GAIA SCIENCE ALERTS

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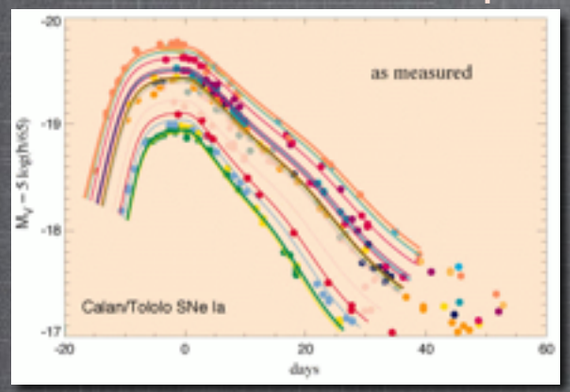
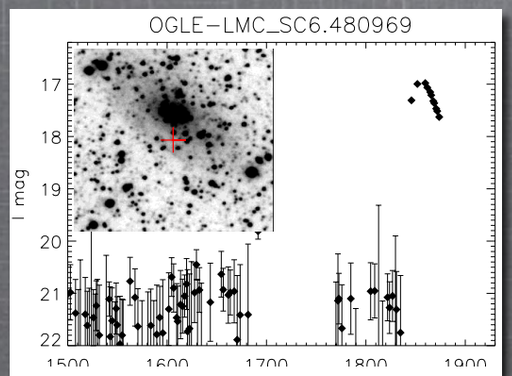
(pron. Woo-cash Vi-zhi-kov-sky)
Warsaw University Astronomical Observatory

7th Gaia Science Alerts Workshop, Utrecht, 7.Dec.2016

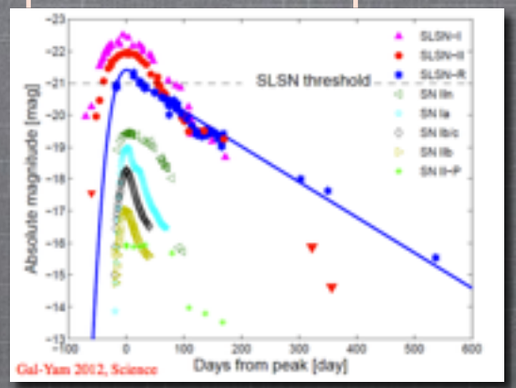
TRANSIENTS ZOO

Supernovae

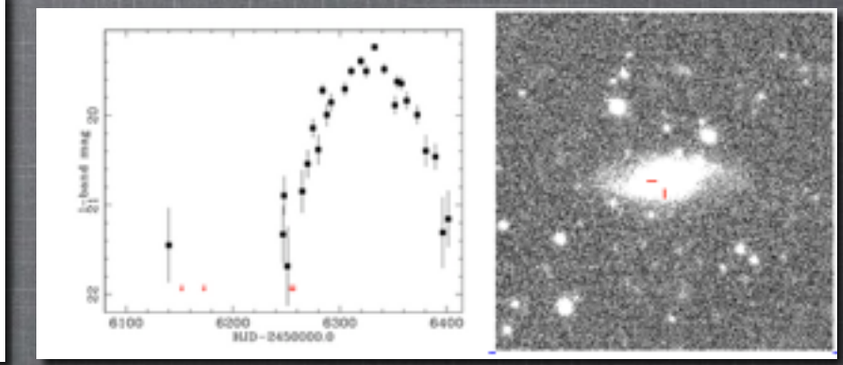




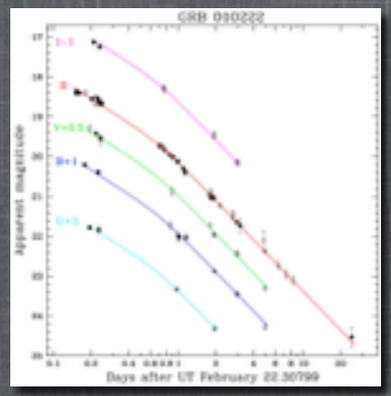
Super-luminous Supernovae



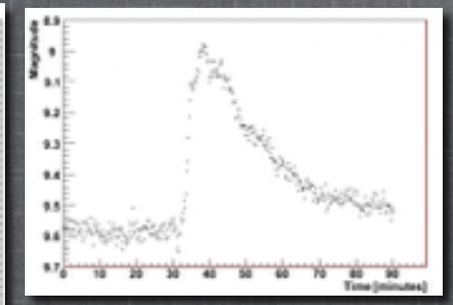
AGN flares/TDE



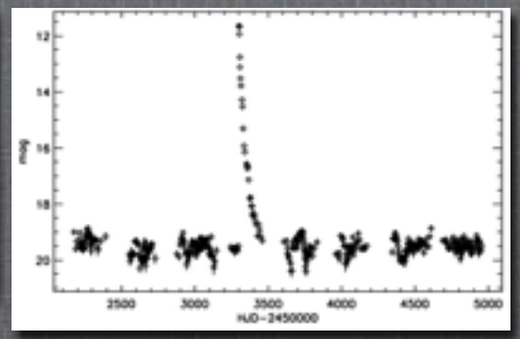
GRBs afterglows



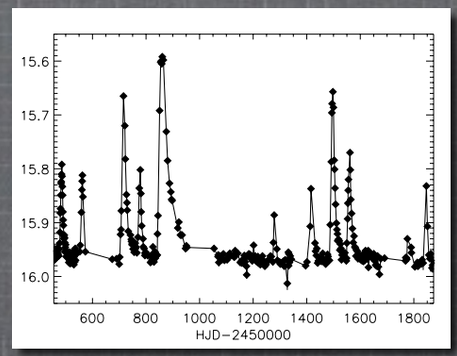
M-dwarf flares



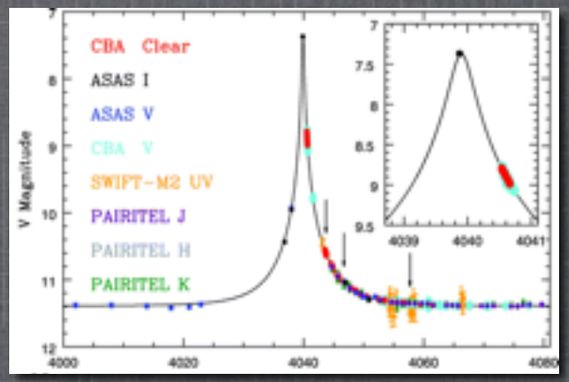
Classical novae



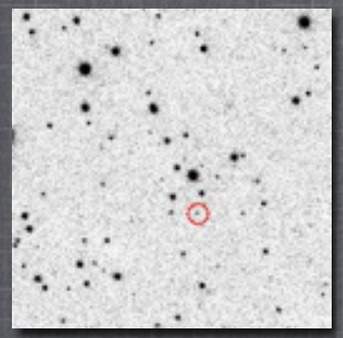
Dwarf novae



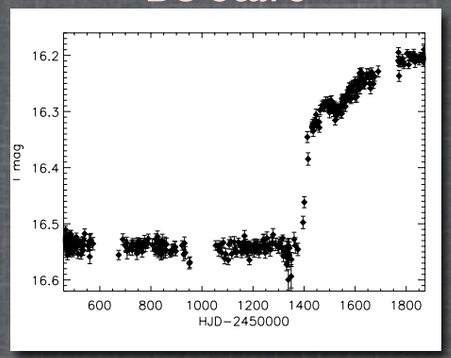
Microlensing events



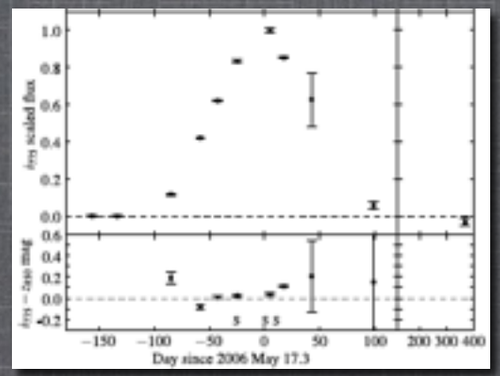
Asteroids



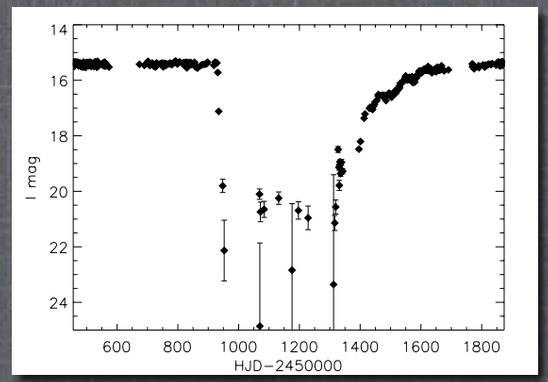
Be stars



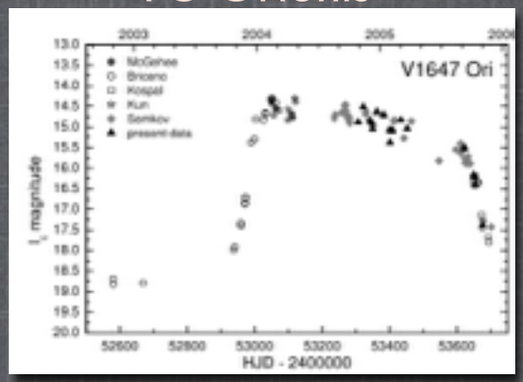
NEW THINGS??



R Coronae Borealis



FU Orionis



TRANSIENTS APPLICATION

- **Stellar astrophysics** (SNe, CVs, MFlares, Be stars, RCrB, FUOri)
- **Final stages of stellar evolution** (CCSNe, CVs, SLSNe)
- **Rare stages of the stellar evolution** (RCrB, FUOri)
- **Distance indicators at local and cosmological scales** (Novae, SNIa, SLSNe?)
- **Stellar-mass black holes** (Microlensing, CCSNe)
- **Supermassive black holes in galaxies** (TDEs, AGN flares)
- **Mass distribution in the Galaxy, extra-solar planets** (Microlensing)

GAIA AND OTHER SURVEYS

	Gaia	OGLE-IV (Magellanic System only)	Catalina Sky Survey	PTF	LSST (from 2020??)
$deg^2\ day^{-1}$	≈ 1230	150	1200	1000	5000
Avg Cadence	≈ 30 days	5 days	14 days	5 days	4 days
Limiting mag	~20.5(19)	21	19.5	21	r=24.7
f_{sky}	all sky	0.02	0.6	0.2	<0.48

spectra

astrometry

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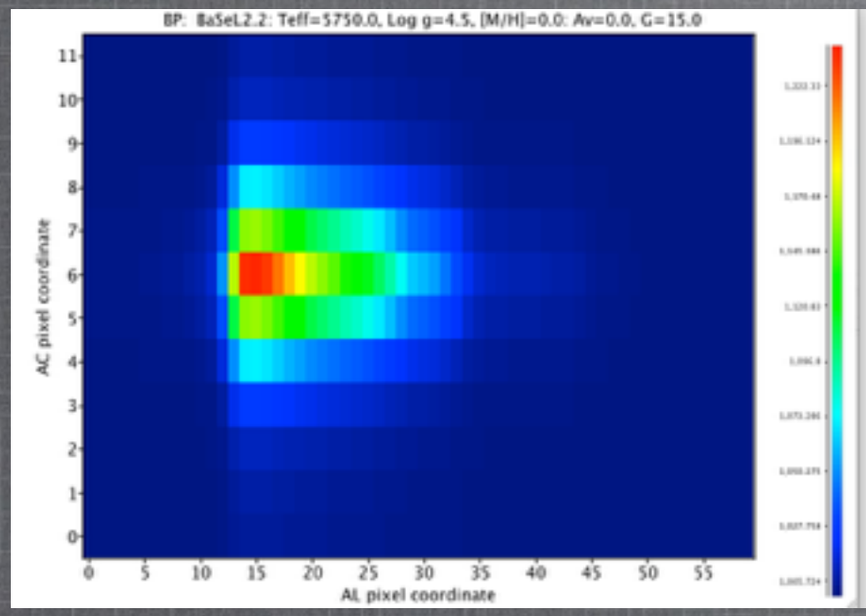
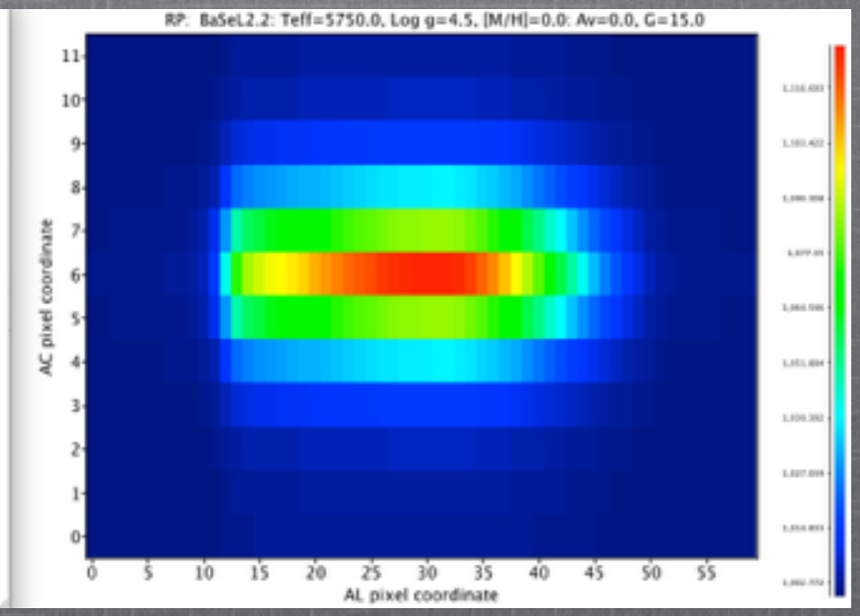
GAIA SPECTRA

Blue photometer

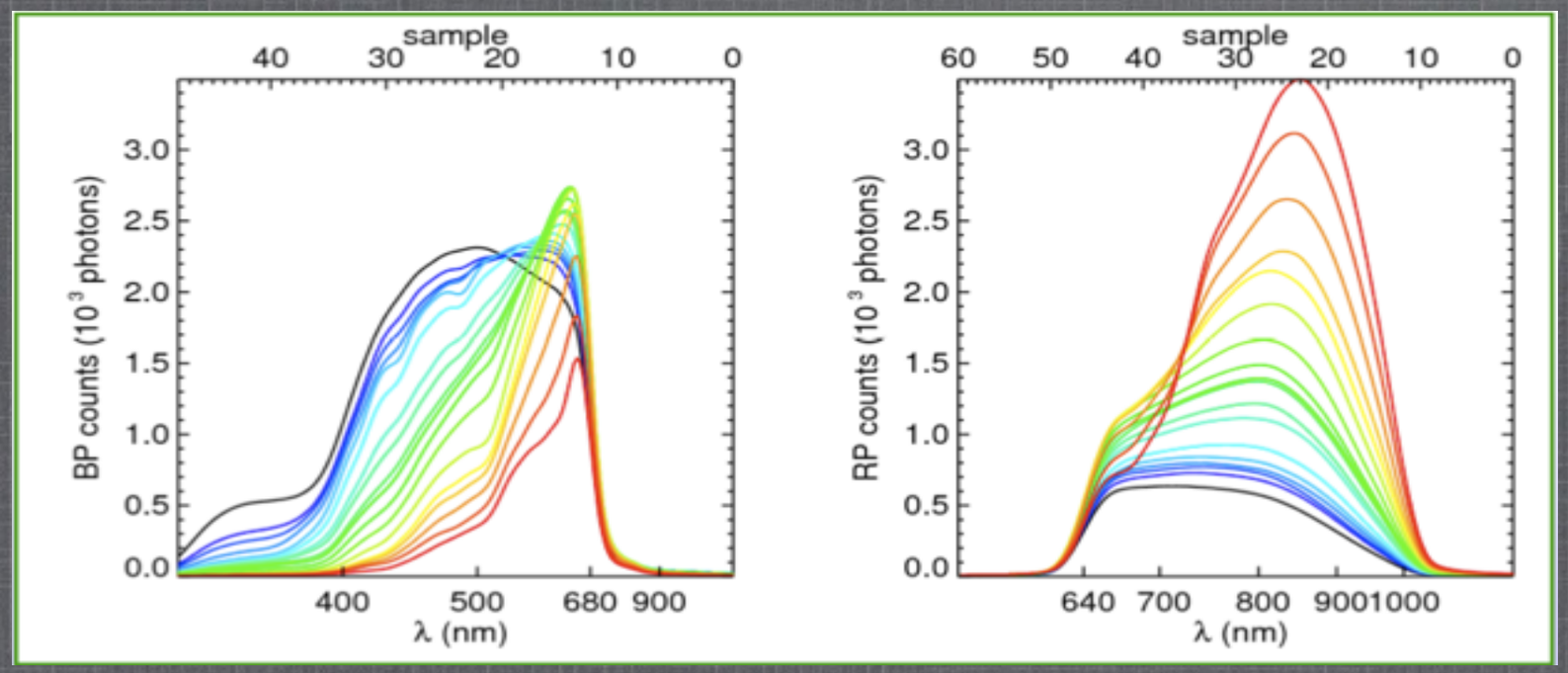


Red photometer



On the CCDs

- two low resolution spectrographs, R~100

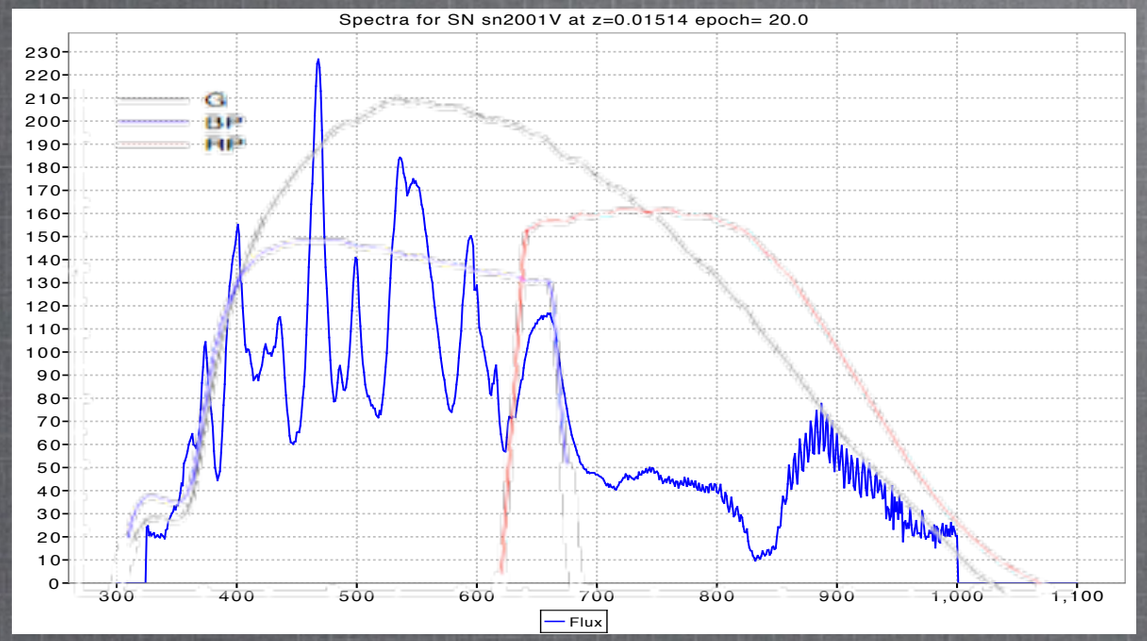


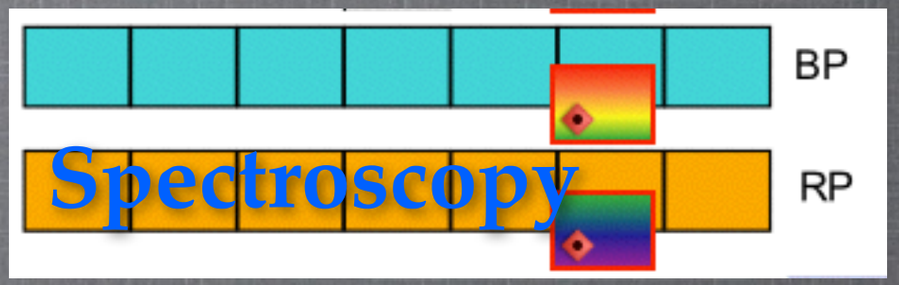
Measurements

- 1 dimensional for stars G>13 mag

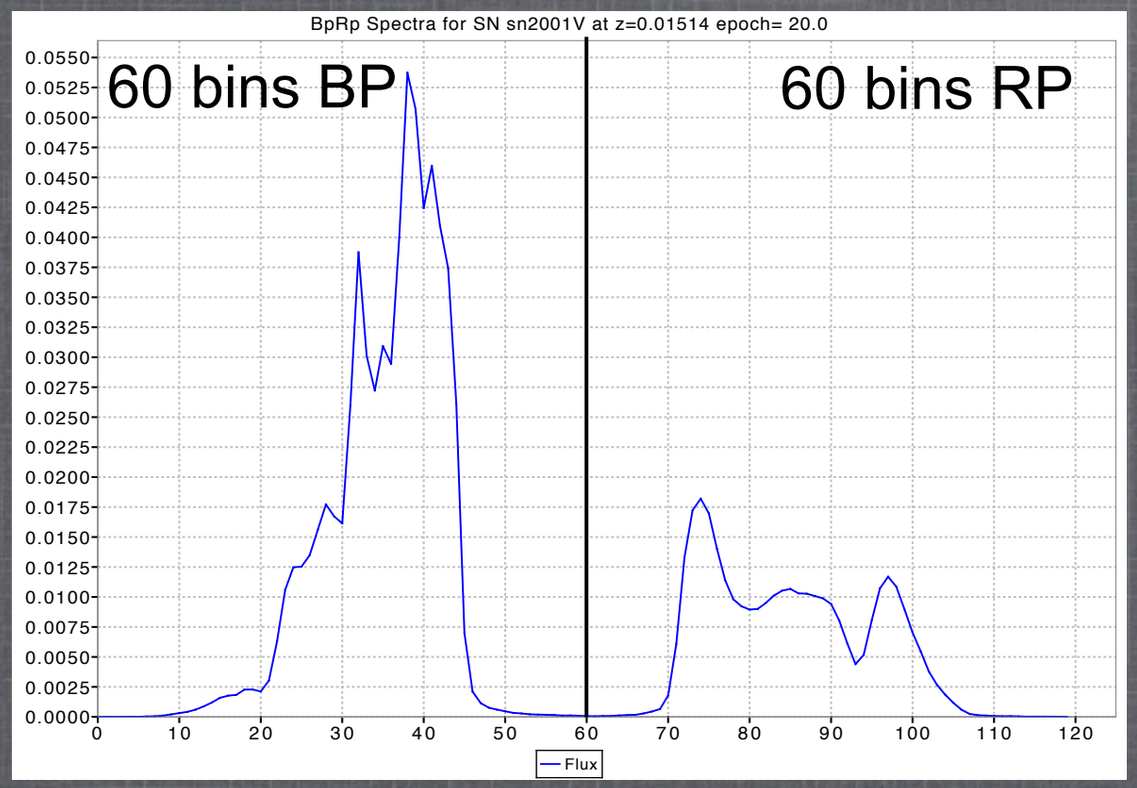
CLASSIFICATION OF ALERTS

Spectral classification - the `secret" power of Gaia





transients typing –
low false-positives rate!

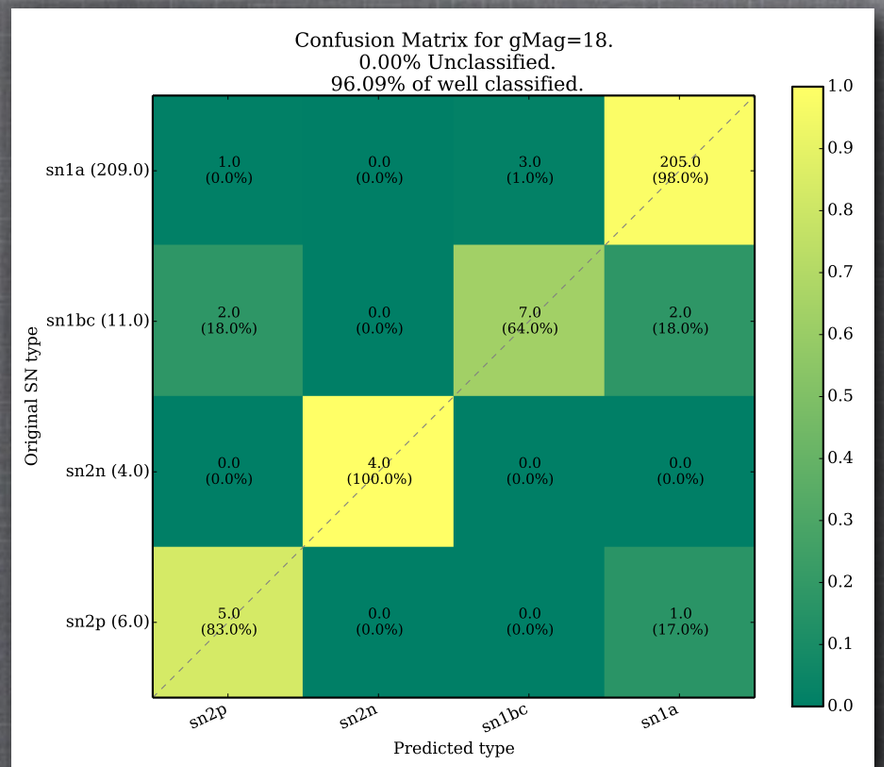


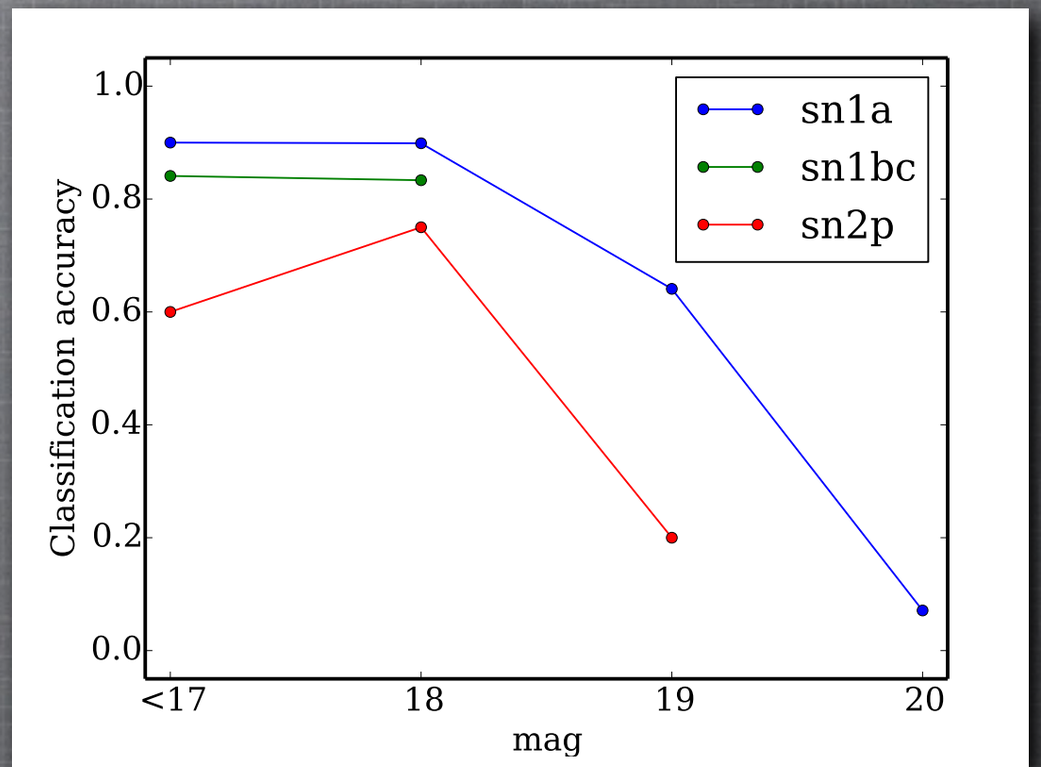
Gaia is equipped with low-resolution **(R~100)** spectrographs. They will allow for classifying transients into types and for supernovae they will provide estimates for redshift and epoch based on just a single observation!

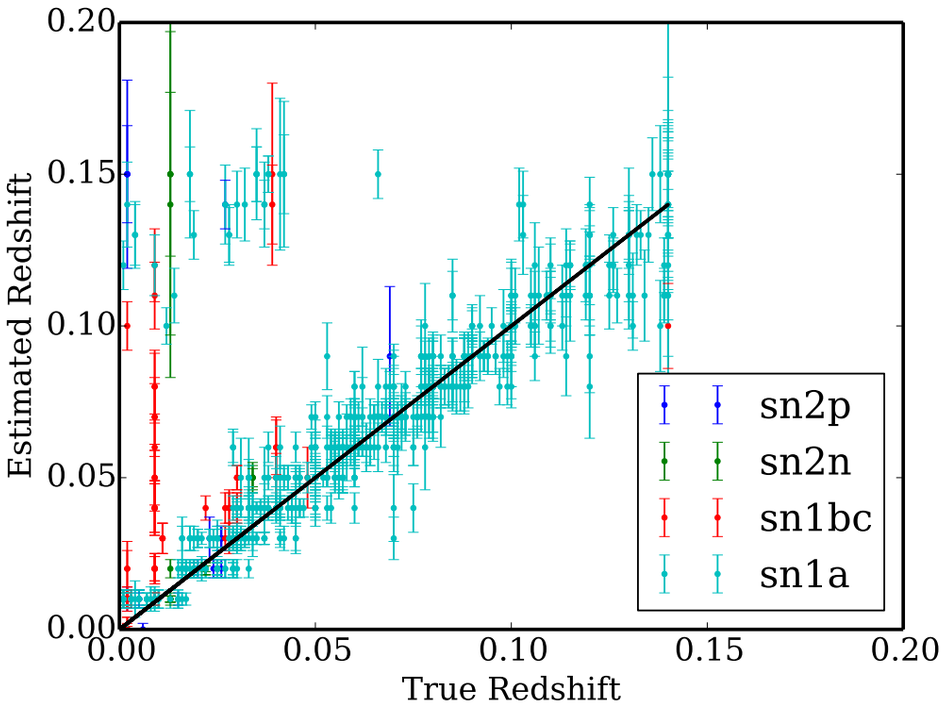
Blagorodnova et al. 2014

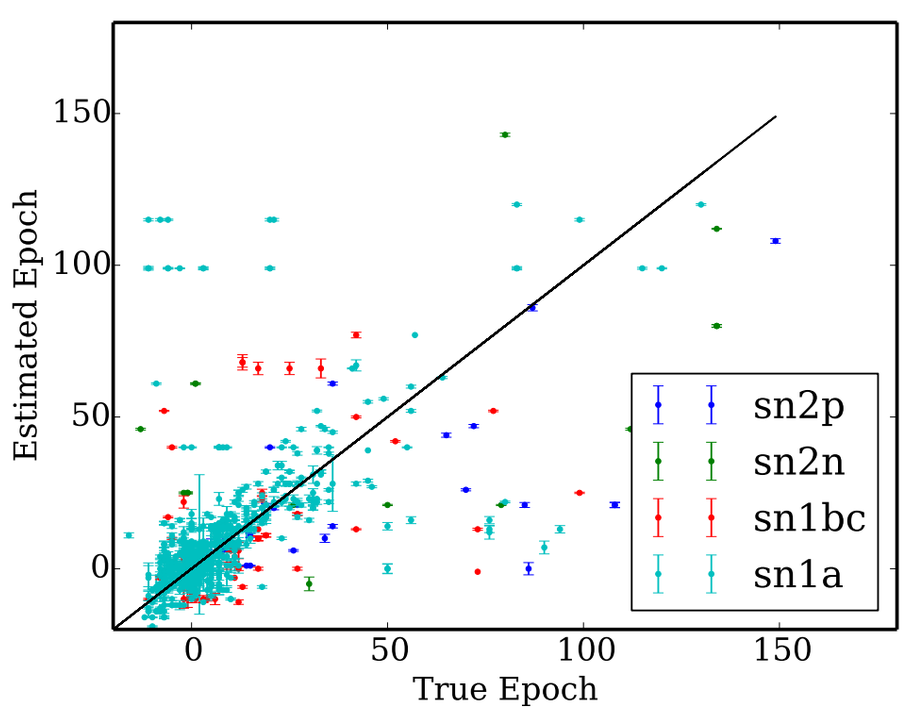
CLASSIFICATION OF ALERTS

Spectral classification - the ``secret" power of Gaia



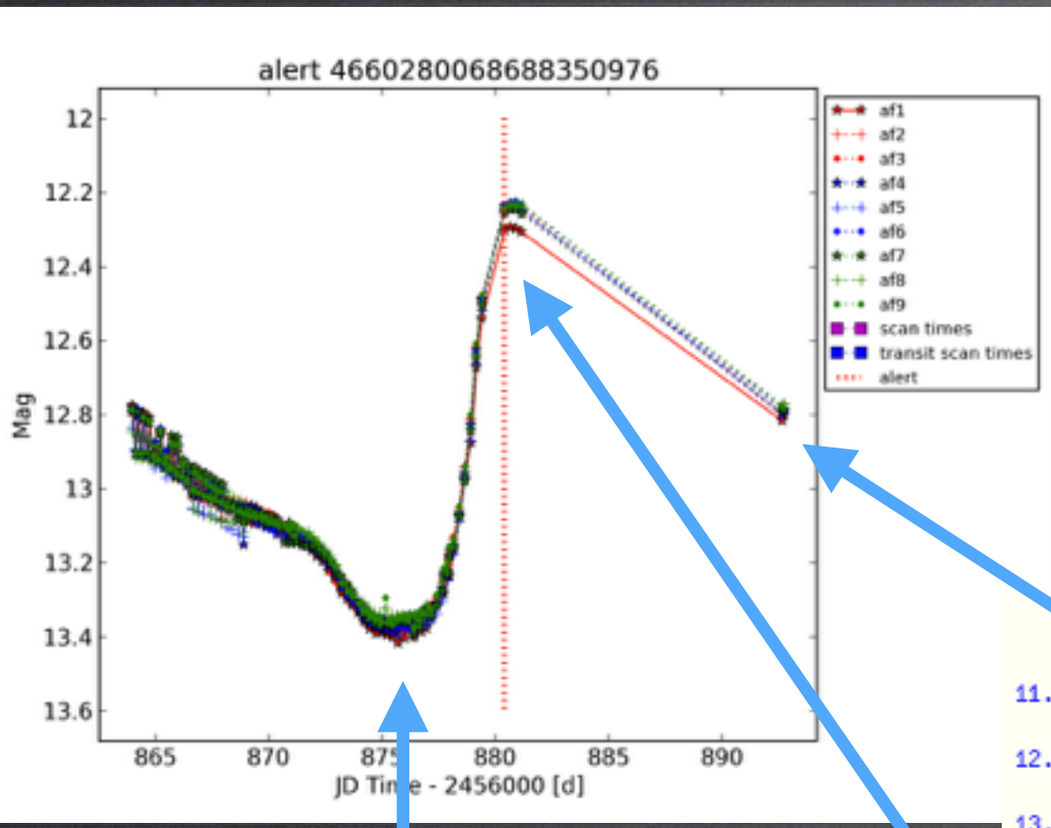


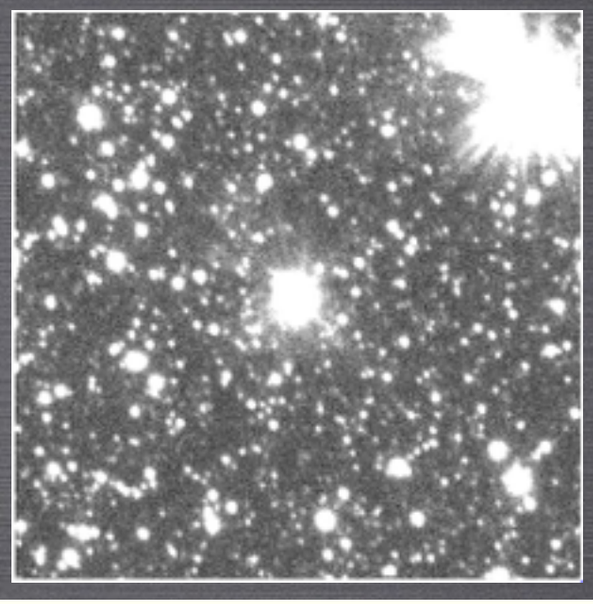




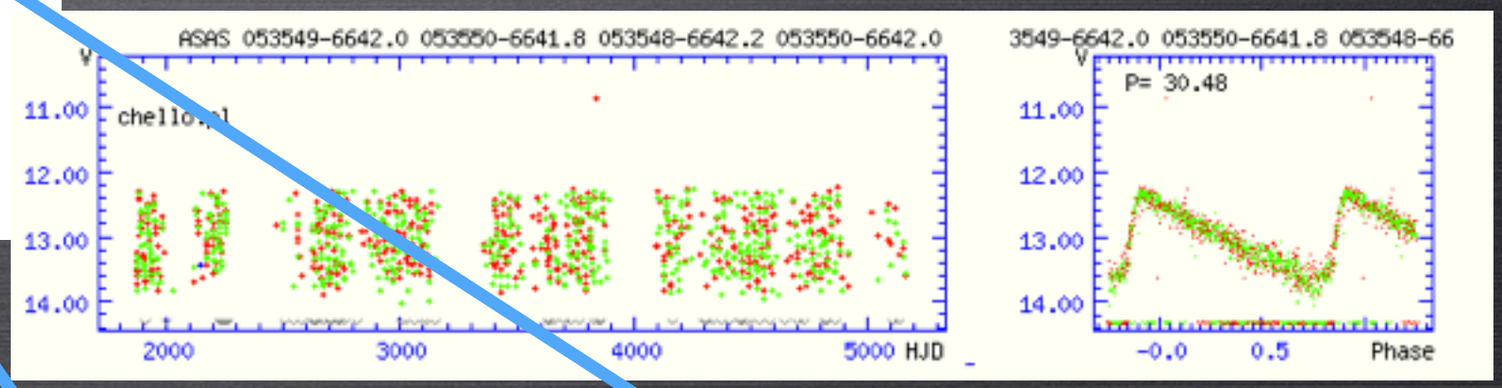
Blagorodnova et al. 2014

EXAMPLES ALERTS

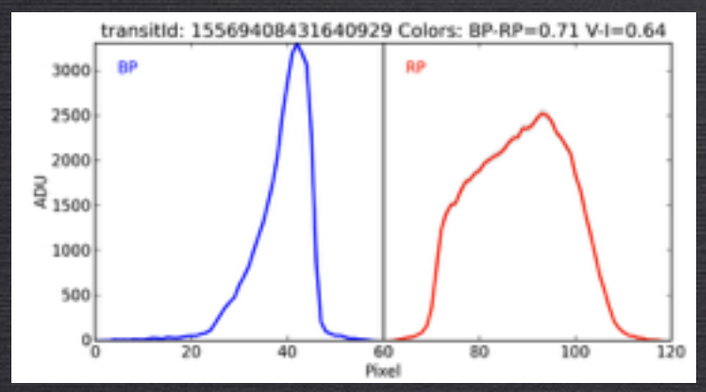


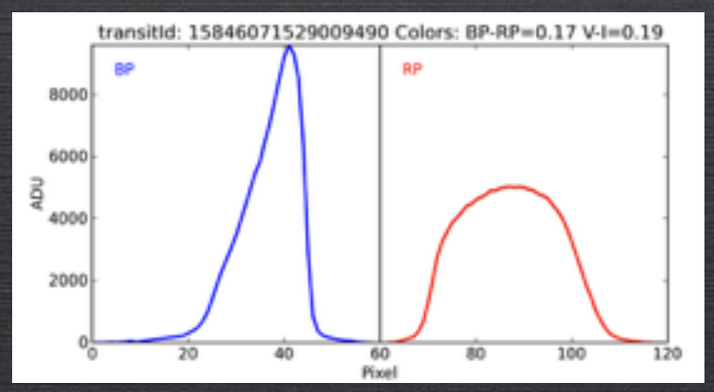


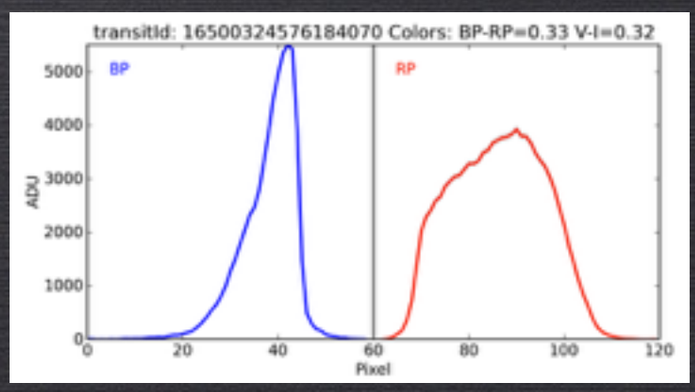
Cepheid, P=30.48d
HV 1002=
ASAS J053550-6642.1



Spectral evolution of cepheid:





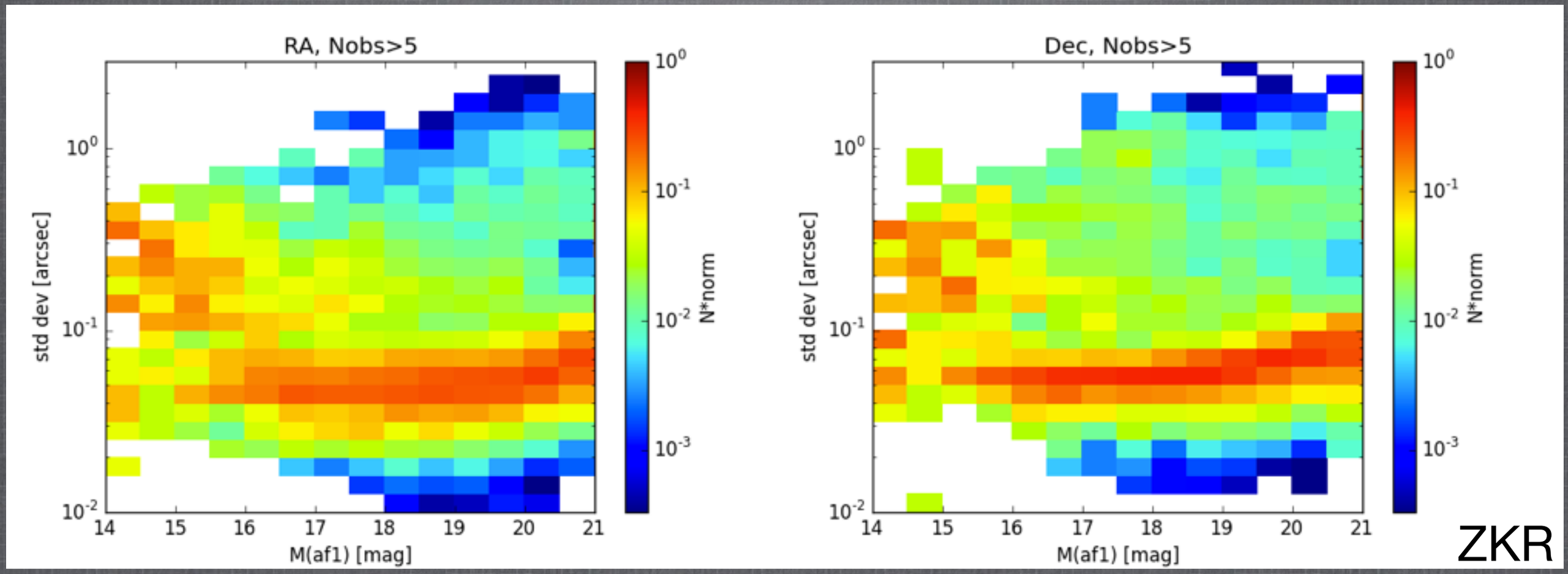


raw Gaia data!

GAIA'S ASTROMETRY

Current Gaia's astrometric precision:

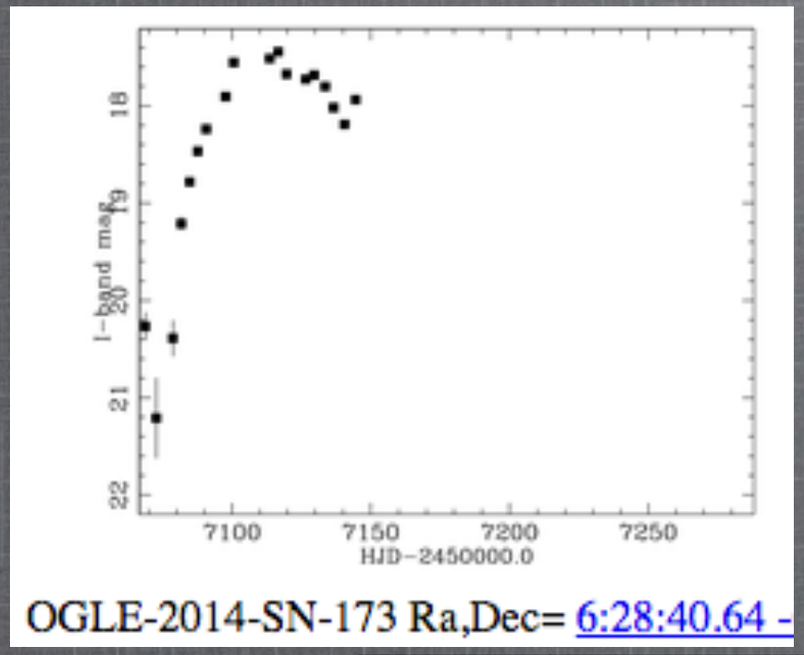
50 mas down to 20 mag



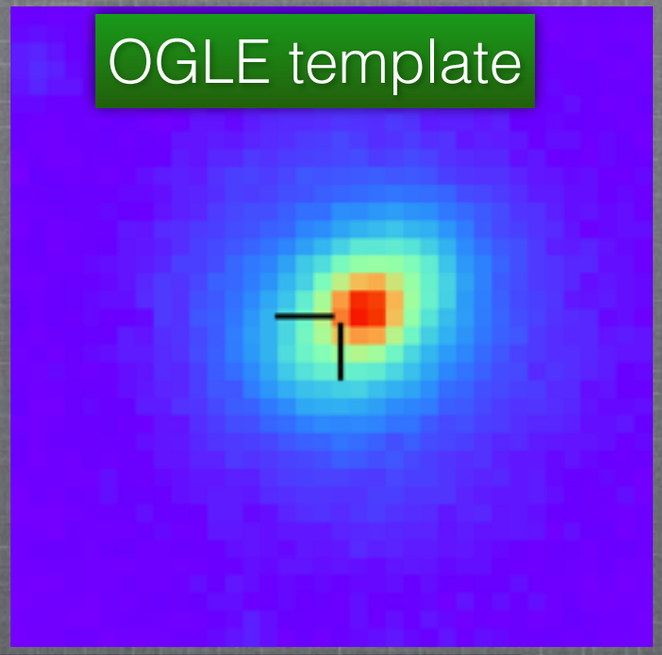
GAIA'S ASTROMETRY

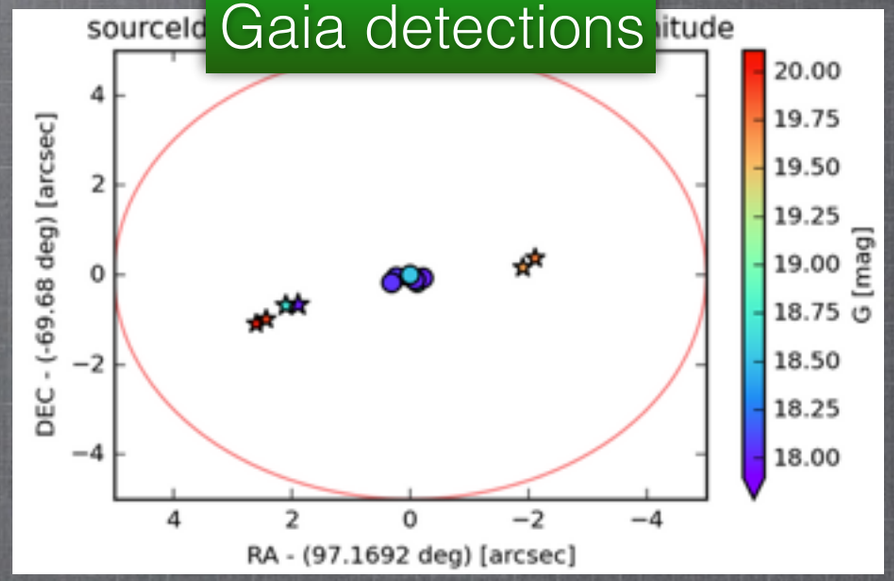
but possible ~1mas!

Nuclear transients classification

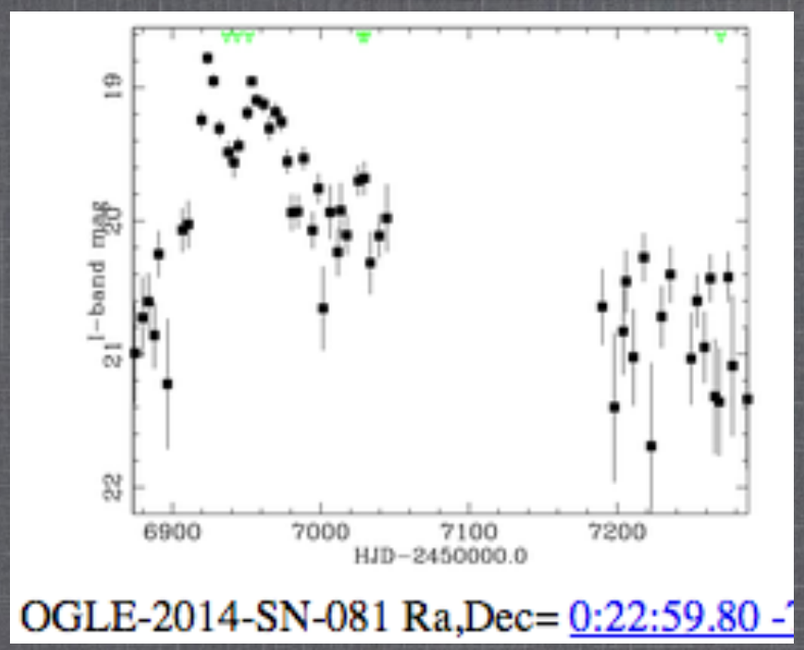


OGLE-2014-SN-173 Ra,Dec= 6:28:40.64 -

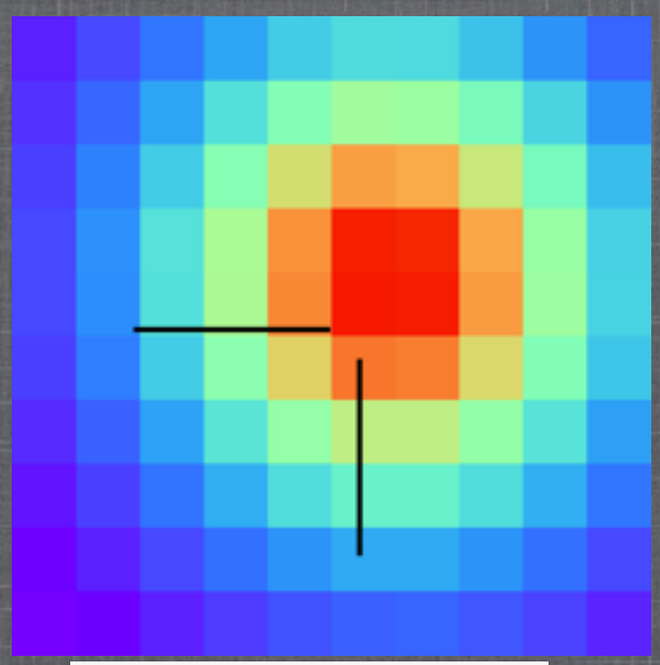




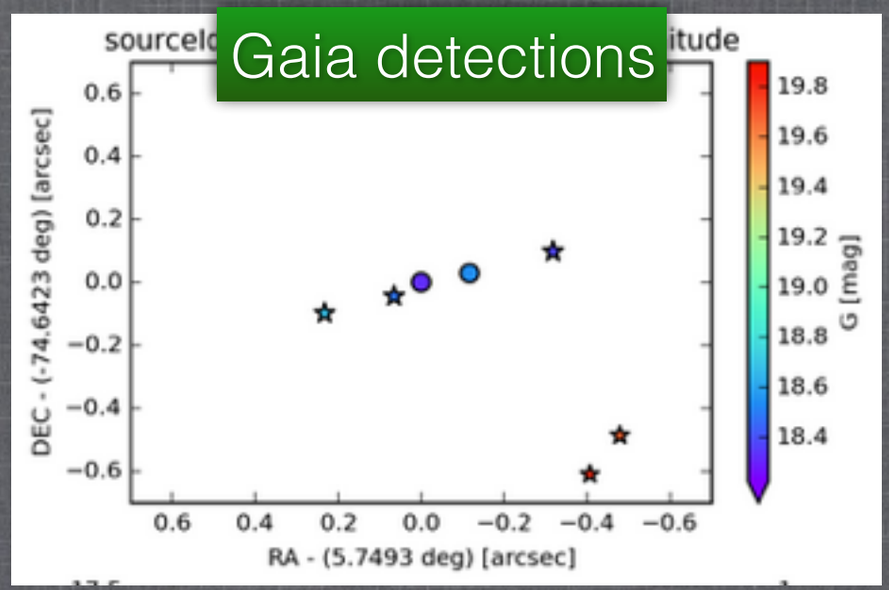
class= IIn z=0.0296 Offset= 0.91pix (0.24as)



OGLE-2014-SN-081 Ra,Dec= 0:22:59.80 -



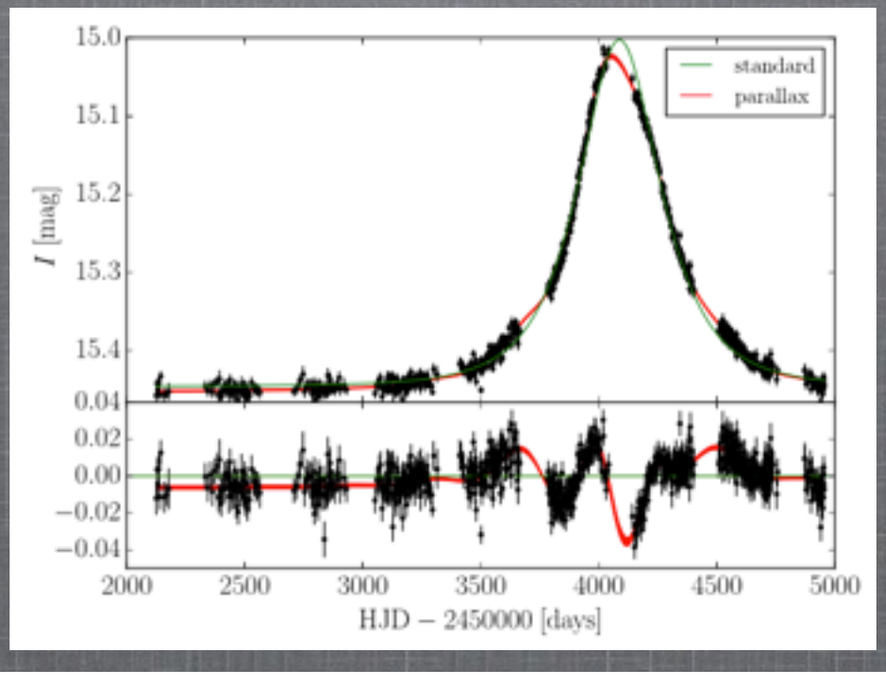
Offset= 0.53pix (0.14as)

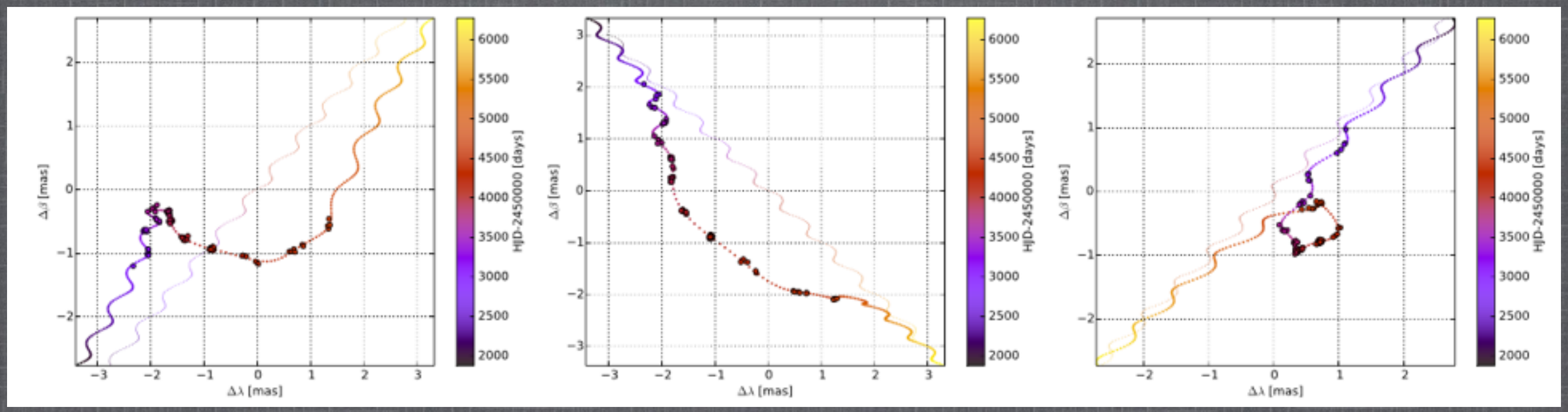


GAIA'S ASTROMETRY

Astrometric microlensing

recognising black hole lenses



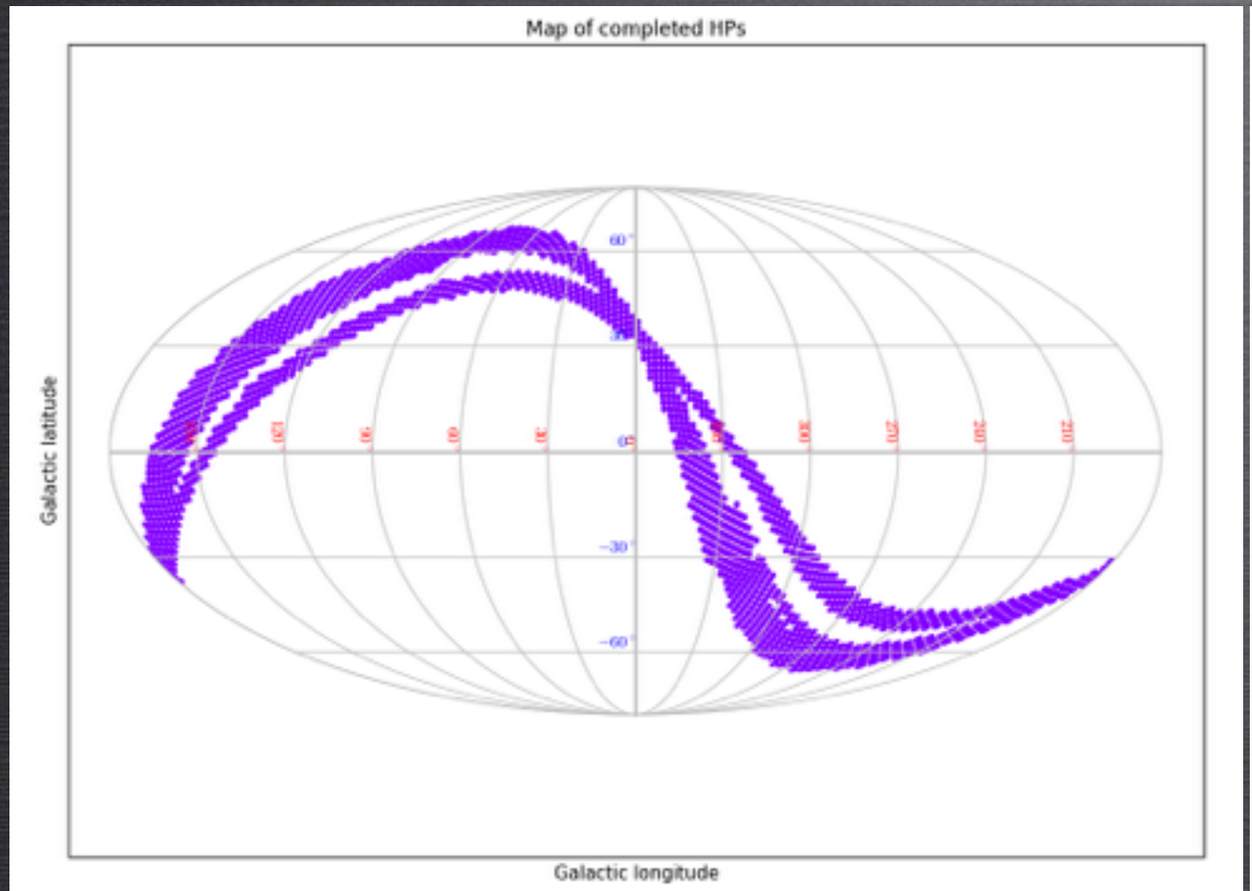


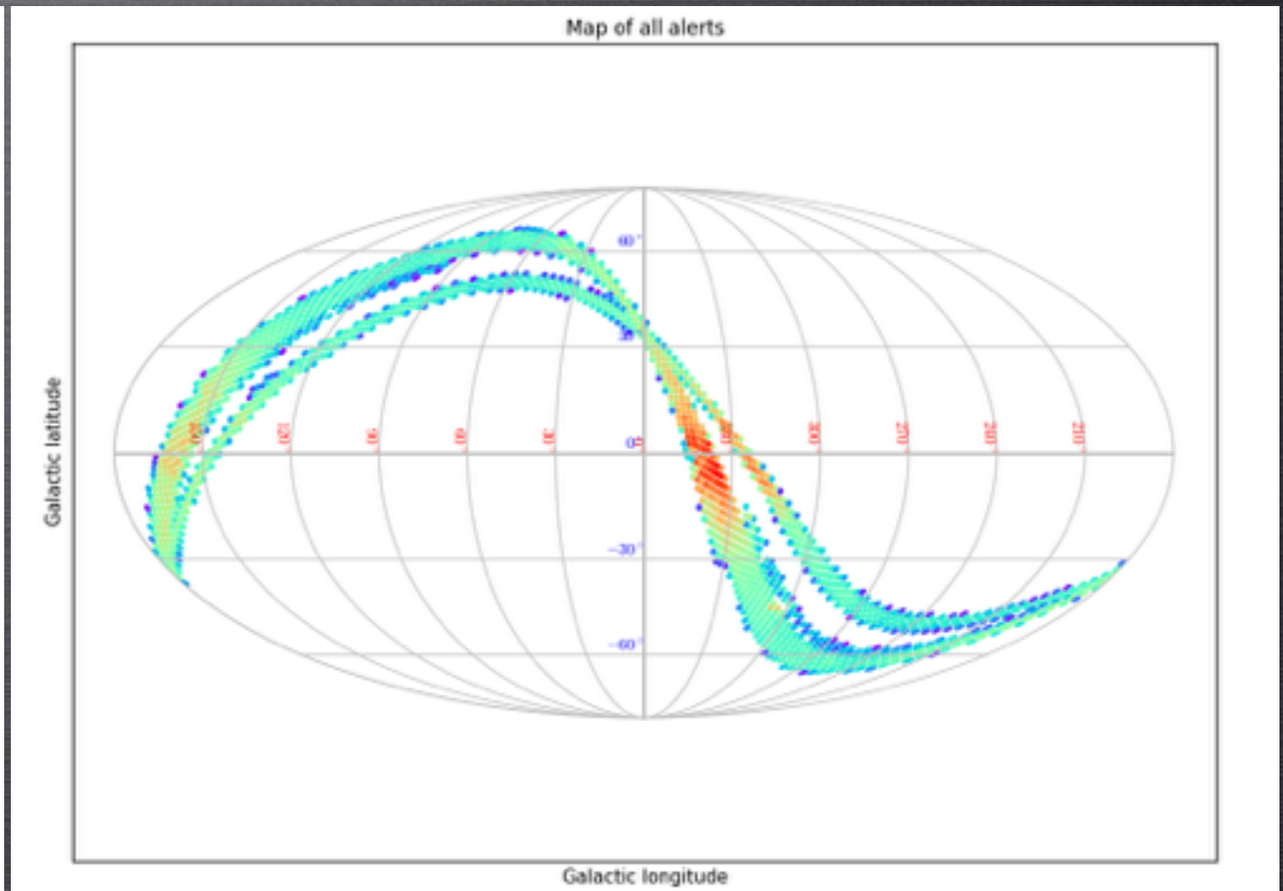
see Kris Rybicki's talk

EYE-BALLING

run 459 tstart 2015-04-05 08:25:31.587000 tend 2015-04-05 16:41:20.201000

1619 HPs completed for run 459



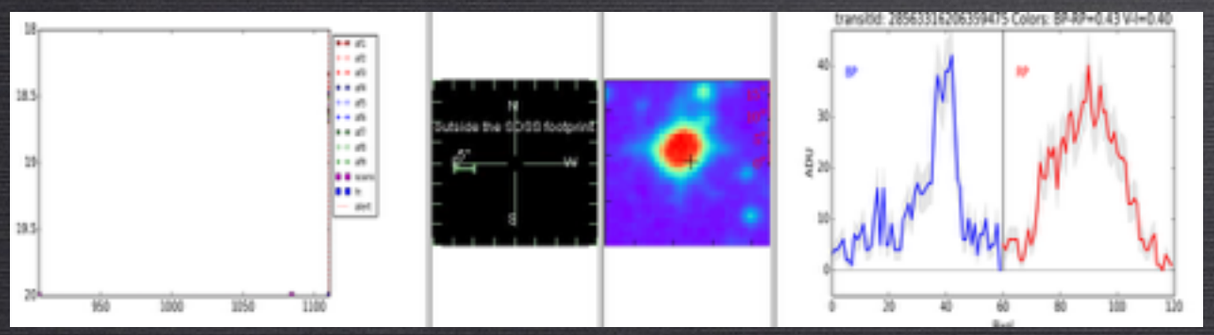


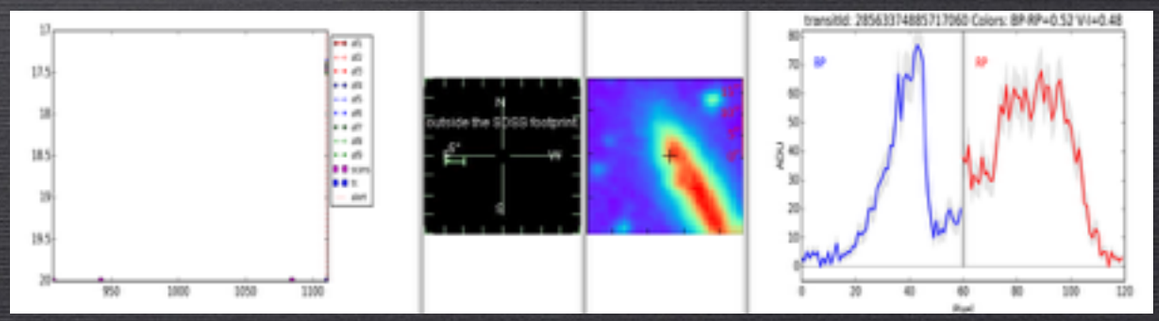
EYE-BALLING

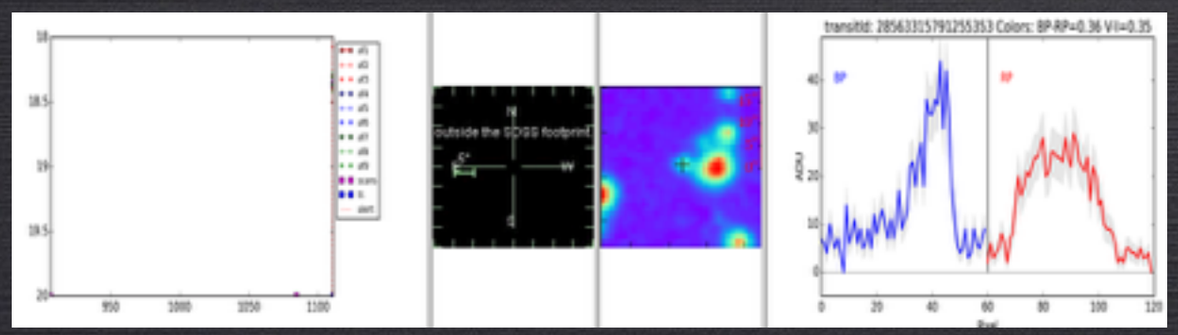
filter search-leda (LW also runs three more other filters, with different purposes)
brightness: 18.9 - 13.1
NewSource alerts only (of 84,774,199 total, of 2,593,333 alerting) 850444

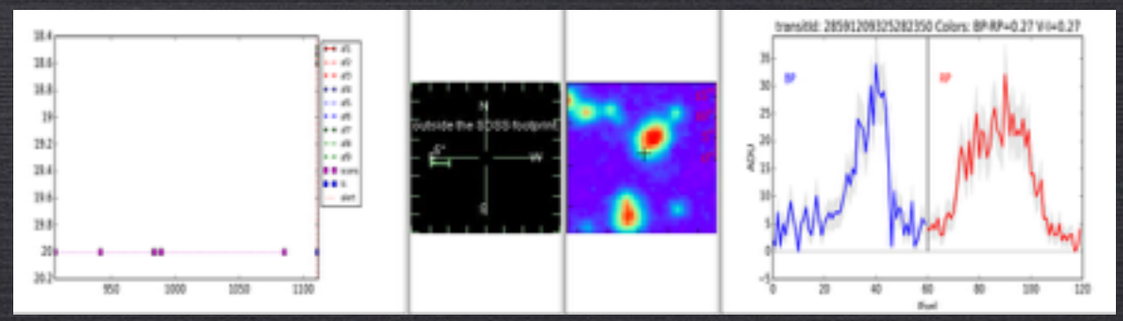
cut1: galactic plane removal |b|>15 deg 27276
cut2: ecliptic plane removal |beta|>15 deg 18956
cut3: saturated SDSS star (flag+g<17) found nearby (30") 17254
cut4: saturated GSC2 star (vpg<16 or bmag<16 or rmag<16) (30") 13802
cut5: LEDA catalogue of galaxies has a galaxy nearby (30") 234

234 left to eyeball









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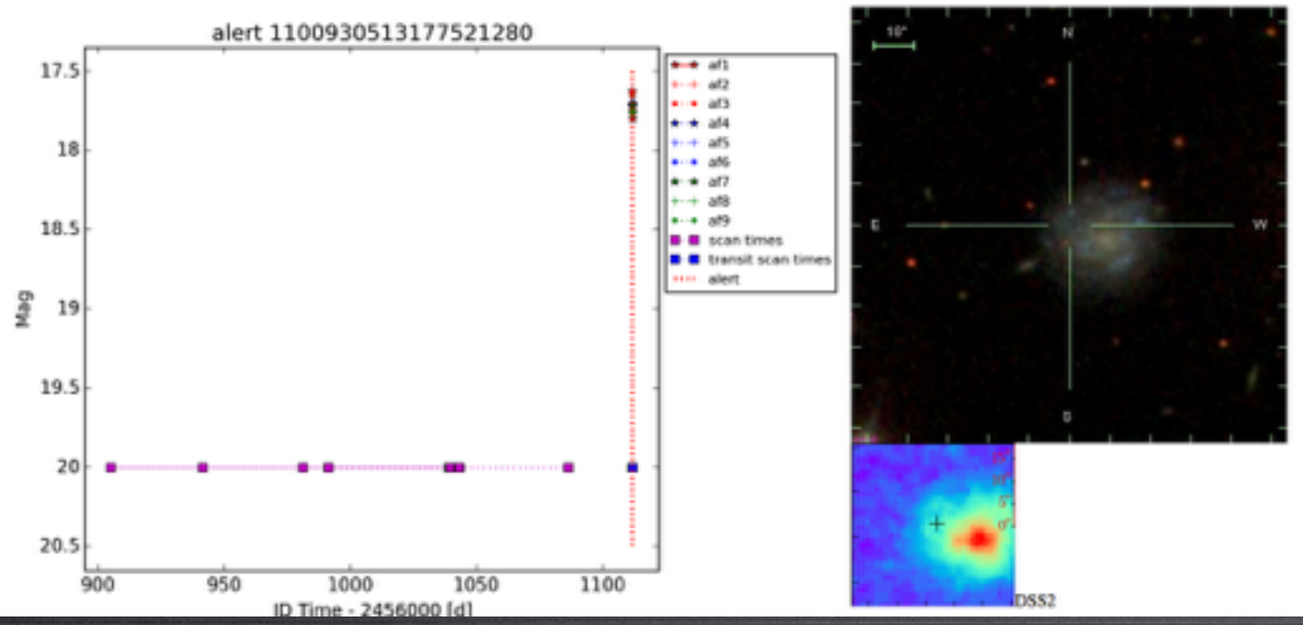
EYE-BALLING

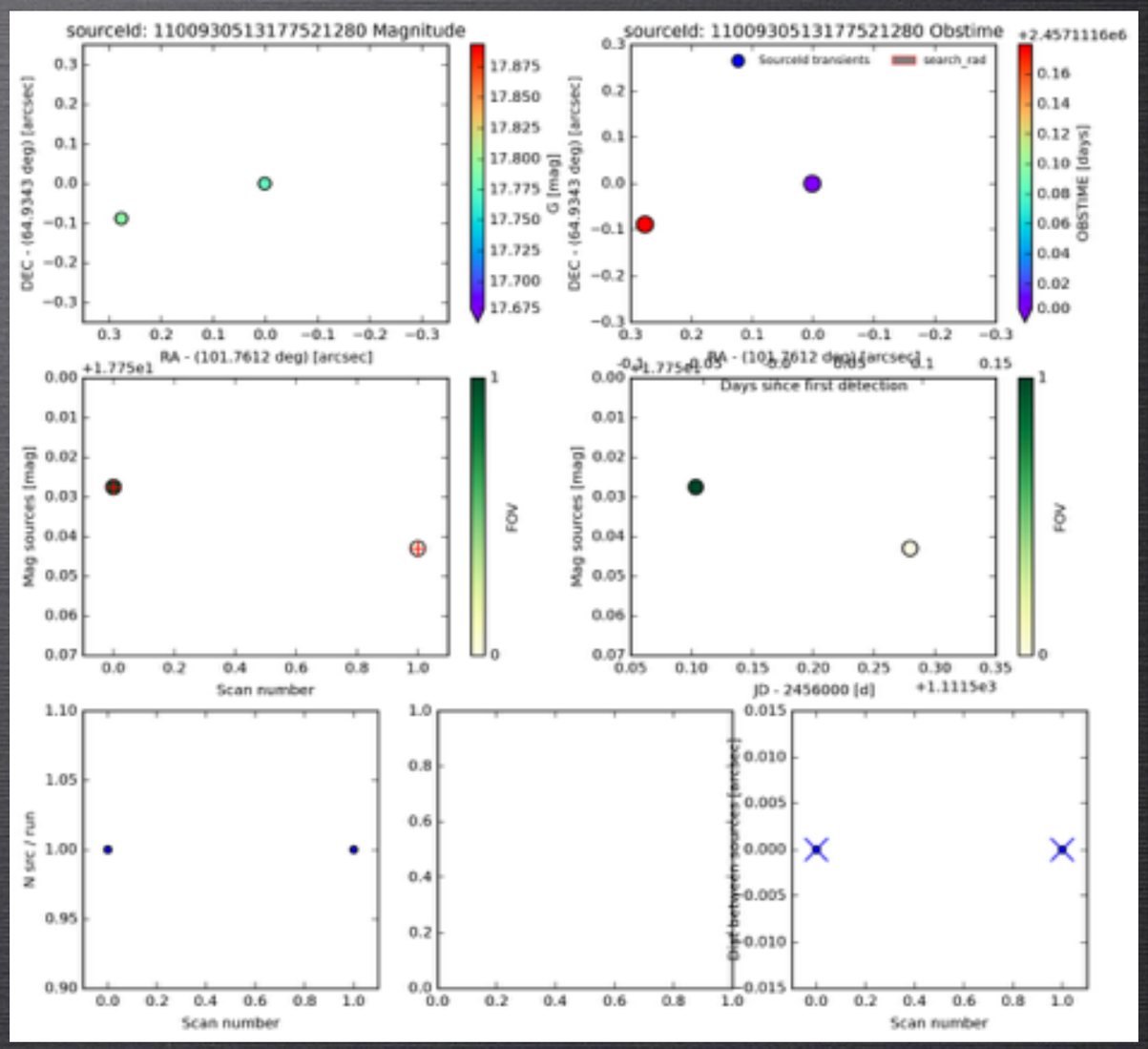
further detailed inspection of candidates

NewSource. Last non-detection date: 2015-03-04T20:39:42"

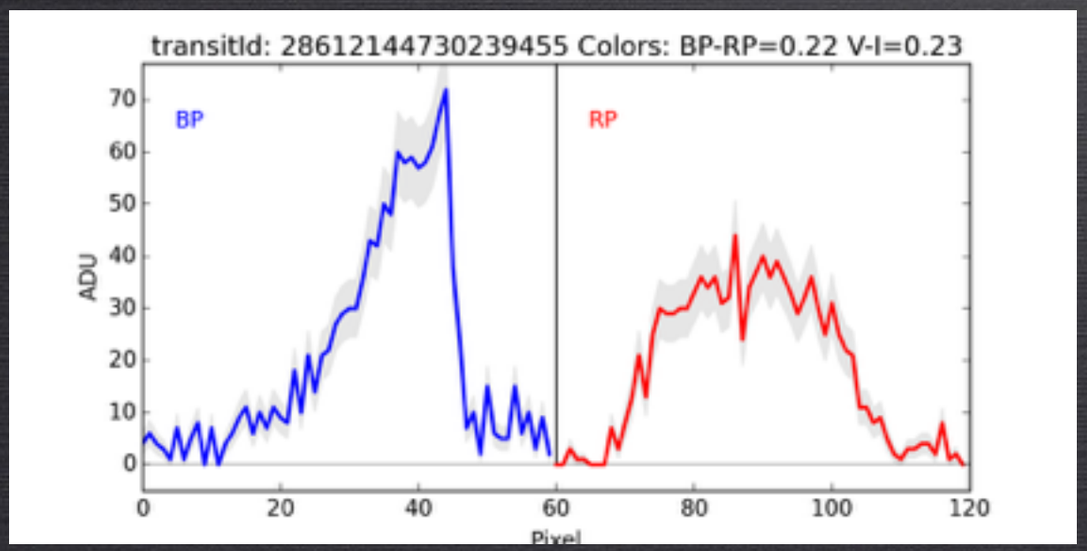
JD time-2456000	transitId	af1[mag]	af2[mag]	af3[mag]	af4[mag]	af5[mag]	af6[mag]	af7[mag]	af8[mag]	af9[mag]	mean
1111.603507	2860240391795956O	17.63	17.63	17.66	17.72	17.70	17.73	17.72	17.76	17.77	17.70
1111.779664	28612144730239455	17.80	17.74	17.77	17.76	17.72	17.69	17.70	17.66	17.75	17.73



checking other Gaia detections nearby



checking Gaia BPRP spectra



NOT and LT spectroscopic classification of supernovae Gaia15acz and Gaia15aek

ATel #7378; *S. Mattila, J. Harmanen, T. Kangas (University of Turku), A. S. Piascik, C. Davis, I. A. Steele (Liverpool John Moores University), N. Blagorodnova, M. Fraser, H. Campbell, S. Hodgkin, N. Walton (University of Cambridge), L. Wyrzykowski (Warsaw University Observatory), E. Kankare, R. Kotak (Queen's University Belfast)*
on 13 Apr 2015; 11:49 UT

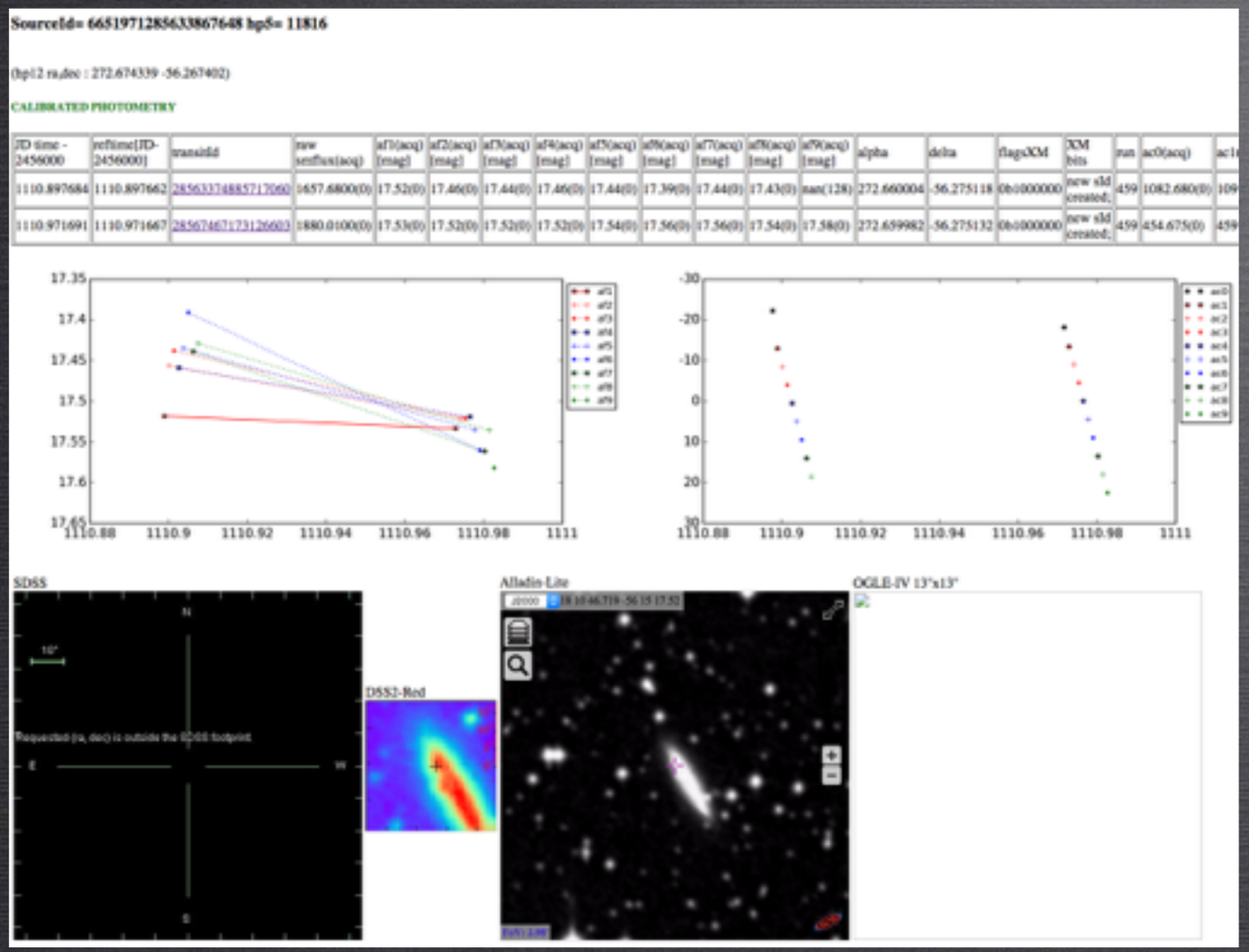
=> Gaia15aek

Supernova type IIP 2 weeks past max

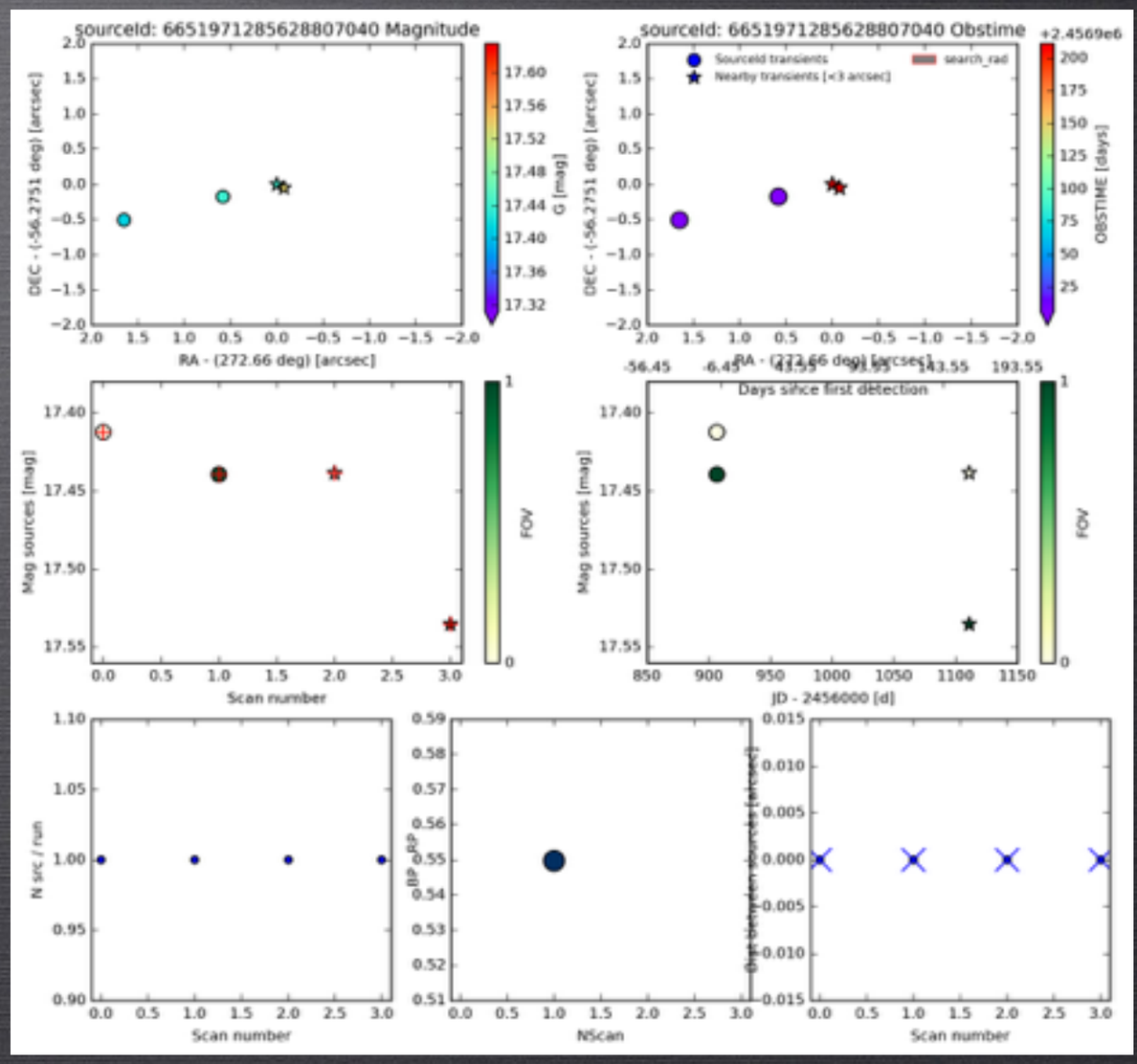
Łukasz Wyrzykowski

EYE-BALLING

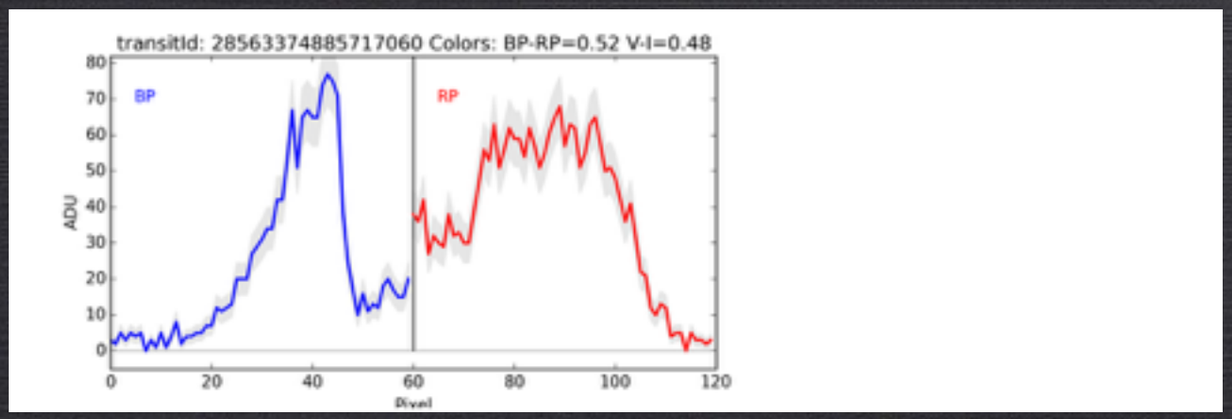
further detailed inspection of candidates



checking other Gaia detections nearby



checking Gaia BPRP spectra



false alert

-> spectrum suggests contamination from the host

-> cross-matching problem

-> old source observed again with new sourceid

PUBLISHING

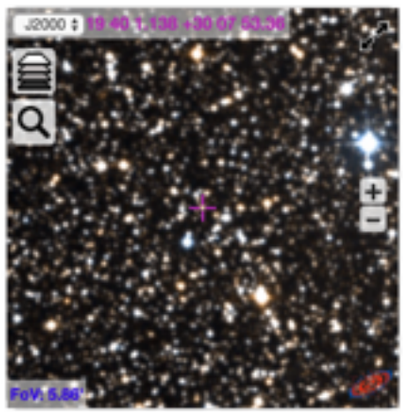
http://gsaweb.ast.cam.ac.uk/alerts/alert/Gaia16aye/

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

<< previous next >>

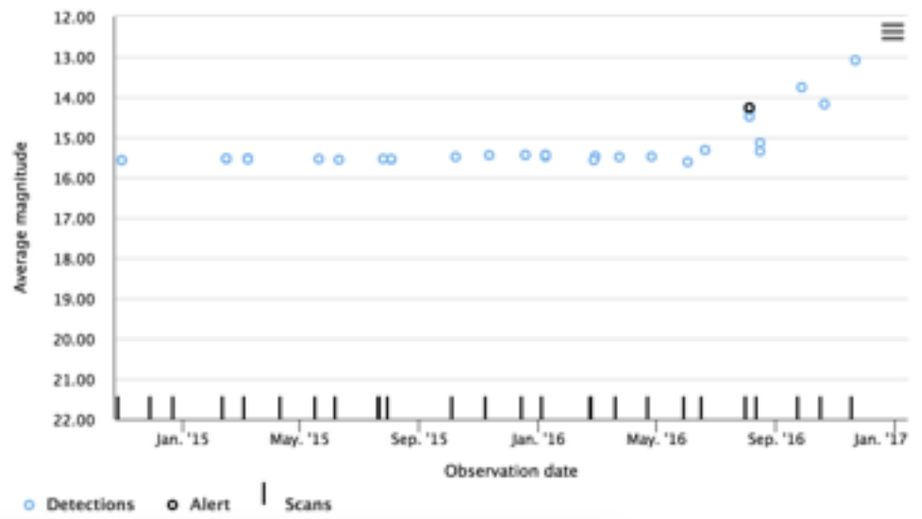
Gaia16aye

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.

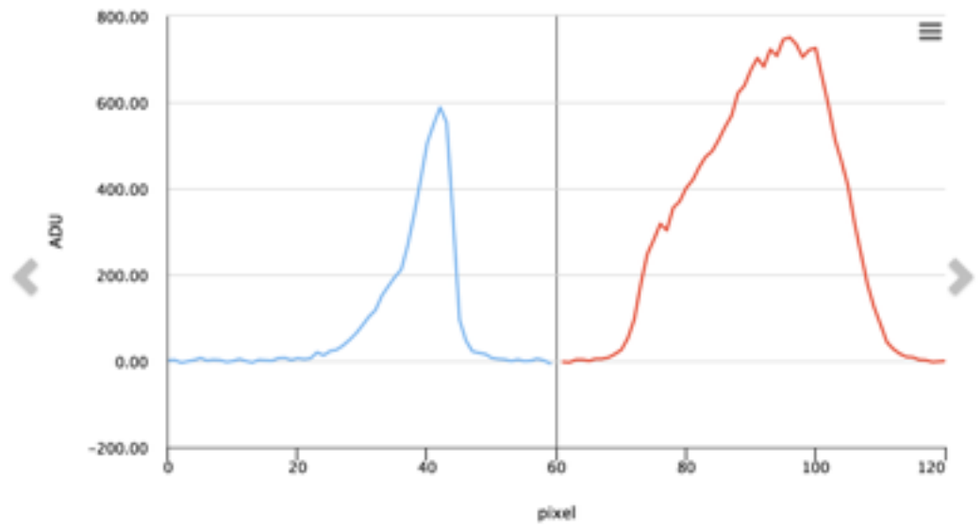


Other surveys detections
None
Comments
1.2 mag rise in red star near Galactic Plane
ATels
9376 9507 9533 9753 9770 9780

Get lightcurve data

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

2016-06-02 20:18:58	2457542.35	15.62
2016-06-20 04:10:14	2457559.67	15.32
2016-08-05 00:53:52	2457605.54	14.27
2016-08-05 02:40:26	2457605.61	14.28
2016-08-05 06:54:06	2457605.79	14.49
2016-08-05 08:40:40	2457605.86	14.34
2016-08-15 14:47:03	2457616.12	15.14
2016-09-27 13:28:37	2457659.06	13.76
2016-10-21 05:33:21	2457682.73	14.18



PUBLISHING

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

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

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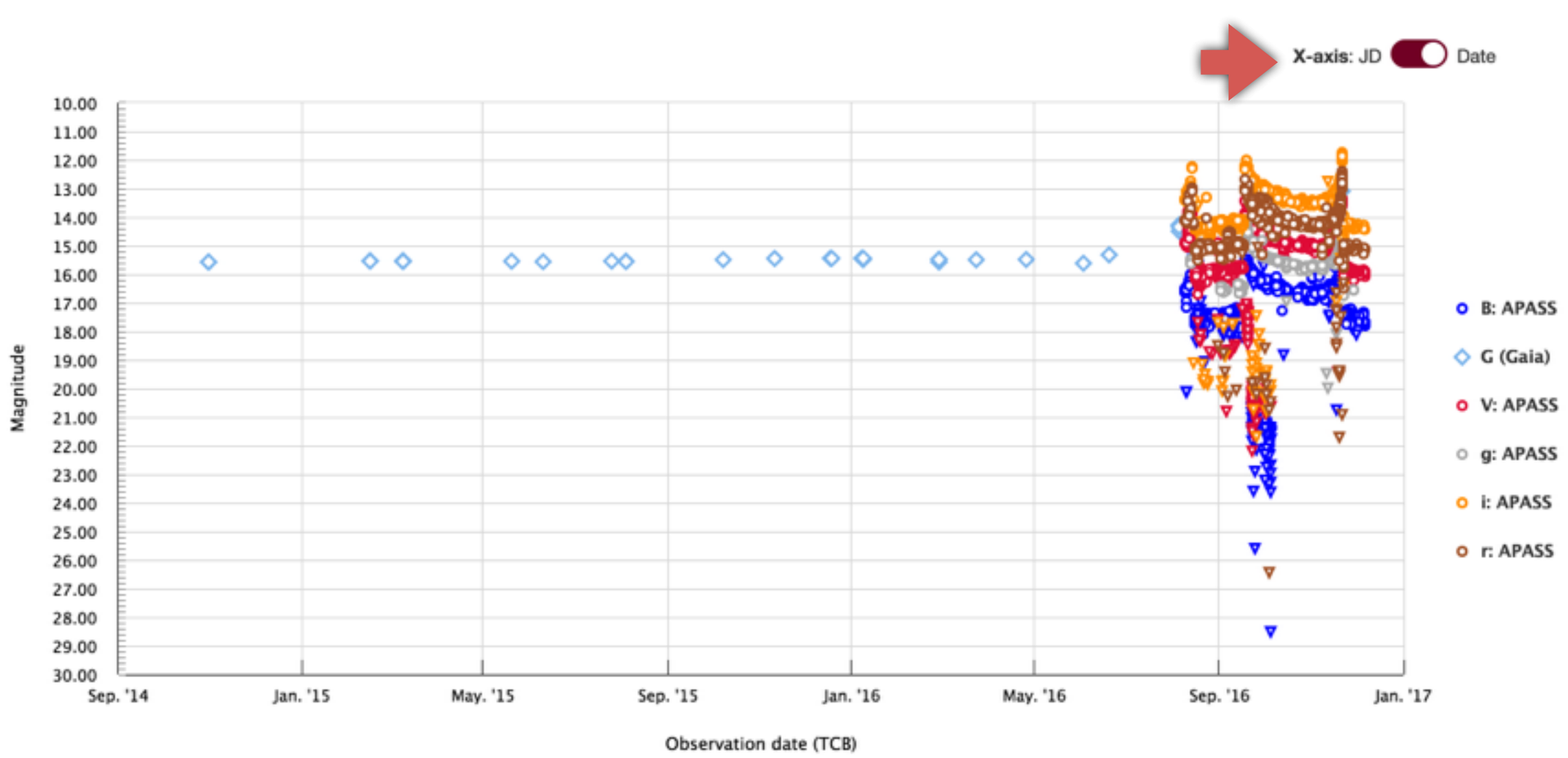
Gaia16aye

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.



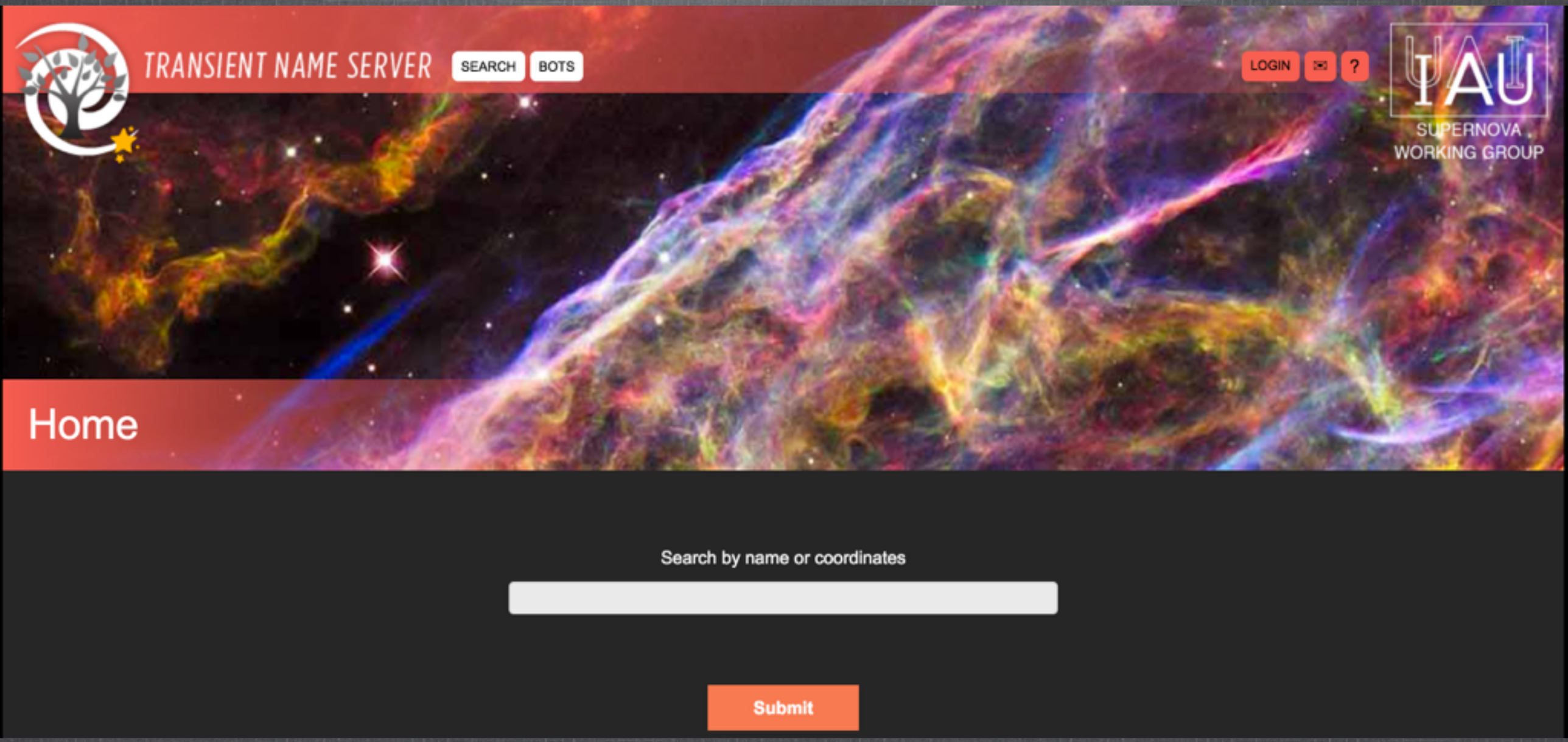
STATS 2015

```
1980 objects were discovered by PS1 (prof)
 267 objects were discovered by CRTS (prof)
 240 objects were discovered by OGLE (prof)
 182 objects were discovered by ASAS-SN (prof)
 135 objects were discovered by Dark Energy Survey (prof)
 127 objects were discovered by PTF (prof)
 112 objects were discovered by Gaia (prof)
  87 objects were discovered by High Cadence Transient Survey (HiTS) (prof)
  62 objects were discovered by MASTER (prof)
  60 objects were discovered by Subaru/Hyper Suprime-Cam (prof)
  49 objects were discovered by La Silla-QUEST (prof)
  26 objects were discovered by Kamil Hornoch et al.
  22 objects were discovered by THU-NAOC Transient Survey (TNTS) (prof)
  20 objects were discovered by Italian Supernovae Search Project
  19 objects were discovered by SPitzer InfraRed Intensive Transients Survey (prof)
  17 objects were discovered by Tim Puckett, Jack Newton, et al.
  16 objects were discovered by Koichi Itagaki
  13 objects were discovered by LOSS (prof)
  13 objects were discovered by Stu Parker
   9 objects were discovered by Xing Gao et al. (prof)
   5 objects were discovered by Berto Monard
   5 objects were discovered by Ron Arbour
   5 objects were discovered by SkyMapper (prof)
```

STATS 2016

```
3797 objects were discovered by PS1 (prof)
 897 objects were discovered by Gaia (prof)
 323 objects were discovered by CRTS (prof)
 177 objects were discovered by ATLAS (prof)
 177 objects were discovered by OGLE (prof)
 155 objects were discovered by ASAS-SN (prof)
  98 objects were discovered by PTF (prof)
  62 objects were discovered by Dark Energy Survey (prof)
  45 objects were discovered by MASTER (prof)
  44 objects were discovered by PMO-Tsinghua Supernova Survey (PTSS) (prof)
  35 objects were discovered by La Silla-QUEST (prof)
  23 objects were discovered by TNTS (prof)
  23 objects were discovered by Tim Puckett, Jack Newton, et al.
  20 objects were discovered by Kamil Hornoch et al.
  20 objects were discovered by Stu Parker
  17 objects were discovered by LOSS (prof)
  13 objects were discovered by Italian Supernovae Search Project
  11 objects were discovered by Xing Gao et al. (prof)
   9 objects were discovered by SkyMapper (prof)
   7 objects were discovered by Koichi Itagaki
   7 objects were discovered by SPitzer InfraRed Intensive Transients Survey (prof)
   6 objects were discovered by Emmanuel Conseil
   5 objects were discovered by Koichi Nishiyama and Fujio Kabashima
   4 objects were discovered by Ron Arbour
   3 objects were discovered by Leonardo Tartaglia
   2 objects were discovered by GSST / Constantine Emmanouilidi / Emelie Selander
   2 objects were discovered by Grzegorz Duszanowicz and Michal Zolnowski
   2 objects were discovered by HST (prof)
```

TNS



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

TNS

ID	Name	Reps	Class	RA	DEC	Type	Redshift	Host Name	Host Redshift	Source Group	Disc. Internal Name	Public	Object Spectra	Discovery Mag	Discovery Mag Filter	Discovery Date (UT)	Sender
16584	AT 2016iqi	1		12:50:26.51	-22:40:27.88					GaiaAlerts	Gaia16bzg	Y		18.53	G-Gaia	2016-11-29 19:07:40	Gaia_Bot1
16583	AT 2016iqh	1		03:35:39.91	-38:39:32.33					GaiaAlerts	Gaia16bzf	Y		18.71	G-Gaia	2016-11-28 22:49:26	Gaia_Bot1
16582	AT 2016iqg	1		12:40:34.39	-21:13:26.83					GaiaAlerts	Gaia16bze	Y		18.94	G-Gaia	2016-11-28 19:06:14	Gaia_Bot1
16581	AT 2016iqf	1		22:39:38.29	+52:41:20.51					GaiaAlerts	Gaia16bzd	Y		18.39	G-Gaia	2016-11-29 16:53:45	Gaia_Bot1
16580	AT 2016iqe	1		22:24:52.10	+52:05:38.11					GaiaAlerts	Gaia16bzc	Y		17.91	G-Gaia	2016-11-29 04:55:12	Gaia_Bot1
16579	AT 2016iqd	1		17:52:11.81	+57:24:47.88					GaiaAlerts	Gaia16bzb	Y		18.32	G-Gaia	2016-11-29 11:29:45	Gaia_Bot1

ID	Name	Reps	Class	RA	DEC	Type	Redshift	Host Name	Host Redshift	Source Group	Disc. Internal Name	Public	Object Spectra	Discovery Mag	Discovery Mag Filter	Discovery Date (UT)	Sender
16543	SN 2016iou	1	1	01:24:26.61	-02:08:26.05	SN Ia	0.042			GaiaAlerts	Gaia16byl	Y	1	17.39	G-Gaia	2016-11-26 03:50:24	Gaia_Bot1
16299	SN 2016ifk	2	2	02:47:33.24	-26:29:21.98	SN Ia	0.058			GaiaAlerts	Gaia16bvs	Y	2	17.65	G-Gaia	2016-11-16 03:11:31	Gaia_Bot1

TNS

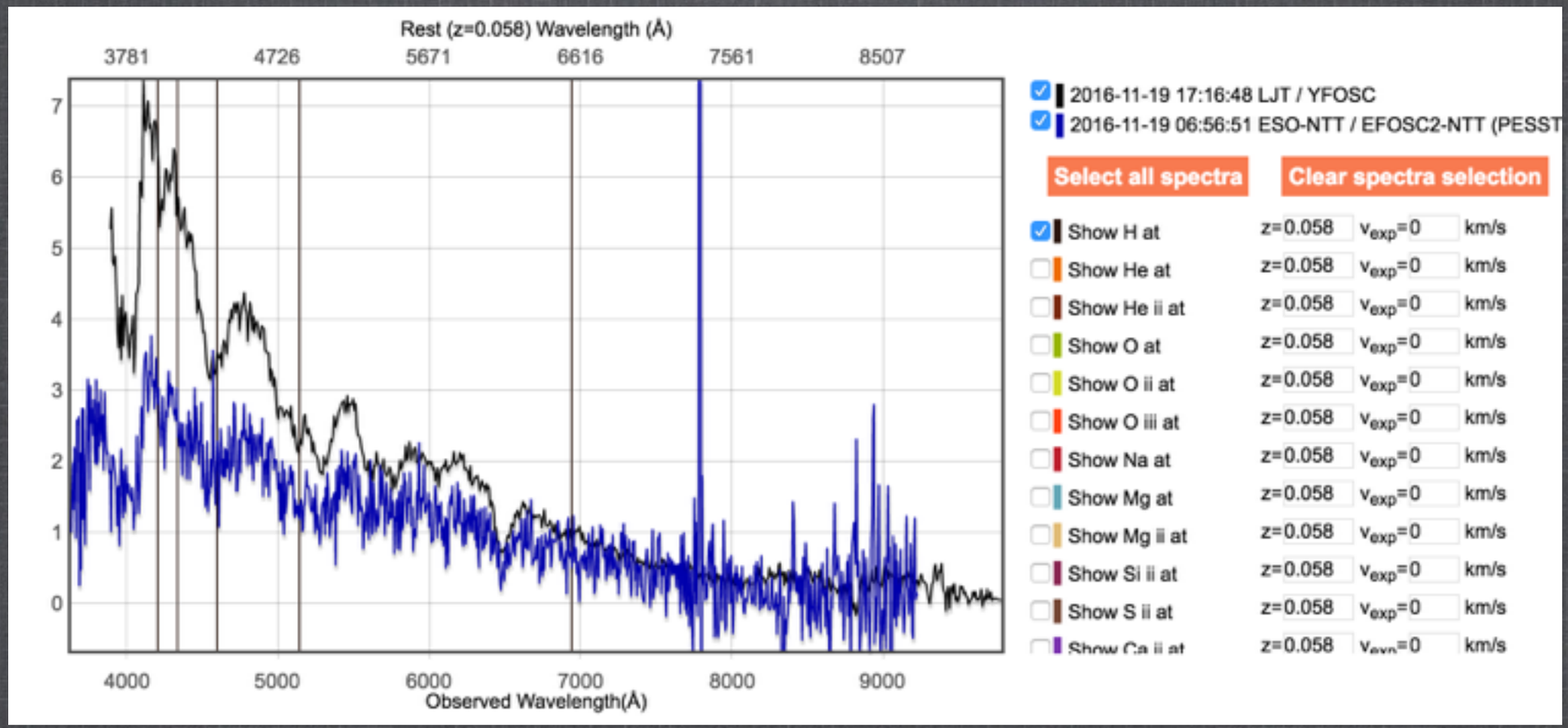
SN 2016ifk

RA/DEC (2000)	Type	Redshift
02:47:33.24 -26:29:21.98	**SN Ia**	**0.058**
41.8885 -26.489439		

NED | SIMBAD | VizieR | WISE | DSS | ADS

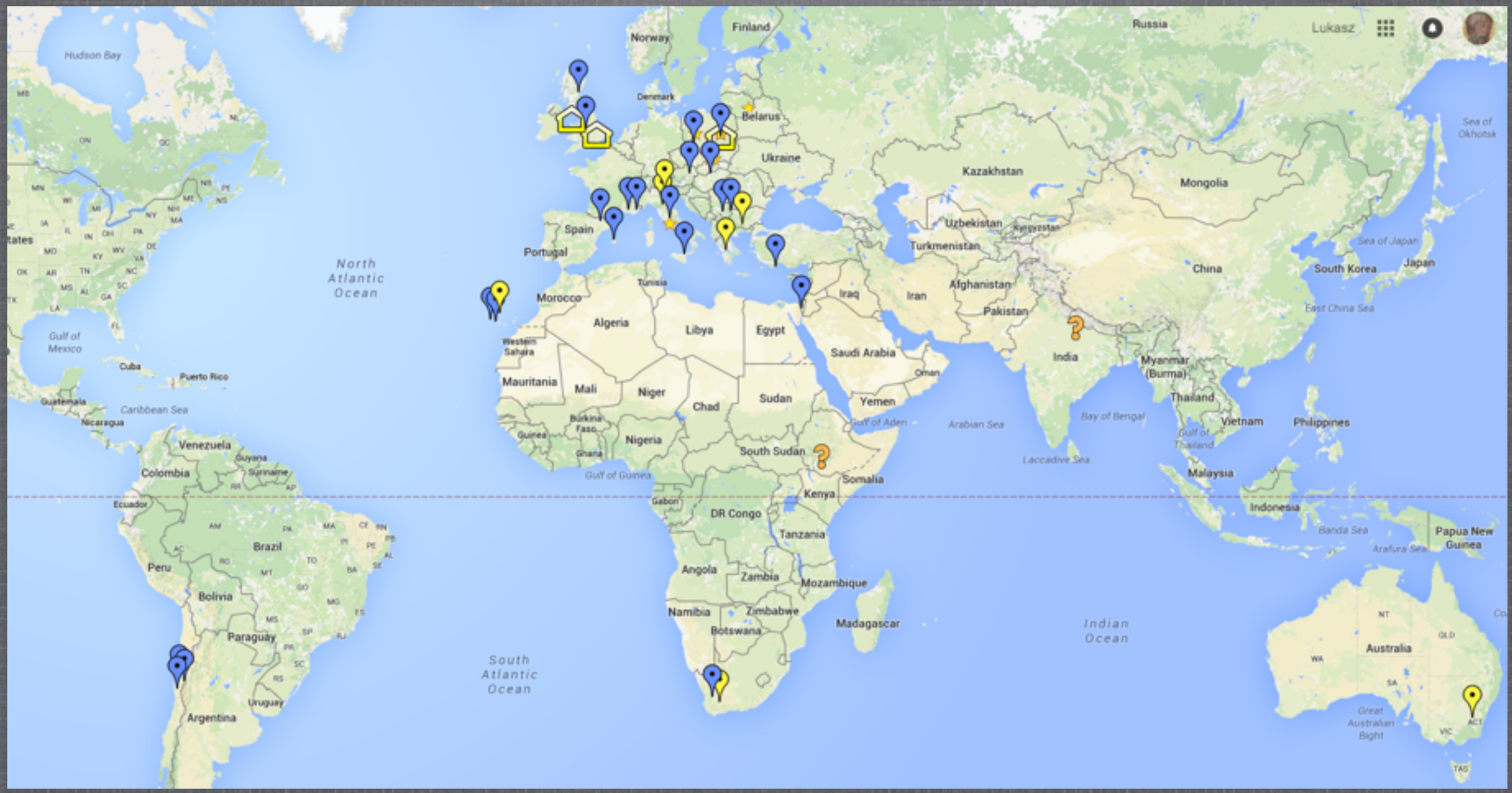
Source Group	Discoverer	Discovery Date	TNS AT	Public	Discovery Mag
GaiaAlerts	**GaiaAlerts**	**2016-11-16 03:11:31**	**Y**	**Y**	**17.65**

Discovery Mag Filter
G-Gaia



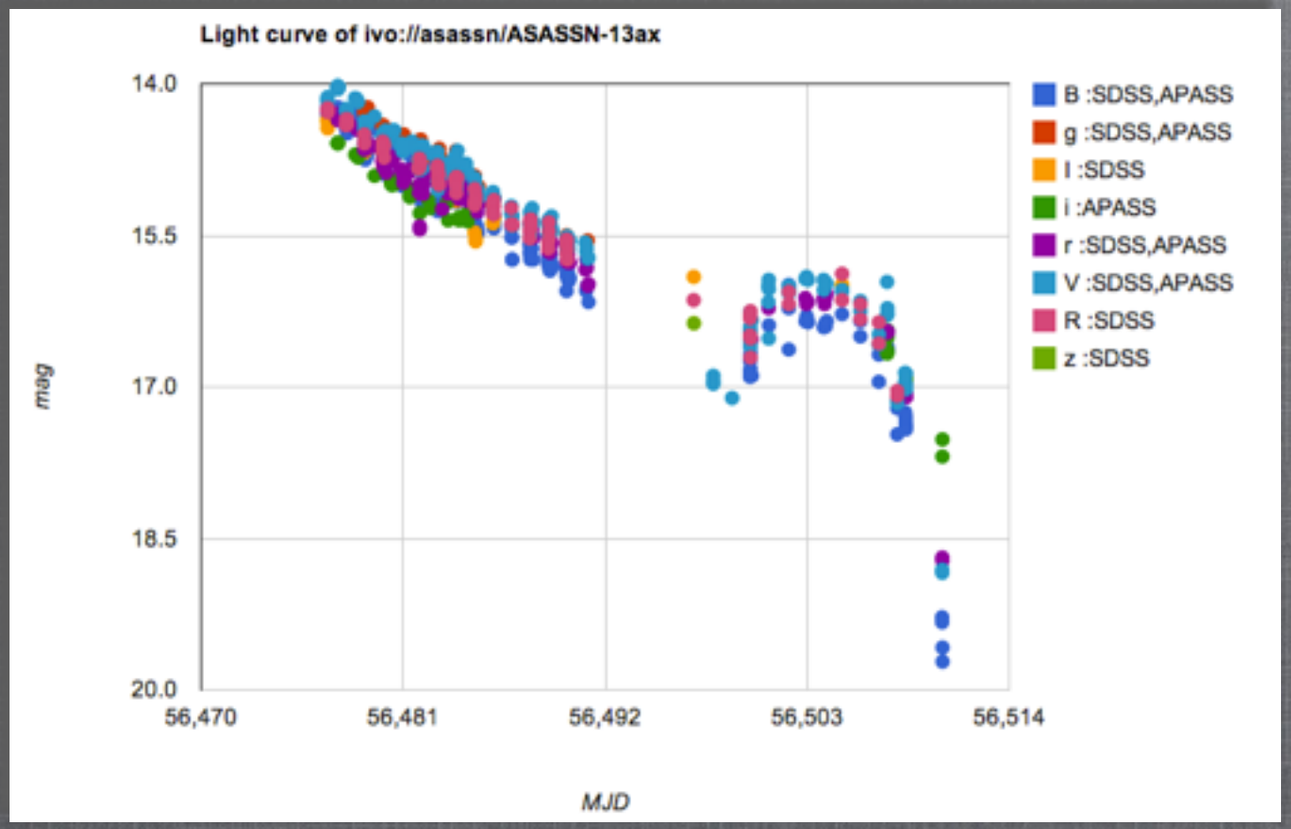
OPTICON FOLLOW-UP NETWORK

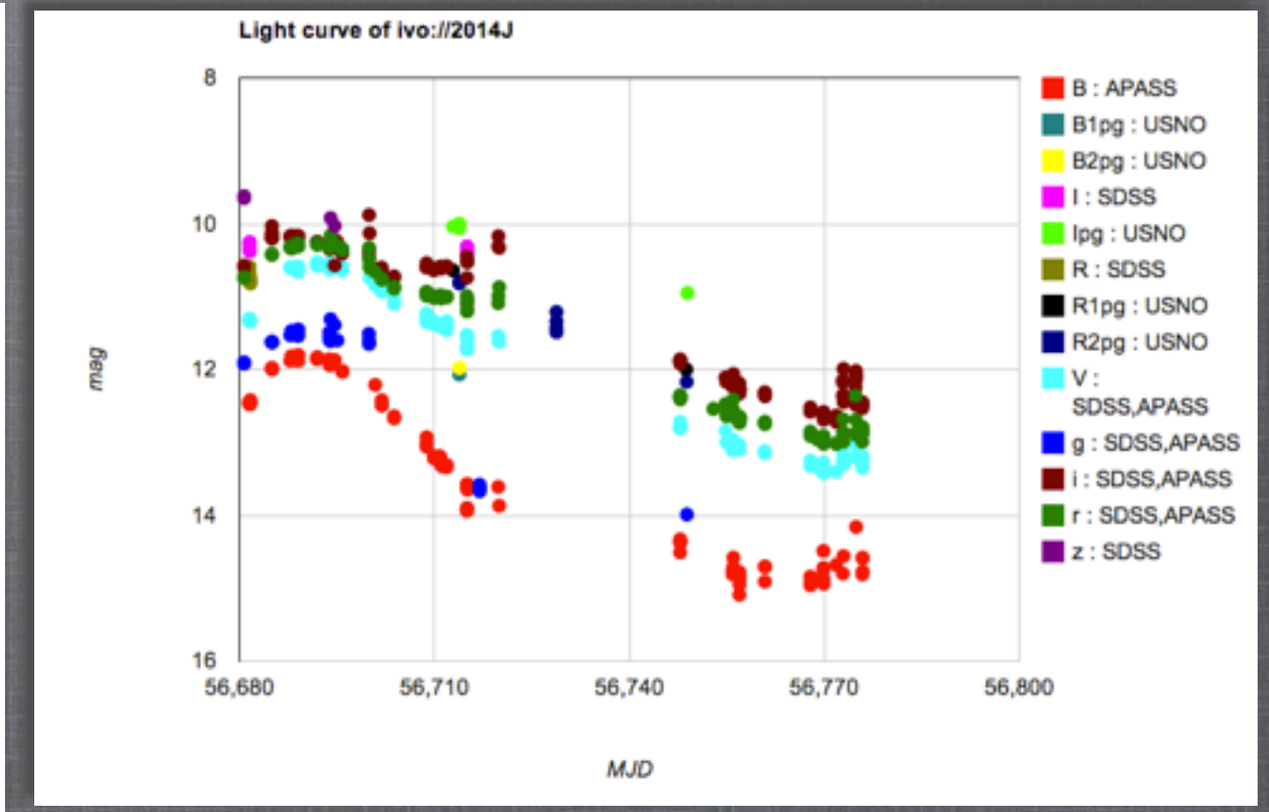
~20 active partners, ~30000 data points collected 2014-2016



FOLLOW-UP CALIBRATION SERVER

gsaweb.ast.cam.ac.uk/followup/





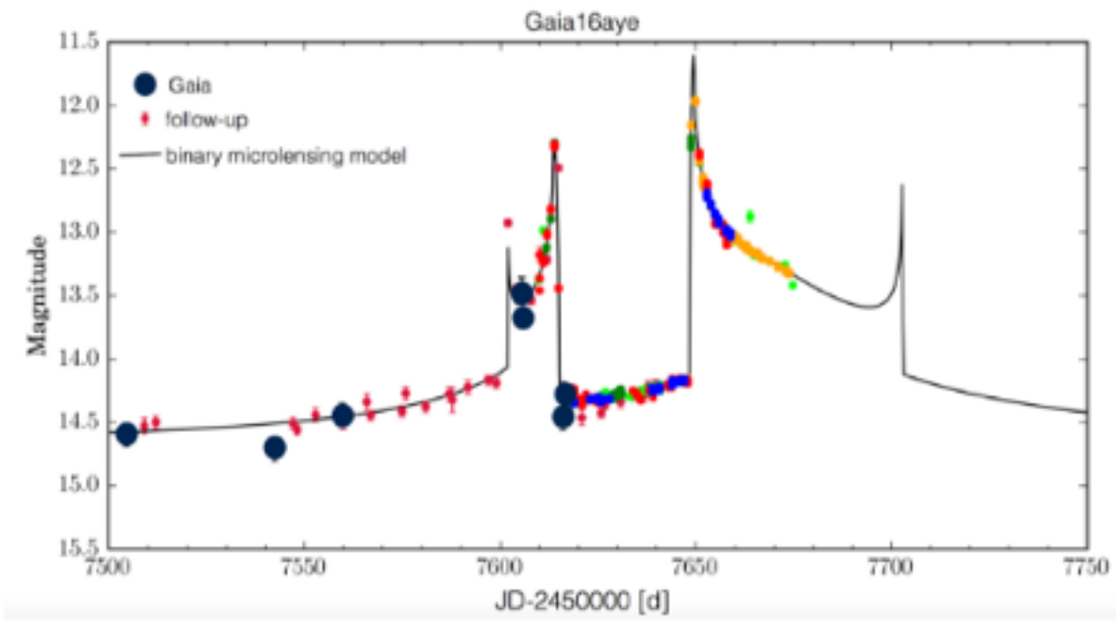
GAIA16AYE (AYERS ROCK)

First binary microlensing event outside of the Galactic Bulge

Follow-up was essential!

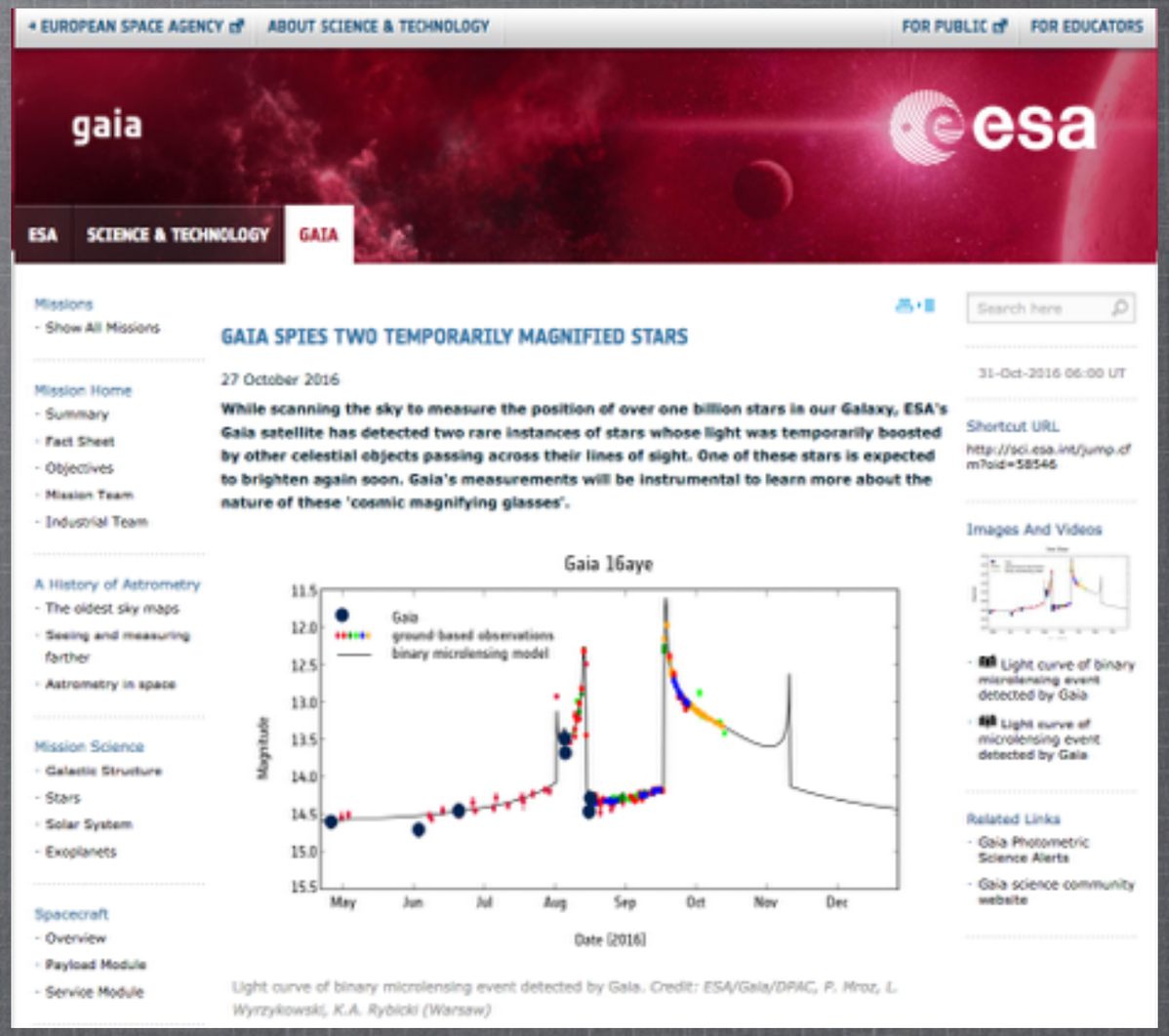
IMAGE OF THE WEEK

FOLLOW-UP OPPORTUNITY OF A RARE MICROLENSING EVENT



Light curve of the microlensing event Gaia16aye, composed by data from Gaia (dark spots) and supported by data from ground-based follow-up telescopes (each colour indicates a different observatory). The solid black line shows the current best microlensing model computed by Przemek Mróz. The sharp rises are called caustic crossings as explained in the text below.

http://www.cosmos.esa.int/web/gaia/IoW_20161027



http://sci.esa.int/gaia/58546-gaia-spies-two-temporarily-magnified-stars/

Involves AAVSO (US), amateurs from Italy, schools via LCOGT/Cardiff.
Will add German amateurs associations.

will be published as a scientific paper soon

NOTE ON ATELS

The Astronomer's Telegram

Gaia16bhp, Gaia16bhq, Gaia16bht and Gaia16bhj transients confirmed by Mercator/Maia imaging

ATel #9525; *S. Blanco-Cuaresma, T. Semaan, M. Roelens, L. Palaversa, N. Mowlavi, L. Eyer*
(Department of Astronomy, University of Geneva, Switzerland)
on 21 Sep 2016; 17:16 UT

The photometric calibrations were obtained using the Cambridge Photometric Calibration Server (CPCS), designed and maintained by Sergey Koposov and Lukasz Wyrzykowski. We acknowledge ESA Gaia, DPAC and the Photometric Science Alerts Team (http://gsaweb.ast.cam.ac.uk/alerts).

NEW CHALLENGES FOR 2017+

- lower thresholds - more alerts
- need for full automatisation
  (downside: more false alerts)
- calibrated BP-RP:
  full exploitation of transients spectra for classification
- improved astrometry of transients, to ~1mas
- photometric follow-up – towards robotisation
- spectroscopic follow-up – expand network