Photometric Science Alerts from Gaia

Łukasz Wyrzykowski
(pron. Woocash Vizhikovsky)
Simon Hodgkin, Nadia Blogorodnova
Sergey Koposov, Ross Burgon

Warsaw University Astronomical Observatory, Poland
Institute of Astronomy, University of Cambridge, UK

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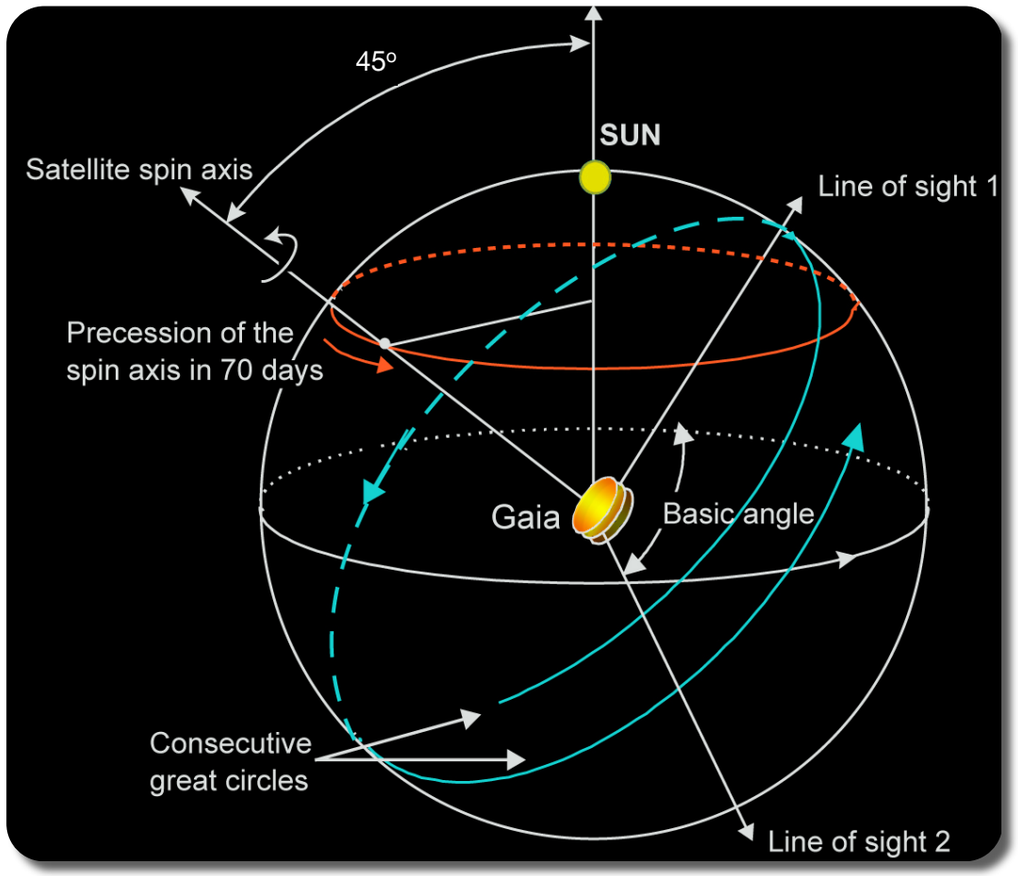
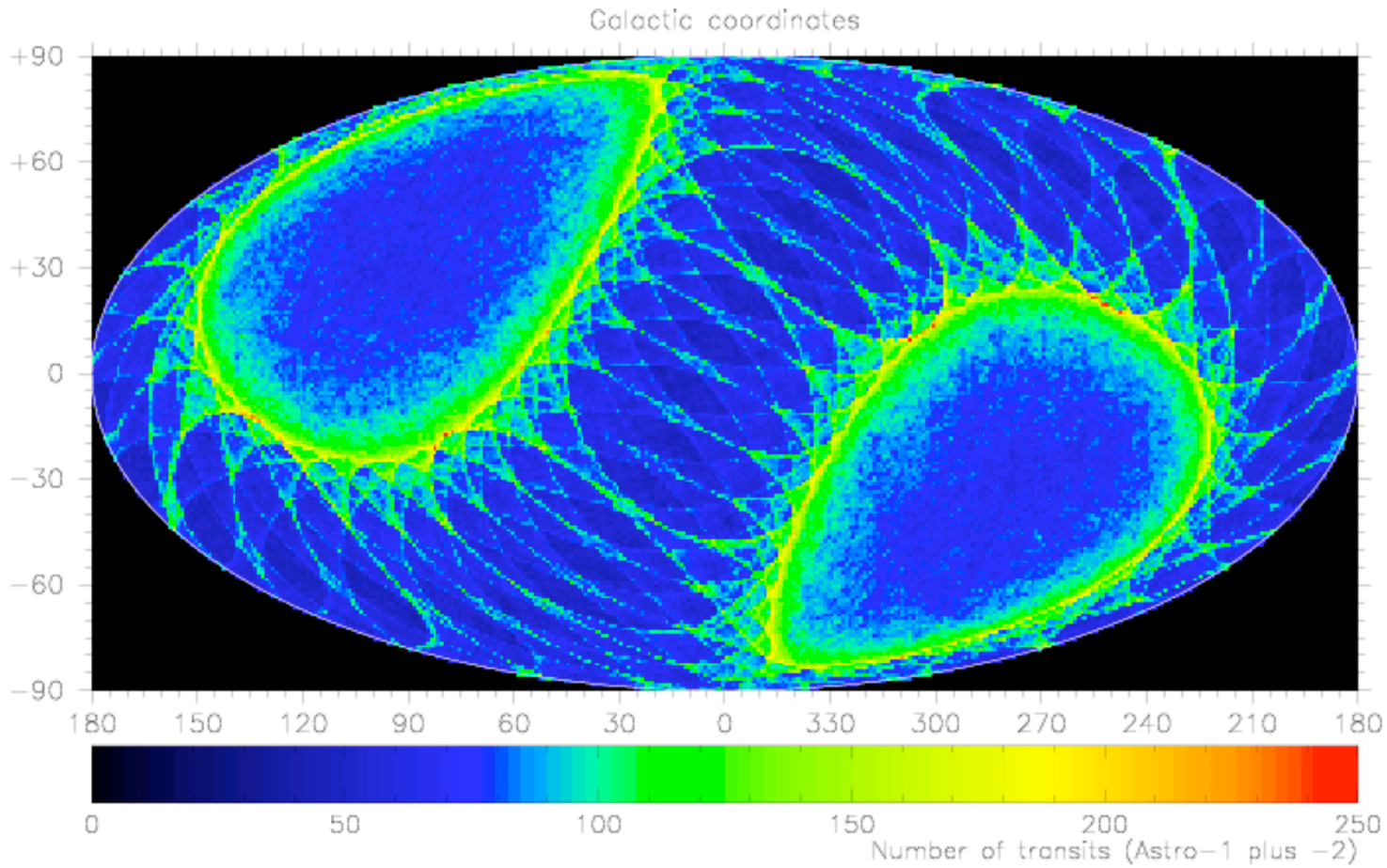
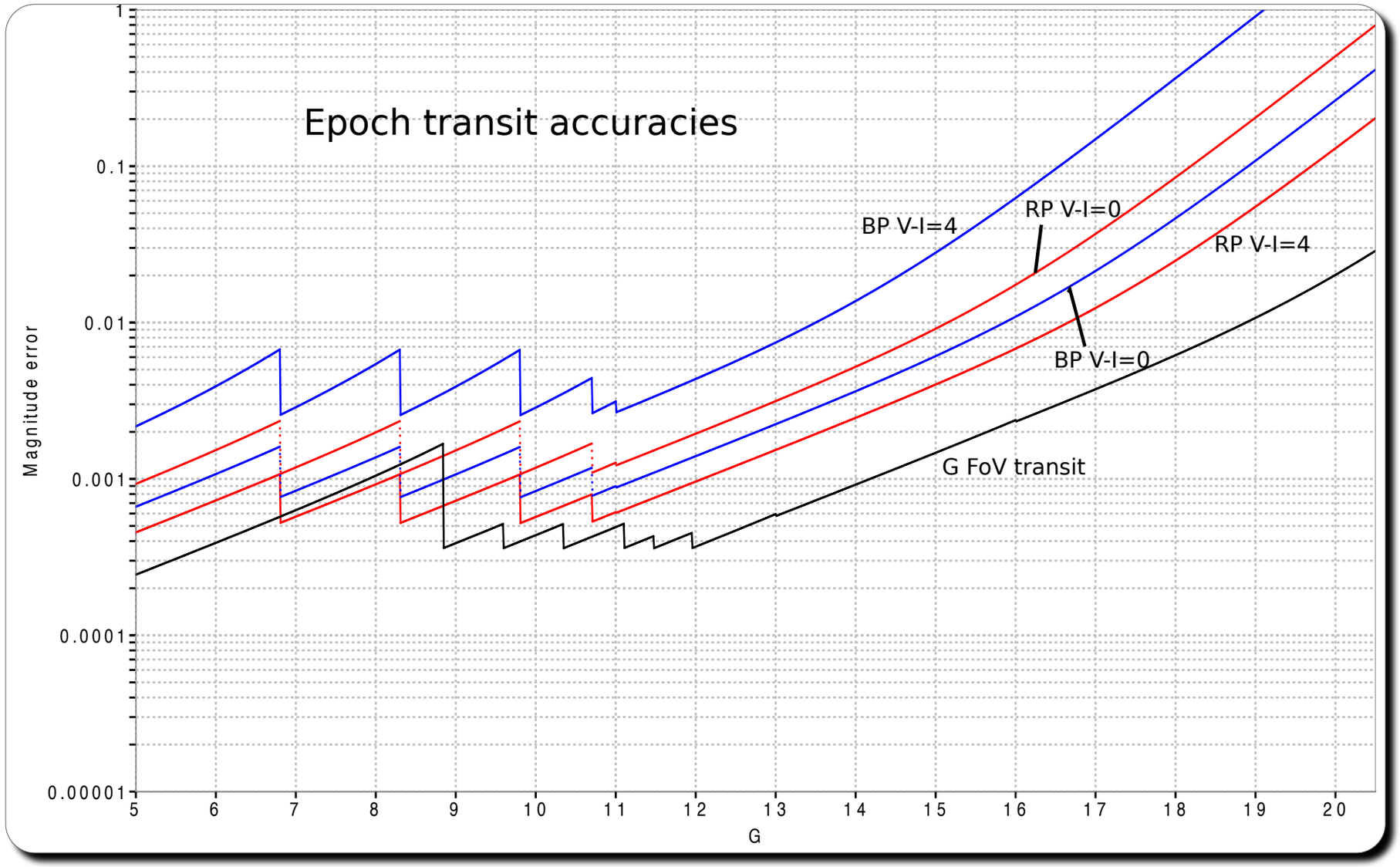
Scanning Law





- Two telescopes, one focal plane
- Time between FOVs: 106.5m
- Time between successive scans: 6h
- Field revisited every ~30 days
- Each object measured ~70 times
- Densest coverage ~200 epochs

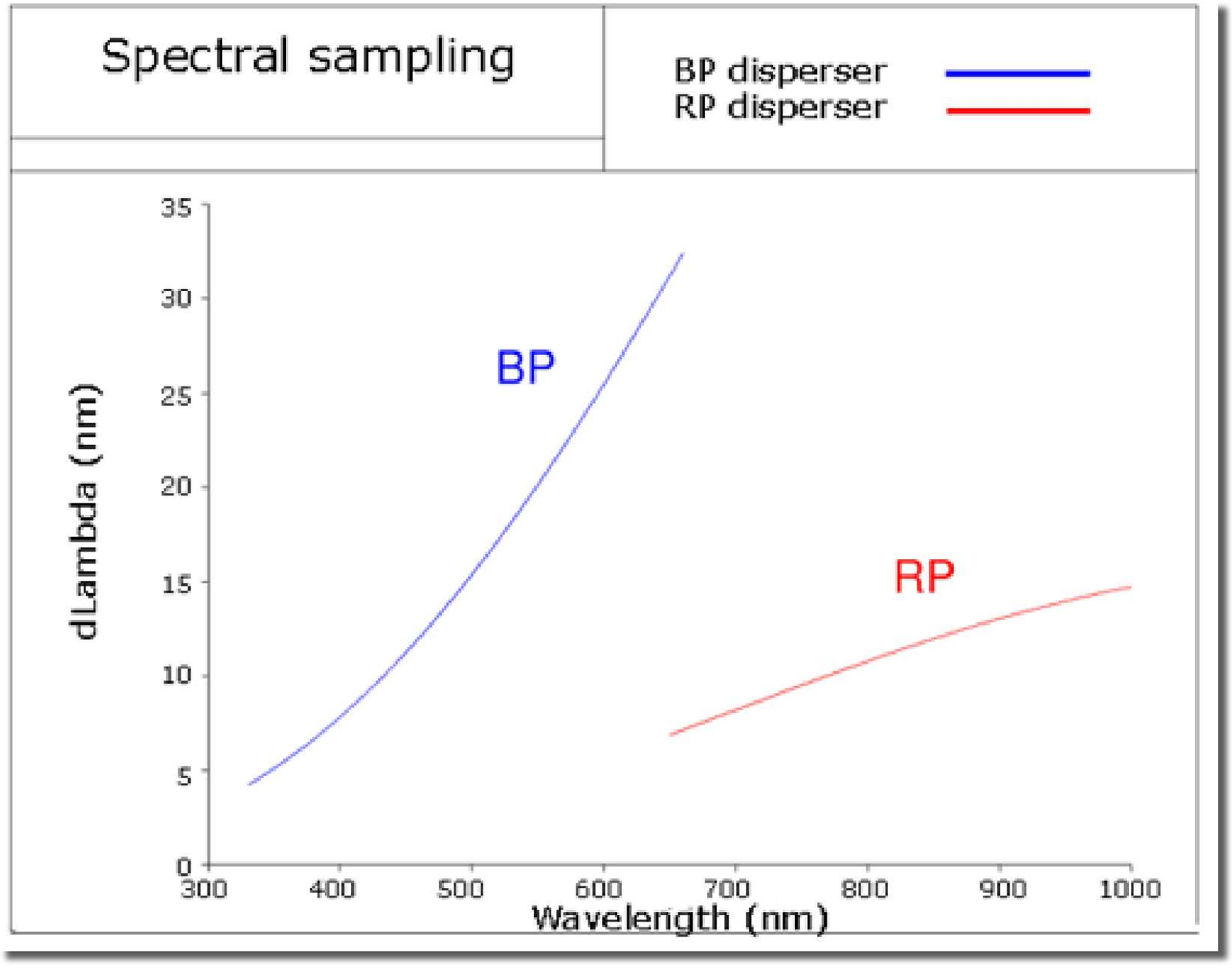
Photometry per transit



- 1% at G=19 (colours to ~10%)
- <2 mmag precision for G<12
- CCD TDI gates avoid pixel saturation for bright stars

BP/RP spectra

- two low-res fused-silica prisms
- BP 330-680nm @ 4-32 nm/pixel
- RP 640-1000nm @ 7-15 nm/pixel



Timeline for Data Flow

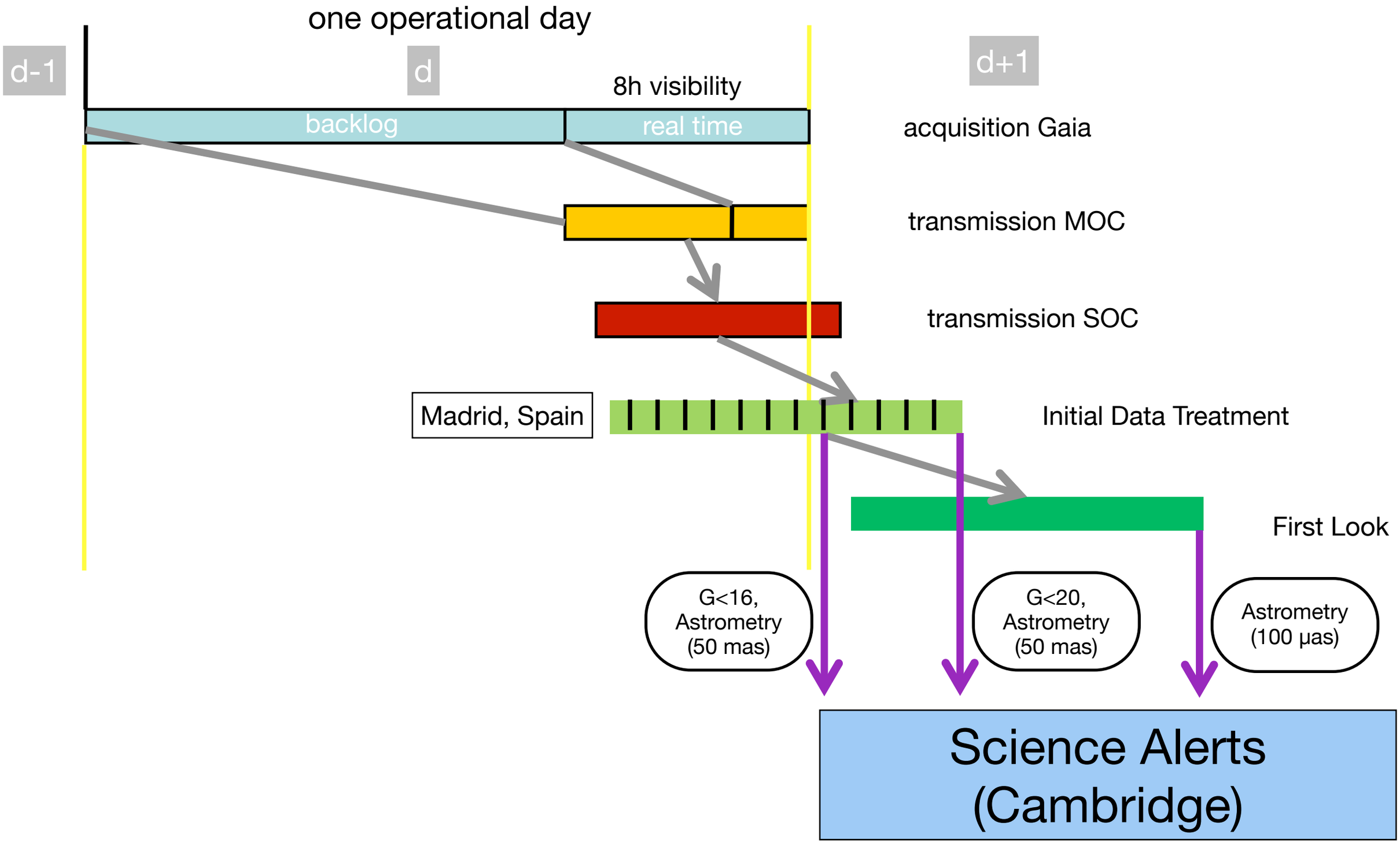
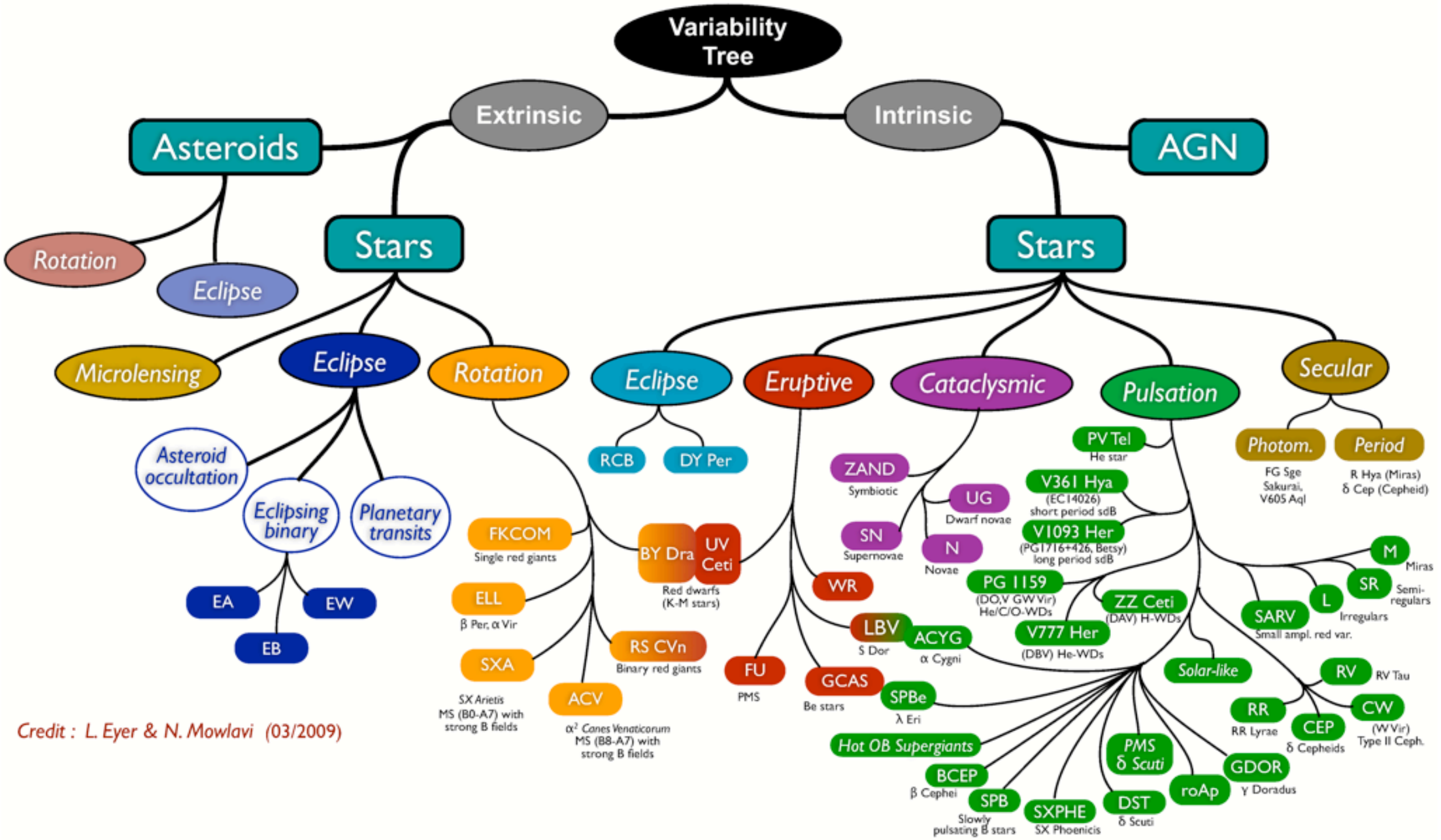


Figure courtesy Francois Mignard, updated by LW+STH

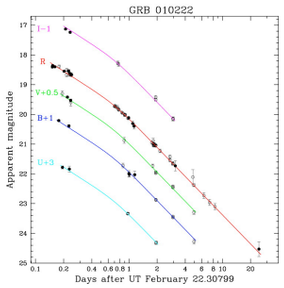
Variable stars vs Science Alerts

Science Alerts: science data that would have little or no value without quick ground-based follow-up

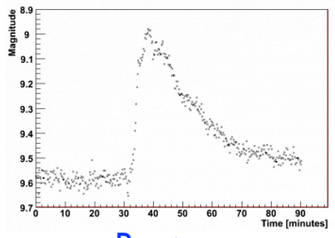


Potential Triggers

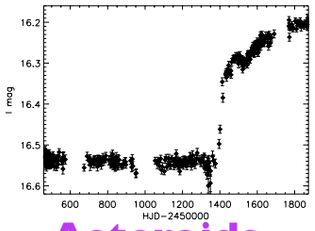
GRBs optical counterparts



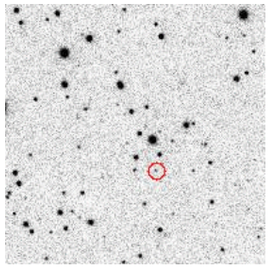
M-dwarf flares

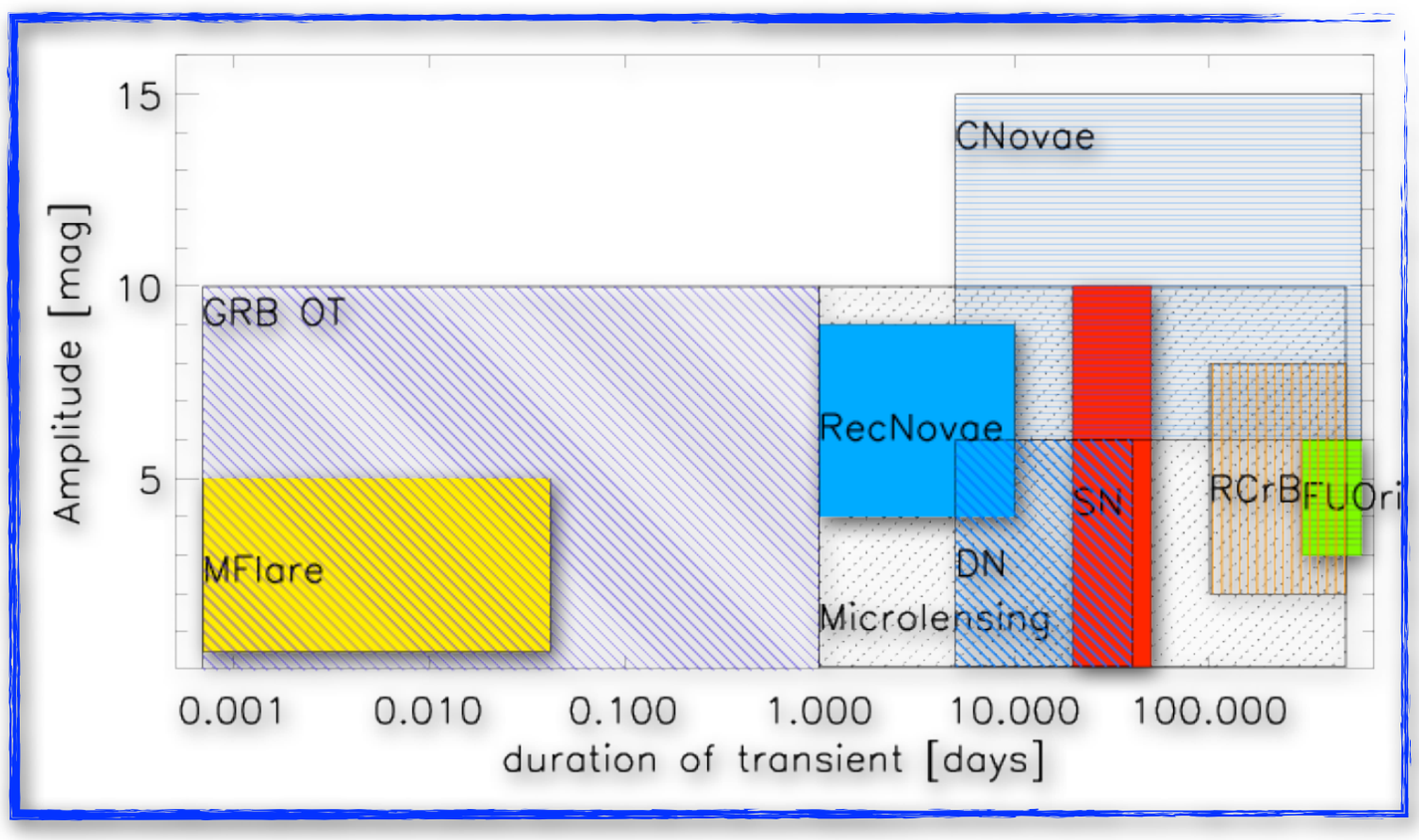


Be stars

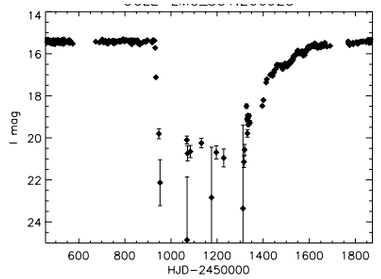


Asteroids

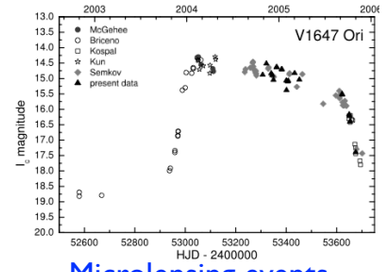




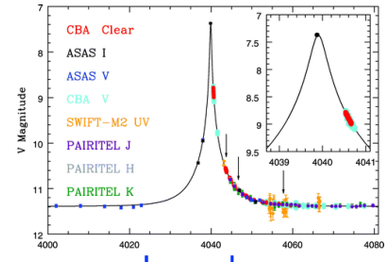
R Coronae Borealis



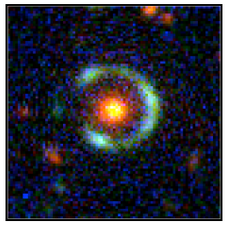
FU Orionis and similar



Microlensing events

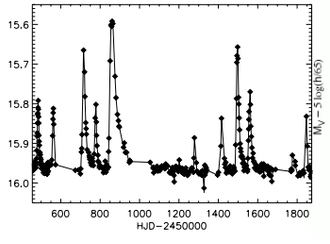


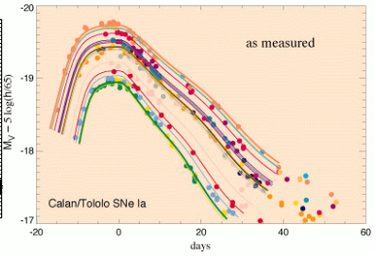
Lensed supernovae



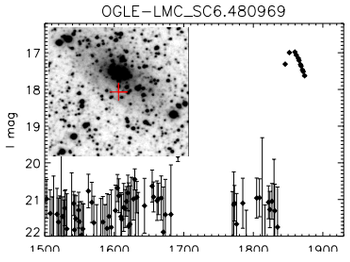
NEW THINGS??

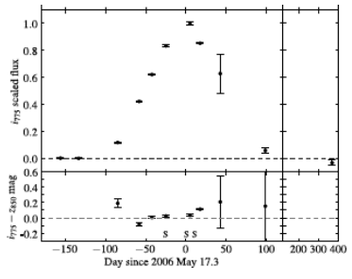
Dwarf novae



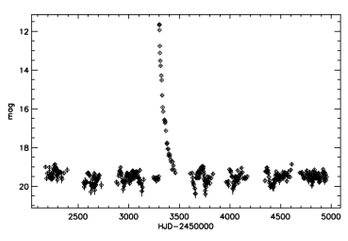


Supernovae



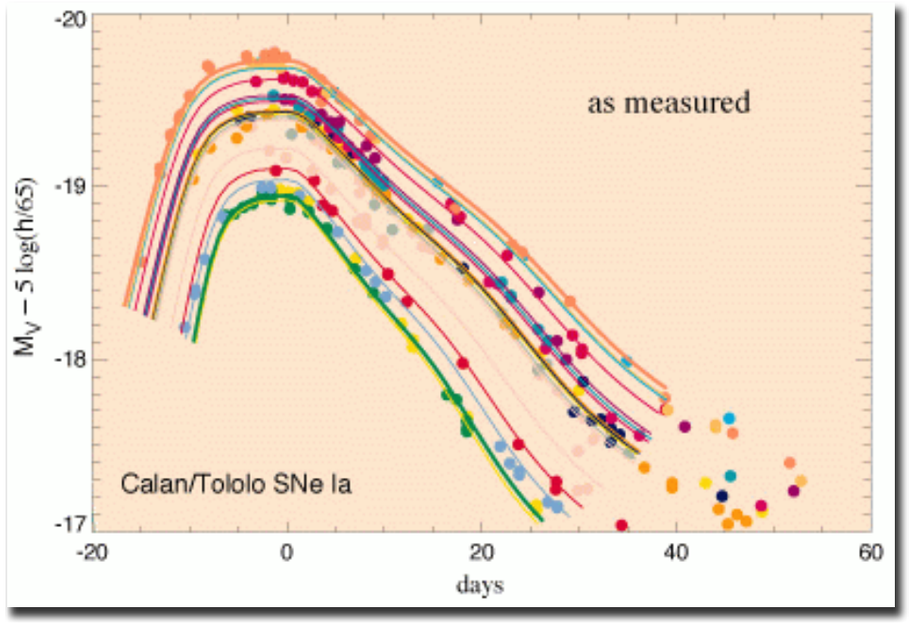


Classical novae

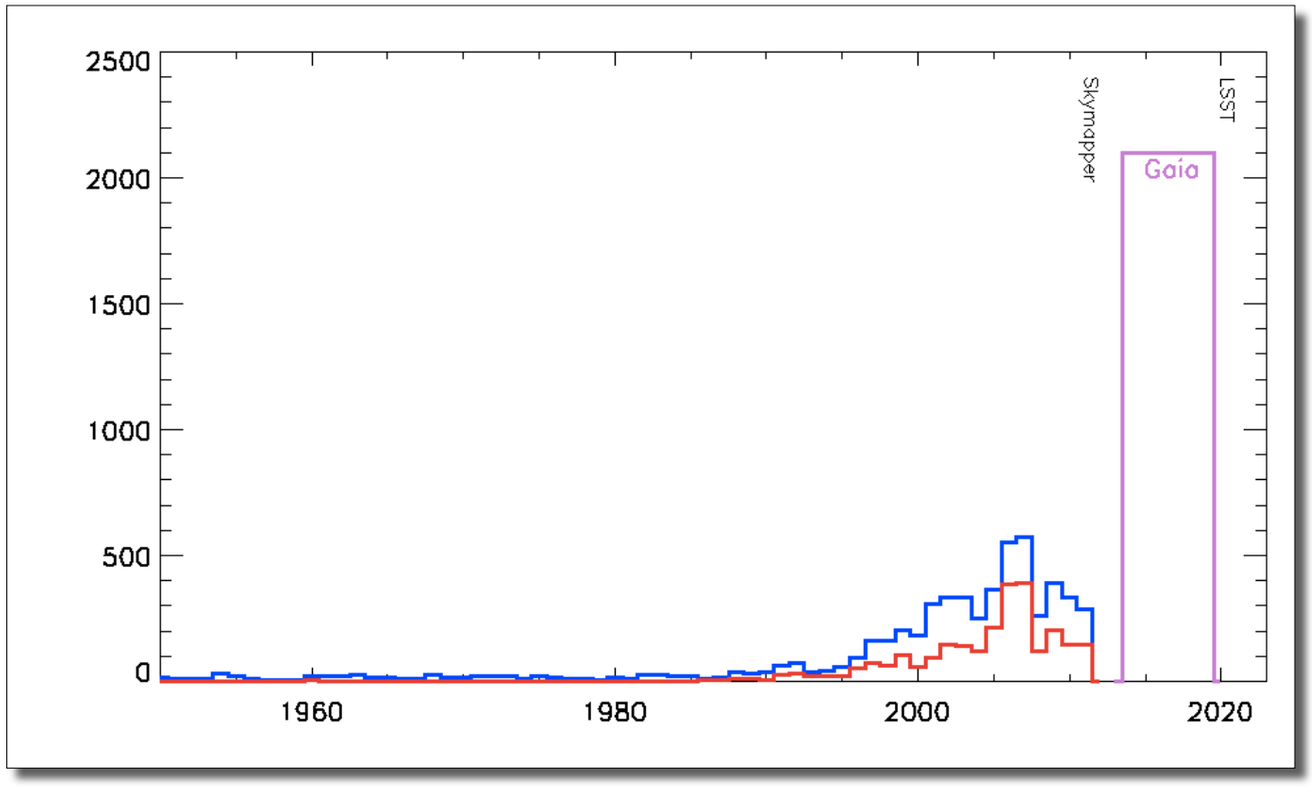


scientific opportunities:
(i) SNe

- **Large “unbiased” samples of SNe:** statistical studies on low-redshift SNe rates
- **6000 over the entire mission** down to 19mag
- **3-4 supernovae daily**
- **1/3 before max - follow-up needed**

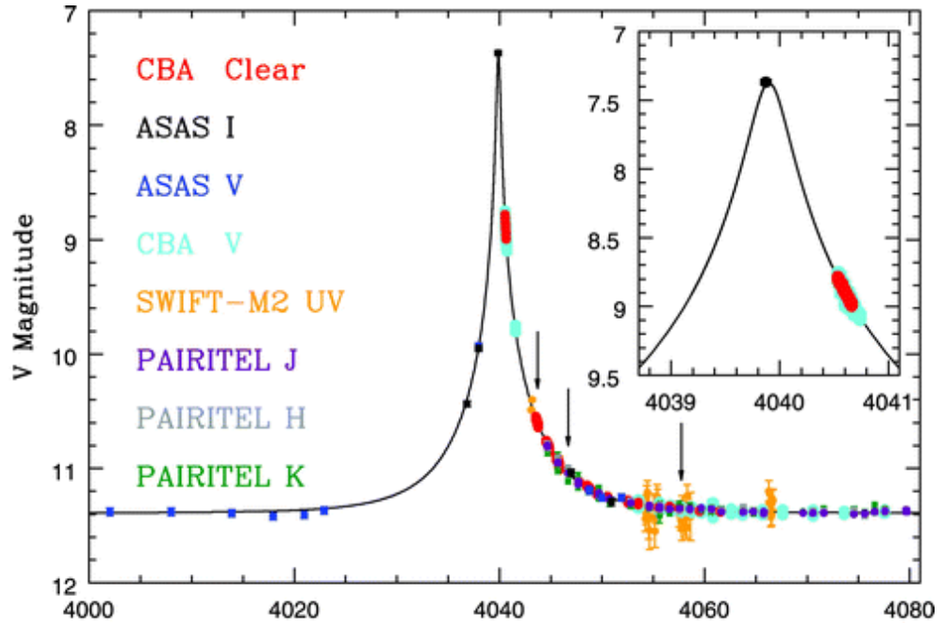


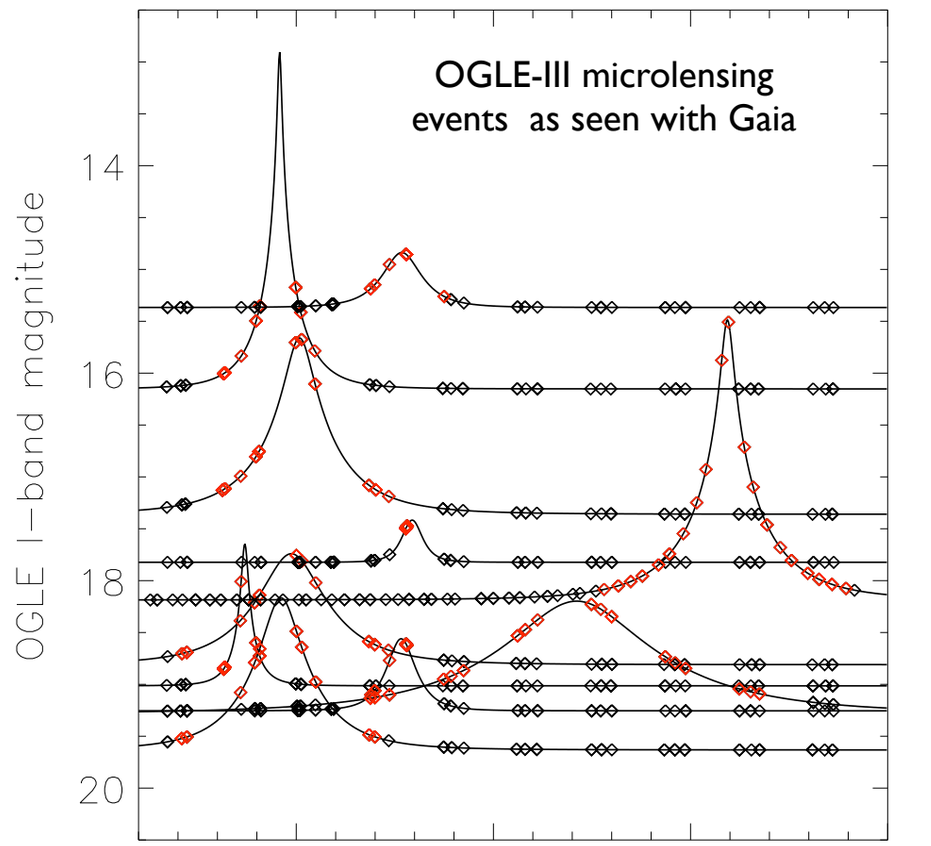
- **Ultra-luminous Surpernovae:** Peculiar light curves, U band magnitude reaching -23, host galaxies faint, e.g. Quimby et al. (2010), link to the relationship between GRBs and SNe.
- **Luminous Red Novae:** bridge the gap between classical novae and supernovae - 4 known, e.g. Kasliwal et al. 2011)



scientific opportunities: (ii) microlensing

- **7,500 photometric events** expected during the mission, mainly in the **Galactic Bulge**, but many lost due to crowding
- **15,000 astrometric events** (higher optical depth)
- **photometric alerts expected on 1000+ events**, mainly long - the most interesting ones (nearby or massive lens)
- **Gaia sampling alone not enough to model the events - follow-up needed!**
- **potential for finding planets** with microlensing if very dense sampling provided from the ground
- **potential for finding black-holes** and neutron stars





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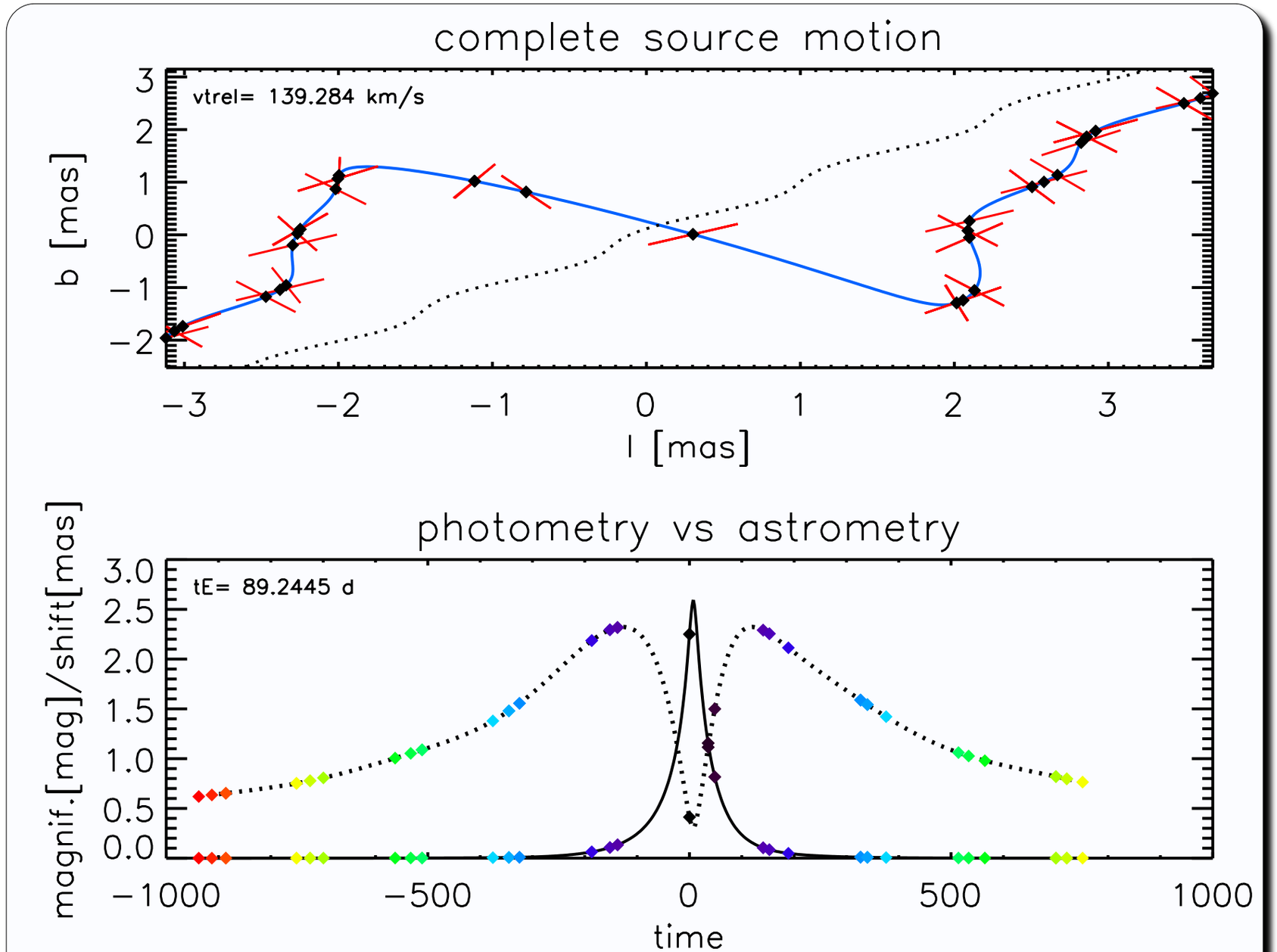
scientific opportunities: (ii) microlensing

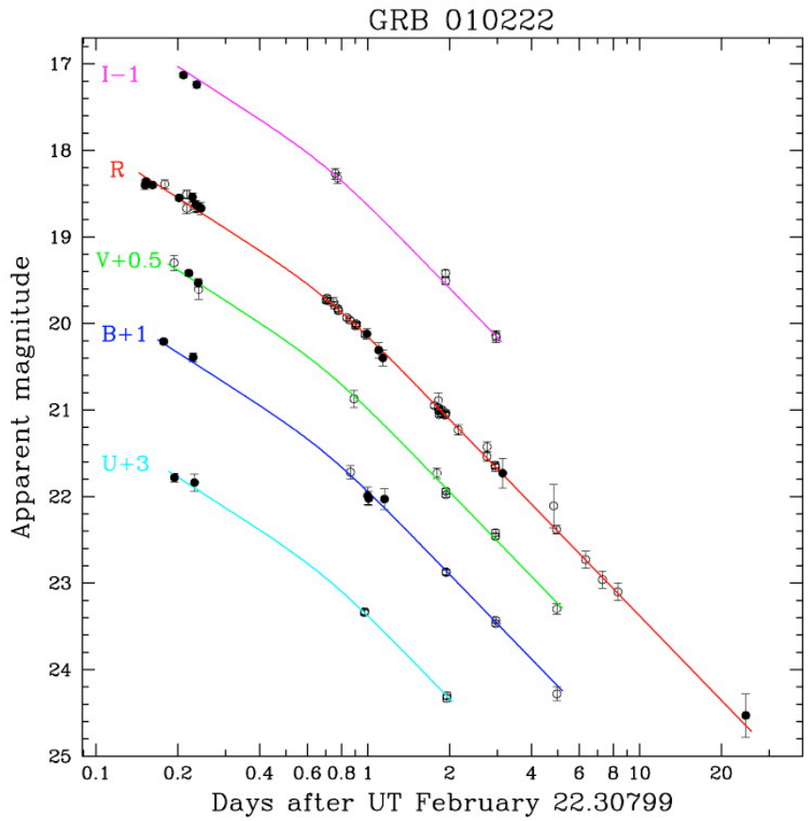
- **Black Hole** lens events will cause astrometric signals around **2 milliarcsec** (distance dependent).
- Combine **astrometric** and **photometric** data to solve for the lens mass and distance
- Synergy with OGLE and MOA microlensing surveys - but only towards the Bulge
- **intense photometric follow-up needed to provide full light curve!**



simulation by Lukasz Wyrzykowski: ds=8.6kpc, dl=1kpc, ml=6msun

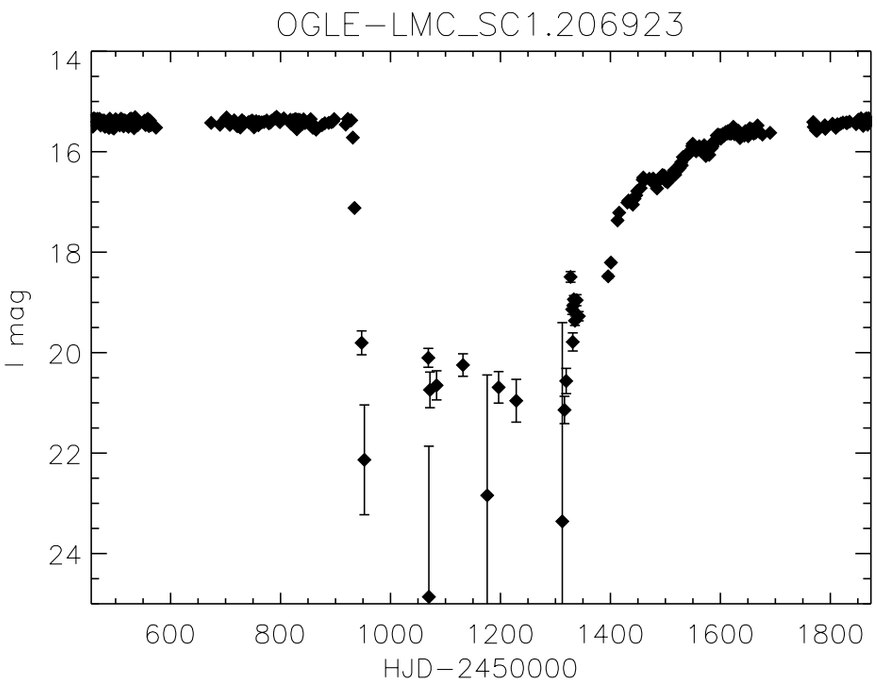
scientific opportunities:
(iii) GRBs and high energy physics

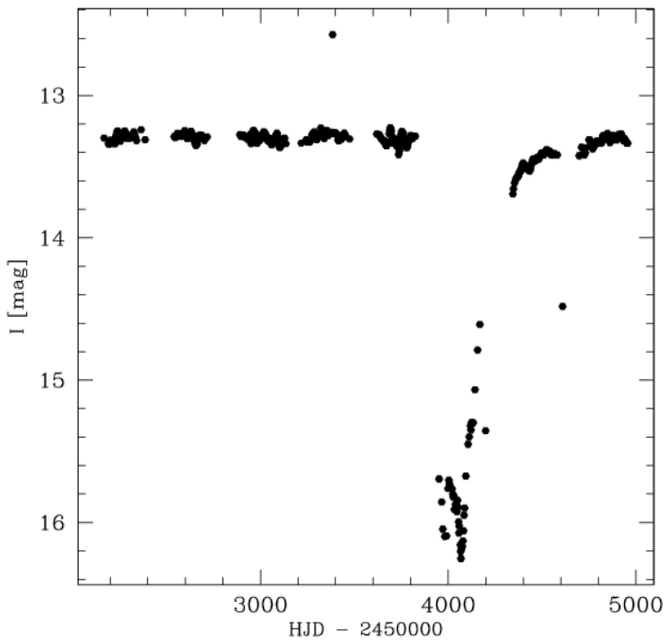
- **time scales: few seconds to hours** - very hard to detect with Gaia sampling
- **only about 20** brigher (and usually longer) **GRBs** and **Orphan Afterglows** will be detected
- **rapid follow-up crucial to confirm!**
- **Synergies**: There is overlap with high energy missions: XMM-Newton, MAXI/ISS (whole sky in 90 mins 0.5-30 keV), Swift (all-sky 15-150 keV - but has ToO capability with the XRT). Future missions include SVOM (Swift like), JANUS (proposal: NIRT +XCAT), ASTROSAT.

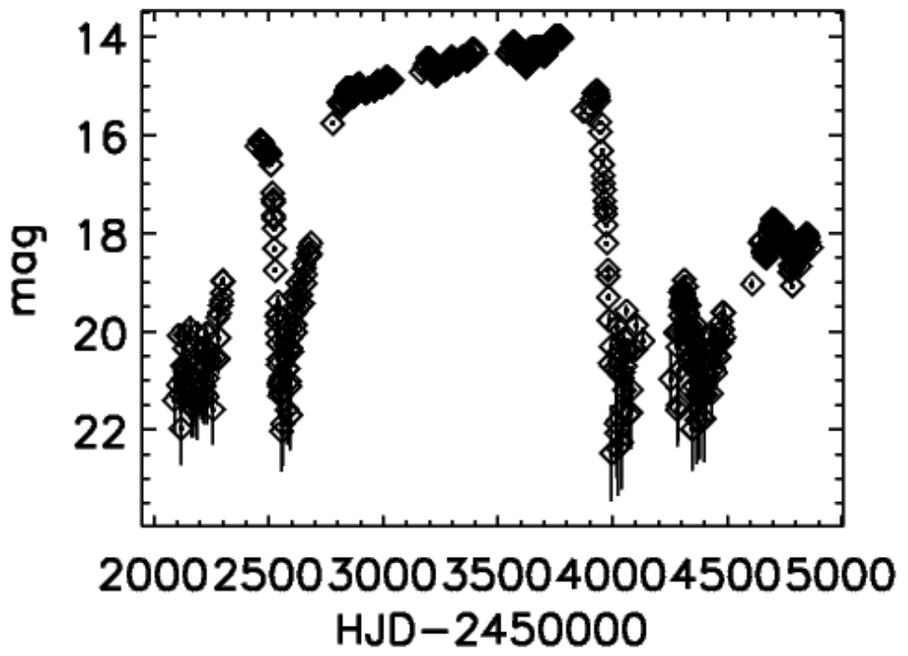


scientific opportunities:
(iv) R CrB-type stars

- **can drop up to 8 mag** in brightness over a week! - *ideal time-scale for Gaia sampling*
- **very few known** (~50), but ~3000 expected
- Gaia will easily find new fainter RCrBs
- mechanism of these dimmings remains unknown
- **spectroscopic follow-up** during an event can help solving their mystery







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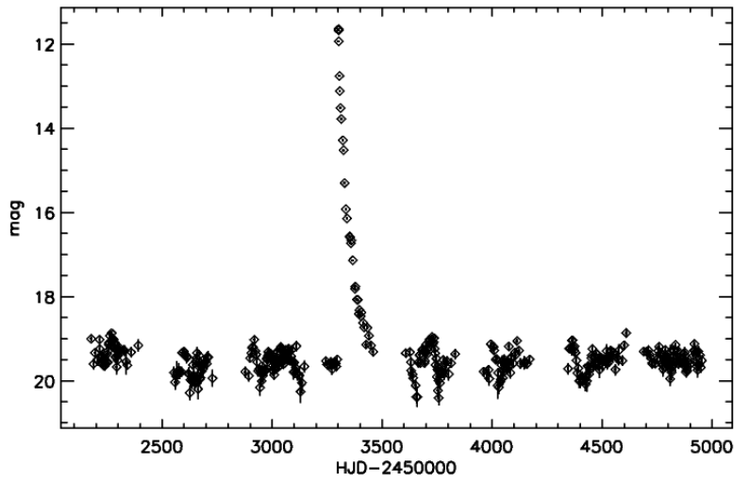
scientific opportunities: other interesting triggers

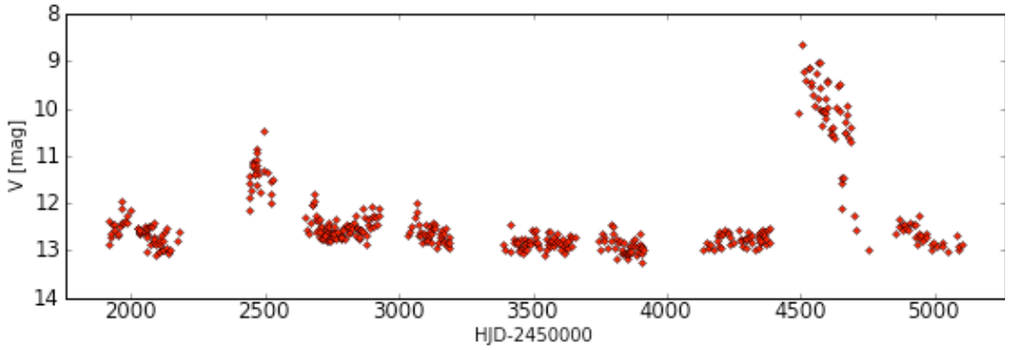


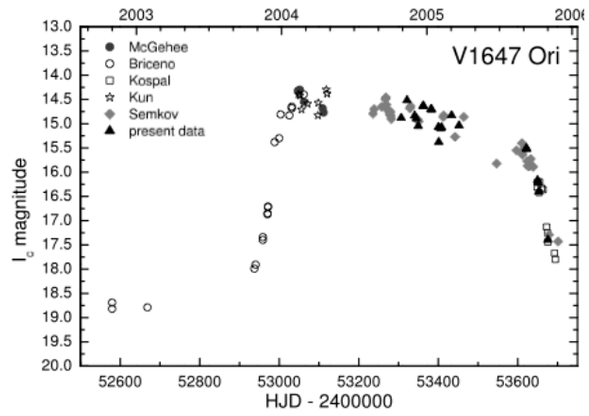
✦ Classical and recurrent novae

- **unbiased and efficient** survey of novae
- can be detected in MW and other galaxies
- large amplitudes, wide range of time-scales

✦ FU Orionis/EX Lupi

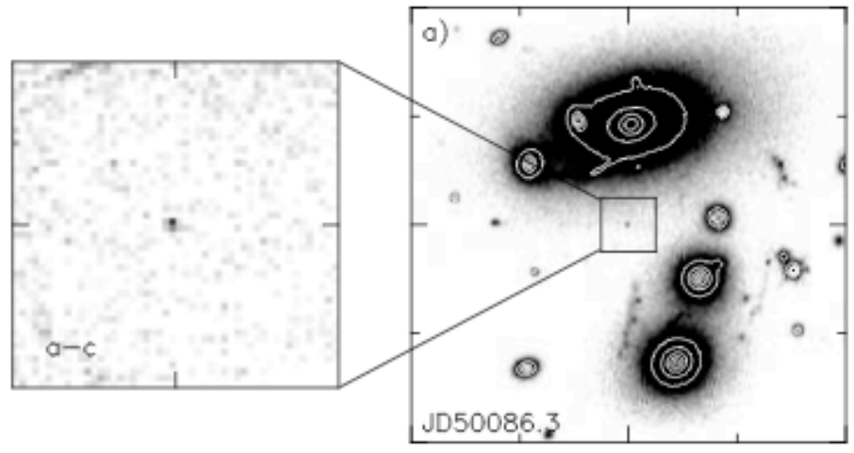
- unstable pre-MS stars
- rare class (few known)
- several magnitudes up
- X-ray variability
- long time-scales
- FU Ori repeats every ~40 years!





✦ Gravitationally lensed distant supernovae

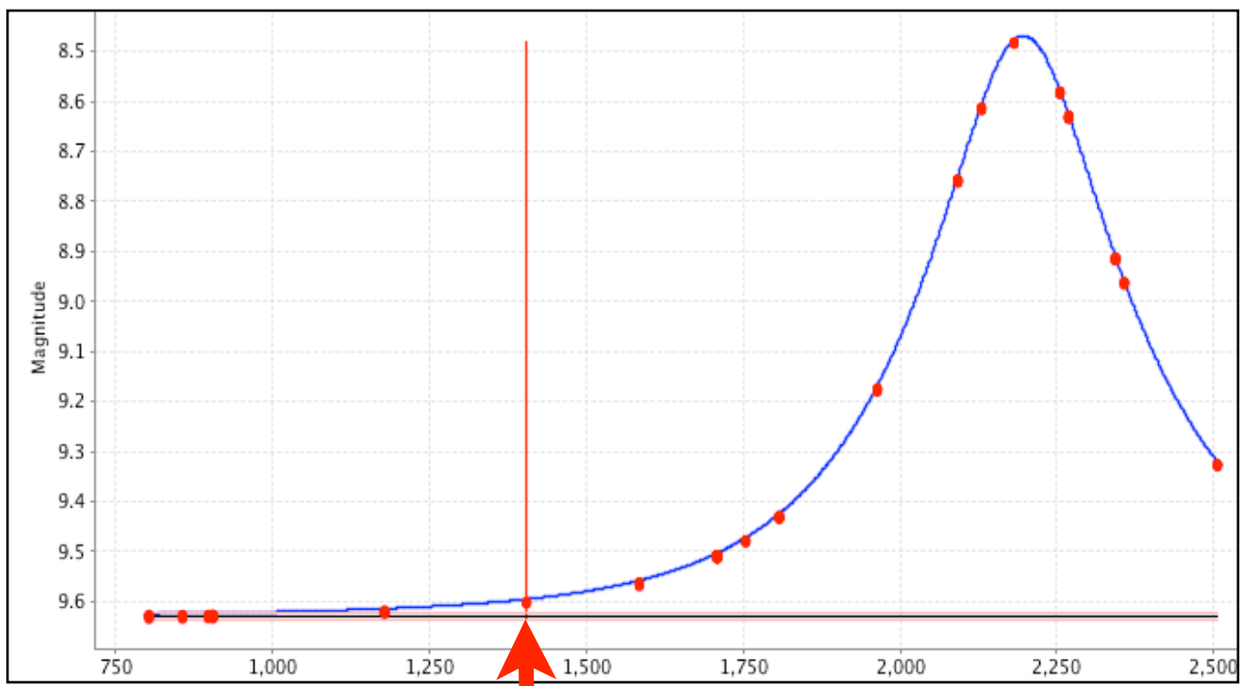
- unique uniform all-sky monitoring
- high redshift SNe rates, distances, H0

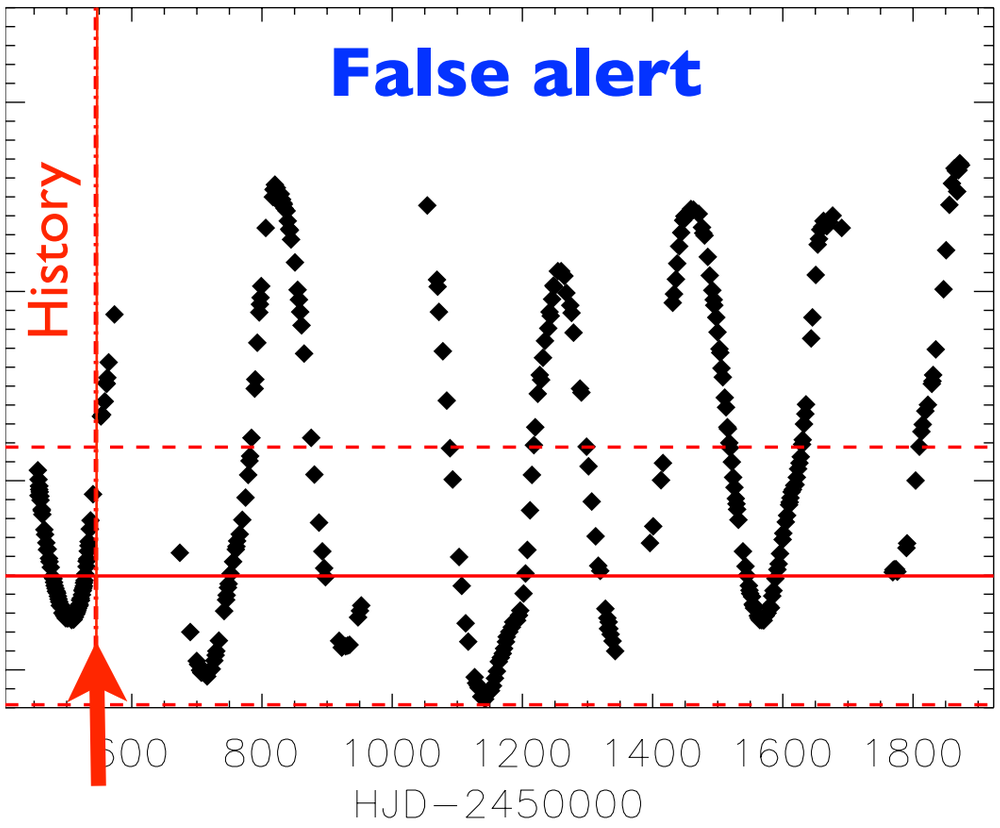


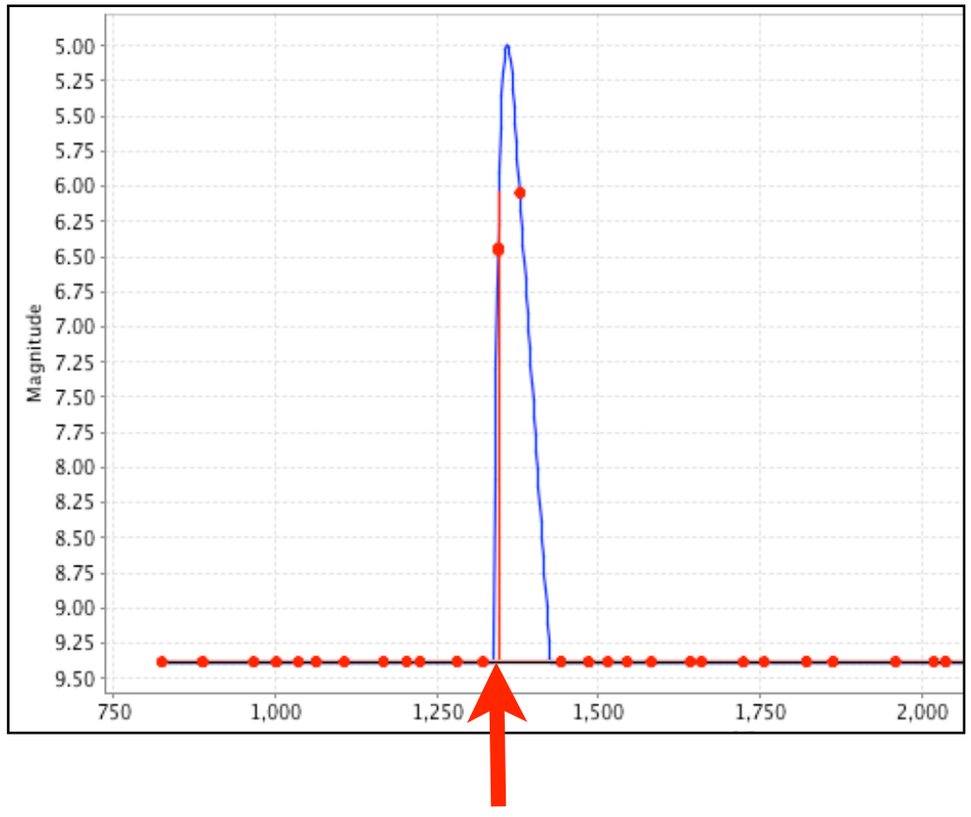
Watch List

- Typically, known variables will be excluded from a transient survey.
- So we will be monitoring a pre-decided set of known and interesting objects.
- Flexible - add an object to the list of alerts during the mission.
- Normally detected alerts will end-up in the Watch List.
- Real power will come from comparing with other surveys

Detection: the simplest algorithm

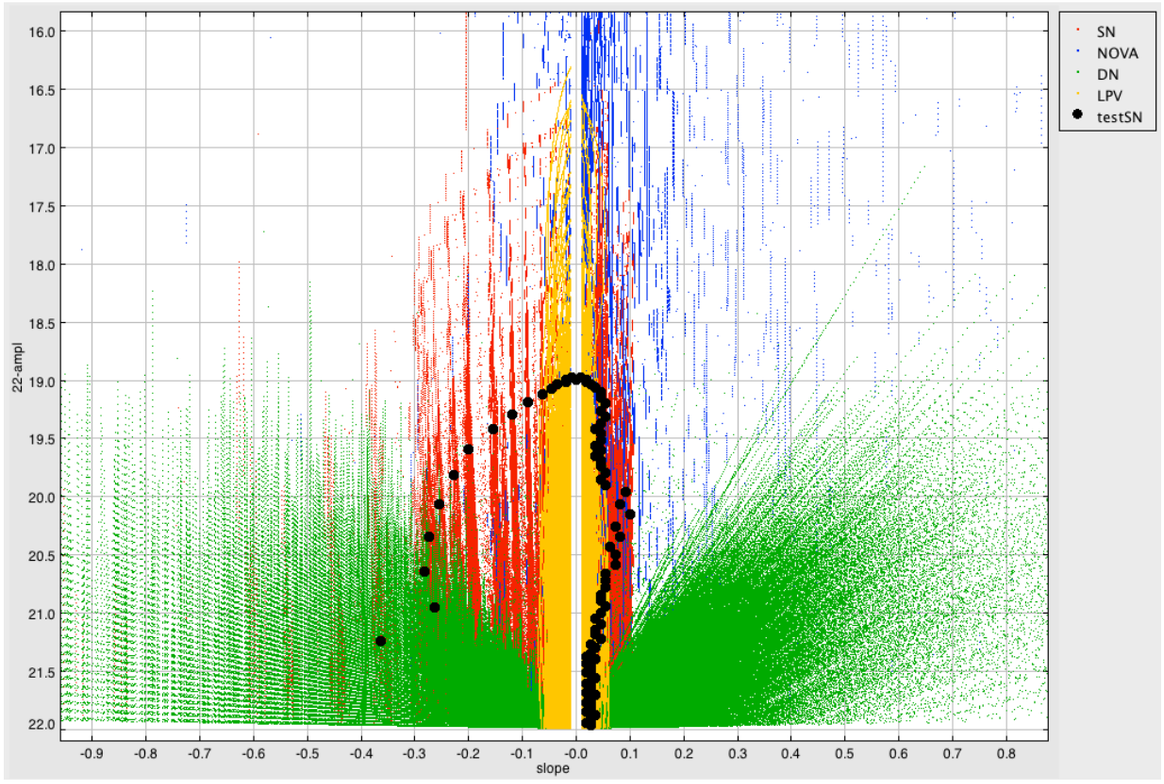






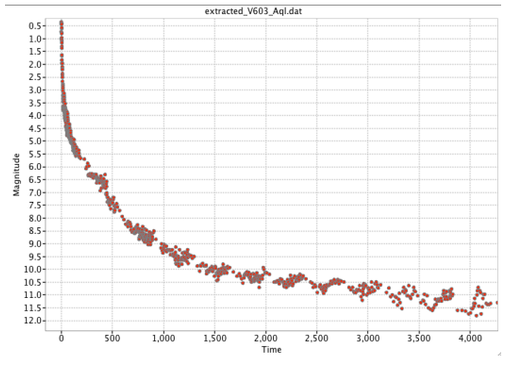
Crude lightcurve-based classification

Magnitude change between two Gaia's FoVs (106.5min) can separate some supernovae from Novae and Dwarf Novae

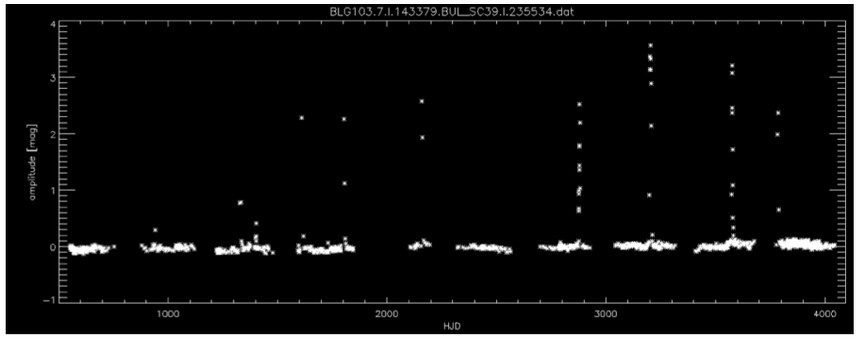


slope

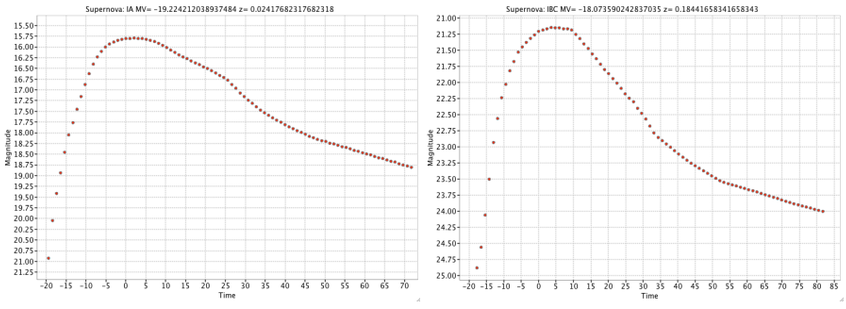
novae



dwarf novae

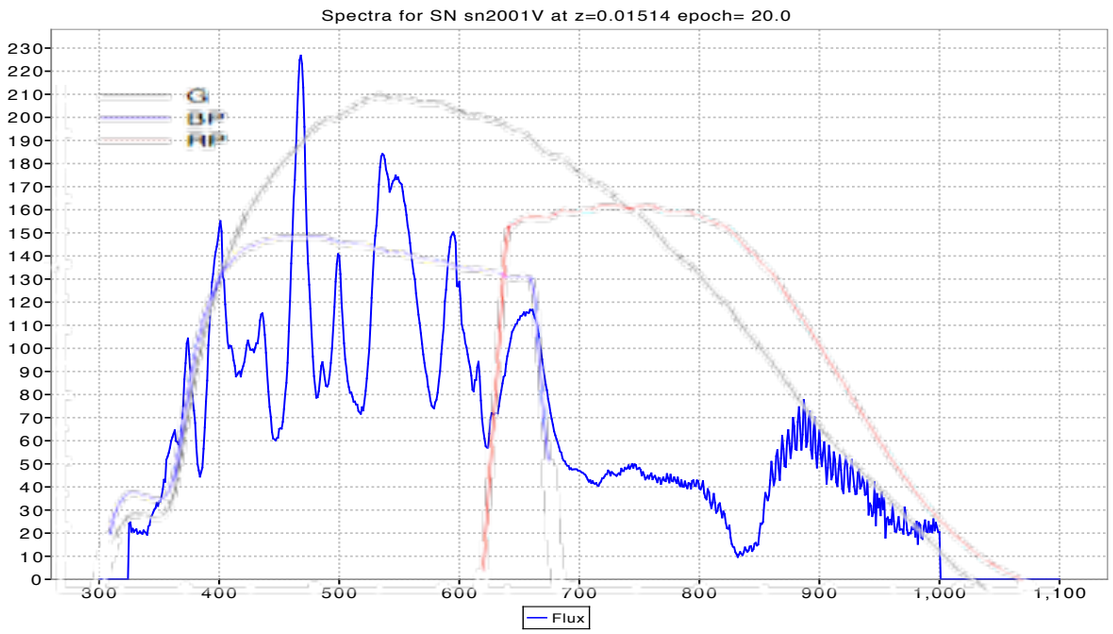


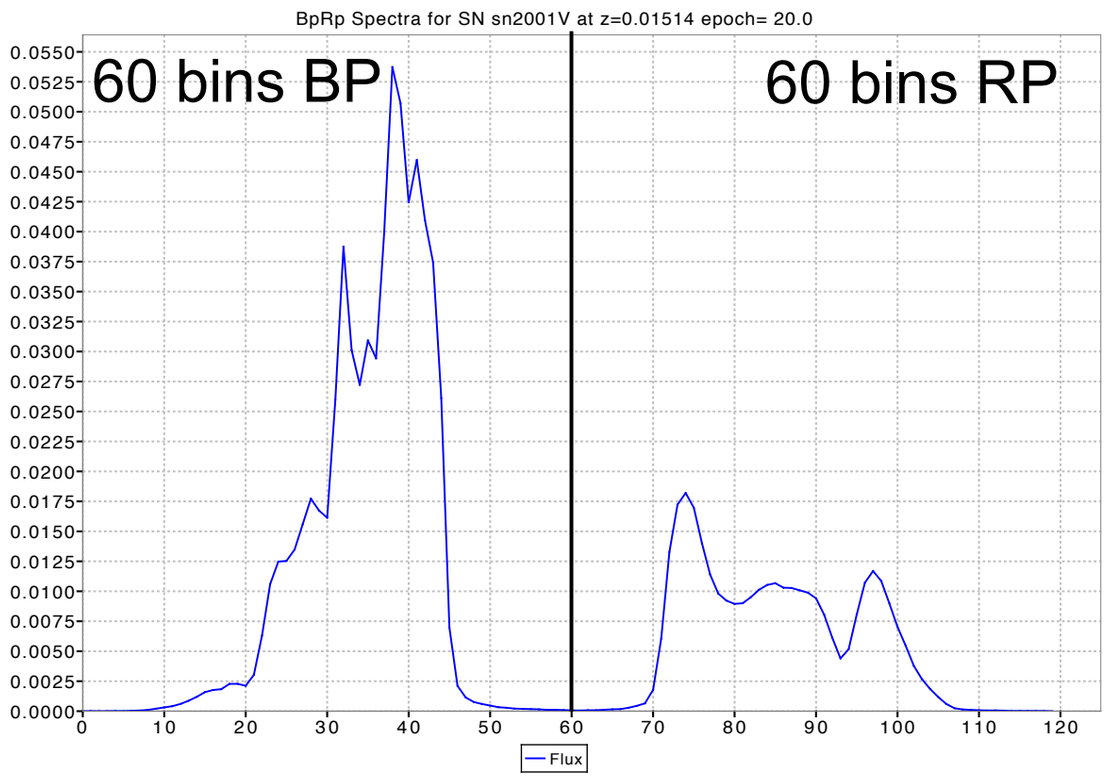
supernovae



Supernovae with Gaia

(work of Nadia Blogorodnova, GREAT PhD student @ IoA)





- Template spectra converted into Gaia low-res BP-RP
- 60+60 pixels
- tests on retrieving SNe's

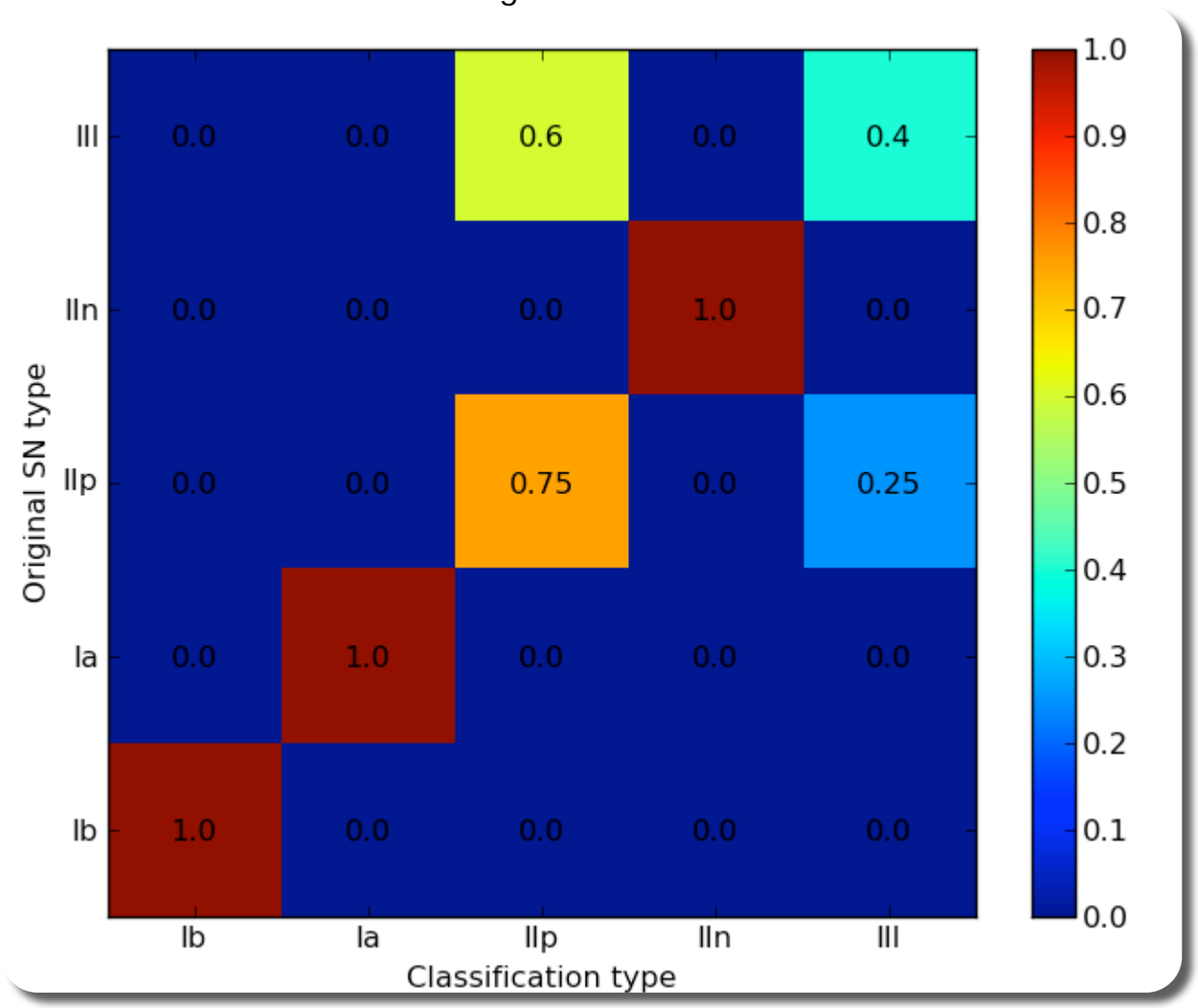
Epoch

z

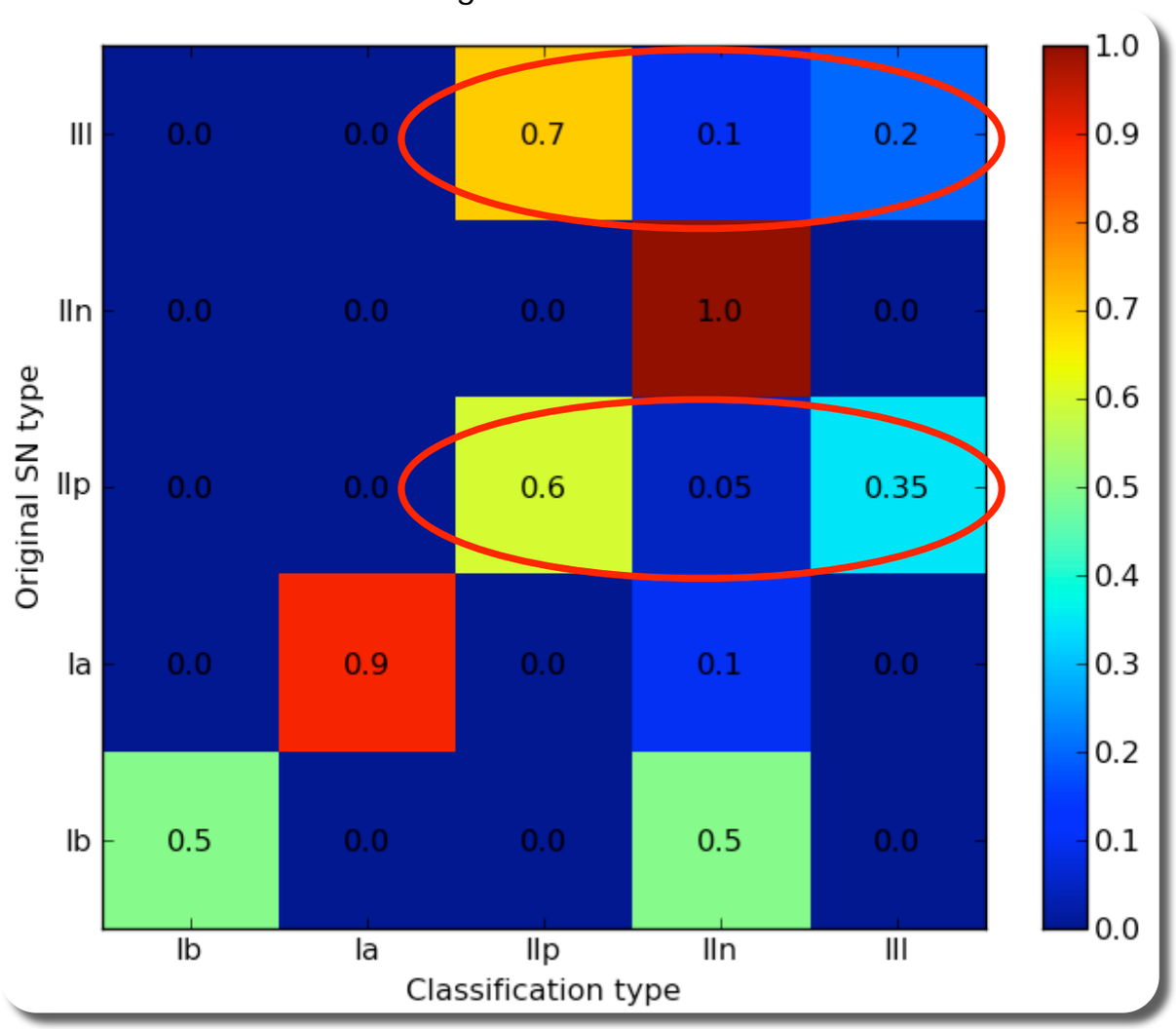
A_V

BP/RP SN Spectra: Classification of Type

m_g = 17 mag



m_g = 18 mag



- Range of model templates (Nugent, Hsiao)
- Perturb spectra (magnitude, redshift), add noise.
- Classify

Nadejda Blagorodnova, PhD @ IoA

Confusion among SNIIp and IIL.
→Very similar spectra.
→Main differences in lightcurve.

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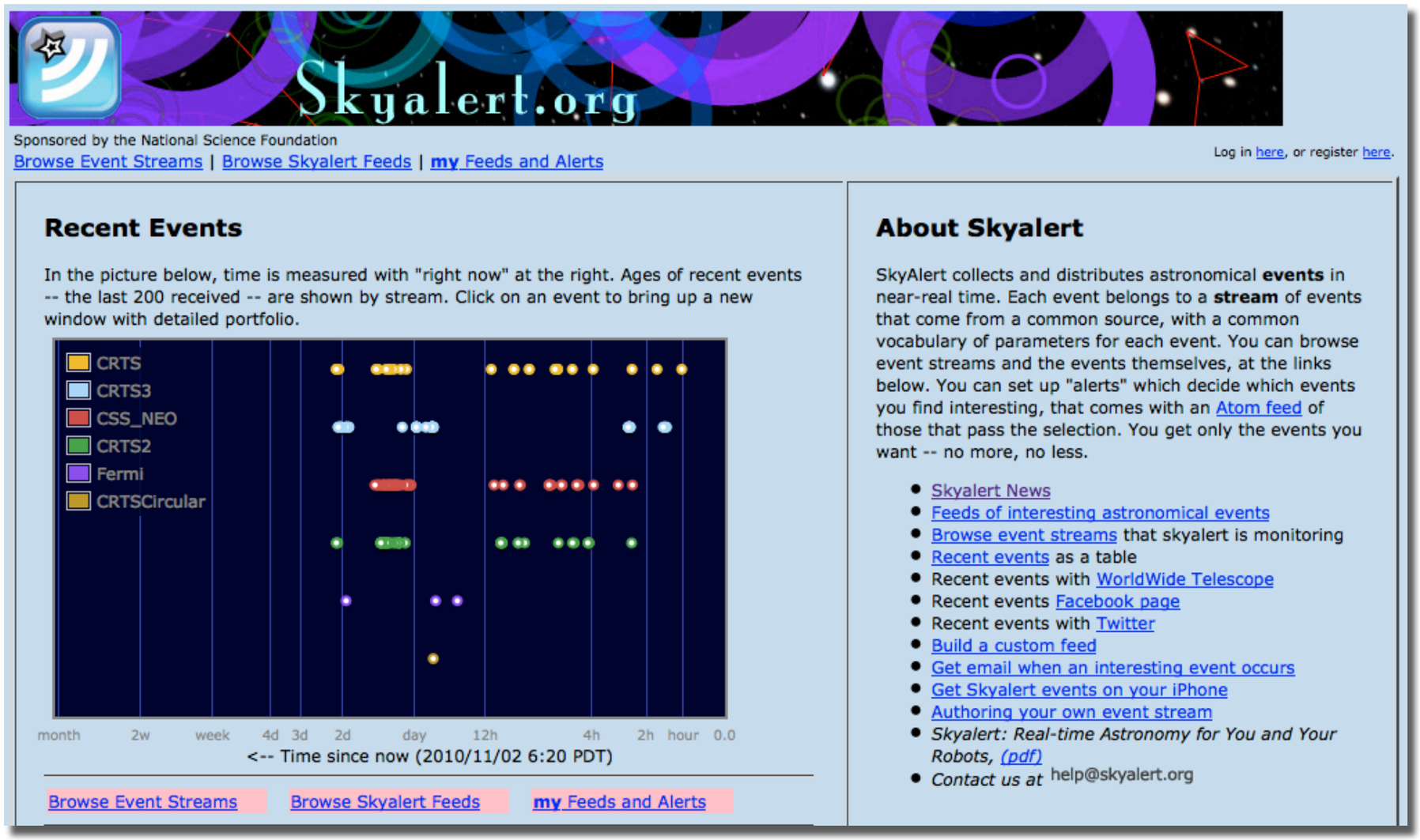
Alerts dissemination

- Publication of Alerts to the entire community: no proprietary data.
- VOEvent - machine-readable format, can be displayed in e.g. Google Sky
- email + WWW server
- System like Skyalert.org - will host both alerts and follow-up data



Alerts will contain:
coordinates, light curve, spectra
classification results

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Follow-up network requirements

- photometric follow-up (imaging) to confirm an alert
- multi-band photometric monitoring to build light-curve and classify an alert
- low-, mid-, high-resolution spectroscopy to confirm the classification of an alert

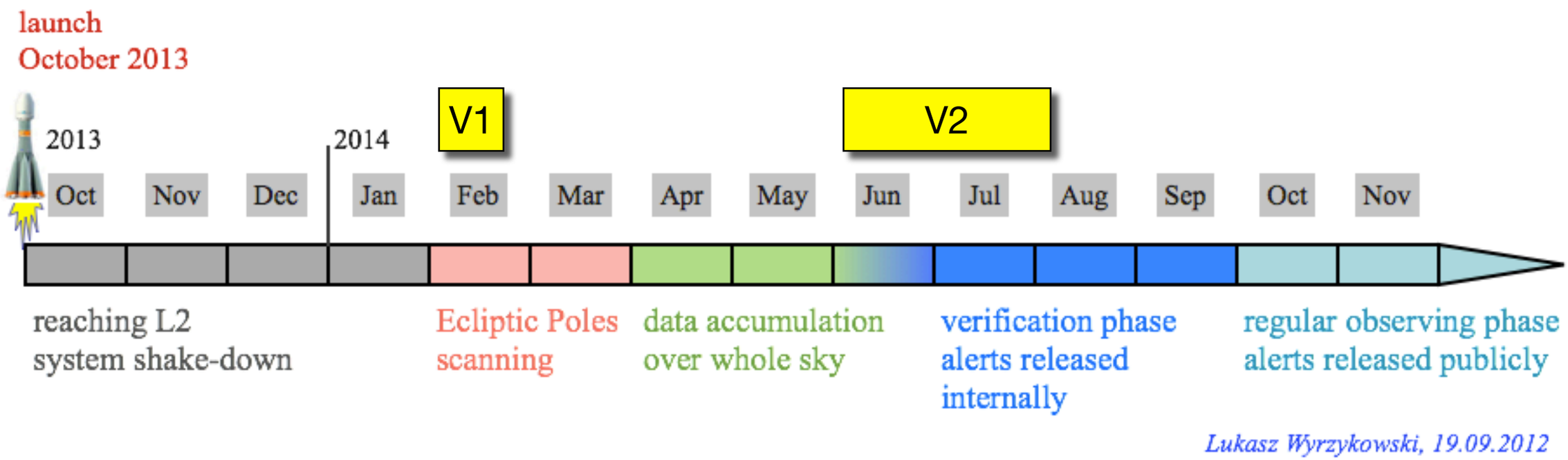
- 0.5-2m telescopes on both hemispheres, east and west
- ideally, fully robotised telescopes, easy to schedule with ToO
- human operated telescopes also useful because of long lag of alerts (not so time-critical in many cases)
- unified/standardised observational output, centralised repository of data
- clear rules on data policy, publications, etc.

Gaia Alerts Verification Phase

- alerts NOT public for couple of first months of Gaia
- available only to a dedicated group of follow-up telescopes
- Two main stages:

  V1 : towards the end of Ecliptic Poles scanning mode

  V2 : commences as soon as sufficient sky has been observed enough times to define the baseline catalogue

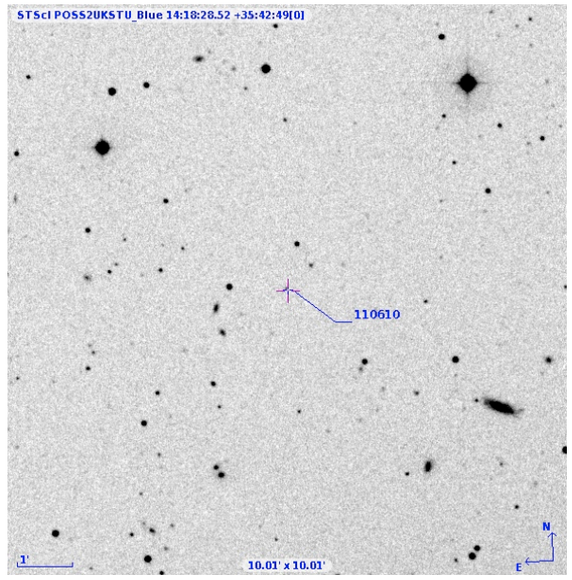


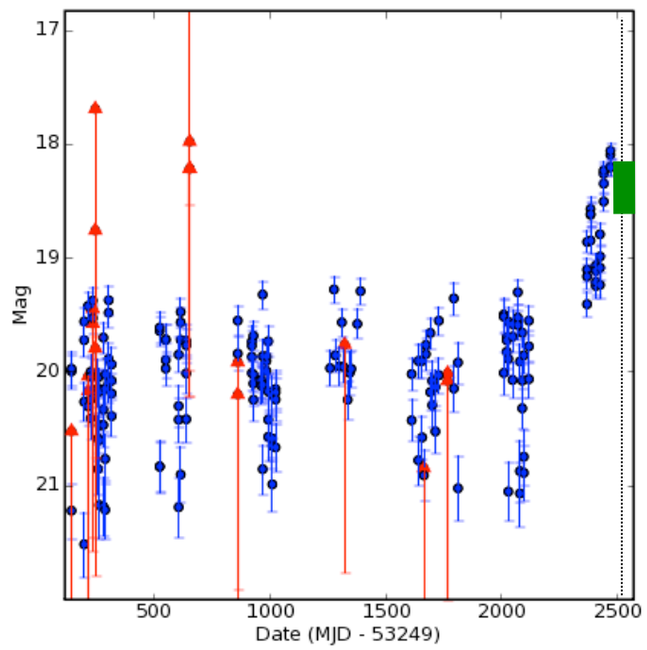
Purposes of Verification

- Demonstrate transient detection works
- Demonstrate transient classification works
- Test thresholds
- Validate associated classification probabilities
- Investigate Gaia Science Alert population : completeness and contamination
- **To build a training data set**

Pre-launch test phase

- to prepare the telescopes and people for Gaia alerts
- using CRTS survey transients as proxy to Gaia
- a potential new partner needs to prove capability to perform the rapid follow-up in order to join the verification
- formal Memoranda of Understanding will be signed with partners





follow-up example
from G. Altavilla

Simple guide:

1. observe an alert from CRTS
2. reduce the data *asap*
3. attach astrometry (WCS)
4. run SExtractor
5. submit to Calibration Server

Astrometry.net

Astromatic.net
Your first stop for astronomical pipeline software

SExtractor

Follow-up calibration server

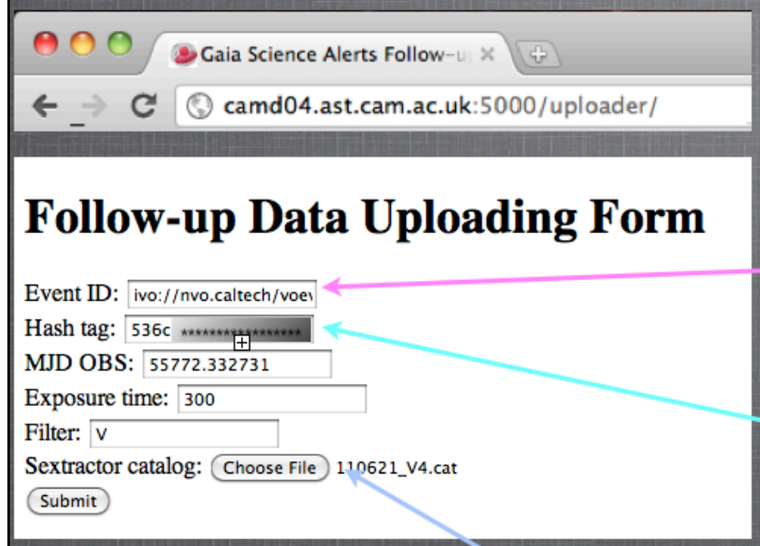
GAIA SCIENCE ALERTS

Follow-up server manual

gaia

Łukasz Wyrzykowski & Sergey Koposov
Institute of Astronomy, University of Cambridge, UK
November 2011

UPLOADING THE FOLLOW-UP DATA

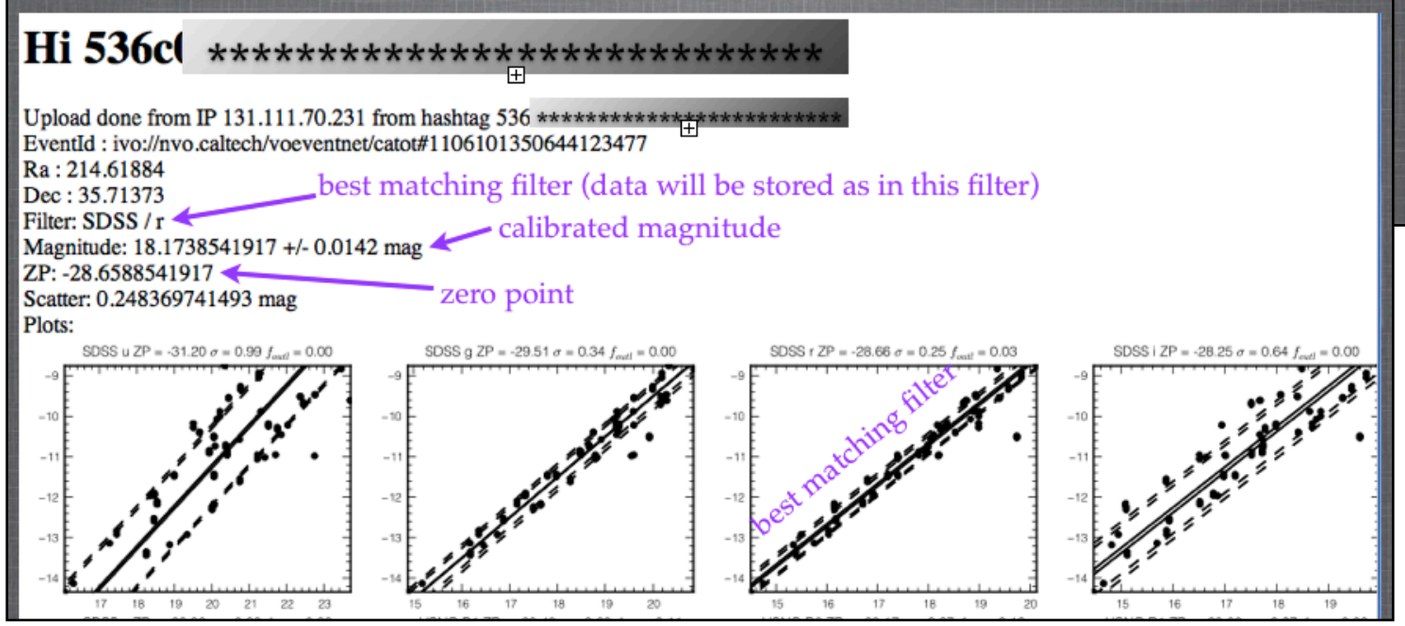


Your unique access name / pass
(provided by Cambridge)

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]
```

RESULT OF CALIBRATIONS



access can be fully automatised

software developed by Sergey Koposov, IoA

Now is the time to join!

Gaia
Follow-Up Network
for Transient Objects

Telescopes for Gaia

File Edit View Insert Format Data Tools Help All changes saved

Share

Size [m]

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Telescope/obse name	Location	Longitude (+ for E, - for W)	Latitude (+ for N, - for S)	Altitude [m]	Size [m]	Field-of-view, [deg^2]	Limit DEC	Limit HA	instruments	CCD size [arcsec/pix]	limiting magnitude (R or equivalent)	filters	spectral range	spectral resolution	time available for alerts follow-up
5	Besancon Obs	France				2				spectropolarime						
6	Ondrejov	Czech Rep.	14.78	49.92	524	2		-20	no	Coude spectrograph				4000 - 9000 A	10 000	upon request from the GAIA Alerts WG
7	Asiago	Padova, Italy	11.57	45.84	1352	1.82	8.7'x8.7'			AFOSC	0.52" (2x2bin)	V~21 at S/N~10 with 10min	UBVRI	370-950	200-5000	7-10 nights per month during the period August to April.
8	Danish 154	La Silla, Chile	-70 44 08	-29 15 14	2340	1.54	13.7x13.7 arcmin			DFOSC only camera in use		18		n/a	n/a	upon request from the GAIA Alerts WG pending the internal agreement of 3 participants, Ondrejov, Chareles University, Brno University total quota 90 nights per year.
9	Loiano	Bologna, Italy	11.33	44.26	785	1.5	13'x12.6'	-5 -- +70 optimal		BFOSC	0.58"	V~22 in 30min, V~6-7 in 2-3 sec; in spectroscopy V~18 in 30min, V~5-6 in 10sec	UBVRI, Gunn	370-850	200-2000, 4200 in echelle mode	2-3 nights/month (August 2011-January2012) , 5 nights/months afterwards
10	Maidanak	Uzbekistan				1.5										
11	Toppo di Castelgrande	Italy				1.5				photometry/LDS						
12	Vienna	Austria				1.5										
13	Belgian Mercator	La Palma, Spain	-17°52'42"	17°52'42"	2333	1.2	6.5'x6.5'			Merope, Hermes, Maia(soon)	0.19		7 Geneva filters + R + I		85000	From Geneva: upon request and pending acceptance by Geneva group of Stellar Variability.
14	Swiss Euler	La Silla, Chile	-70.73	-29.2567	2347	1.2	10'x10'	=+29 deg (z=2)		Coralie (spectrograph), ECAM CCD	0.3"	CCD: ~19?	Geveva filters (U,B1,B2,B,V G) plus RG, ZG (Gunn?), IC (Cousins)	380 nm to 690 nm (69 Echelle orders)	65000	tentative: upon request and pending internal (Geneva Stellar Variability Group) acceptance.

Telescopes | backup 30.06.2011 | backup of 24.06.2011 | Sum: 30.12

contact me at
wyrzykow@ast.cam.ac.uk
and
sign in here:
www.tinyurl.com/telescopes-for-gaia

http://www.ast.cam.ac.uk/ioa/research/gsawg/