GAIA AS A TRANSIENT SURVEY

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PEOPLE INVOLVED

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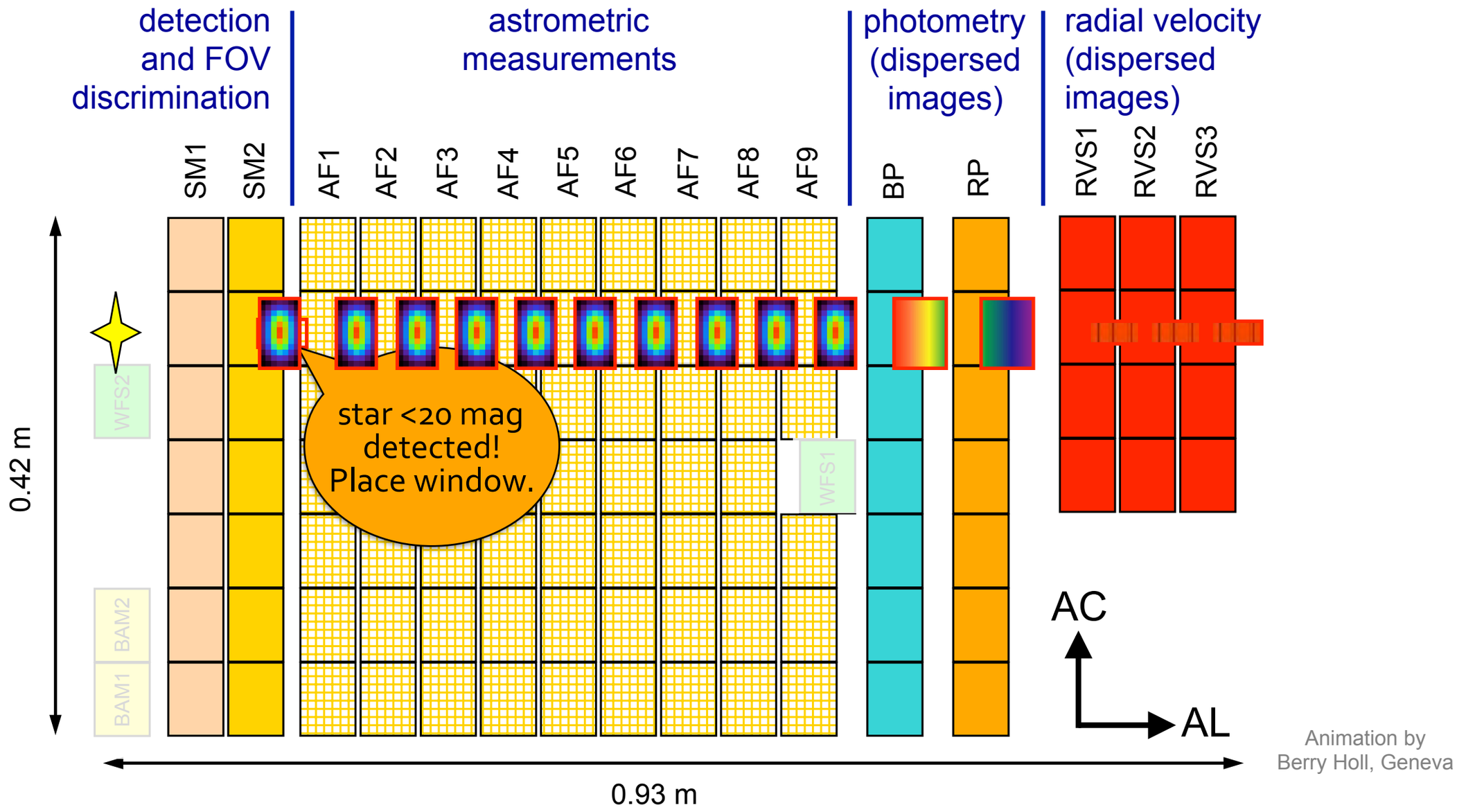
Michał Pawlak
Krzysztof Rybicki
OGLE team

SINGLE GAIA OBSERVATION = TRANSIT

Camera:

0.75 deg²

pixel:
10x30 µm
(59x177 mas)



Animation by
Berry Holl, Geneva

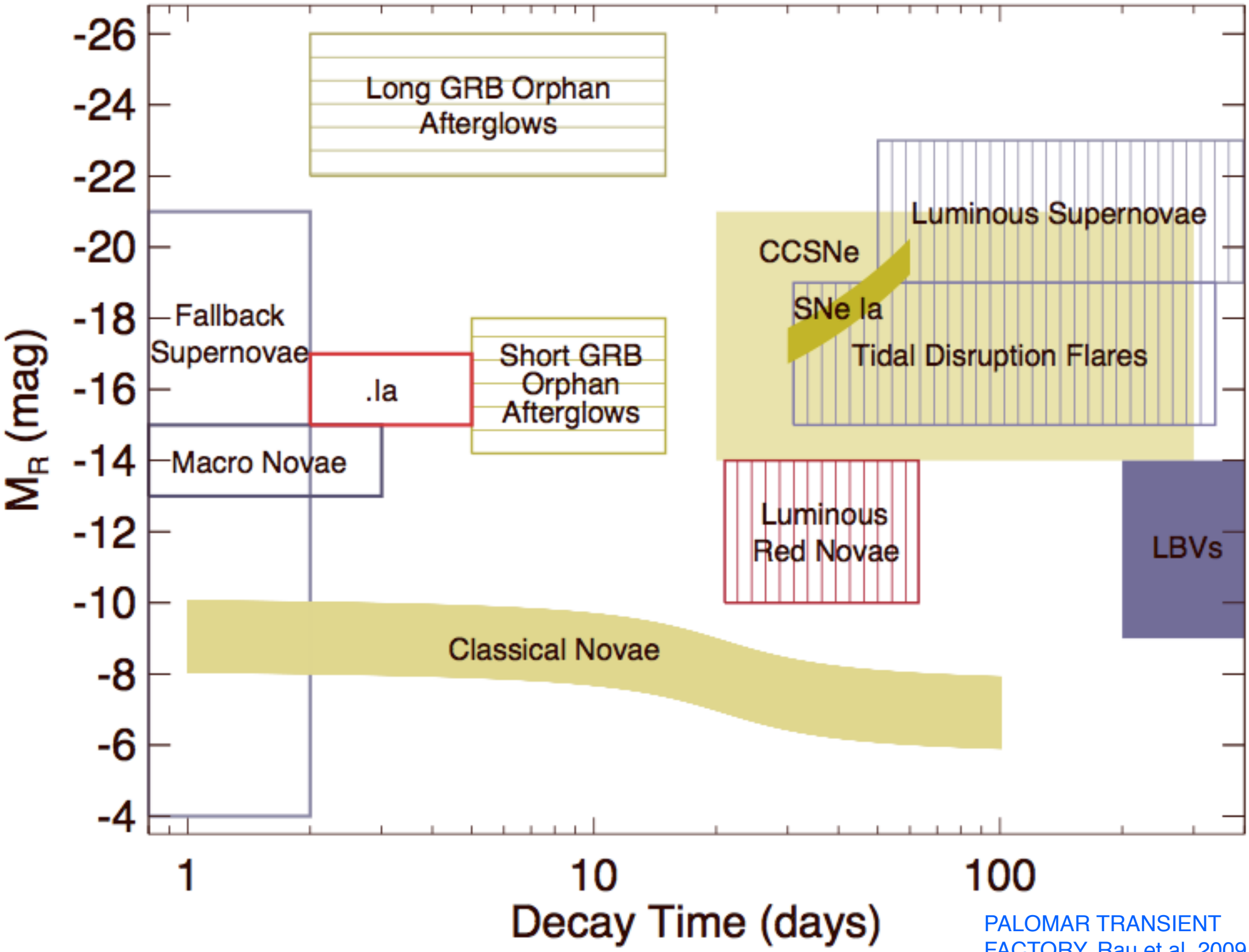
windows observed:

→ ~4.4 sec

~45 sec

GAIA AS A TRANSIENT SURVEY

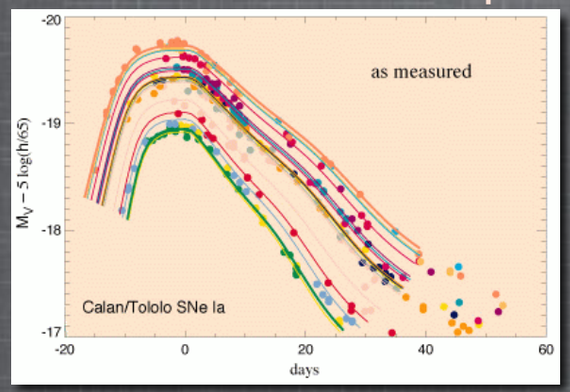
	Gaia	Catalina Sky Survey	PTF	OGLE-IV (Magellanic System only)	LSST (from 2020??)
deg	**≈ 1230**	1200	1000	150	5000
Avg Cadence	**≈ 30 days**	14 days	5 days	5 days	4 days
Limiting mag	**20 (21?)**	19.5	21	21	r=24.7
f	**all sky**	0.6	0.2	0.02	<0.48

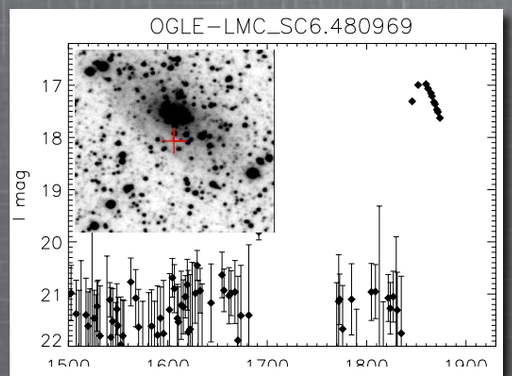


PALOMAR TRANSIENT FACTORY, Rau et al. 2009

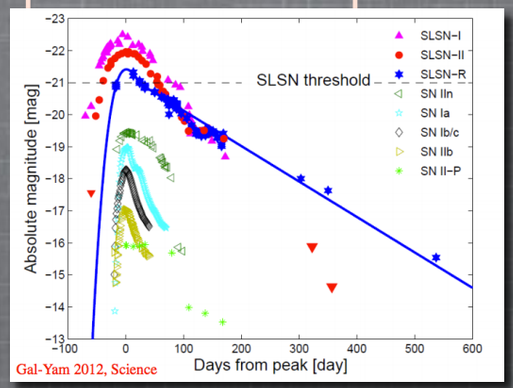
TRANSIENTS ZOO

Supernovae

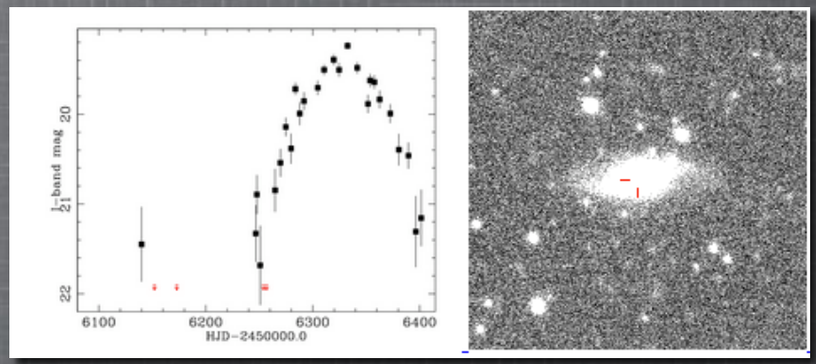




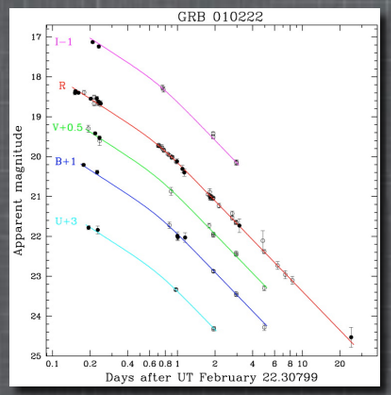
Super-luminous Supernovae



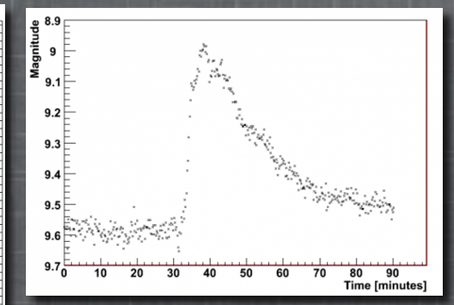
AGN flares/TDE



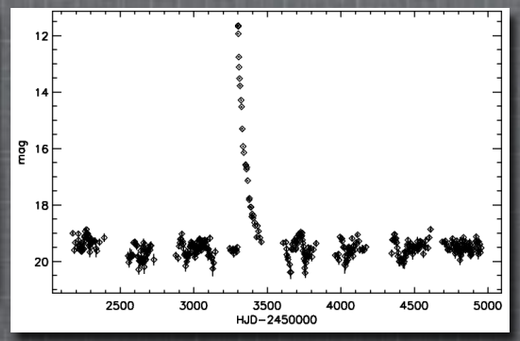
GRBs afterglows



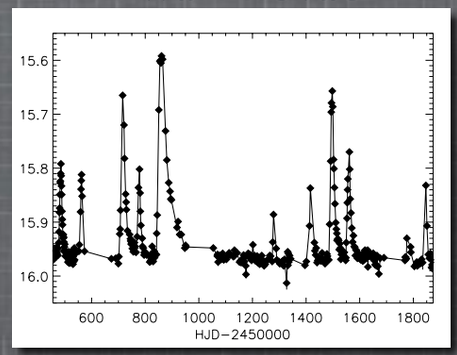
M-dwarf flares



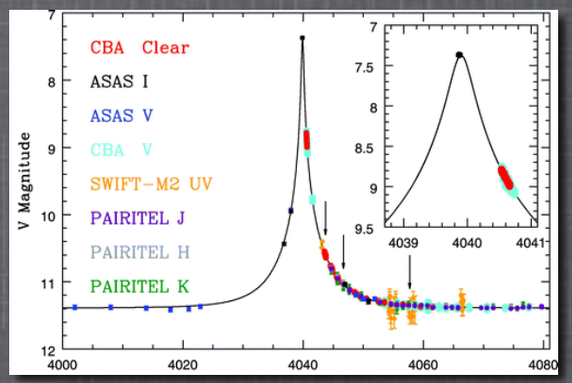
Classical novae



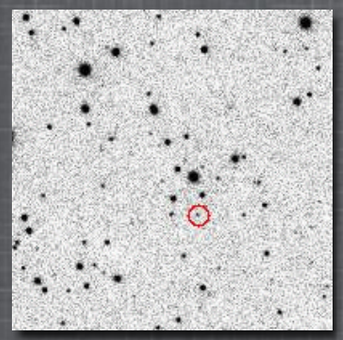
Dwarf novae



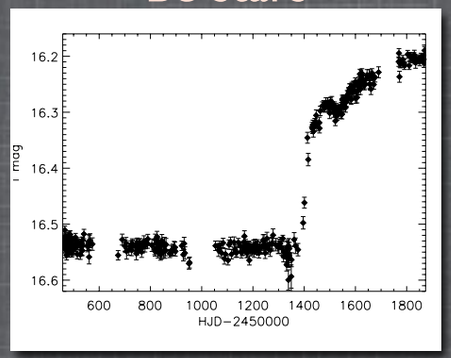
Microlensing events



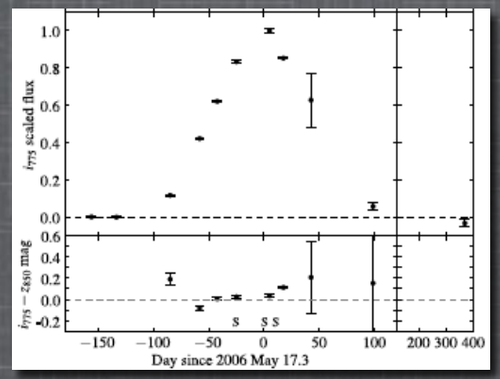
Asteroids



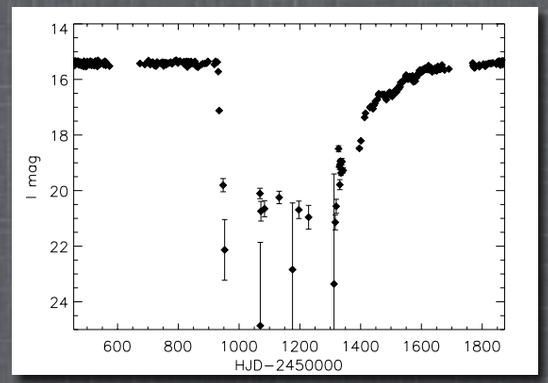
Be stars



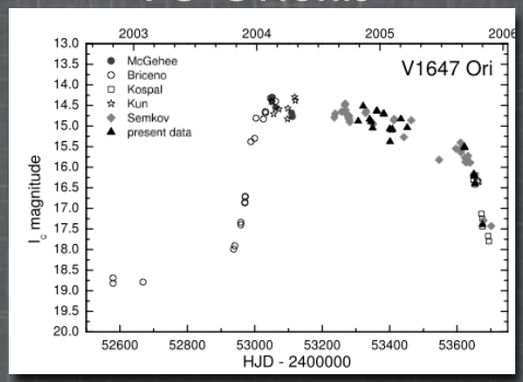
NEW THINGS??



R Coronae Borealis



FU Orionis



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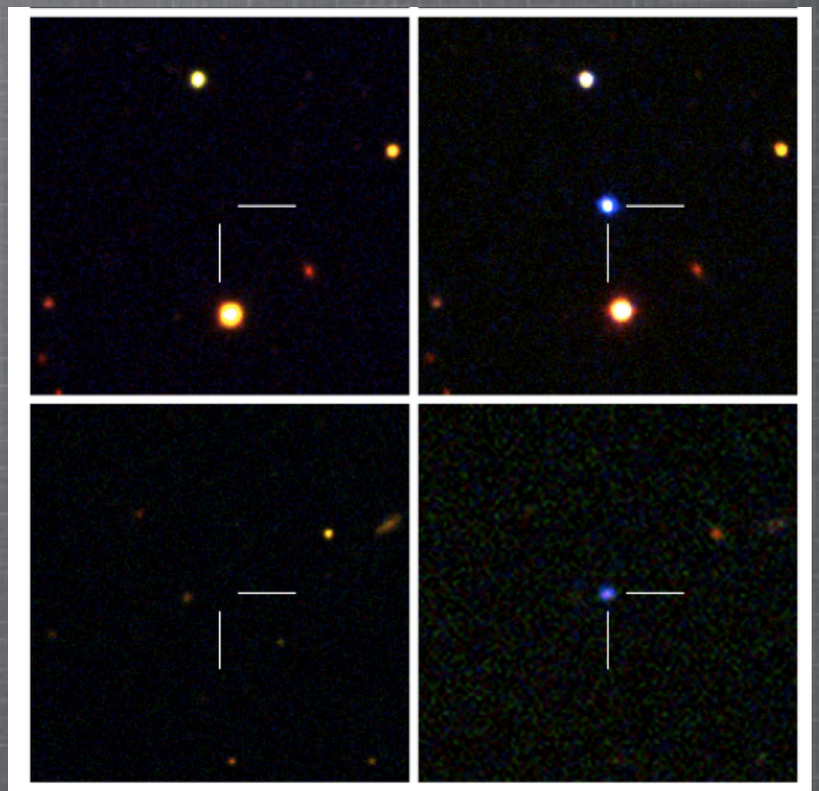
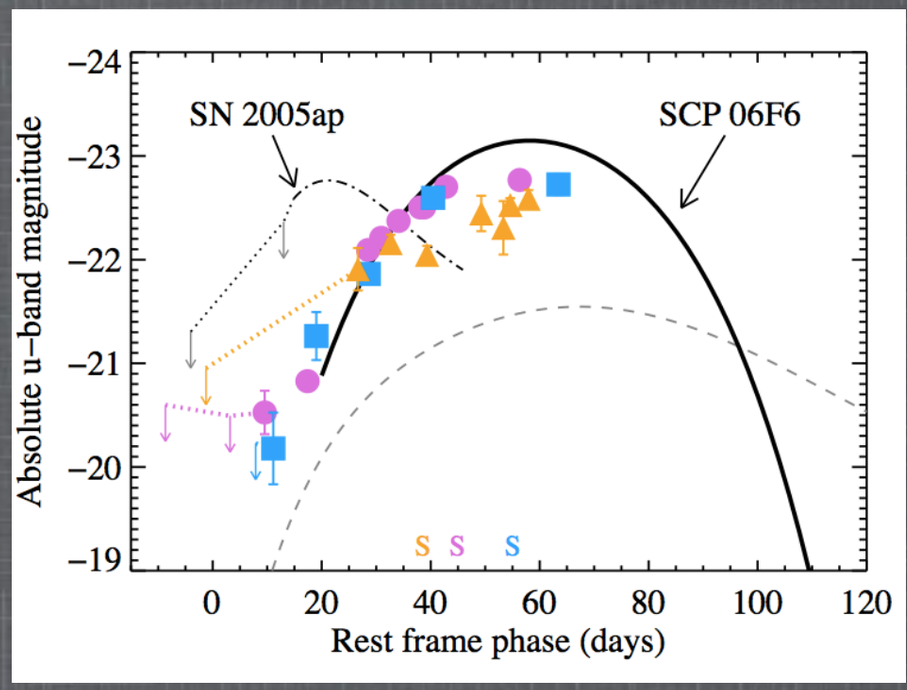
SUPERNOVAE IN GAIA

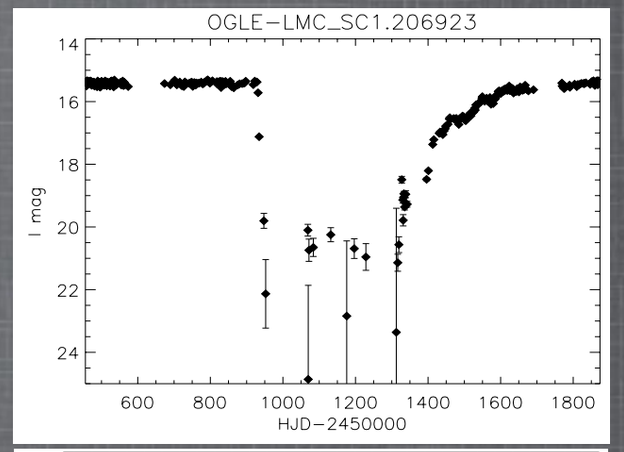
- **6000**
- **Local supernovae**
  calibration of the SNe cosmology projects.
- **Ultra-luminous Surpernovae:**
  curves, U band magnitude reaching -23, host galaxies faint, e.g. Quimby et al. (2010), link to the relationship between GRBs and SNe.
- **Large "unbiased" samples of core-collapse supernovae**
  and progenitors
- **Supernovae in galaxy cores:**
  metallicity, homogenous sample, Gaia's superb astrometry in use

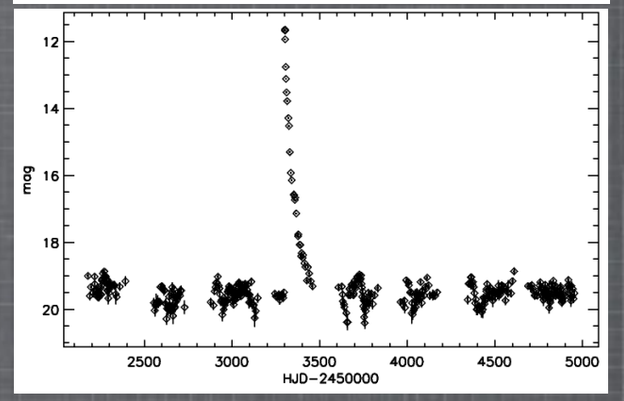


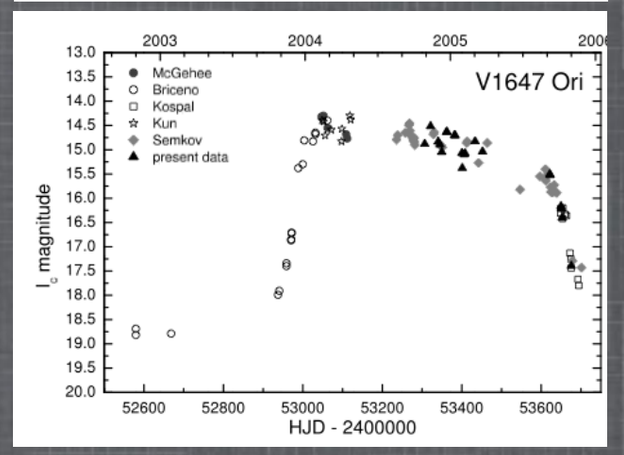


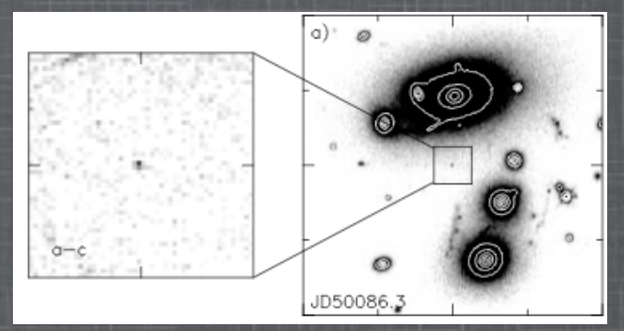
OTHER INTERESTING TRANSIENTS

- **RCrB-type stars**
  - carbon stars, emitting sooth
  - rare class (~50 known), but 3000 expected
  - can drop by 8 mag in a week - perfect time-scale for Gaia
- **GRB Afterglows**
  - very short duration events - expecting just a few
- **Classical and recurrent novae**
  - potential distance indicators
  - can be detected in MW and other galaxies
  - large amplitudes, wide range of time-scales
- **FU Orionis/EX Lupi**
  - unstable pre-MS stars
  - rare class (few known)
  - several magnitudes up, long time-scales
  - X-ray variability
  - FU Ori repeats every ~40 years!
- **Gravitationally lensed distant supernovae**
  - unique uniform all-sky monitoring
  - high redshift SNe rates, distances, H0



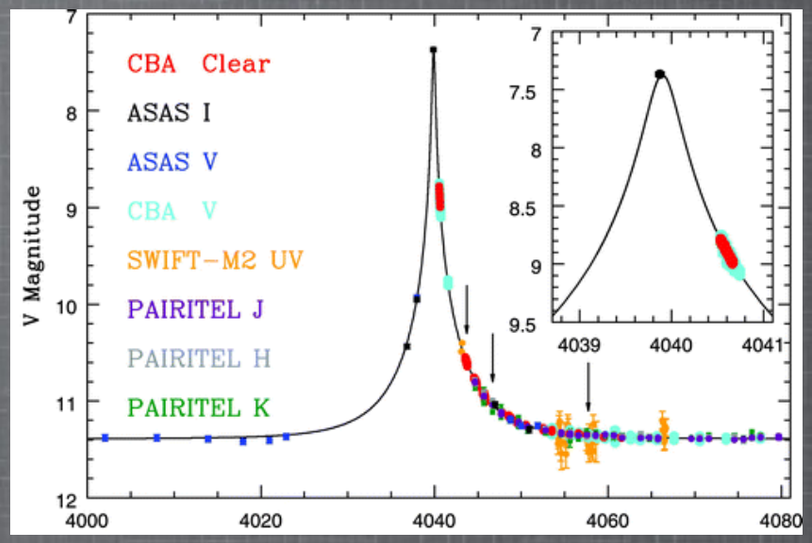


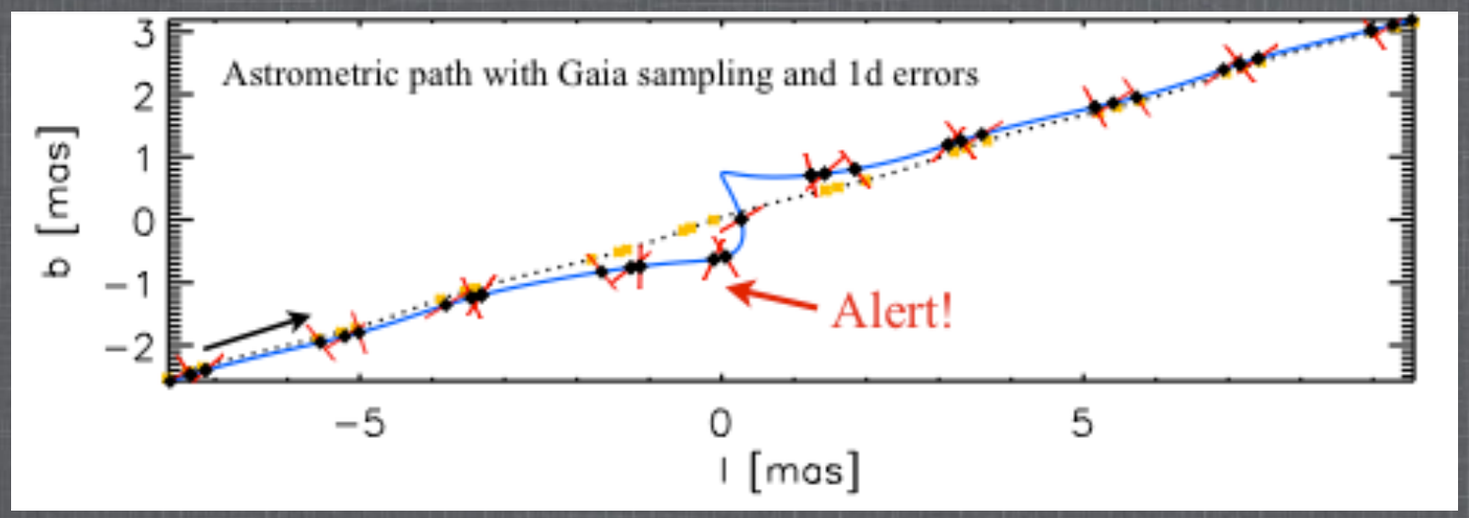


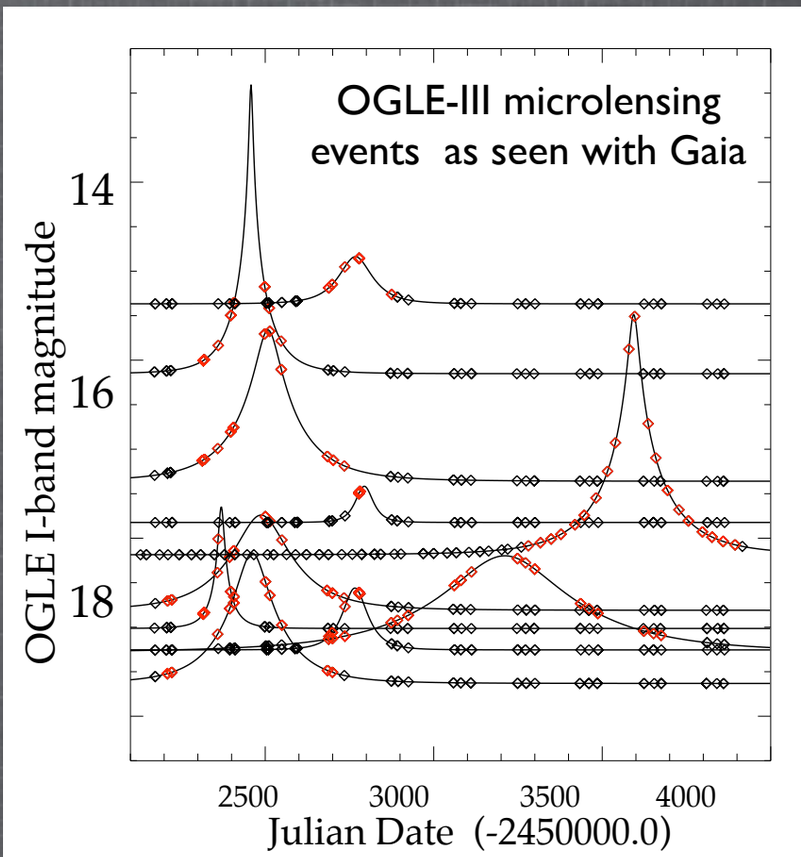


MICROLENSING IN GAIA

- 7,500 events expected during the mission,
  mainly in the Galactic Bulge but many lost (crowding)
- 15,000 astrometric events (higher optical depth)
- photometric alerts expected on 1000+ events,
  mainly long - the most interesting ones
  (nearby or massive lens)
- astrometric microlensing - unique opportunity with Gaia!
  - measure masses and distances of the dark lenses
  - detect black-holes: astrometric deviation of ~few mas

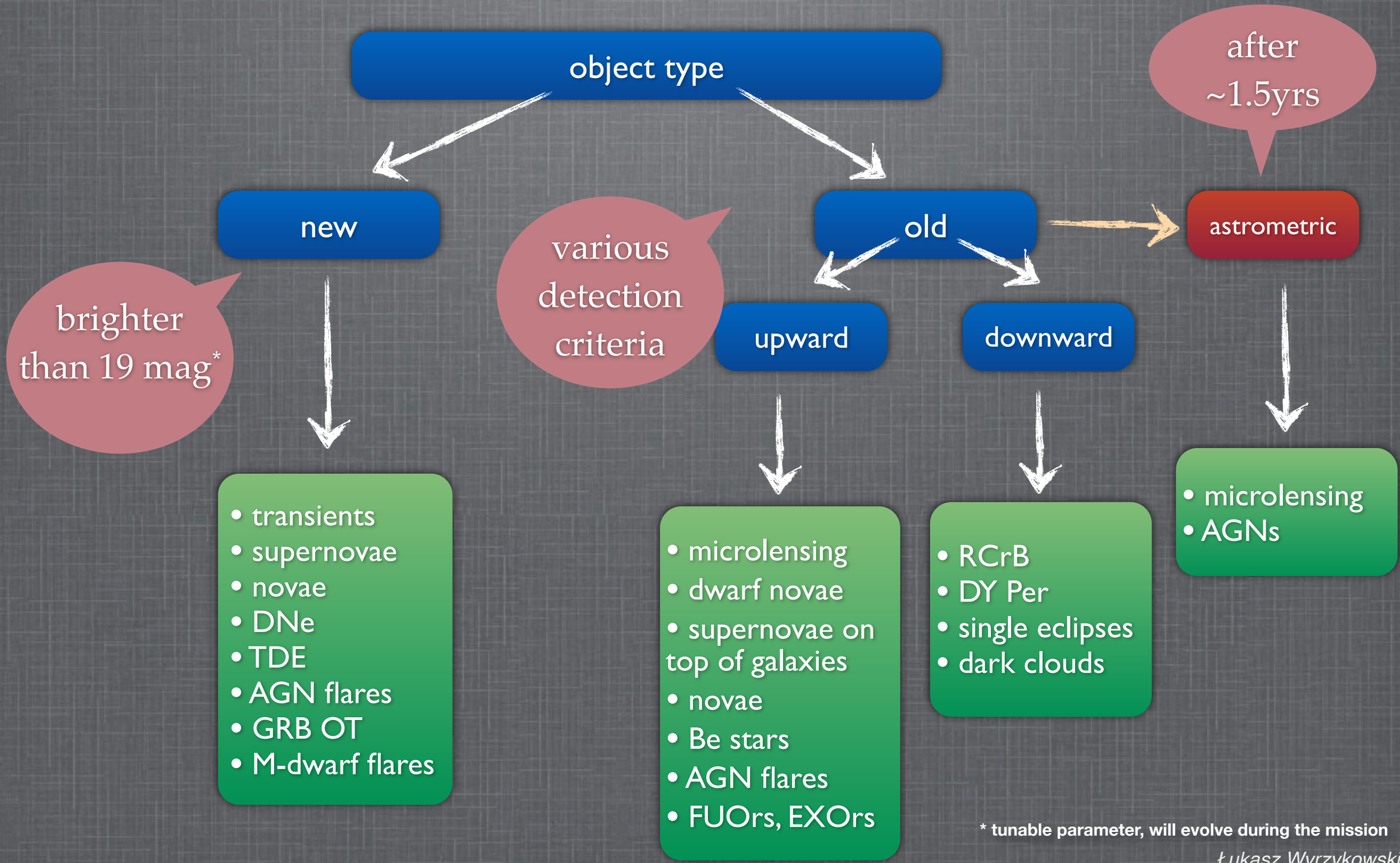






ANOMALY DETECTION SYSTEM

running in Cambridge on daily basis



* tunable parameter, will evolve during the mission

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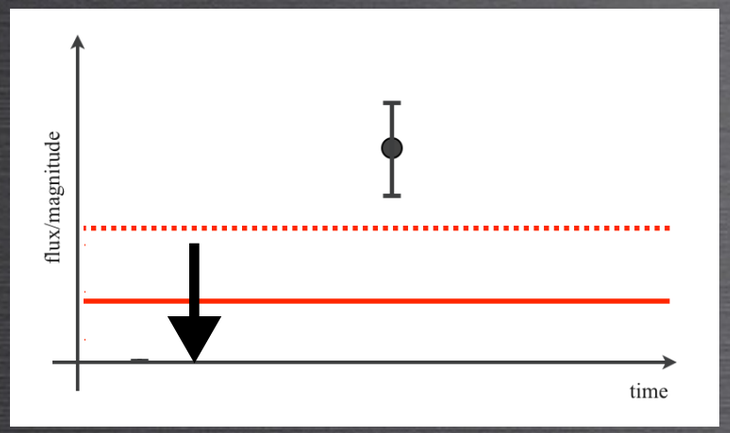
ANOMALY DETECTION SYSTEM

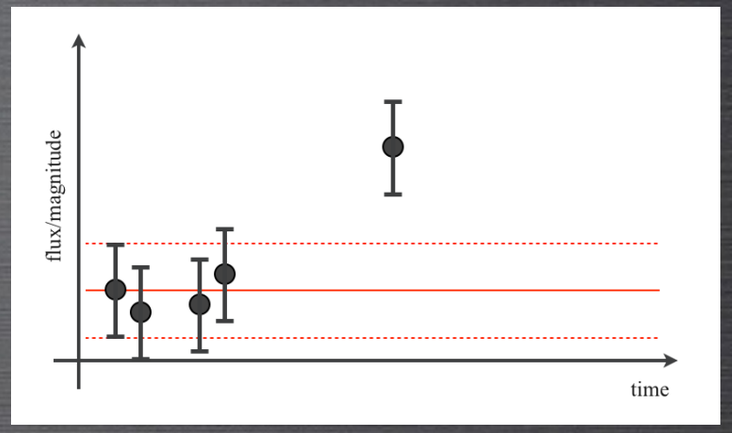
Classification



object type

new

old



transient

bump

artefact

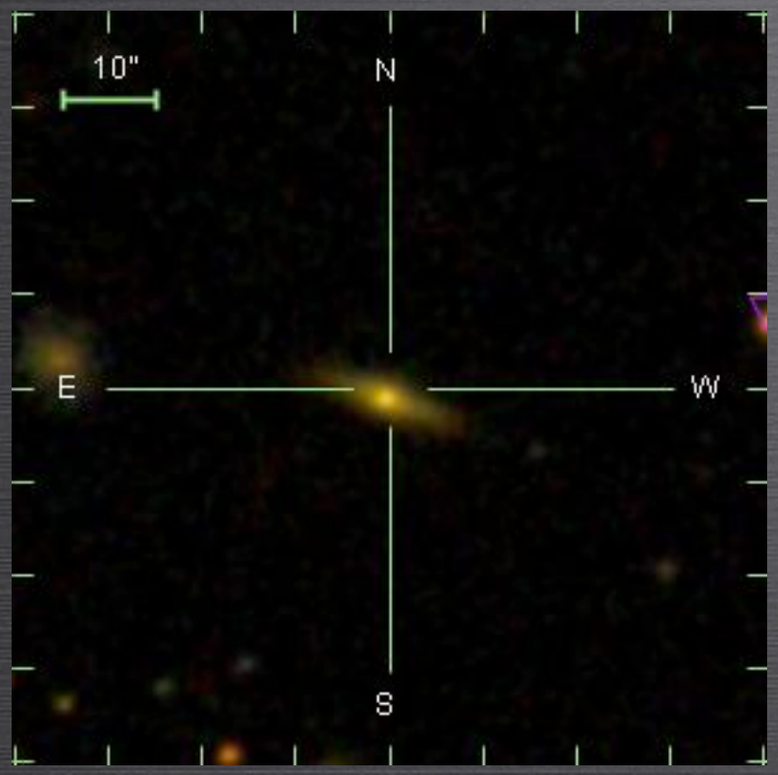
dip

work in progress:
expand with more sophisticated methods

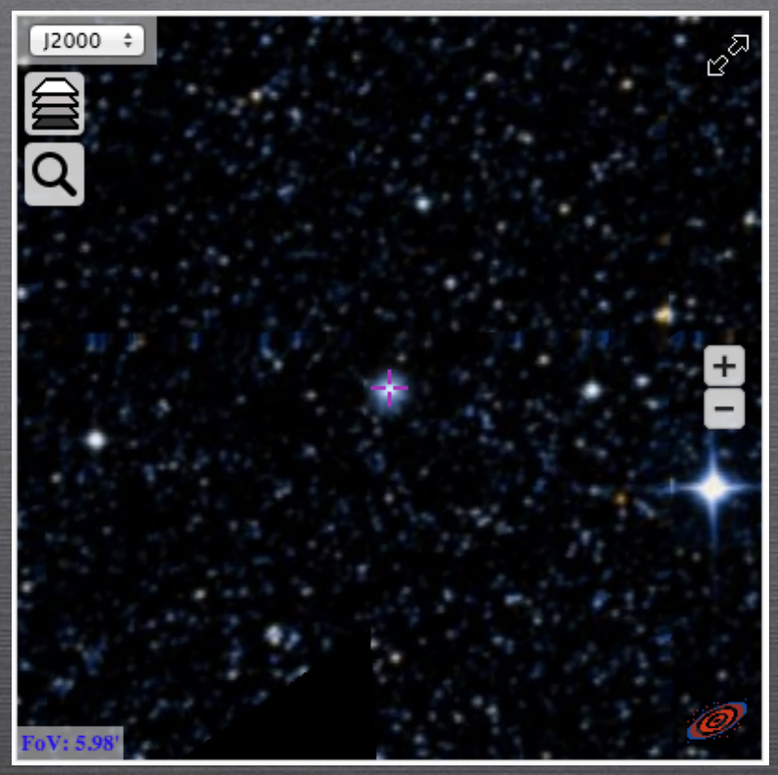
ANOMALY DETECTION SYSTEM

Cross-match with archives

SDSS



DSS



OGLE-IV

work in progress:
fully-automatise the cross-match

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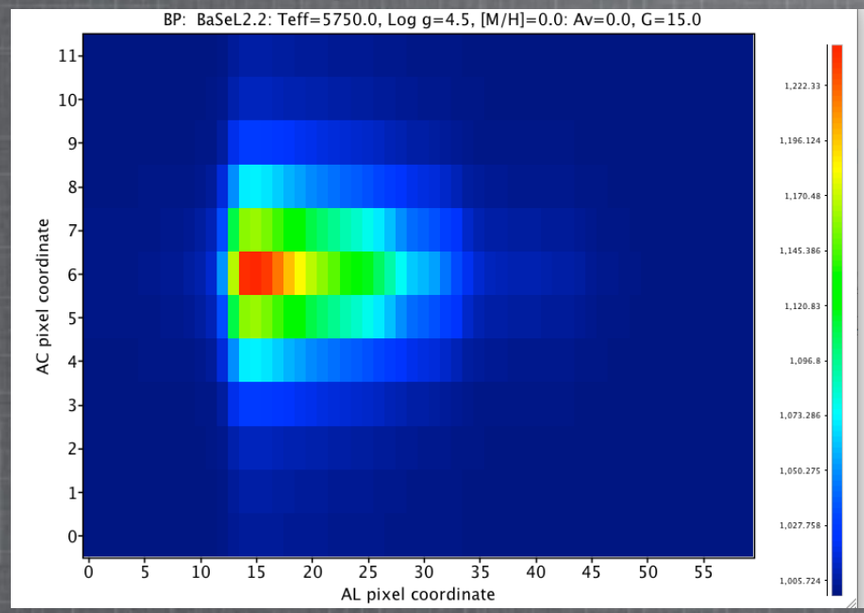
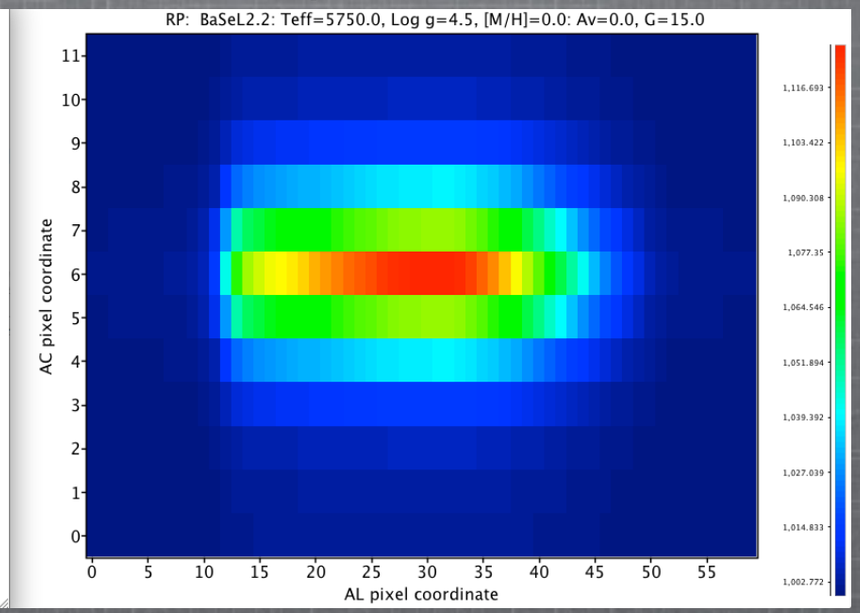
GAIA SPECTRA

Blue photometer

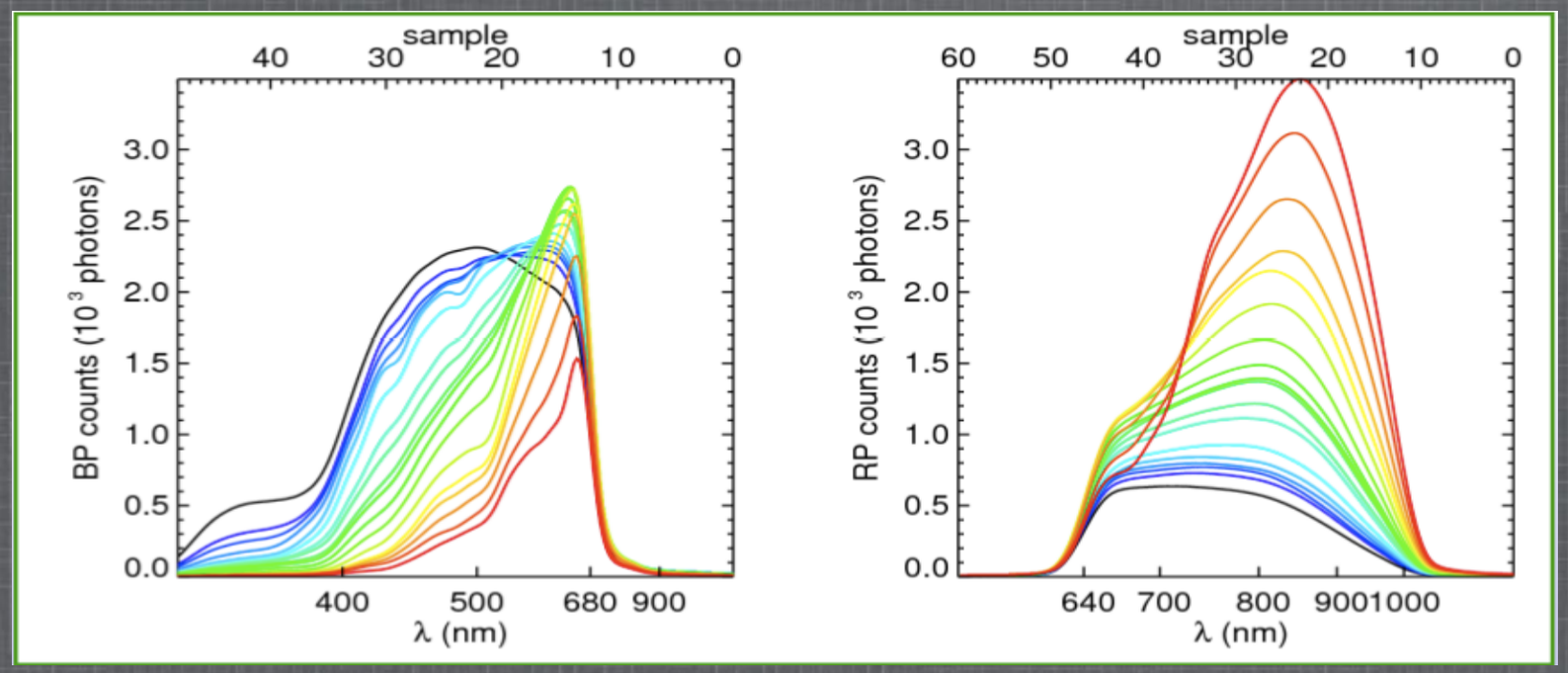


Red photometer



On the CCDs

- two low resolution spectrographs, R~100

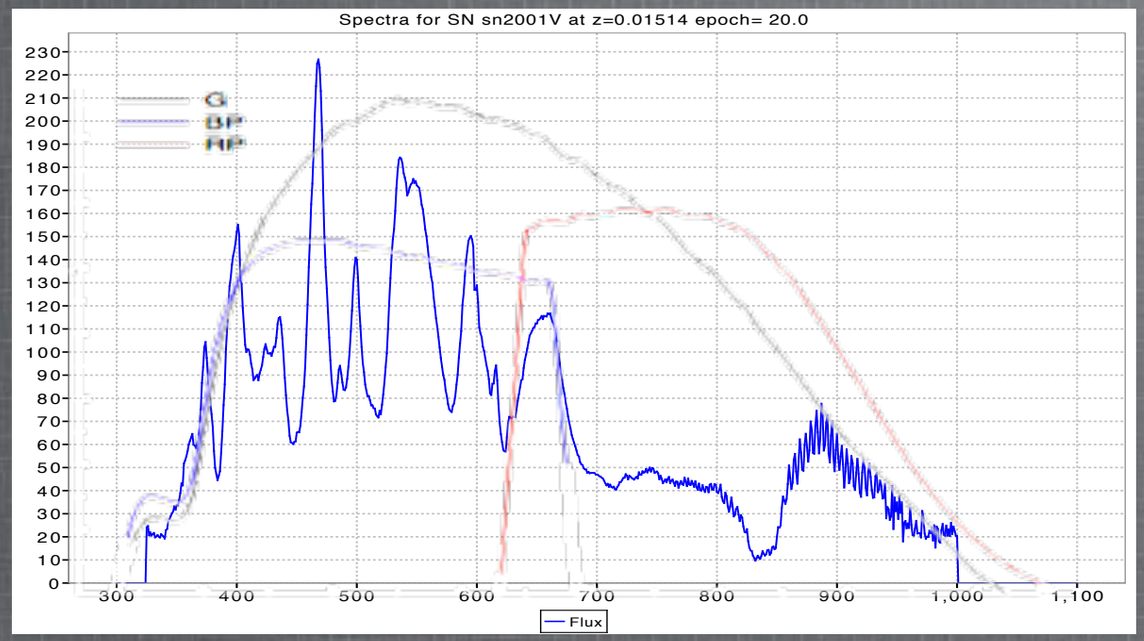


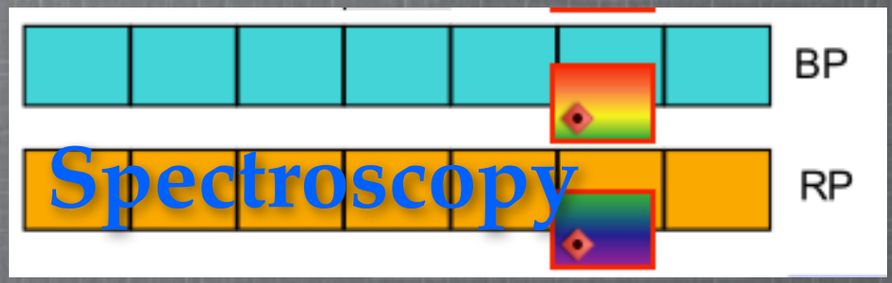
Measurements

- 1 dimensional for stars G>13 mag

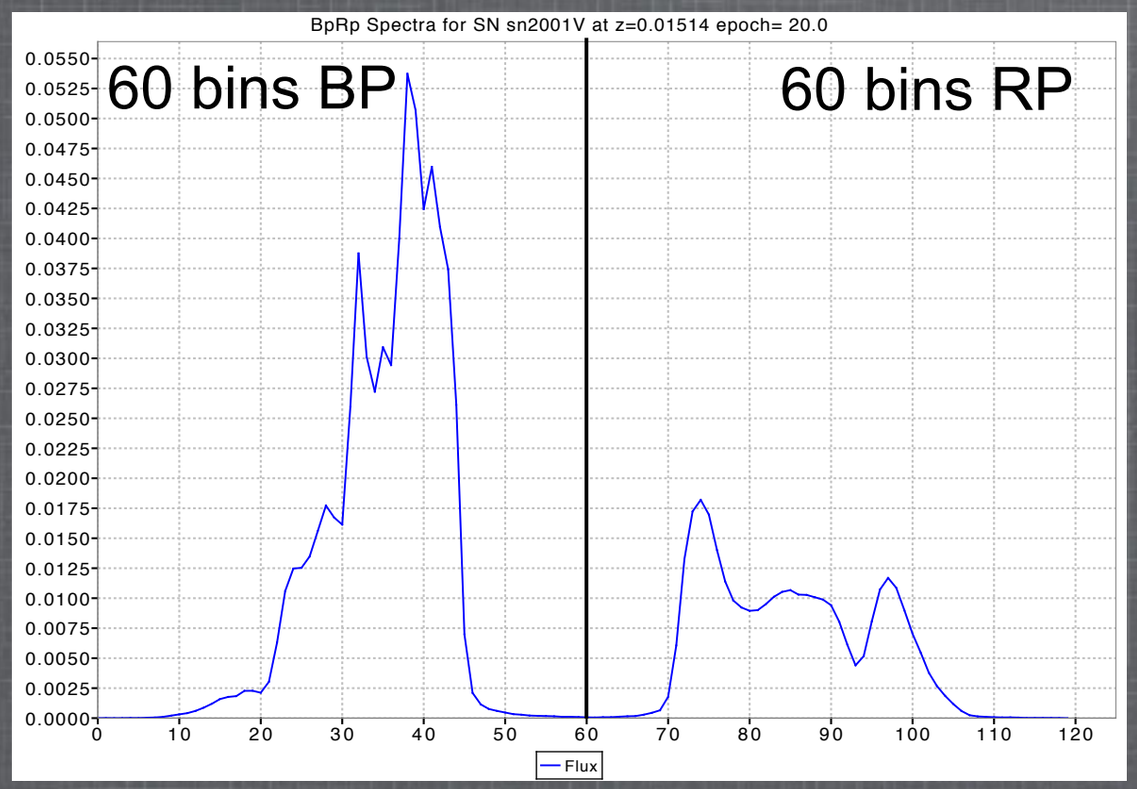
CLASSIFICATION OF ALERTS

Spectral classification - the ``secret" power of Gaia





transients typing –
low false-positives rate!

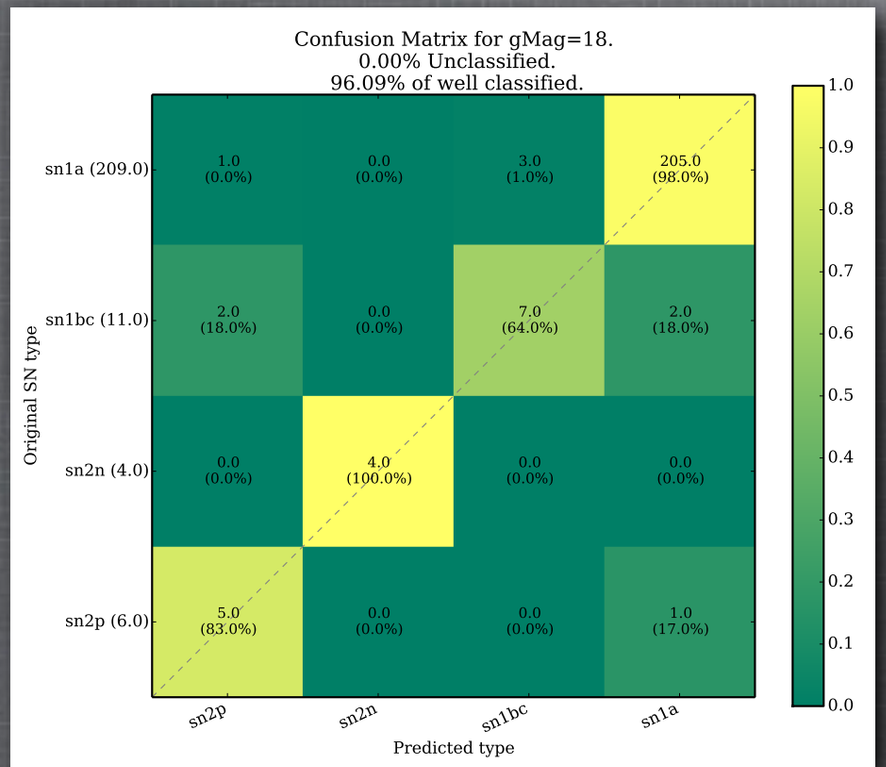


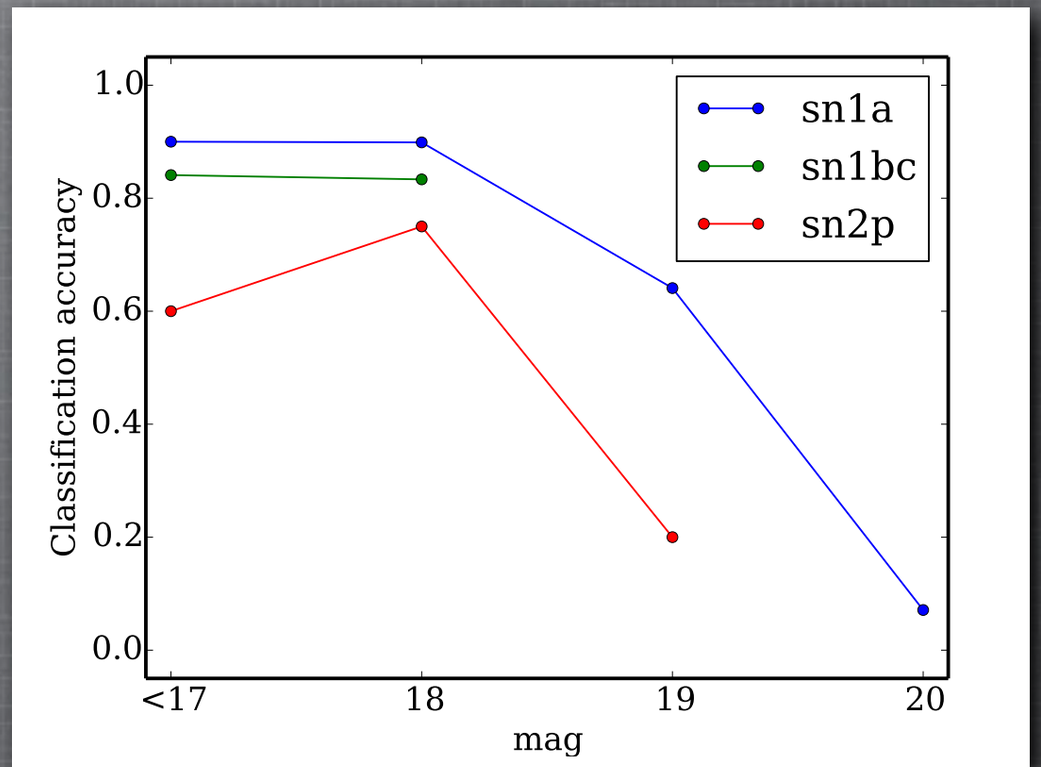
Gaia is equipped with low-resolution **(R~100)** spectrographs. They will allow for classifying transients into types and for supernovae they will provide estimates for redshift and epoch based on just a single observation!

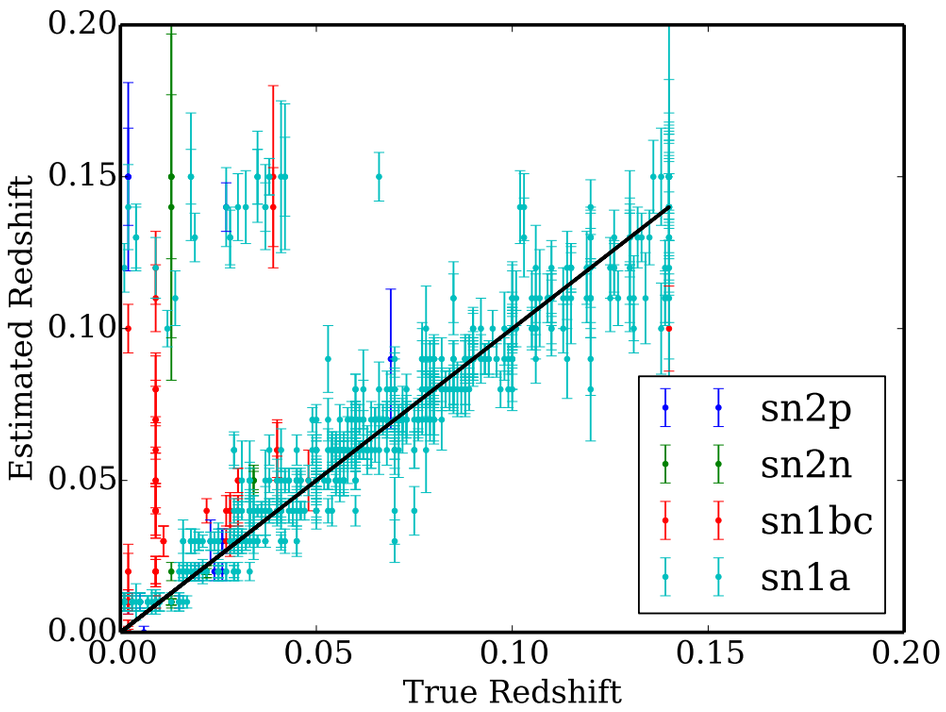
Blagorodnova et al. 2014

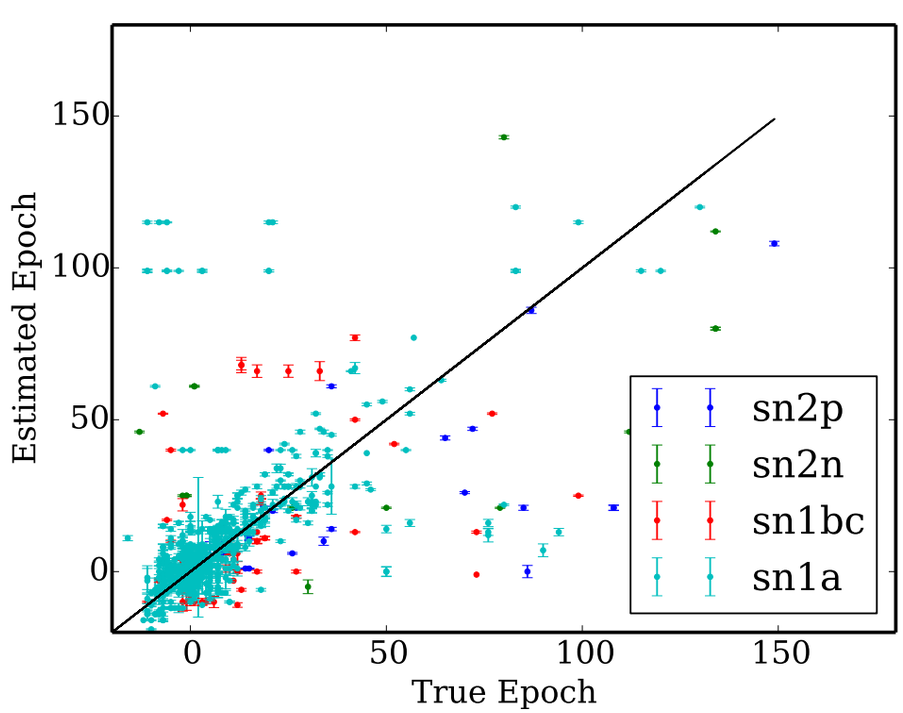
CLASSIFICATION OF ALERTS

Spectral classification - the ``secret" power of Gaia





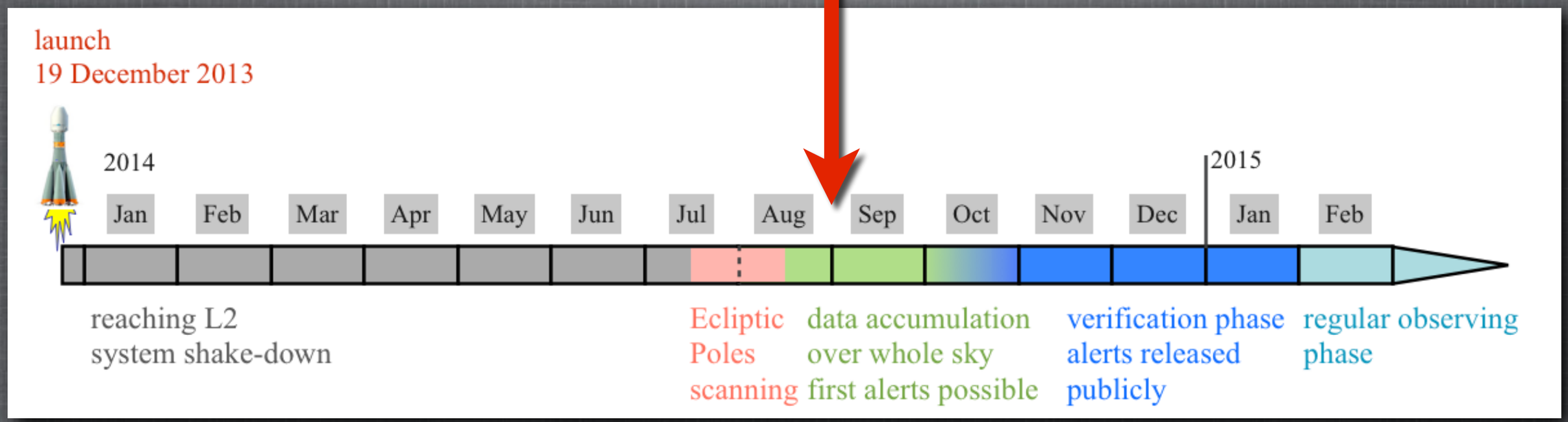




Blagorodnova et al. 2014

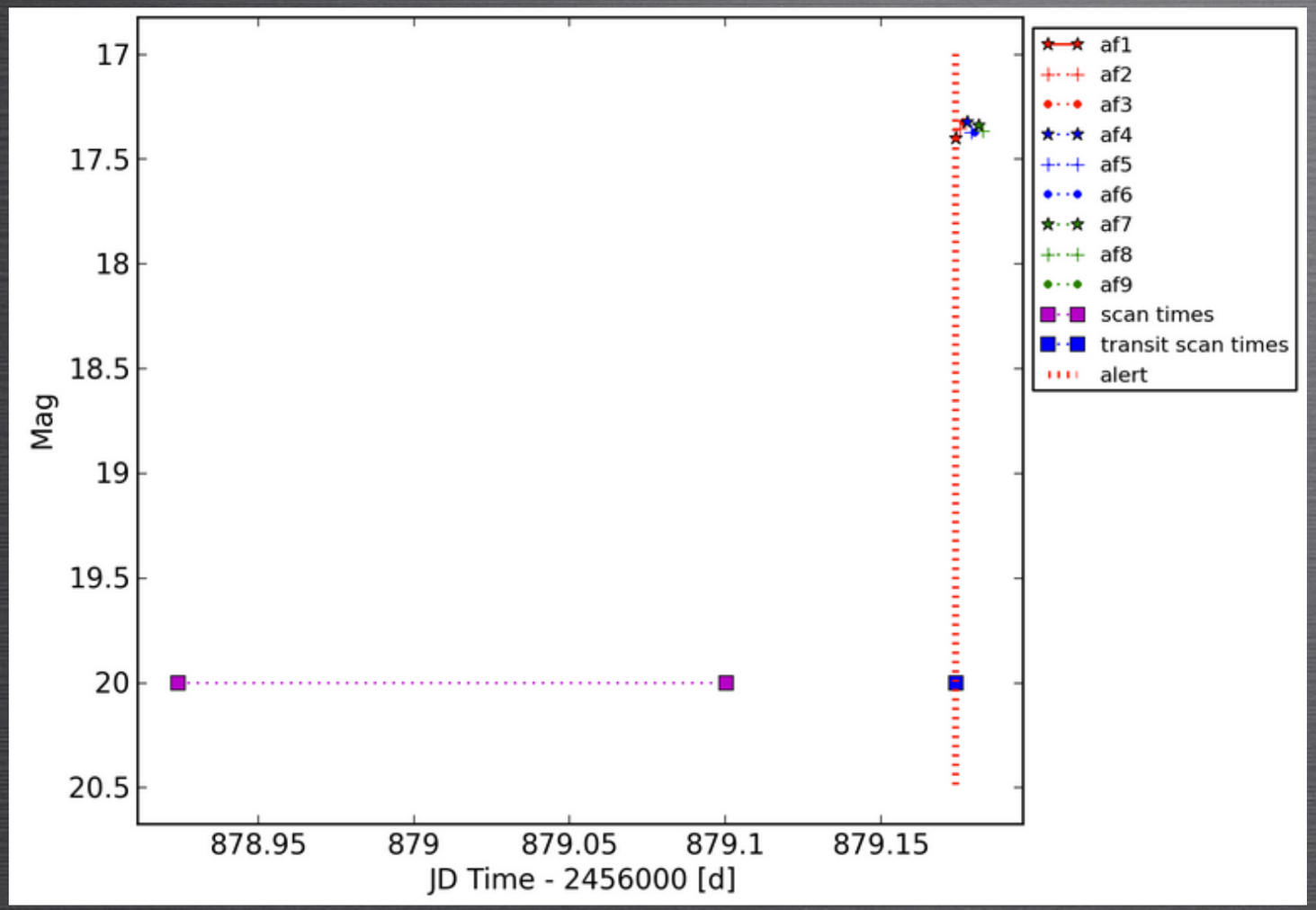
YEAR 1

First alerts!

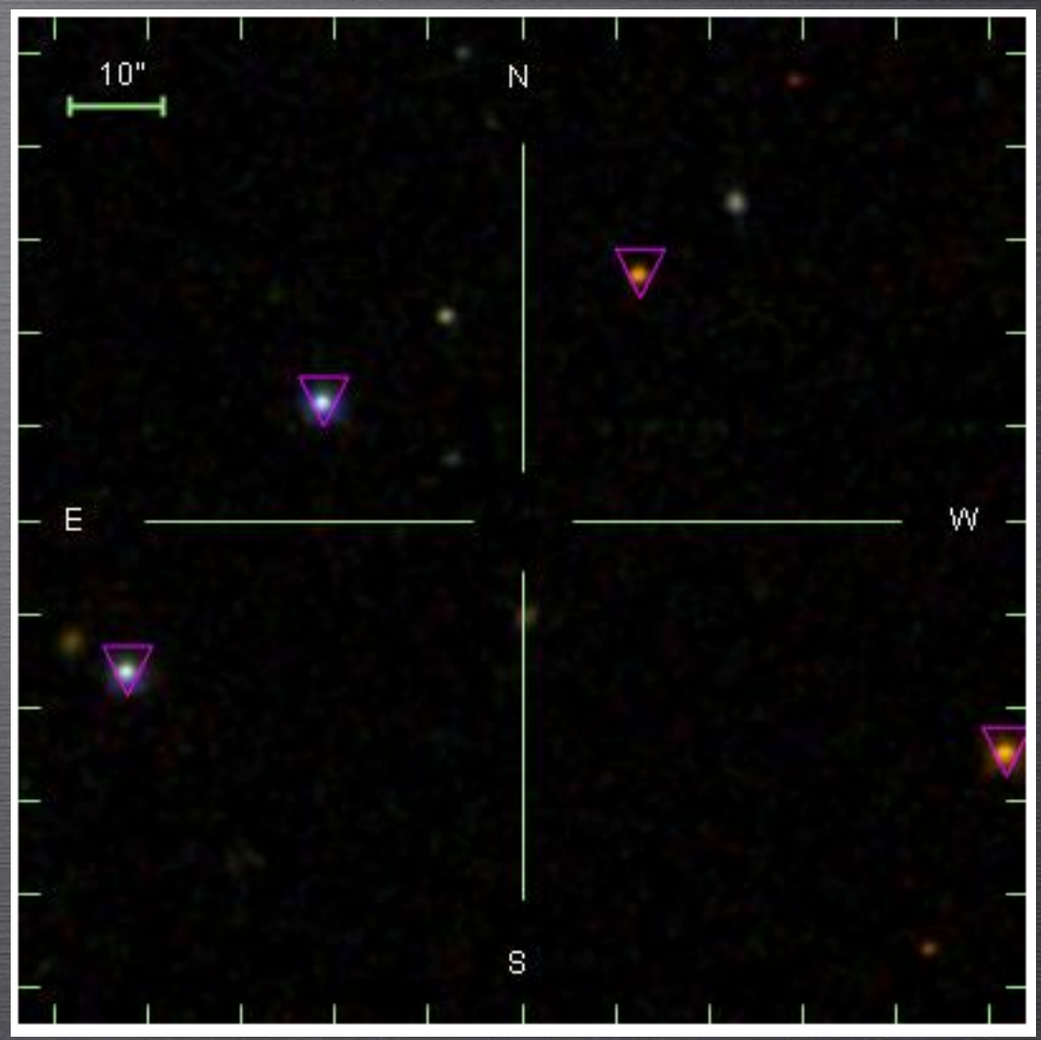


NEW SOURCE ALERT EXAMPLE

Alert:



Finding chart (SDSS):



"sister" alerts found nearby

ecliptic coordinates = 1.810217, -0.698089

Identified as planetoid 9197 Endo

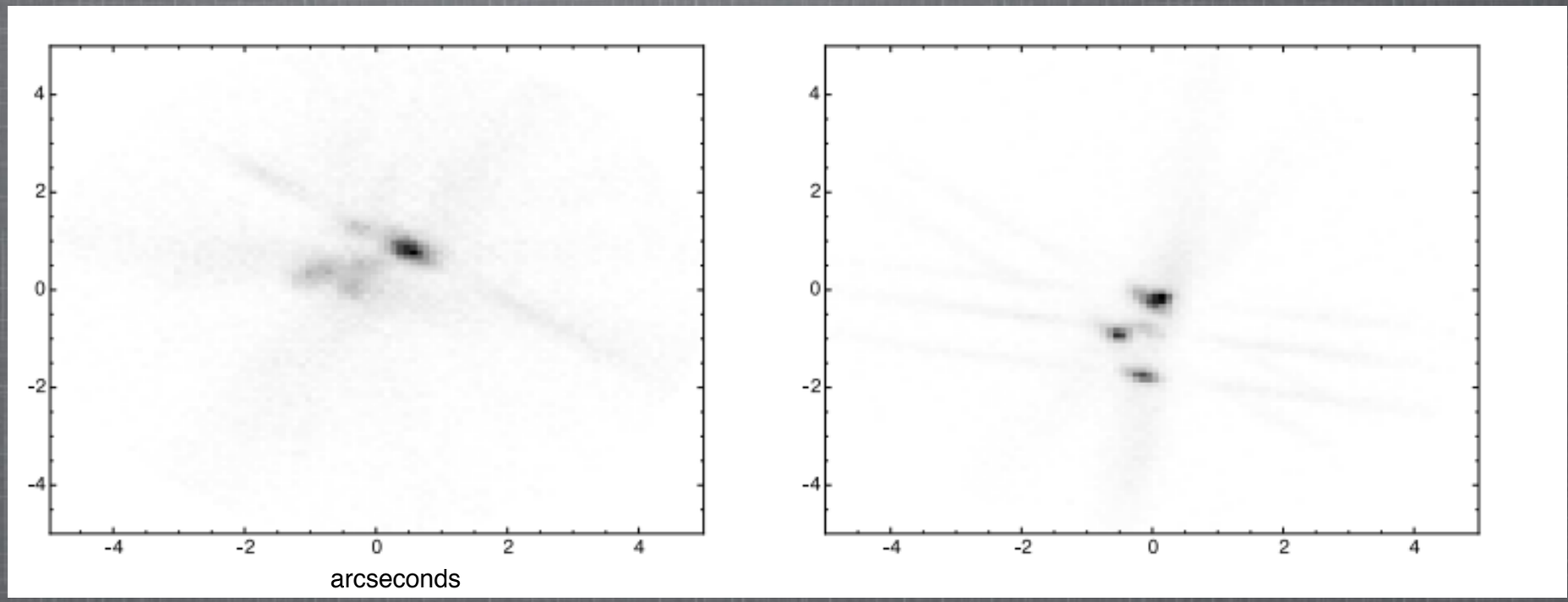
(thanks to Francois Mignard!)

raw Gaia data!

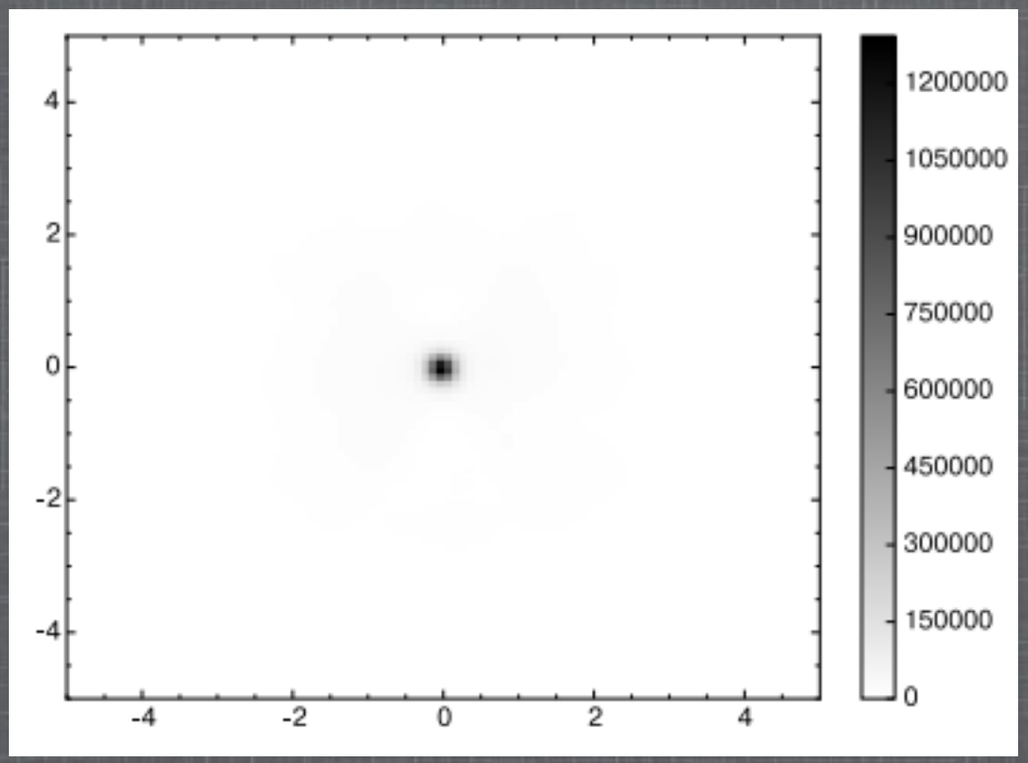
ASTROMETRY

matching Gaia to stellar catalogues

before mid-November 2014



from mid-November 2014



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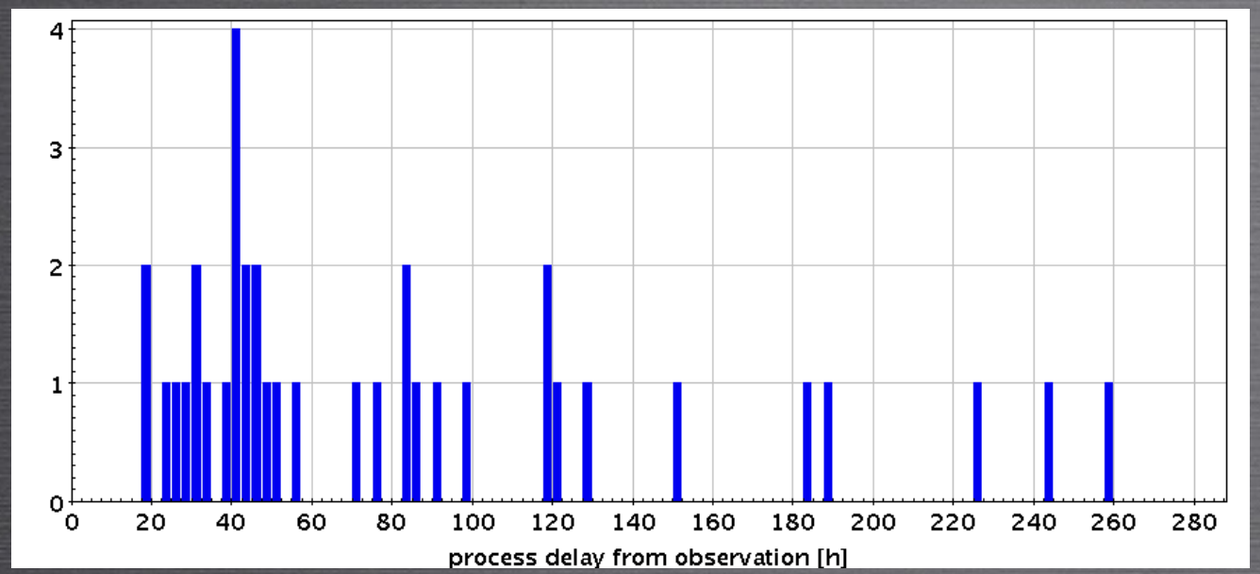
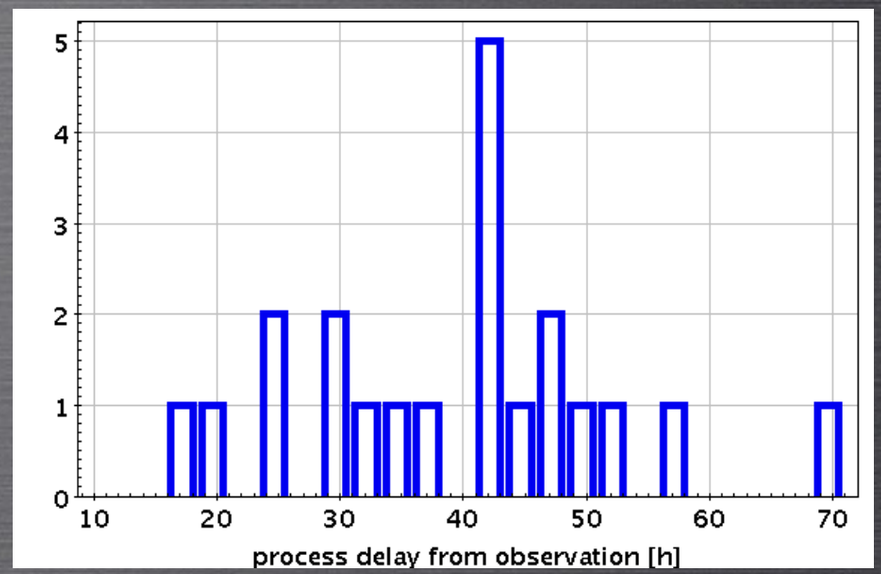
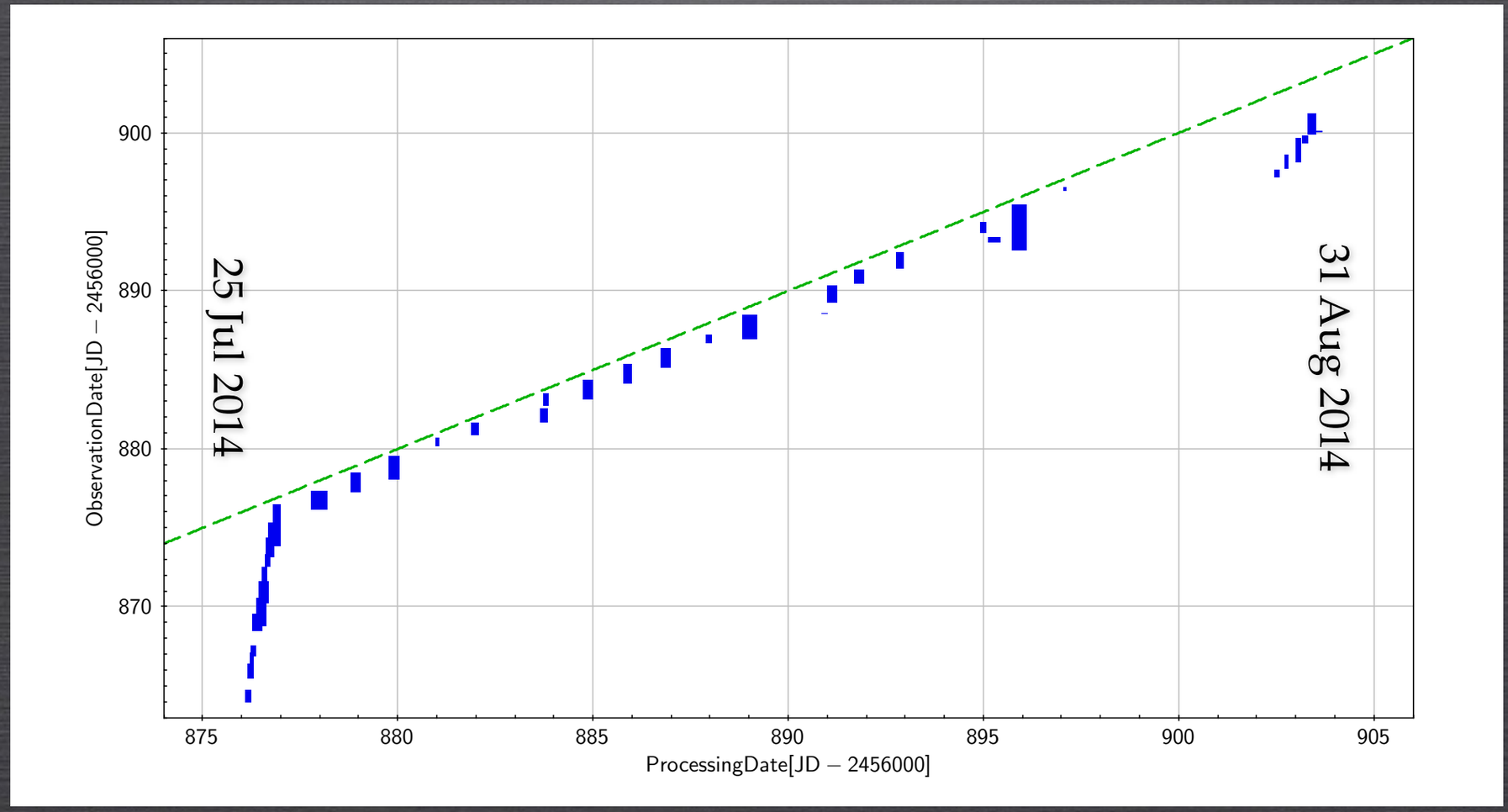
PROCESSING REAL GAIA DATA

delay between observation and end of processing







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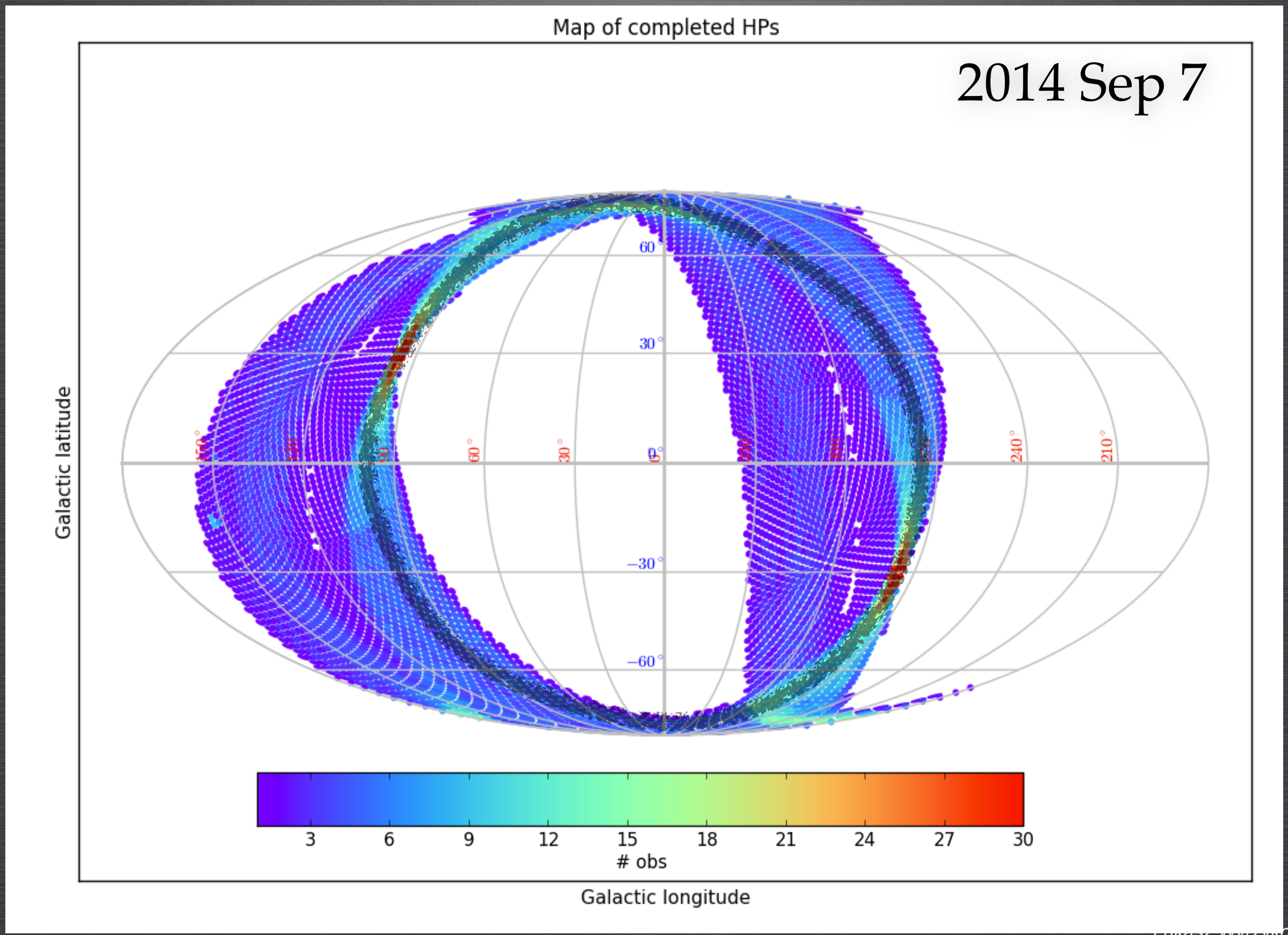
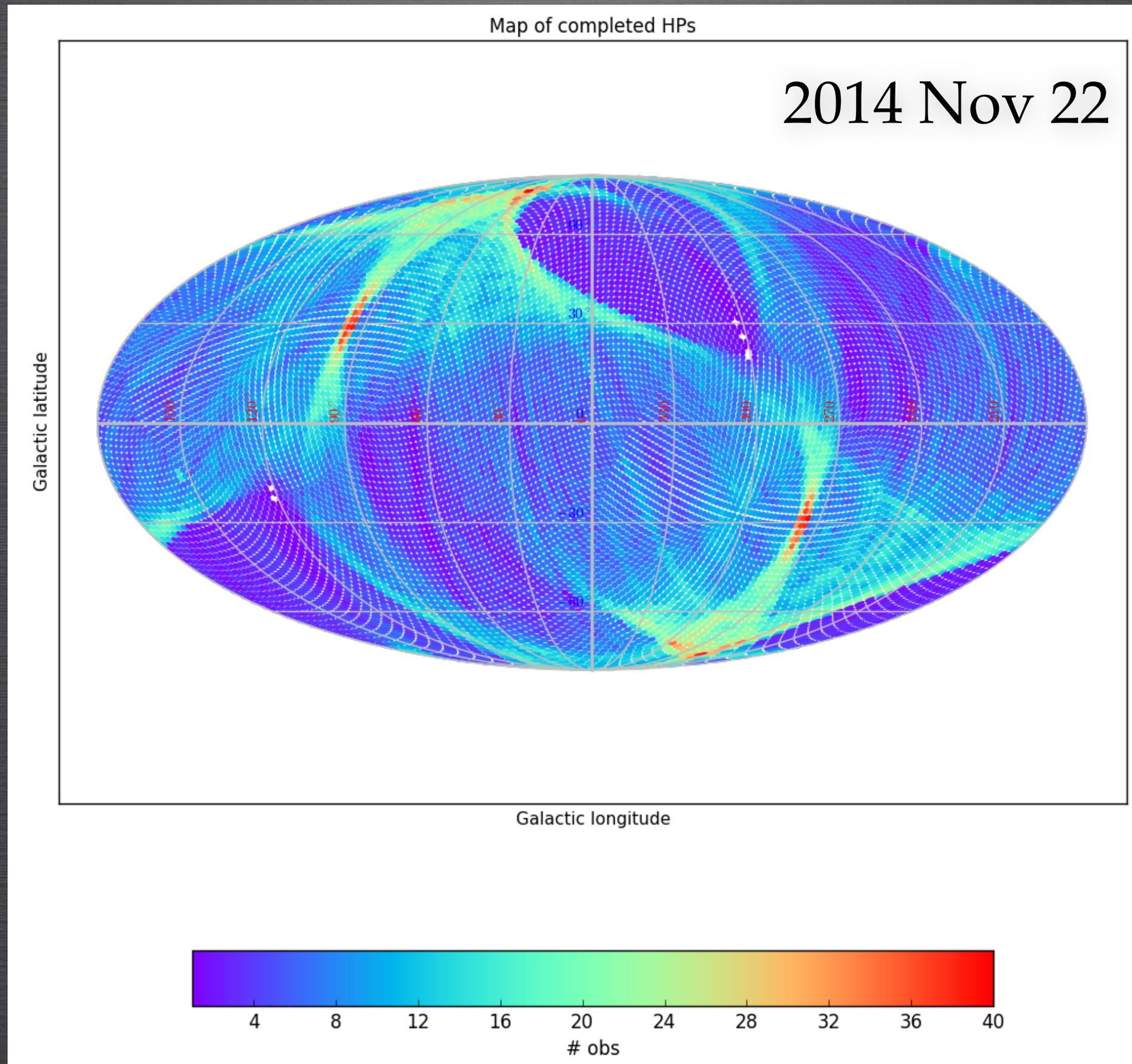
PROCESSING REAL GAIA DATA



PROCESSING REAL GAIA DATA



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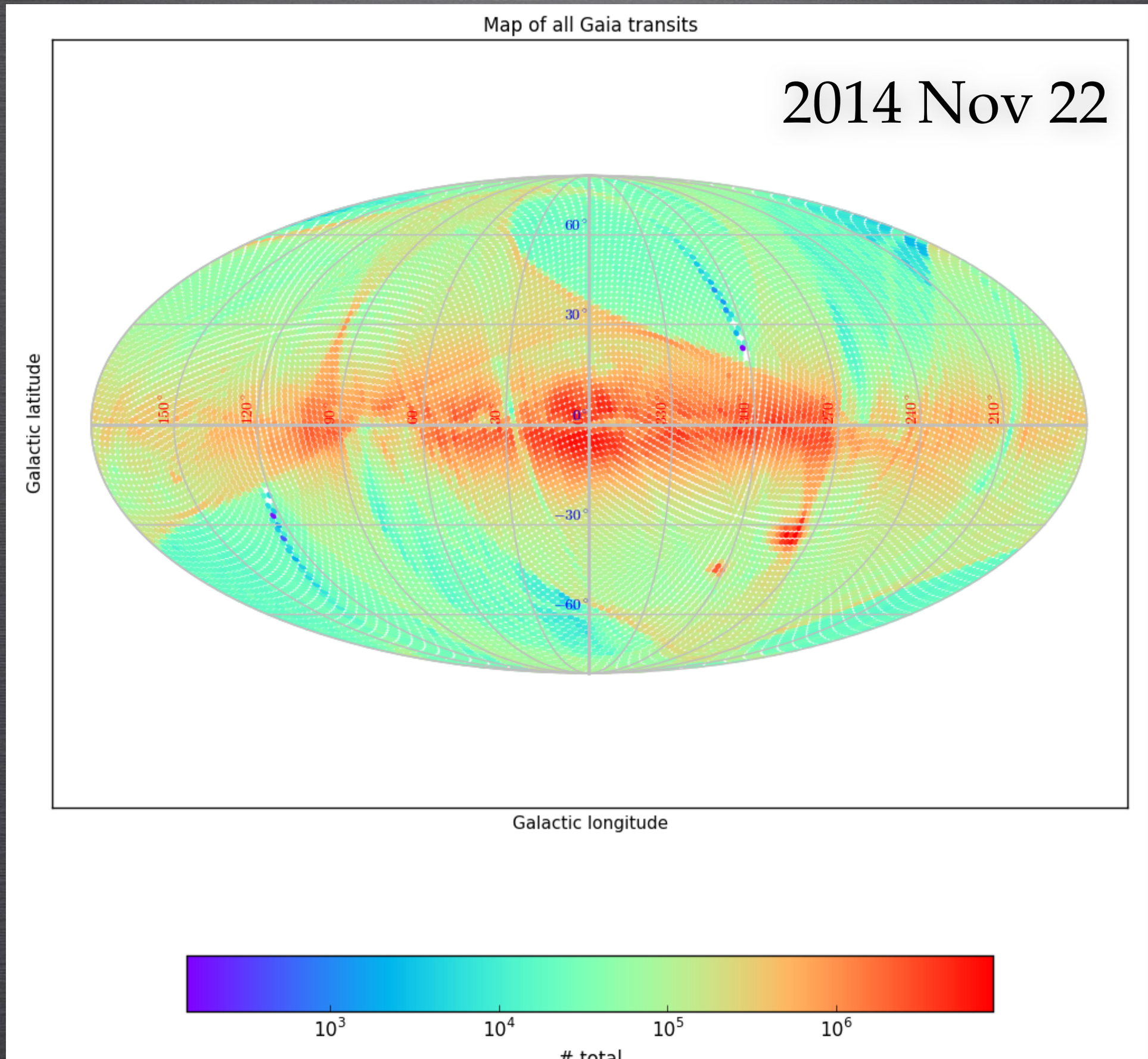
PROCESSING REAL GAIA DATA



WHERE GAIA IS POINTING?

http://gaia.esac.esa.int/tomcat_gost/gost/

Observation Forecast Tool

gaia

Query | Results | Versions

Events forecast submit form

Enter source name [resolved by Simbad]:

Retrieve position

Or

Choose your **CSV** file containing the target positions:

Choose File No file chosen

(first 3 columns name, alpha, delta in degrees)

Enter as angular position in Equatorial coords.

RA:

0.0

[Deg or h:m:s]

DEC:

0.0

[Deg or d:m:s]

Select an observation period FROM

Lookup is by default from 26/09/14 onward + 1 year

2014-09-26T00:00:00

TO:

2015-09-02T00:00:00

Submit for events forecast

I have read the warnings below and agree to continue

source(0) seen 3/4 (SM1/SM2) times

<< -6 months | +6 months >>

September – 2014

01	02	03	04	05	06	07
08	09	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

October – 2014

		01	02	03	04	05
06	07	08	09	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

November – 2014

					01	02
03	04	05	06	07	08	09
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

December – 2014

01	02	03	04	05	06	07
08	09	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

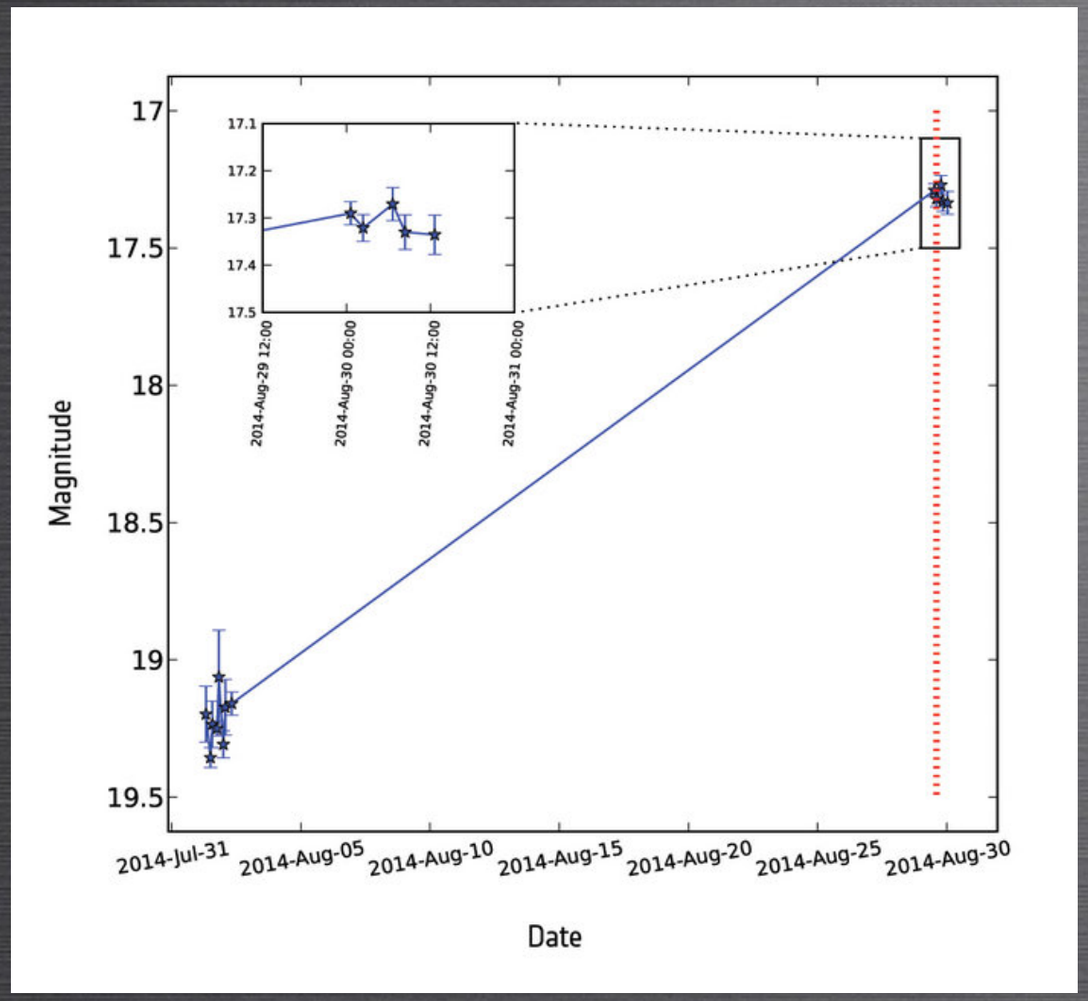
January – 2015

			01	02	03	04
05	06	07	08	09	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

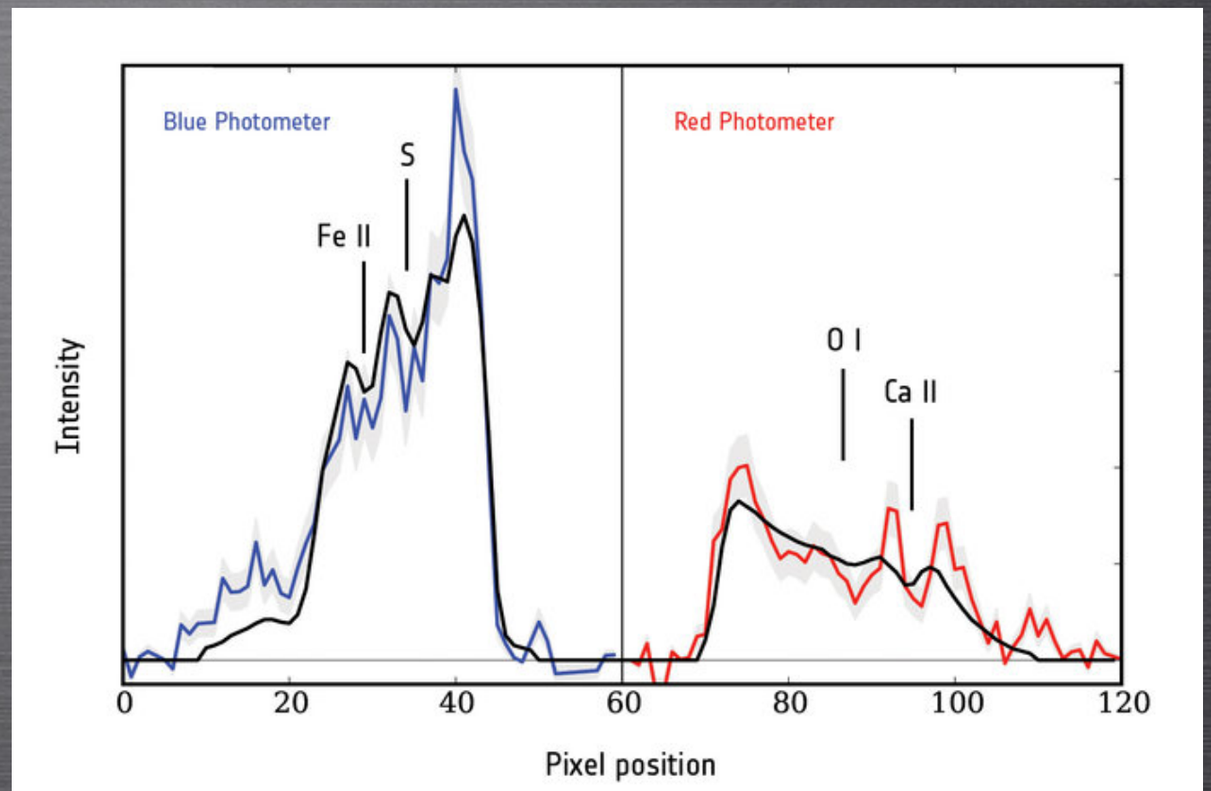
February – 2015

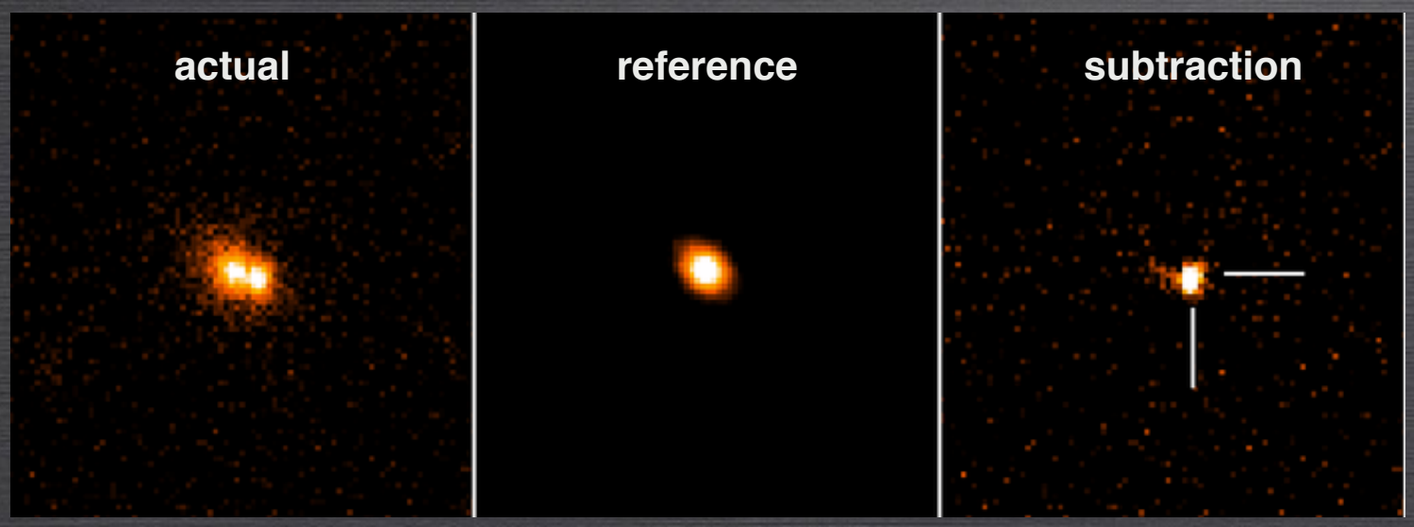
						01
02	03	04	05	06	07	08
09	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	

FIRST CONFIRMED SN FROM GAIA



Gaia14aaa discovered on 30 Aug 2014





Found based on BPRP spectrum match!

Confirmation image from Liverpool Telescope

raw Gaia data!

Łukasz Wyrzykowski

OTHER CONFIRMED TRANSIENTS

Gaia14abz - SN Type Ia at z=0.059 (Asiago)
Gaia14acg - SN Type Ia at z=0.031 (Asiago)
Gaia14act - SN Type II at z=0.027 (Asiago)
Gaia14acz - SN next to SDSS galaxy at z=0.105

Gaia14aat - Dwarf Nova (Liverpool Telescope)

Gaia Verification @ WHT (Rixon et al):
Gaia14aae - AM CnV, a'ka ASASSN-14cn
Gaia14aaf - CV
Gaia14aai - M flare
Gaia14aau - M Flare
Gaia14abg - CV
Gaia14abq - M Flare
Gaia14abr - M Flare

ALERTS VERIFICATION PHASE

http://gaia.ac.uk/selected-gaia-science-alerts

Gaia in the UK

Taking the Galactic Census

Home | Mission | Gaia UK | Science | Alerts | News | Events | Education | Multimedia | Blog

You are here: Home » Gaia Photometric Science Alerts: Validation Phase

Gaia Photometric Science Alerts: Validation Phase

Welcome! We have begun the experiment to validate our AlertPipe software. This software discovers, classifies and publishes Gaia Photometric Science Alerts. We are right at the beginning of the journey, and invite you to join in.

On this web page we are publishing coordinates and photometry for a manually selected subset of alerts as part of our validation process. These sources and the contents of the webpages come with a number of caveats (details below). The methodology used to find the alerts is also described below.

If you do measure any data for these targets, then please let us know (via Contact page and choose the category: Science alerts), and if possible we'd like to get a copy of your data (e.g. via ftp) for inclusion in our verification analysis together with data from collaborating observatories: http://www.ast.cam.ac.uk/ioa/wikis/gsawgwiki/index.php/Working_groups. Anything we use will be credited. Similarly, if you do publish any ATELS, articles, etc, then please do let us know.

If you publish any results based on these Gaia discoveries, we would appreciate an acknowledgement along the lines of: "We acknowledge ESA Gaia, DPAC and the Photometric Science Alerts Team (http://gaia.ac.uk/selected-gaia-science-alerts)".

ALERTS VERIFICATION PHASE

http://gaia.ac.uk/selected-gaia-science-alerts

Name	UTC timestamp	RA	Dec	AlertMag	HistMag	HistStdDev	Class	Comment
Gaia14ade	2014-11-11 08:25:59	357.71672	28.98319	17.78	19.30	0.13	unknown	very blue star: CV?
Gaia14add	2014-11-11 04:44:38	182.15532	11.99387	17.70	18.71	0.04	unknown	QSO at z=0.36. Brightening of 1 mag
Gaia14adc	2014-11-06 02:55:24	316.06927	51.32732	15.92	18.10	0.06	unknown	Very red spectrum, possible Mira
Gaia14adb	2014-10-29 00:13:52	181.30013	21.83836	18.61	20.06	0.06	unknown	Near SDSS galaxy SDSS J120512.03+215018.1 with photometric redshift z=0.05
Gaia14ada	2014-09-10 01:32:01	208.40506	34.82615	18.73	19.68	0.05	unknown	blue star, now faded, ROSAT source within error, CV?
Gaia14acz	2014-11-01 23:47:20	211.56593	36.38459	18.96	Not known	Not known	unknown	blue in BP/RP; 5 arcsec from SDSS galaxy z=0.105
Gaia14acy	2014-10-26 21:01:38	10.16959	-28.95650	18.41	19.63	0.06	unknown	Galaxy (2dFGRS TGS287Z263), small offset?
Gaia14acx	2014-10-27 09:33:08	240.01542	33.18725	15.24	20.20	0.02	CV	Known Dwarf Nova: VW CrB (Blue SDSS star r=19.9, very blue in BP/RP)
Gaia14acw	2014-10-24 03:35:31	37.28835	-32.96673	17.61	18.39	0.04	unknown	
Gaia14acv	2014-10-25 07:06:23	182.44766	29.73023	18.40	18.97	0.03	unknown	very blue SDSS star at r=19.2
Gaia14acu	2014-10-26 00:49:49	202.47026	31.90307	18.23	19.18	0.08	unknown	SDSS star at r=20
Gaia14act	2014-10-26 06:05:30	185.09378	28.41434	18.43	Not known	Not known	SN II	offset from SDSS galaxy;last non-det 2014-07-31;blue BPRP spectrum

ALERTS VERIFICATION PHASE

Gaia Follow-Up Network for Transient Objects = Gaia-FUN-TO

why?

- check if an alert is real
- to weed out errors from the pipeline
- to classify (phot+spec) or confirm BP/RP classification

open to everyone !

requirements for follow-up:

- ideally: fully robotic telescope
- rapid response (<24h)
- automated photometric processing
- data submission to common repository

You can still join us!
email: LW @ astrouw.edu.pl

ACTIVE FOLLOW-UP PARTNERS

NORTH

Loiano, Italy, 1.5m

APT2, Italy, 0.8m

TNT, Italy, 0.72m

Mercator, La Palma (Swiss Time), 1.2m

Konkoly, Hungary, 1m, 0.6/0.9/1.8m, 0.5m

PIRATE, Mallorca (Open University), 0.43m

pt5m, La Palma (Sheffield), 0.5m

Vienna, Austria, 1.5m

ASV, Serbia, 0.6m

Tubitak, Turkey, 1.5m, 1m, 0.6m

Wroclaw, Poland, 0.6m

Ostrowik, Poland, 0.6m

Italian Supernova Project, Italy, 0.53m

Wise, Israel, 1m, 0.7m, 0.45m

OHP, France, 1.2m

SOUTH

Swiss Euler, La Silla, 1.2m

Danish/Czech, La Silla, 1.54m

GROND, La Silla, 2.2m

SAAO, South Africa, 1.9m, 1m

OGLE, La Campanas, 1.3m

MOA, New Zealand, 2m

http://www.ast.cam.ac.uk/ioa/wikis/gsawgwiki/index.php/Status_of_the_verification_partners

FOLLOW-UP CALIBRATION SERVER

for Gaia Science Alerts Photometric Follow-up

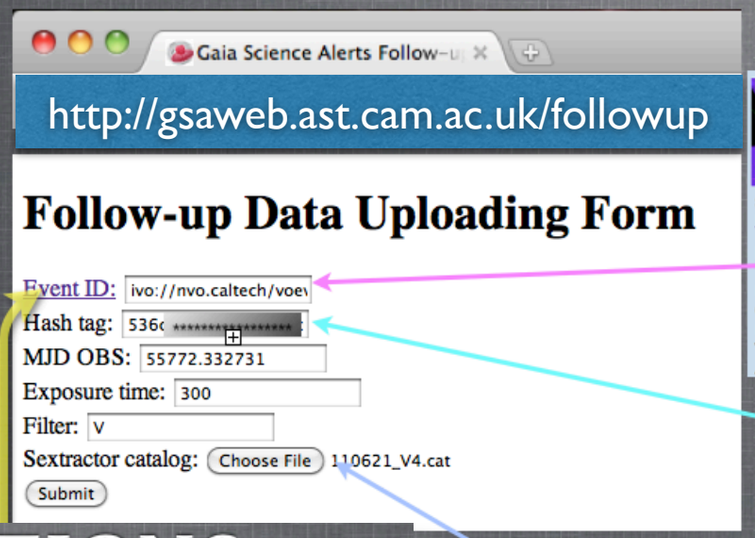
GAIA SCIENCE ALERTS

Cambridge Photometric Calibration Server manual

Łukasz Wyrzykowski & Sergey Koposov
Institute of Astronomy, University of Cambridge, UK
last update: 30 July 2012

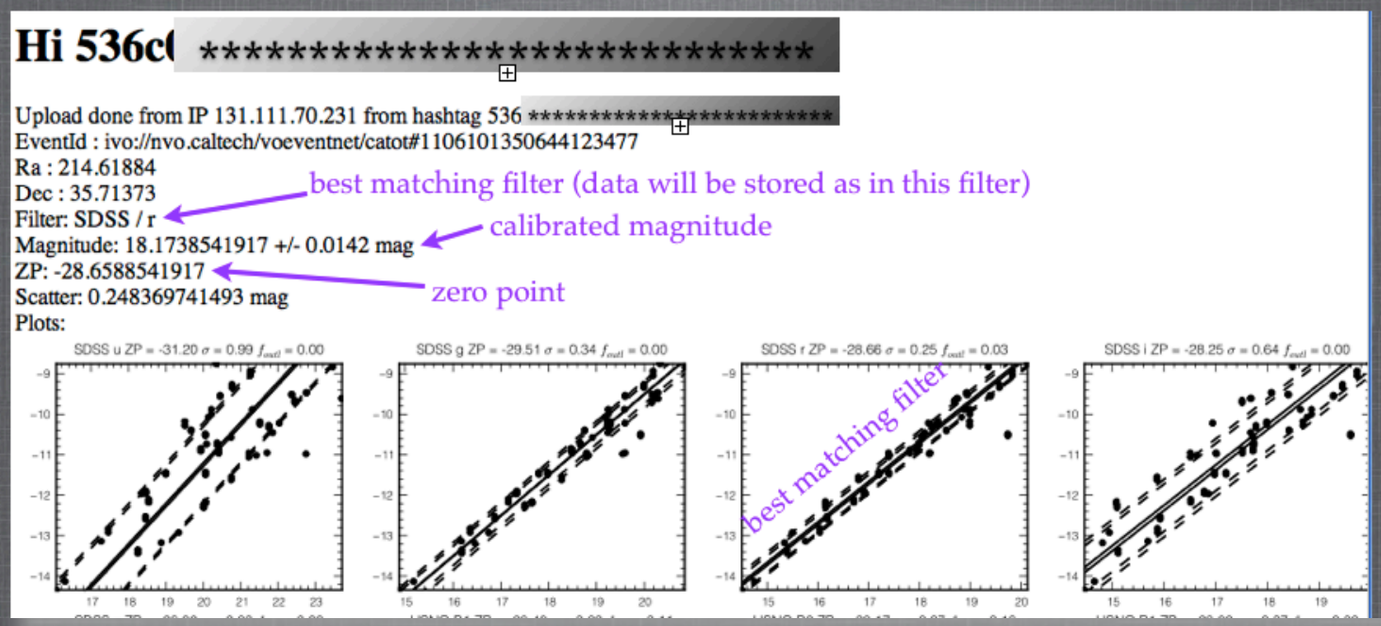
UPLOADING THE FOLLOW-UP DATA

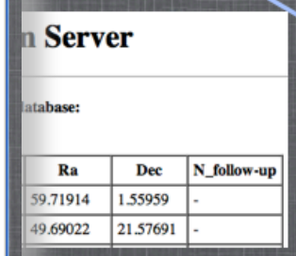
http://gaia020.ast.cam.ac.uk:5000 (temporary site)



Your unique access name / pass
(provided by Cambridge)

RESULT OF CALIBRATIONS





REQUIRED SEXTRACTOR FIELDS:

```
#  ALPHA_J2000    Right ascension of barycenter (J2000)  [deg]
#  DELTA_J2000    Declination of barycenter (J2000) [deg]
then, either:
#  MAG_APER       Fixed aperture magnitude vector [mag]
#  MAGERR_APER    RMS error vector for fixed aperture mag.  [mag]
or:
#  MAG_AUTO       Automatic aperture magnitude [mag]
#  MAGERR_AUTO    RMS error for automatic aperture mag.  [mag]
```

access can be fully automatised

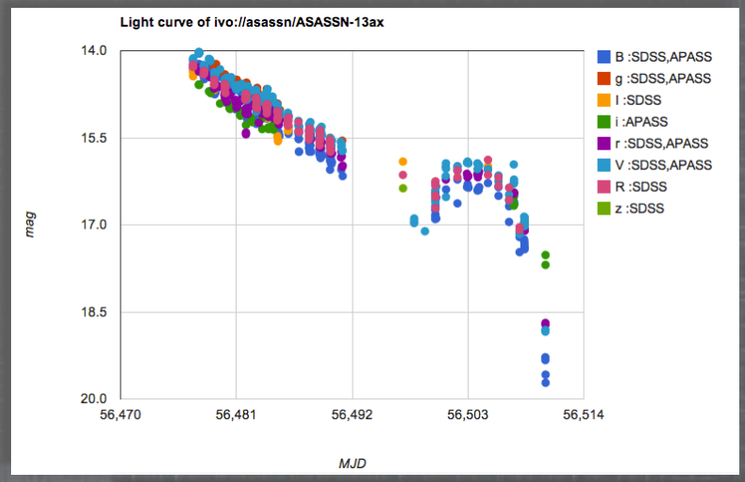
software developed by Sergey Koposov, IoA

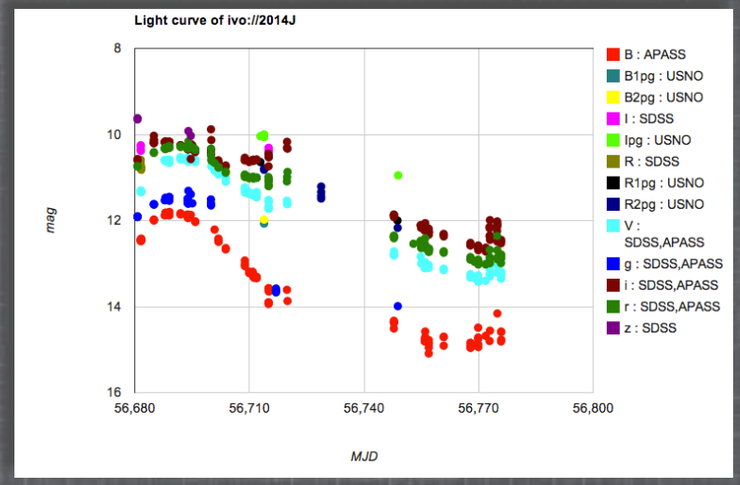
ALERTS VERIFICATION PHASE

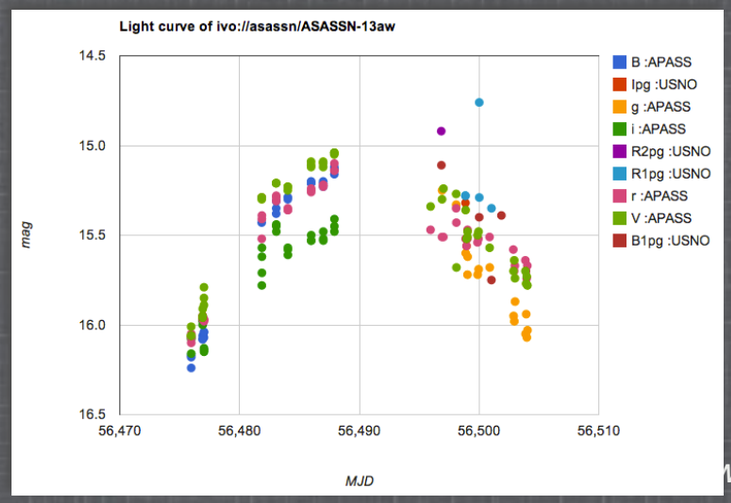
About 15 observatories, >3000 observations of about 50 targets in 2013/14

id	ivorn	published	ra	dec	nfollowup	LC	data
25463	ivo://asassn/ASASSN-14ae	2014-02-03 13:10:42	167.166495	34.097972	81	LC	data
25462	ivo://2014J	2014-01-24 01:25:44	148.9259042	69.6740444	313	LC	data
25461	ivo://iptf/iptf13ebh	2013-11-14 15:40:20					
25460	ivo://nvo.caltech/voeventnet/catot#1311081150044101824	2013-11-08 22:00:17					
25459	ivo://nvo.caltech/voeventnet/catot#1311061180184119159	2013-11-08 02:08:10					
25458	ivo://nvo.caltech/voeventnet/catot#1311061010294118517	2013-11-08 01:25:31					
25457	ivo://nvo.caltech/voeventnet/catot#1310310091164130002	2013-11-04 21:35:15					
25456	ivo://nvo.caltech/voeventnet/catot#1311021400124123088	2013-11-02 22:33:32					
25455	ivo://nvo.caltech/voeventnet/catot#1310271400304156612	2013-10-30 10:03:25					
25454	ivo://nvo.caltech/voeventnet/catot#1310251400954170028	2013-10-29 21:57:36					
25453	ivo://nvo.caltech/voeventnet/catot#1310281380044109757	2013-10-29 21:33:02					
25452	ivo://nvo.caltech/voeventnet/catot#1310231380084126804	2013-10-23 22:42:02					
25451	ivo://asassn/ASASSN-13dl	2013-10-14 08:06:23					
25400	ivo://junk/test	2013-10-09 10:49:22					
25396	ivo://asassn/ASASSN-13dd	2013-09-					

id	Name	Longitude	Latitude	Observations
18	admin	None	None	6
49	Aleks Scholtz James Gregory Telescope 0.94 St.Andrews,UK	-2.8	56.3	0
16	Alex Ball-SMARTS1.3	70.815	-30.16527778	145
1	AnonymousFollowUpAccount	0.0	0.0	0
9	AshishMahabalEulerLaSillaChile	-70.73	-29.257	28
7	AshishMahabalIGOIndia	73.666667	19.083333	0
10	AshishMahabalP60	-116.863889	33.355833	0
8	AshishMahabalSAAO1.9SA	20.811642	-32.378961	0
15	AshishMahabal-SMARTS1.3	70.815	-30.16527778	0
27	BAS NAO 2m Rozhen	24.74	41.7	0
28	BAS NAO 60cm Rozhen	24.74	41.7	0
29	BAS NAO Rozhen 50/70cm Schmidt	24.74	41.7	0
30	Belogradchik, AO, 60cm, Bulgaria	22.67	43.62	0
14	Colin Snodgrass, RoboNET	0.0	0.0	0
31	Gabor Marschalko, Konkoly, Piszkesteto Mountain Station, Hungary	19.8953	47.9181	60
5	GiuseppeAltavillaAPT2Cataniaitaly	14.974722	37.693056	0
3	GiuseppeAltavillaAsiagoObservatoryItaly	11.571375	45.843389	0
2	GiuseppeAltavillaLoianoObservatoryItaly	11.333889	44.259167	0
4	GiuseppeAltavillaTNTTeramoItaly	13.733333	42.6575	0
6	GiuseppeAltavillaToppoNaplesItaly	15.463333	40.817778	0
43	Giuseppe Leto APT2 Catania	14.974722	37.693056	4
26	Goran Damljanovic, ASV, Serbia	21.55	43.15	201
36	Heather Campbell	0.0	0.0	0
41	Irek Khamitov T100	2.02222	36.825278	38
42	Irek Khamitov T60	2.02222	36.825278	10
34	Krzysztof Ulaczyk, Ostrowik, Warsaw	21.42	52.08972	52
33	Krzysztof Ulaczyk, test account	0.0	0.0	0
24	Lukasz Wyrzykowski, OGLE, Las Campanas	-70.7	-29.2	0
23	Milan Bogosavljevic, Astronomical Station Vidojevica 60cm, Serbia	21.555666	43.140166	0
22	Montarrenti Observatory, Siena, Italy	11.18	43.23	22







OPTICON

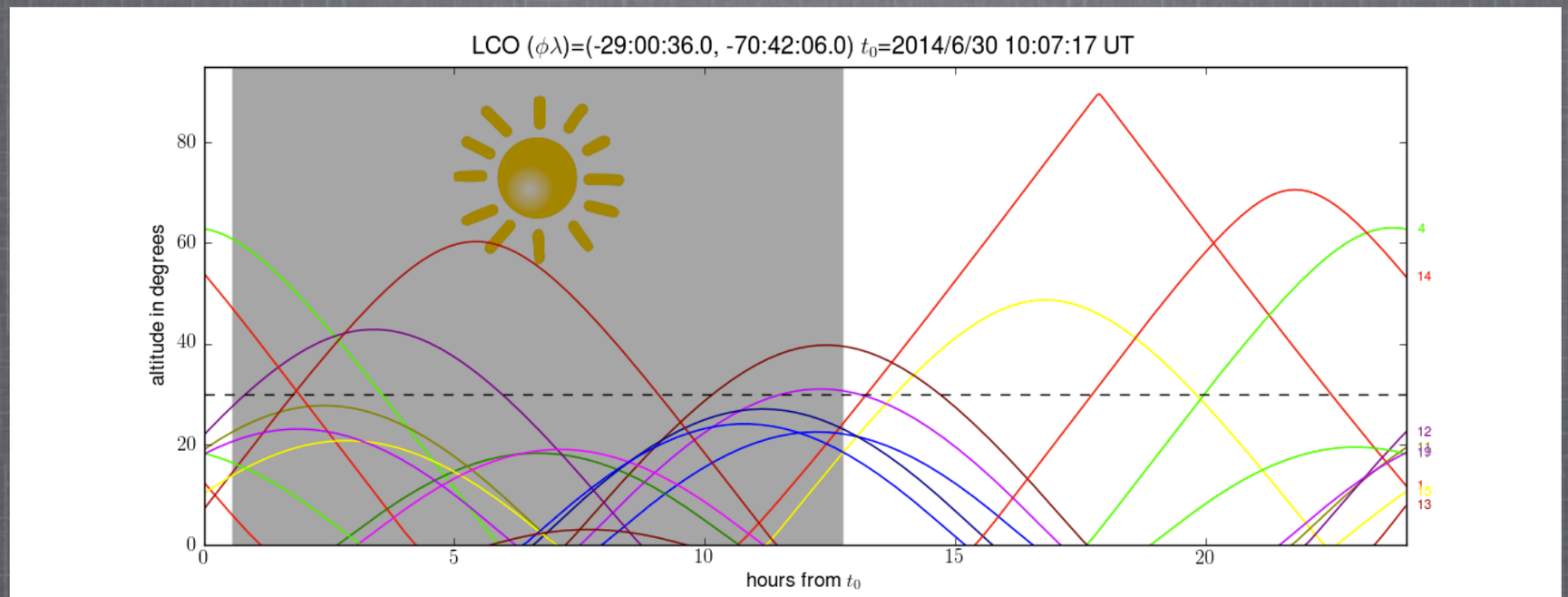
WP11
Time-domain
astronomy

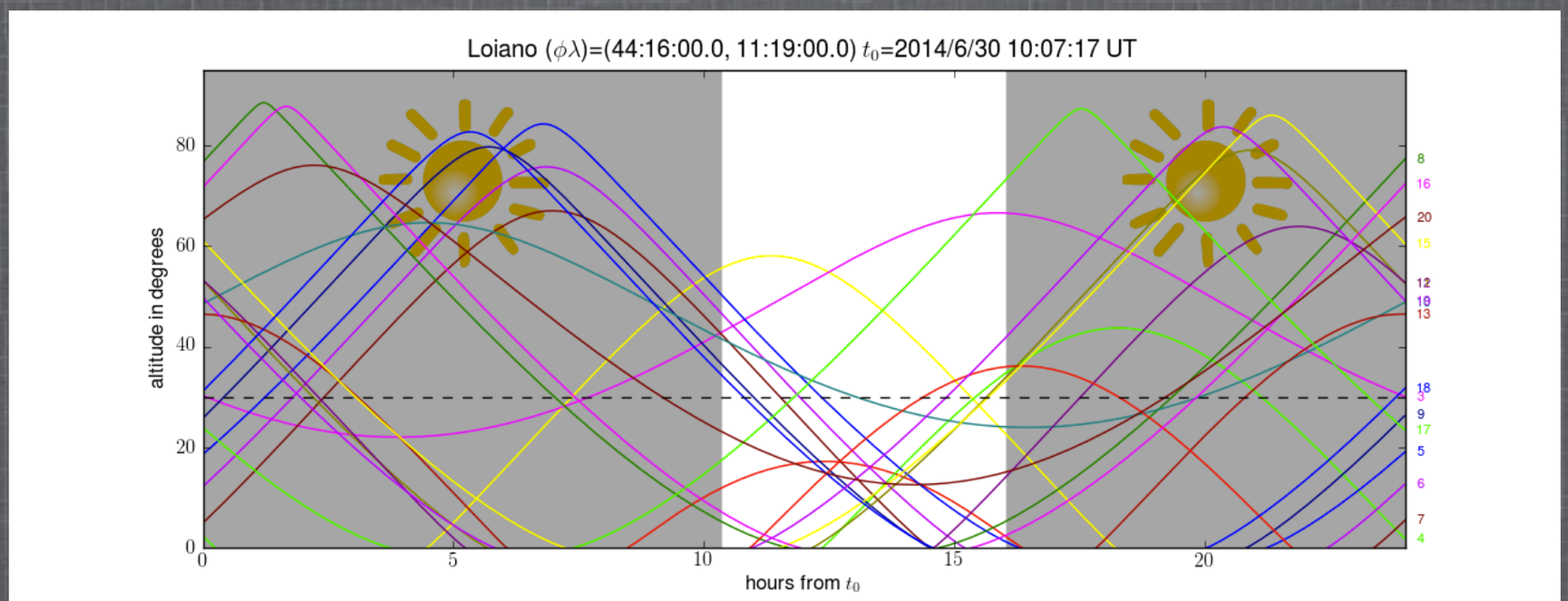
wski

ALERTS VERIFICATION PHASE

Follow-up planning for the network of telescopes

http://www.astrouw.edu.pl/~kulaczyk/ephem/





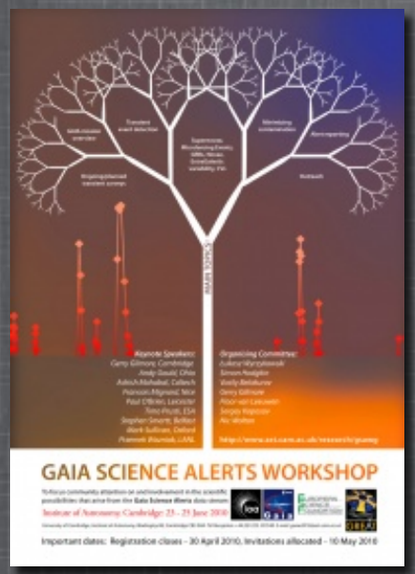
Tool by Krzysztof Ulaczyk

WP11
Time-domain astronomy

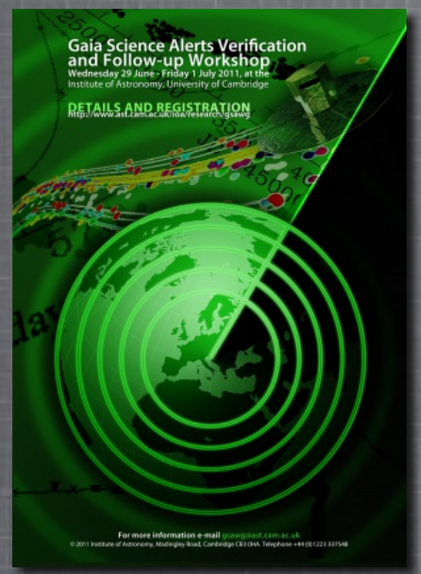
Łukasz Wyrzykowski

GAIA SCIENCE ALERTS WORKSHOPS

2010-Cambridge



2011-Cambridge



2012-Bologna

2013-Paris

2014-Warsaw

(2015-Liverpool)

2013 - 2016 Gaia Time-domain Photometric Follow-up supported by OPTICON,
WP11: Time-domain astronomy (HQ: Warsaw)

Archive of slides and videos:

http://www.ast.cam.ac.uk/ioa/wikis/gsawgwiki

Łukasz Wyrzykowski