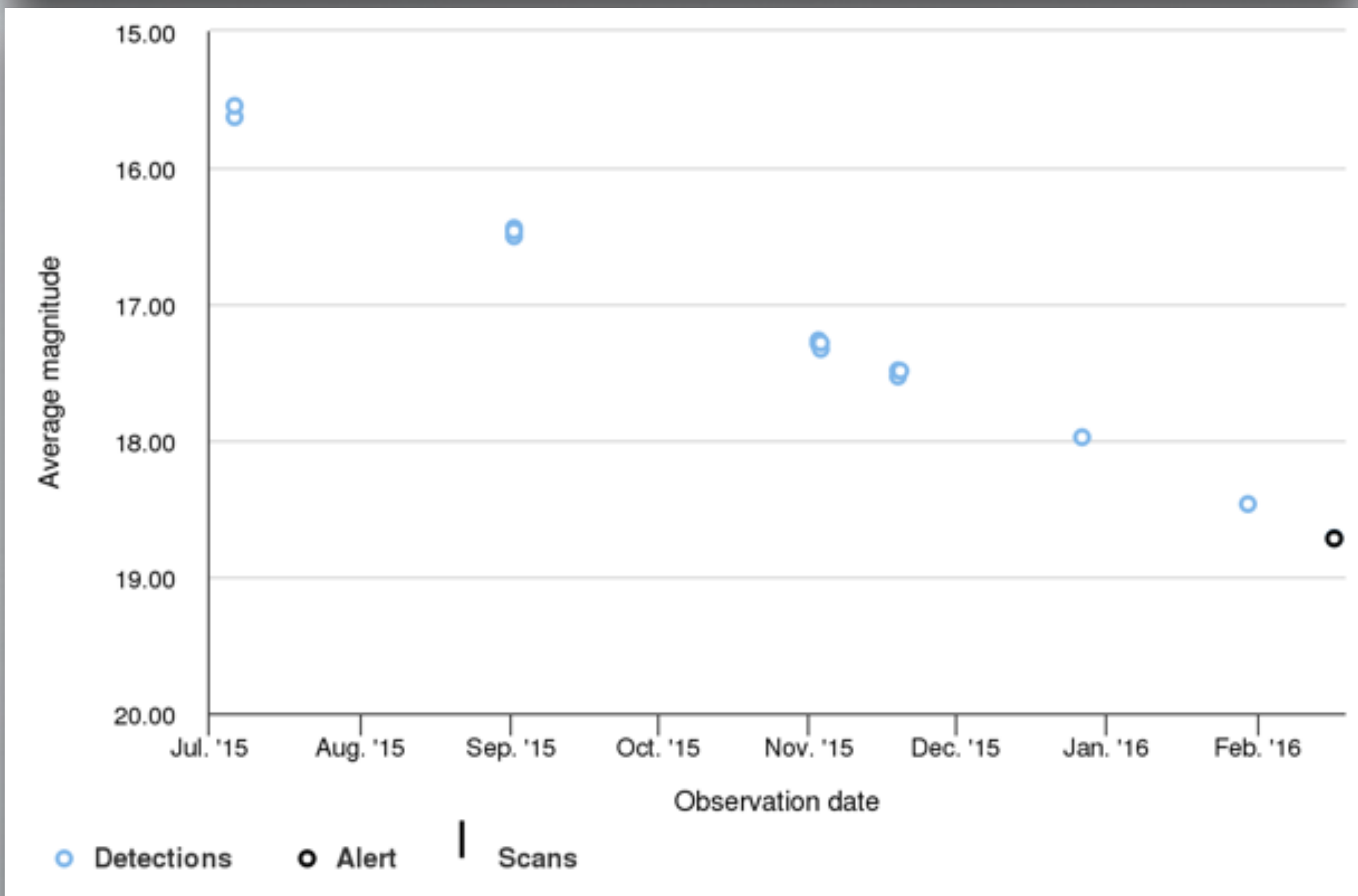


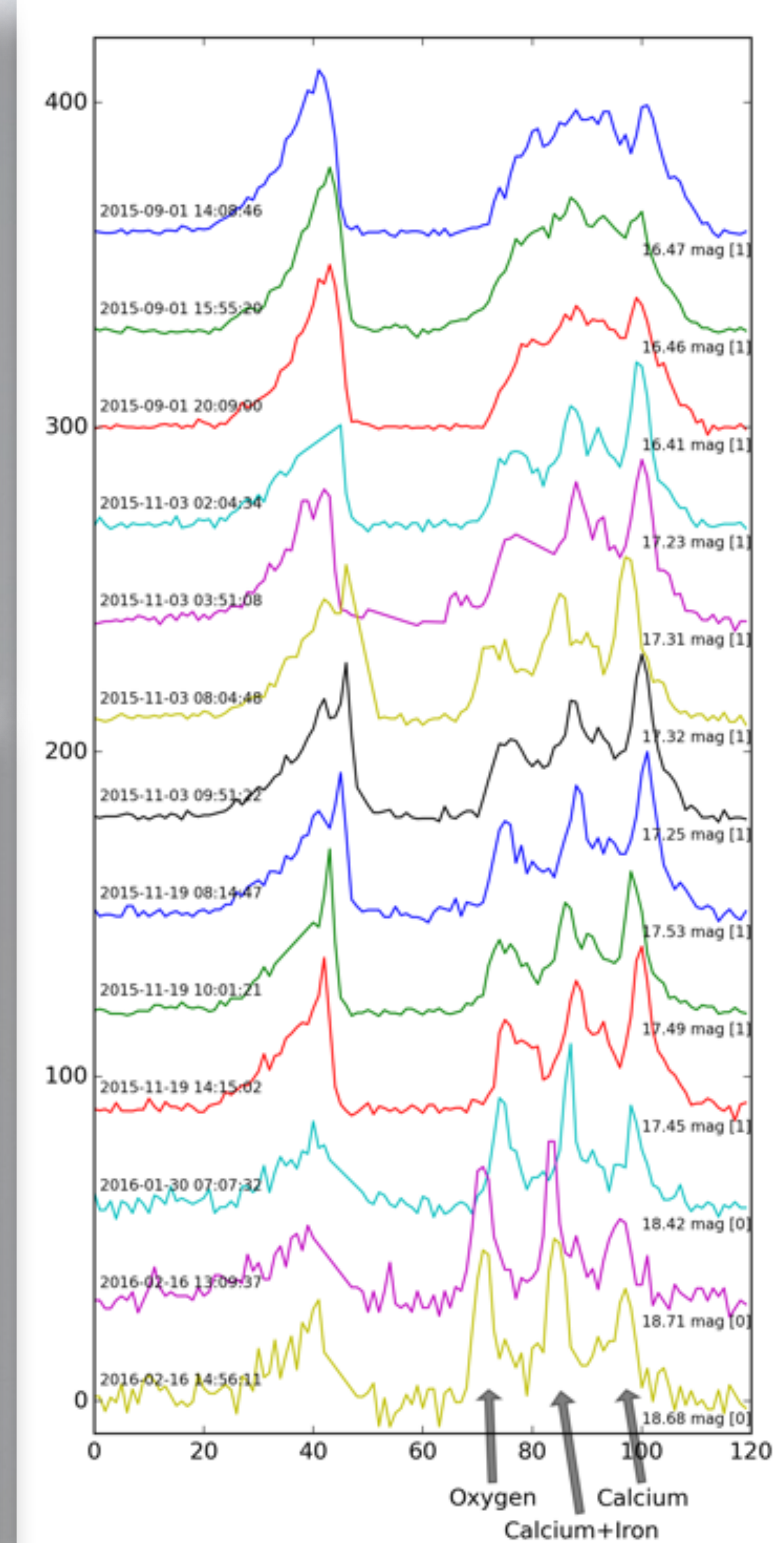
WHAT DOES GAIA OFFER?

- Low Dispersion Spectrum of every transient
- Precise Astrometry and Astrometry
- High Spatial Resolution
- Stable Survey

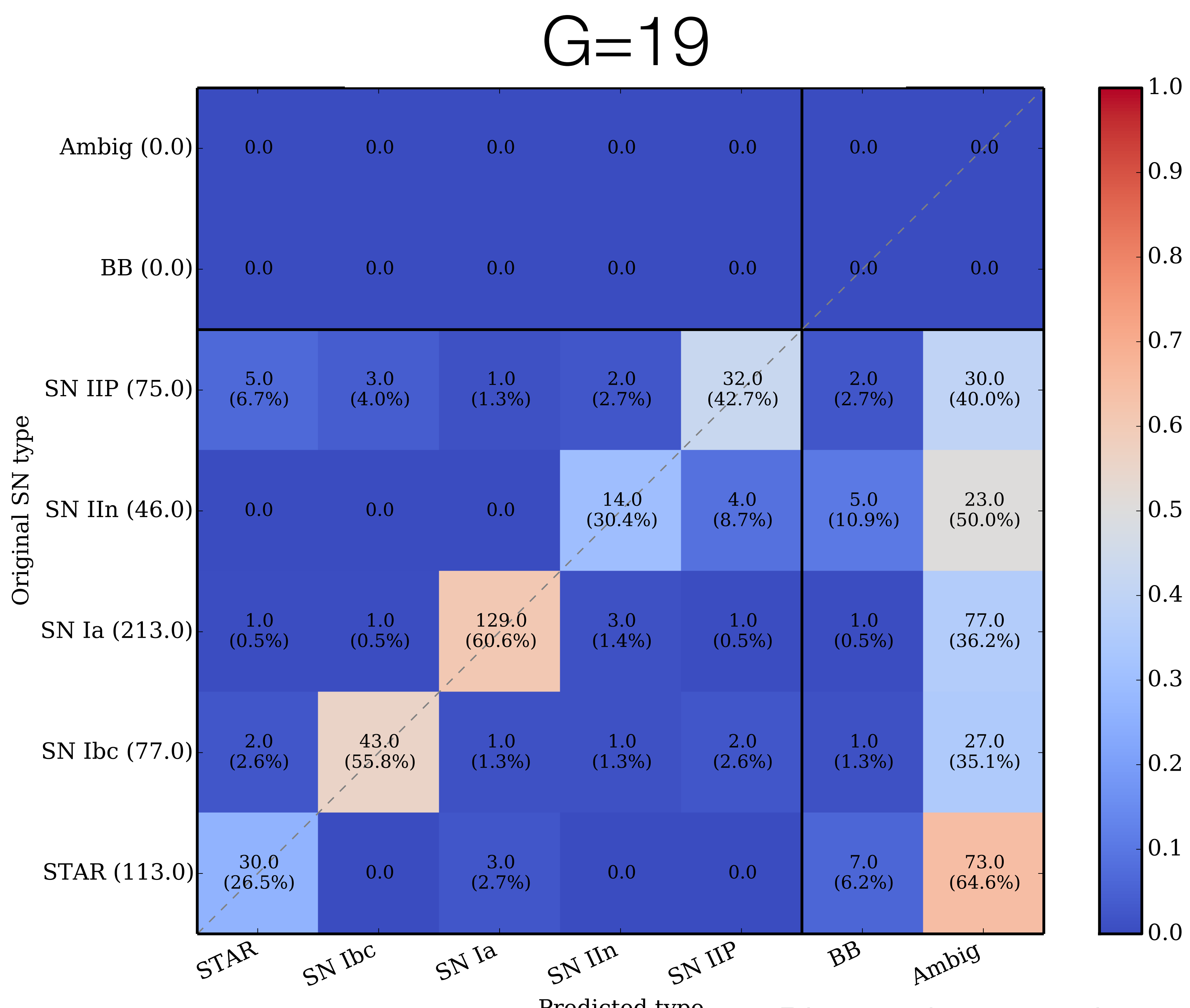
Nearby Supernovae

This sequence of spectra charts the evolution of Gaia16aeg (SN IIb, ASASSN-15lv) as it transitions towards a nebular spectrum. Over a five month period, the continuum fades while strong emission lines of Calcium (including the Ca NIR triplet), Oxygen and Iron are seen to emerge in the red spectrum.



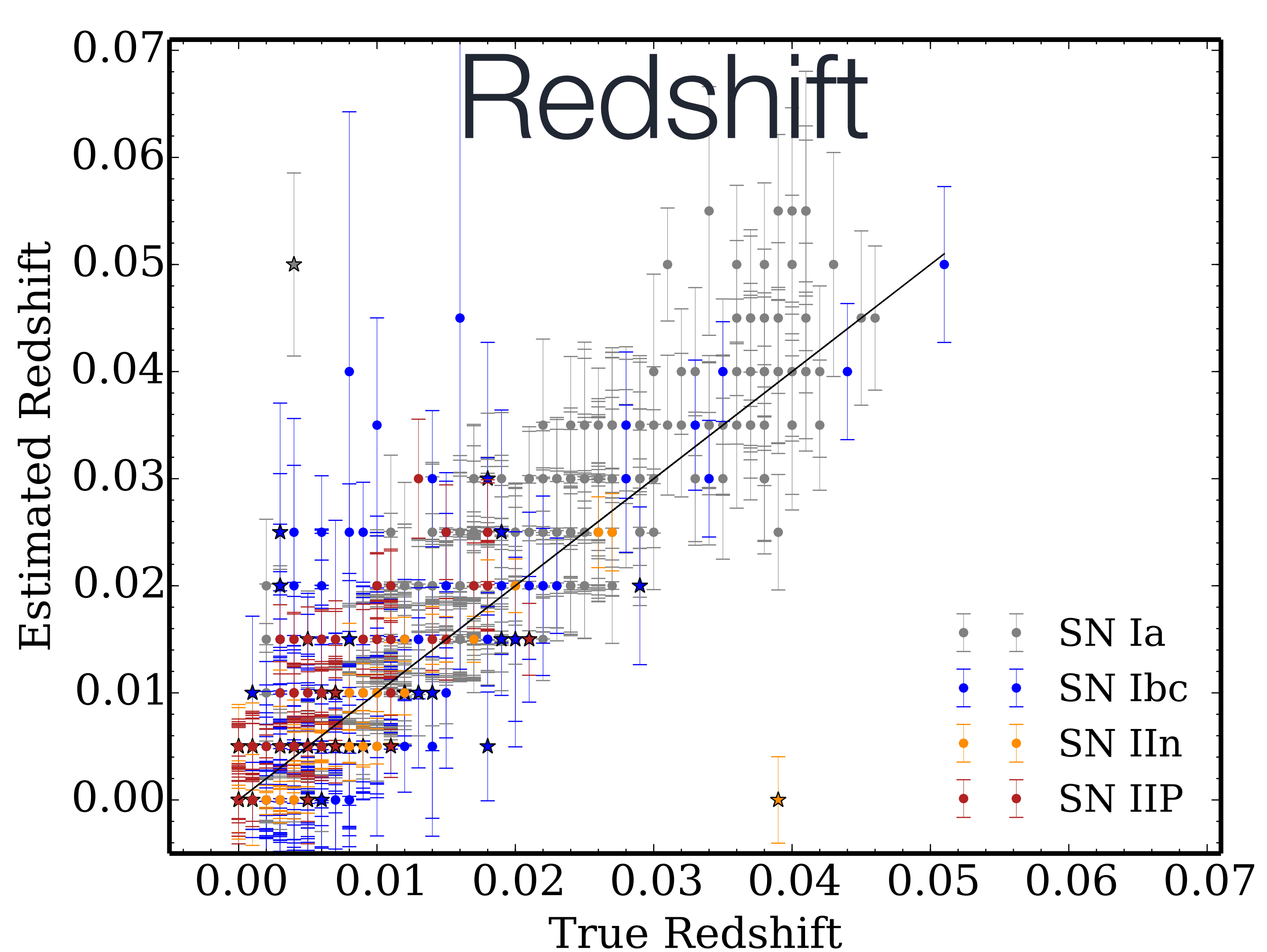


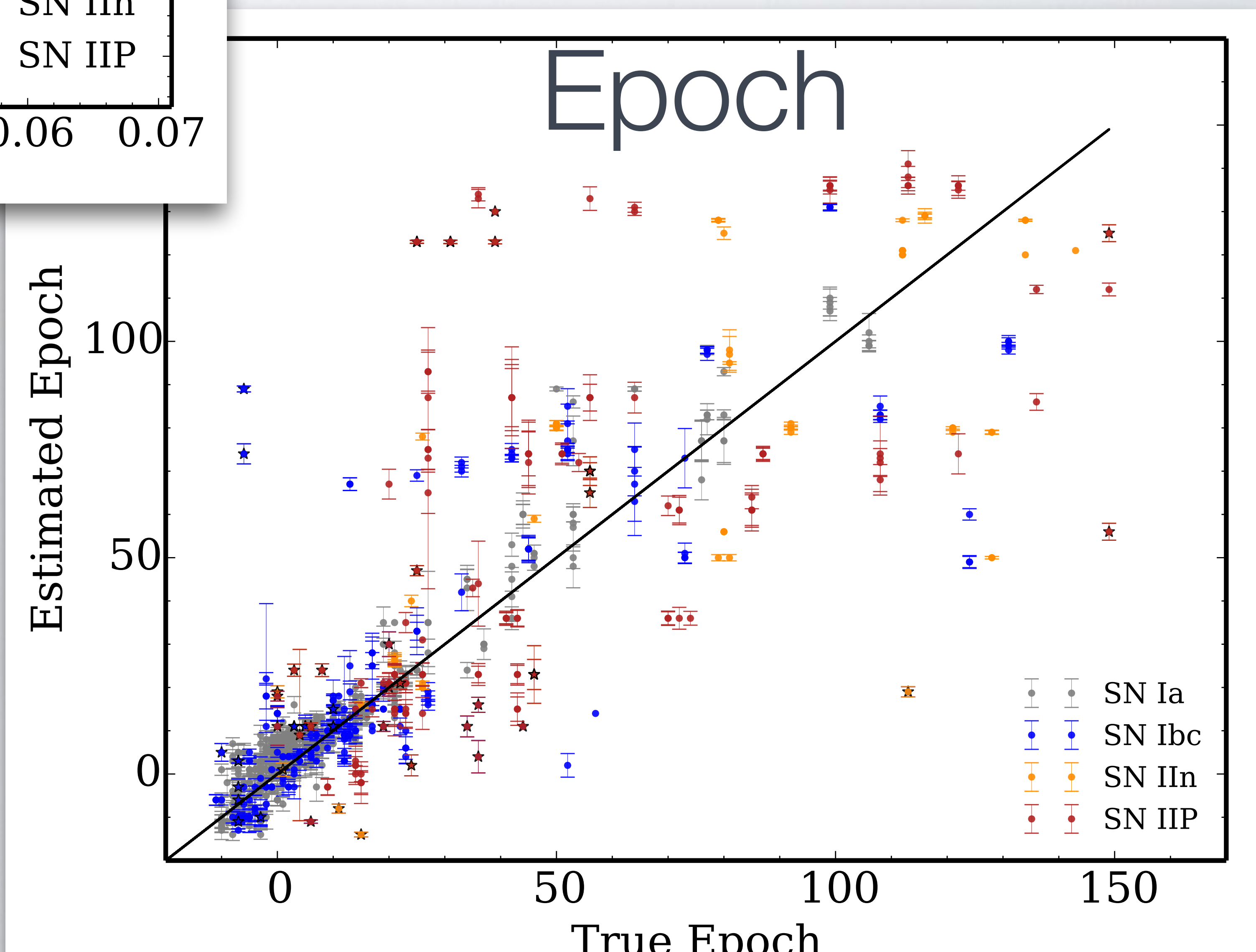
SPECTRAL CLASSIFICATION



Blagorodnova et al 2014

GS-TEC: PARAMETER ESTIMATION





Blagorodnova et al 2014

WHAT DOES GAIA OFFER?

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- Precise Astrometry and Photometry
- High Spatial Resolution
- Stable Survey

Gaia Alerts | Alerts Index | All-Sky | Alerts Search | Surveys-ATels | Tools | About | Related Sites | Log in

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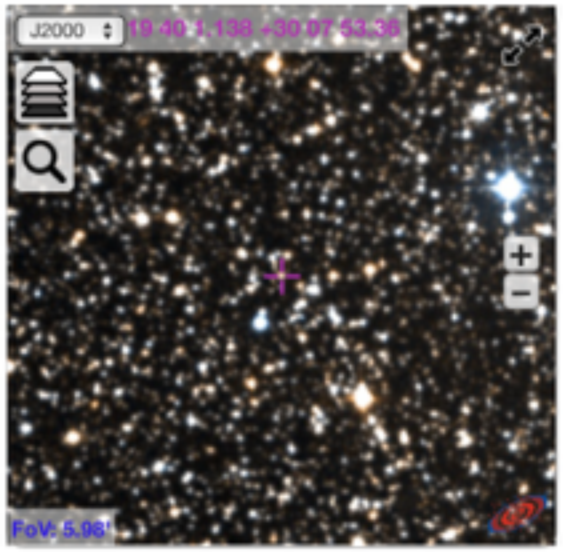
Gaia16aye

http://gsaweb.ast.cam.ac.uk/alerts/alert/Gaia16aye/

Details | Follow-up



RA - DEC
295.00474 30.13149
19:40:01.14 30:07:53.36

Alerting date
2016-08-05 00:53:52

Julian date
2457605.54

Alerting magnitude
14.27

Historic magnitude
15.51

Historic StdDev
0.06

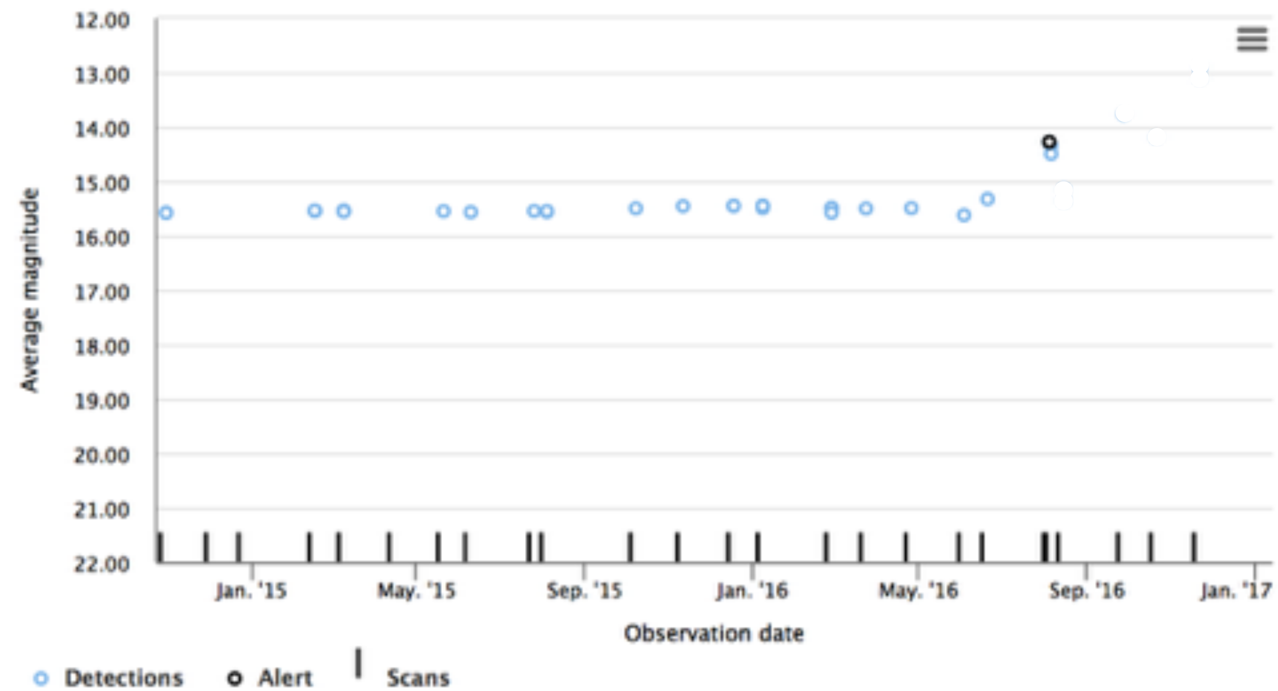
Class
ULENS

Publication date
Aug. 9, 2016, 10:45 a.m.

Other surveys detections
None

Comments
1.2 mag rise in red star near Galactic Plane

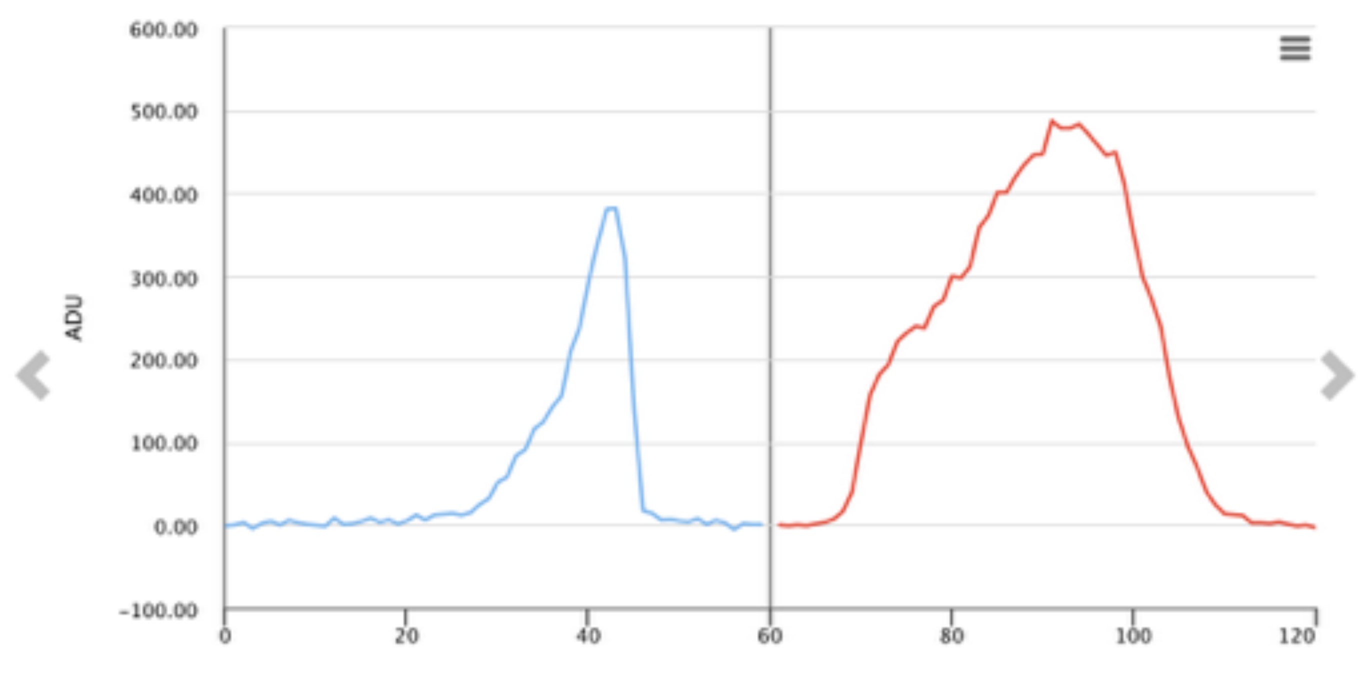
ATels
9376 9507 9533 9753 9770 9780



Get lightcurve data

Click and scroll down and select one row in the table below to display the corresponding spectrum.

Date	JD	Average Mag.
2014-10-30 20:50:59	2456961.37	15.58
2014-10-30 22:37:33	2456961.44	15.57
2015-02-15 14:07:43	2457069.09	15.54
2015-03-09 08:16:20	2457090.84	15.55
2015-03-09 10:02:55	2457090.92	15.53
2015-03-09 14:16:35	2457091.09	15.55
2015-03-09 16:03:10	2457091.17	15.55
2015-05-20 19:20:37	2457163.31	15.54



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Gaia16aye

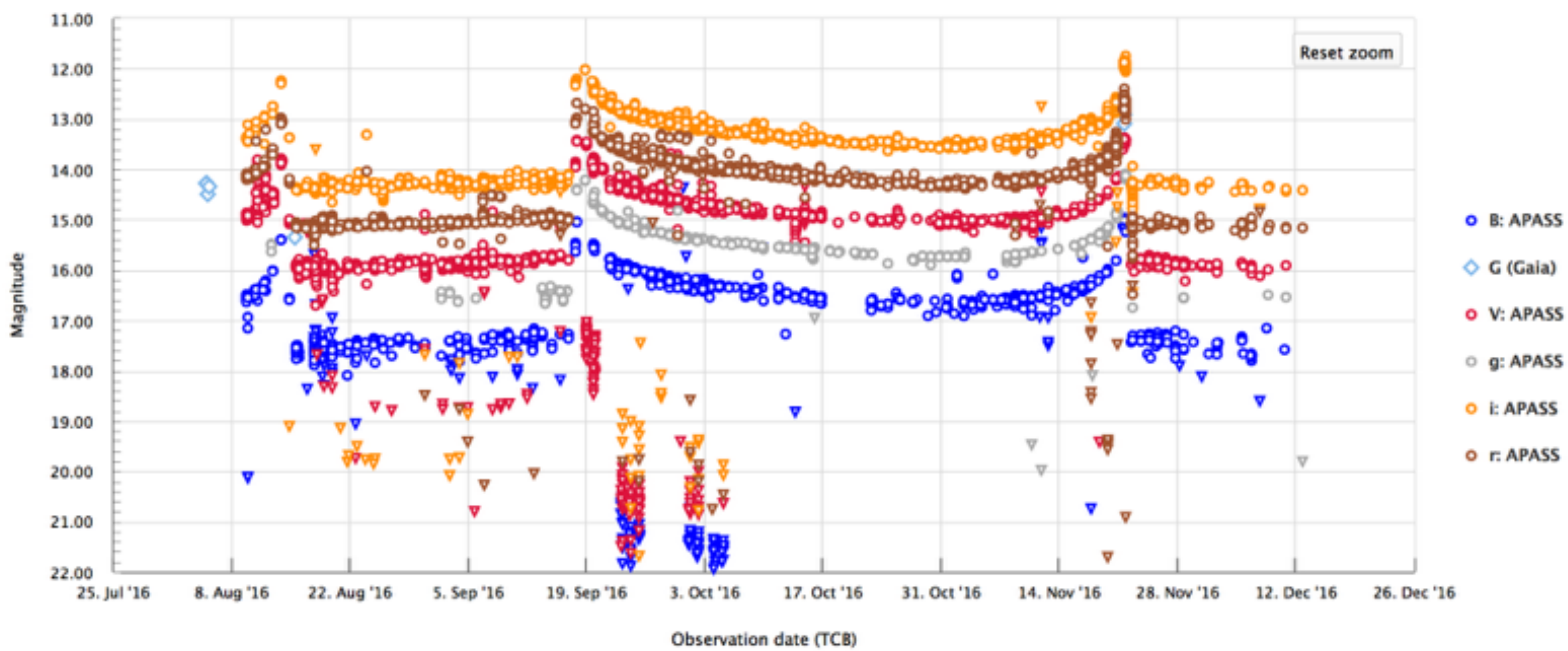
Details | Follow-up

The figure shows the Gaia lightcurve combined with photometric follow-up photometry generously provided by the astronomical community using the Cambridge Photometry Calibration Server (CPCS). Multiple filters are shown in one figure and can be toggled on/off using the legend on the side. Click and drag in the chart to zoom in. Clicking on datapoints provides additional information of the observation.

Access to these photometric data may be requested from the individuals who took the data. Please contact us if you would like to ask for access and we will pass on your request.

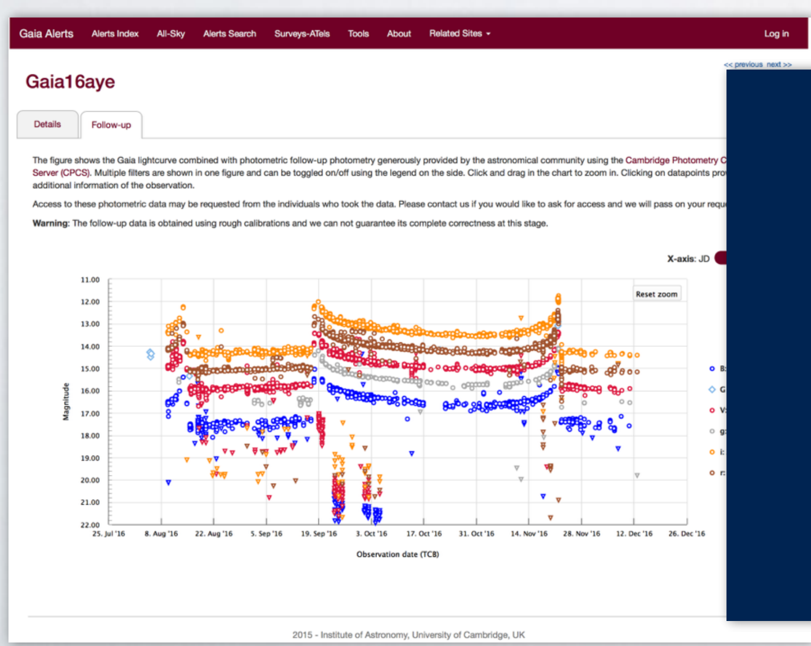
Warning: The follow-up data is obtained using rough calibrations and we can not guarantee its complete correctness at this stage.

X-axis: JD Date



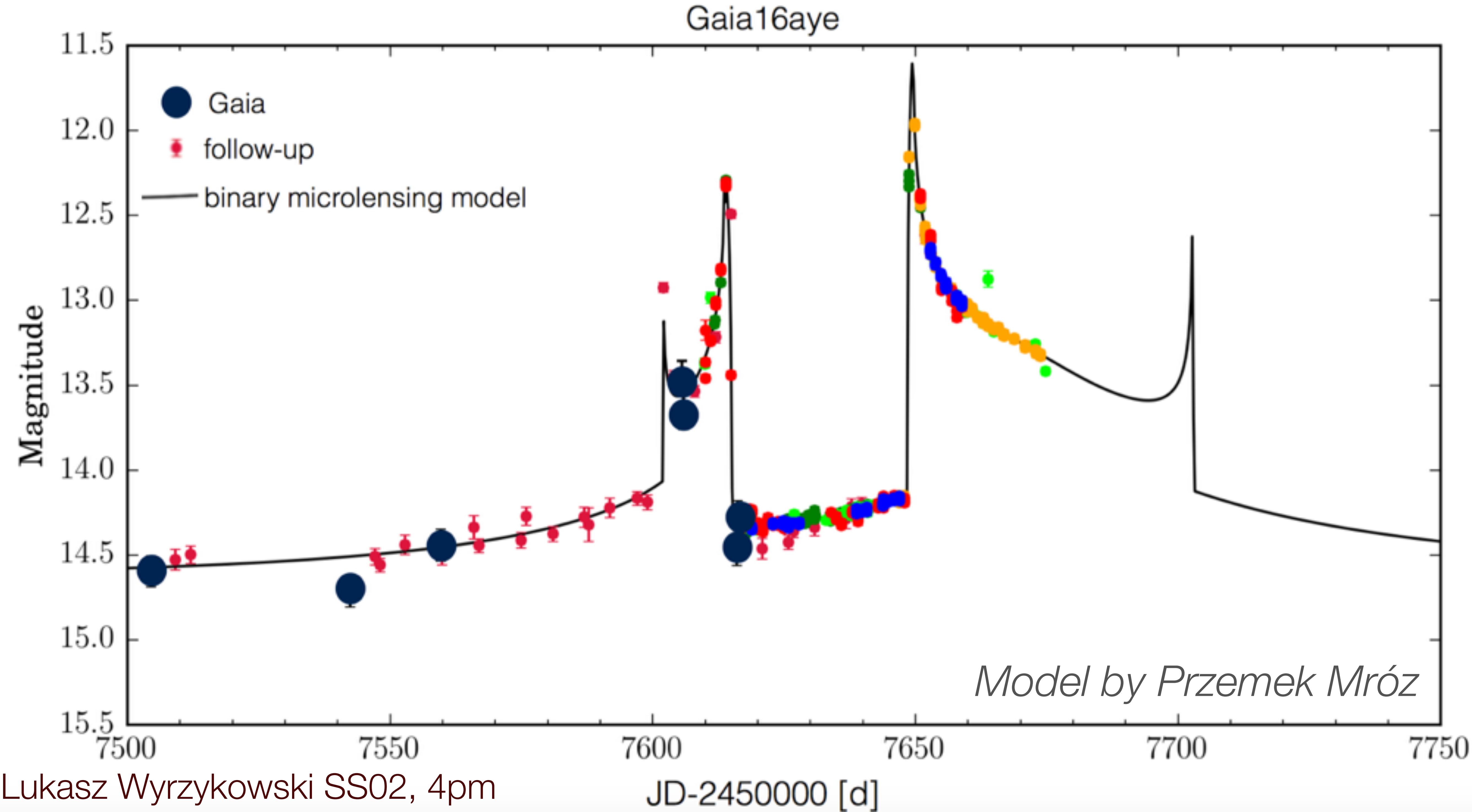
CAMBRIDGE CALIBRATION SERVER

- observers upload astrometrically calibrated catalogues
- we apply photometric calibration from APASS, SDSS
- about 25% of published alerts have follow-up data
- >17000 measurements for Gaia16aye from 33 telescopes



- AAVSO, USA
- APT2, Italy
- Aristarchos Telescope, Greece
- ASAS-SN, Hawaii, USA
- Asiago, Italy
- ASV, Serbia
- Bialkow, Poland
- Kryoneri, Greece
- Leicester University, UK
- LCOGT/SUPAscope network
- Liverpool Telescope, La Palma, Spain
- Loiano, INAF-OABO, Italy
- Joan Oró Telescope, Montsec, Spain
- Mercator, La Palma, Spain
- Montarrenti, Italy
- NOT, La Palma, Spain
- Ondrejov, Czechia
- OmicronC2PU, France
- Ostrowik, Poland
- Palomar 200-inch telescope (P200), Caltech, USA
- PIRATE, Tenerife, Spain
- pt5m, La Palma, Spain
- RTT150, Turkey
- SALT, South Africa
- Skinakas, Greece
- Sternberg Observatory, Russia
- T100, Turkey
- T60, Turkey
- UBT60, Turkey
- University College London, UK
- Watcher, South Africa
- Wise, Israel
- Yerkes-41, USA

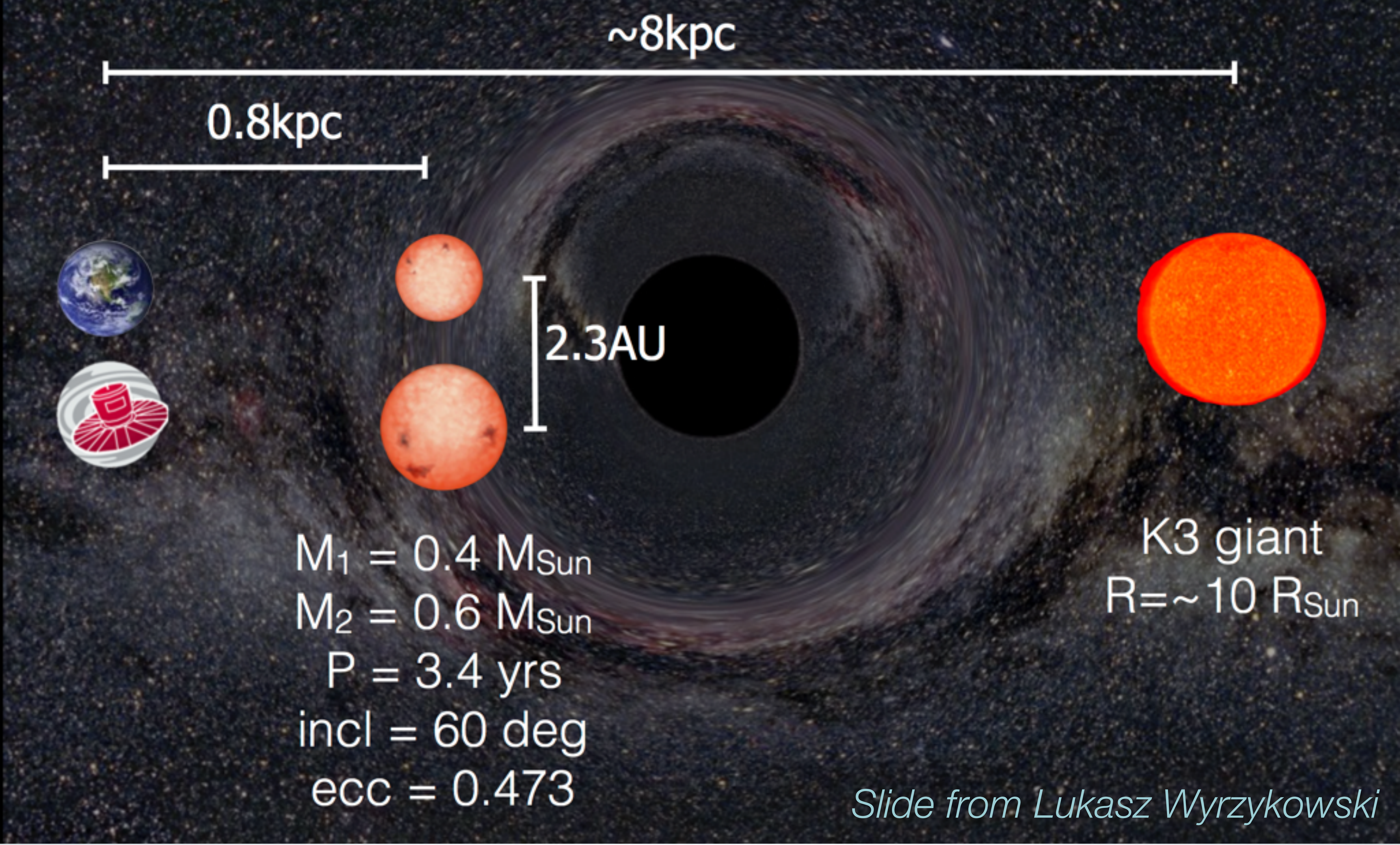
GAIA CADENCE: DETECTION VS DISCOVERY



Lukasz Wyrzykowski SS02, 4pm

GAIA16AYE (AYERS ROCK)

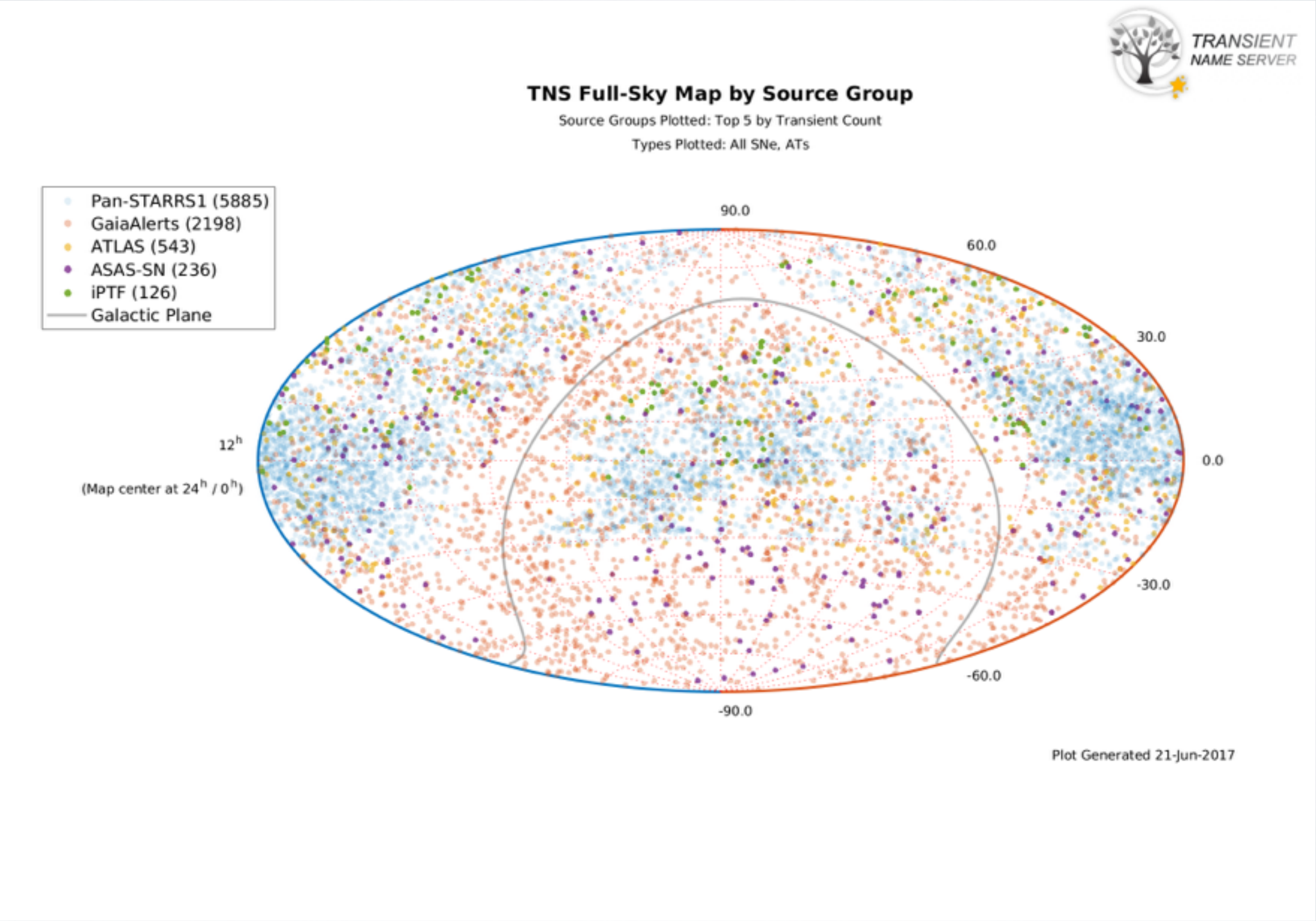
Preliminary solution



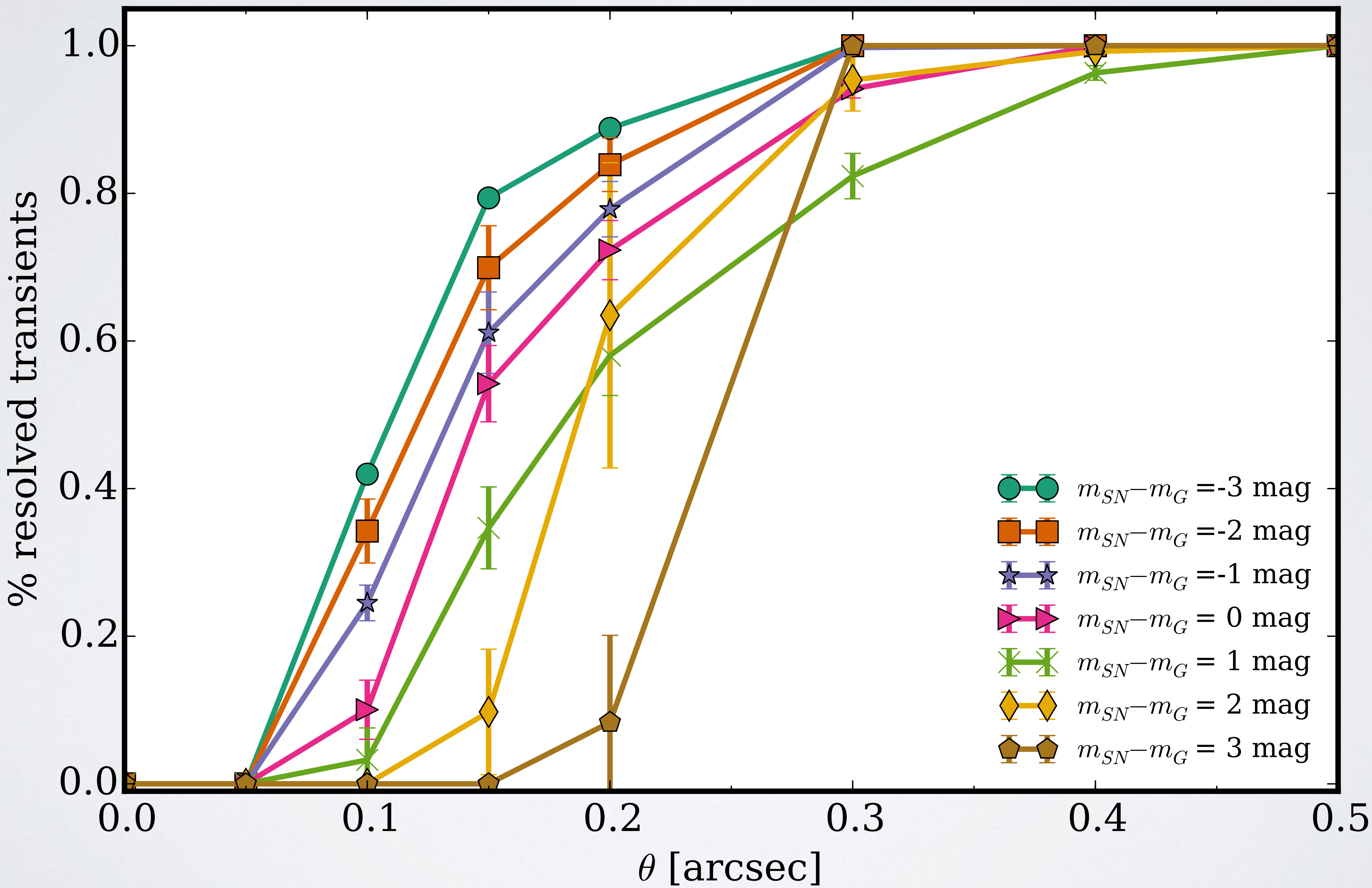
WHAT DOES GAIA OFFER?

- Low Dispersion Spectrum of every transient
- Precise Astrometry and Astrometry
- High Spatial Resolution
- Stable Survey

GAIA ALERTS: GALACTIC PLANE



GAIA RESOLVES SN AT 0.1-0.5 ARCSECS



see talk by Zuzanna Kostrzewa-Rutkowska

Blagorodnova, Van Velzen et al 2015

WHAT DOES GAIA OFFER?

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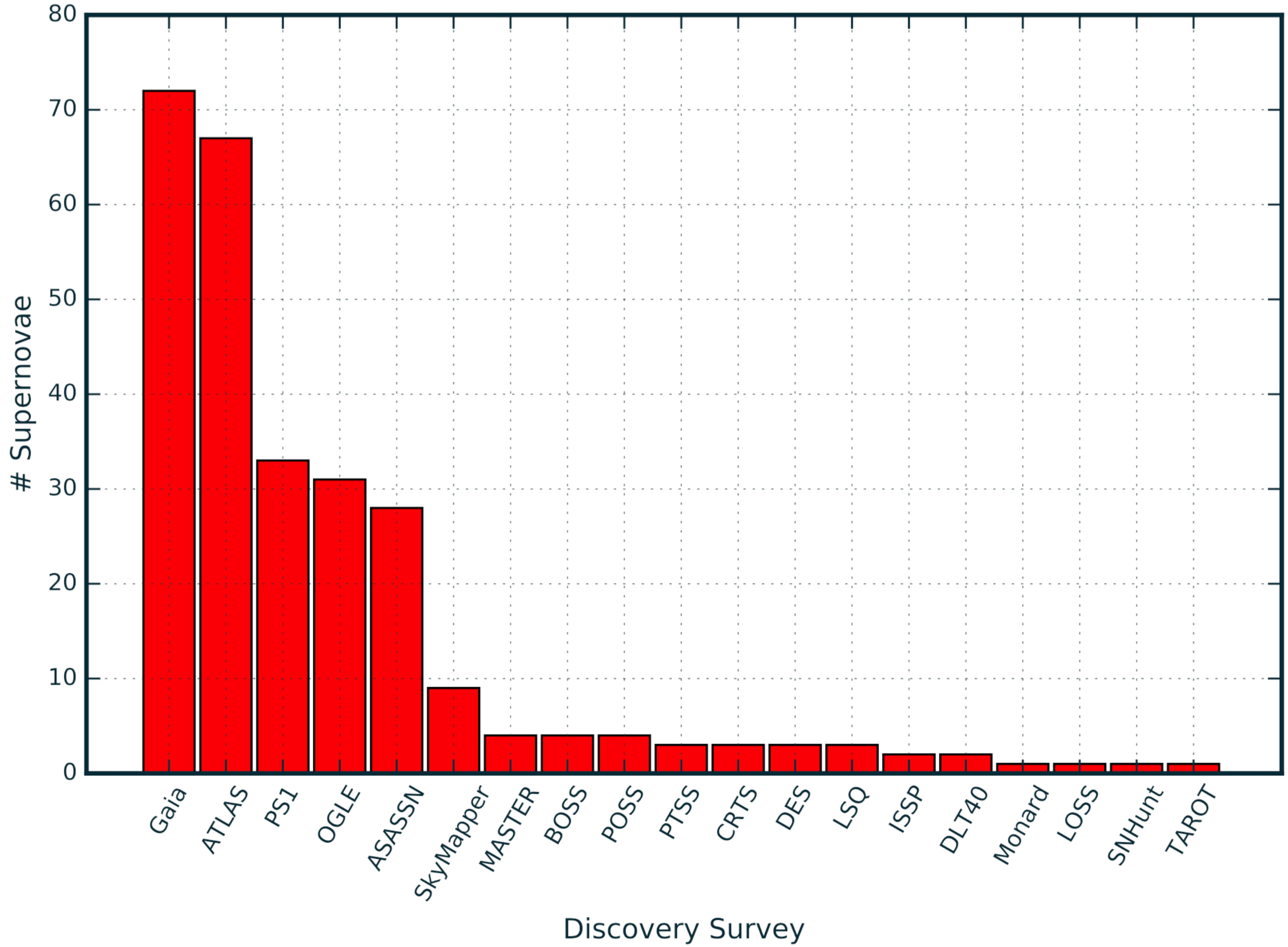
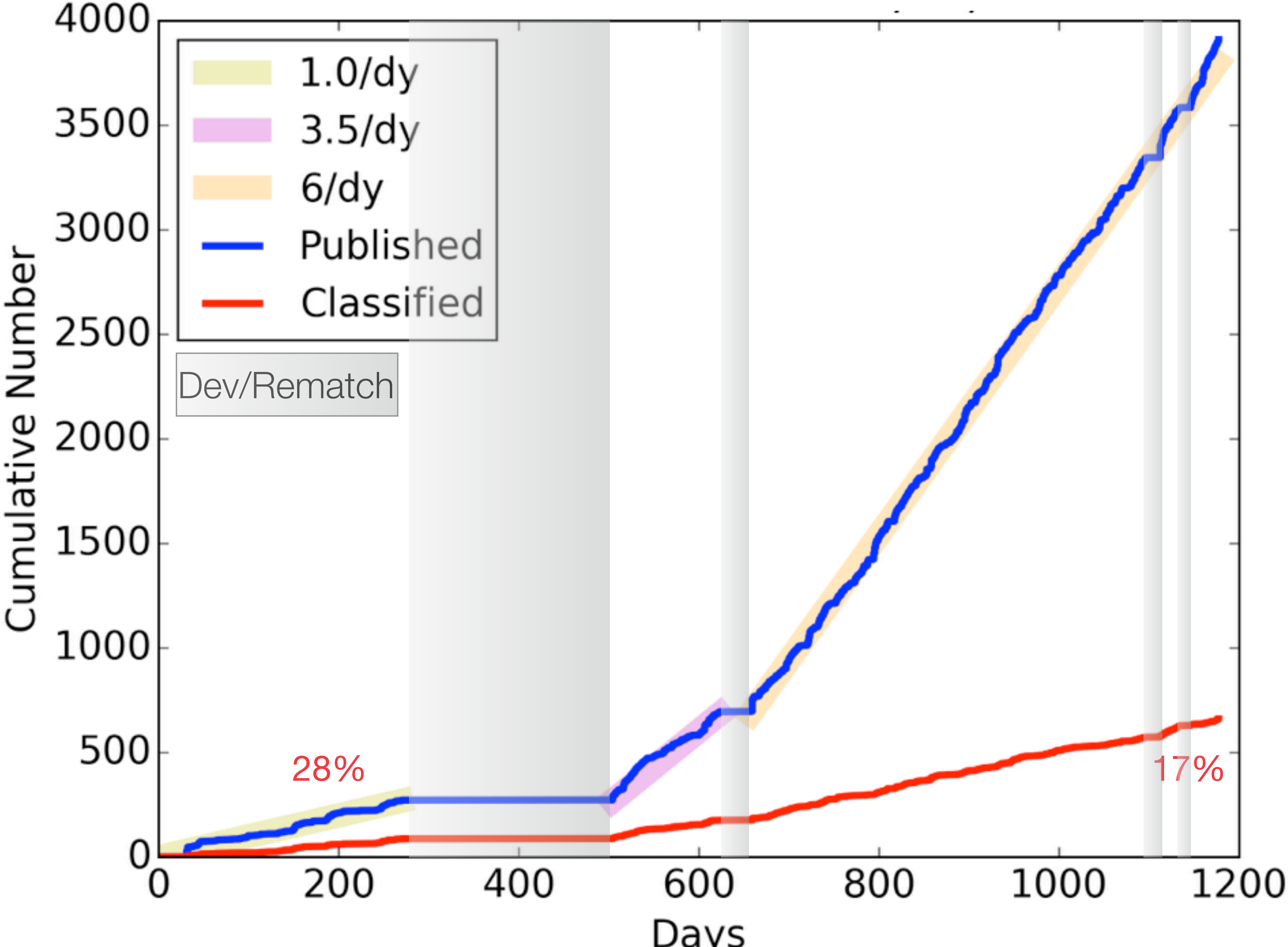
PESSTO classifications

Survey	Count	%
Gaia	72	25.7
ATLAS	67	23.9
PS1	41	14.6
OGLE	31	11.1
ASASSN	28	10.0
SkyMapper	9	3.2
POSS	4	1.4
MASTER	4	1.4
BOSS	4	1.4
CRTS	3	1.1
DES	3	1.1
LSQ	3	1.1
PTSS	3	1.1
DLT40	2	0.7
ISSP	2	0.7
SNHunt	1	0.4
LOSS	1	0.4
TAROT	1	0.4
Monard	1	0.4

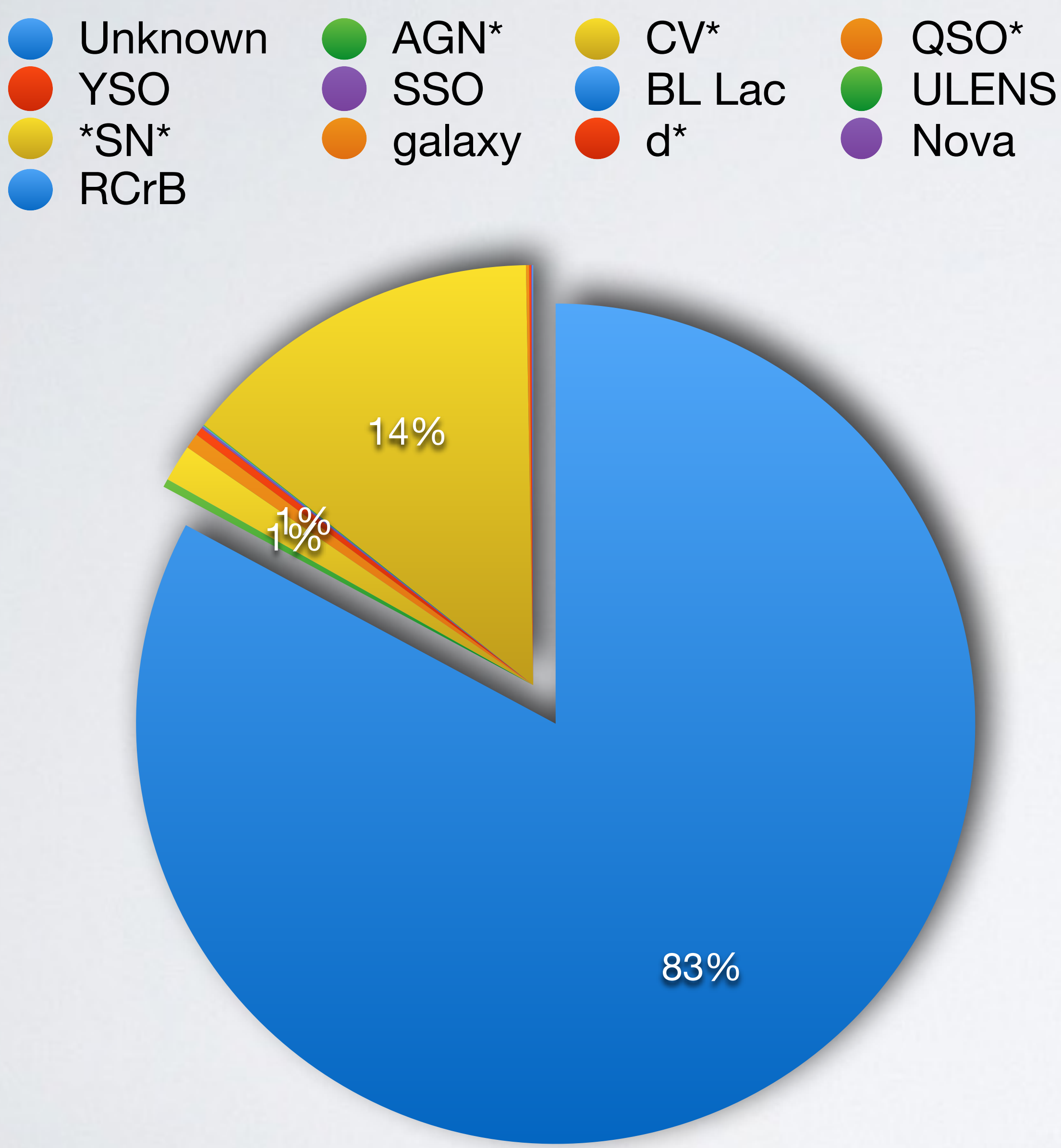


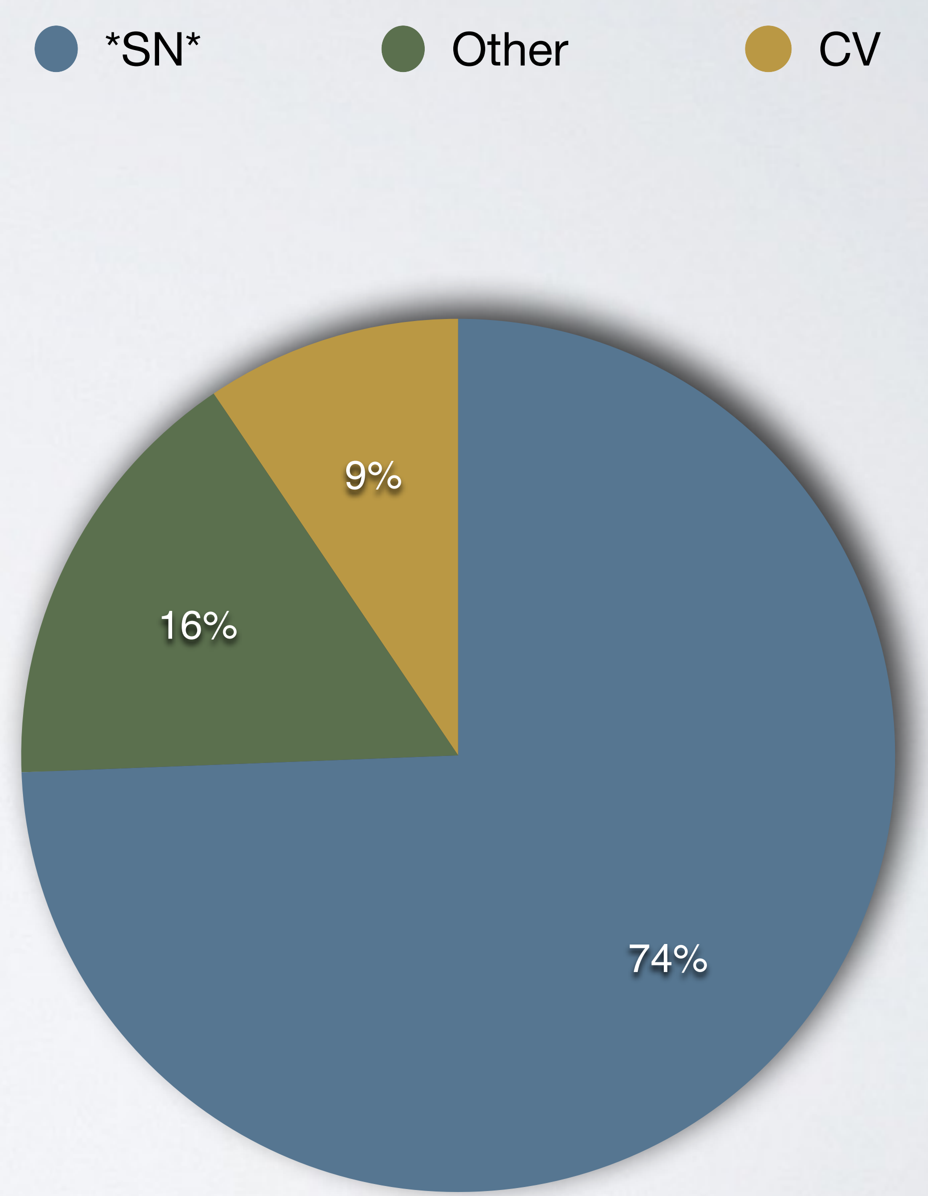
as of Jan 2017

Publication Rate vs Classification Rate



CLASSIFICATION:





We collate from TNS, ATels, our own follow-up, for (mostly spectral) classifications

GAIA-BASED CLASSIFICATION

- We will always be resource-limited for follow-up.*
- Gaia data are rich enough to do a good job of classification (c.f. other transient surveys).
- We have a large training set (>650 classified alerts) - but biased towards SN. OPTICON, ESO, ING, LT proposals focus on Galactic transients.
- Caveat - most of what we are preparing is based on supervised ML approaches.

**LSST*

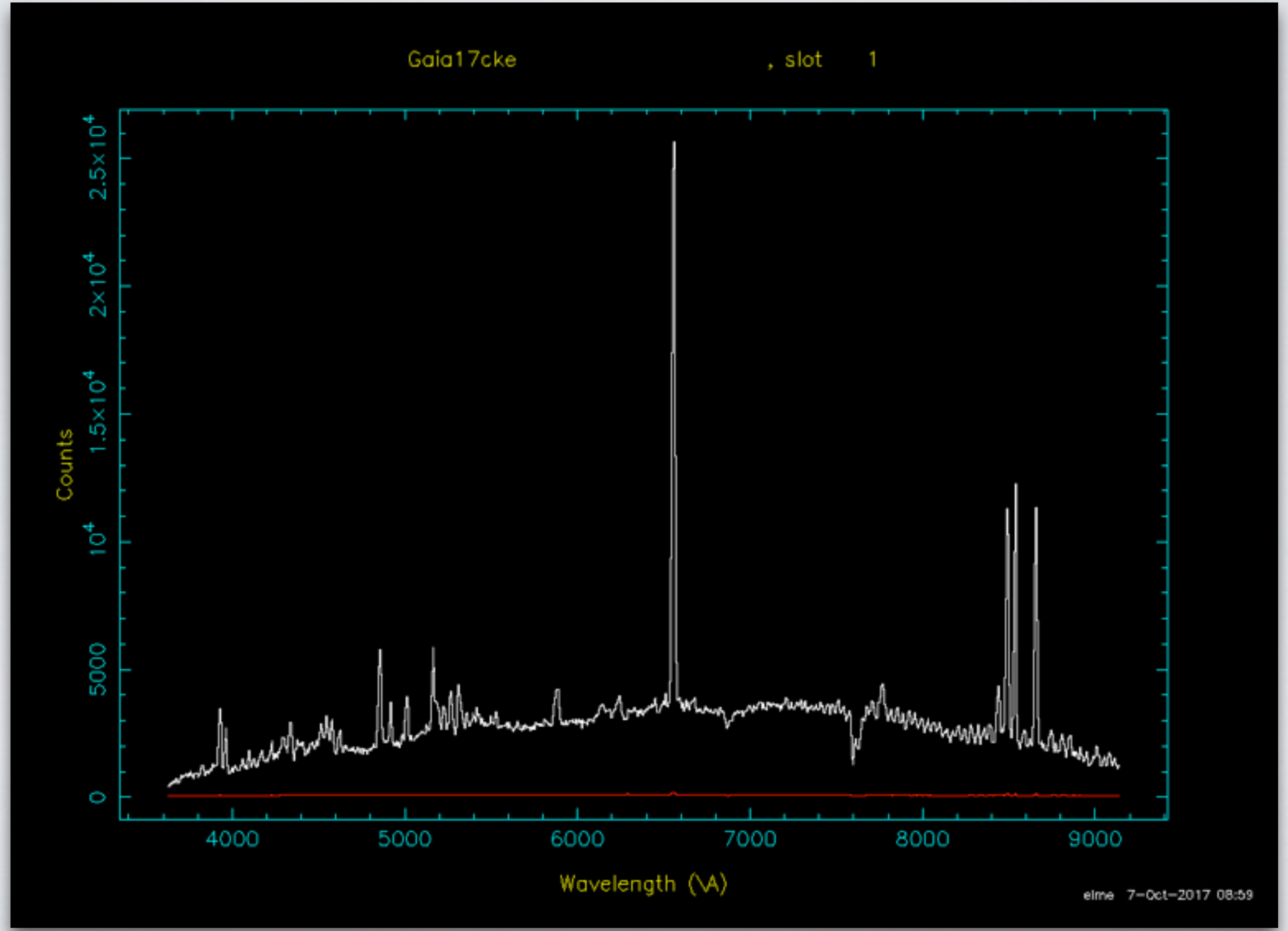
NEXT STEPS FOR GALACTIC TRANSIENT SCIENCE

- I would propose that we can do more, especially with the Galactic Transients (Gaia14aae, Gaia16aye are prime examples)
- Between us, we have phenomenal telescope access. Need to:
  - Coordinate Observations (LW has been doing the brunt of this)
  - Prioritise targets
  - Process + Analyse data
  - Write ATels (where appropriate), and papers
- The Gaia Marshall can support/enable the required interaction and discussion

NEXT STEPS FOR GALACTIC TRANSIENT SCIENCE

- Awarded 82 hours LCO 1m (Opticon, in 2 semesters)
- Awarded 89 hours REM 0.6m (Opticon in 2 Semesters)
- Awarded 13.5 hours Liverpool (Opticon + PATT)
- Awarded 1 night NOT (Opticon)
- Awarded 6 nights NTT (ESO)
- Primary science cases: Microlensing Events, CVs, Black Hole Binaries

IS IT A NOVA?



Elmé Breedt

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