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Around Gaia Alerts in 20 questions

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Abstract. Gaia is a European Space Agency (ESA) astrometry space mission, and a successor to the ESA Hipparcos mission. Gaia's main goal is to collect high-precision astrometric data (positions, parallaxes, and proper motions) for the 1 billion brightest objects in the sky. Those data, complemented with multi-band, multi-epoch photometric and spectroscopic data observed from the same observing platform, will allow astronomers to reconstruct the formation history, structure, and evolution of the Galaxy.

Gaia will observe the whole sky for 5 years, providing a unique opportunity for the discovery of large numbers of transient and anomalous events such as supernovæ, novæ and microlensing events, GRB afterglows, fallback supernovæ, and other theoretical or unexpected phenomena. The Photometric Science Alerts team has been tasked with the early detection, classification and prompt release of anomalous sources in the Gaia data stream. In this paper we discuss the challenges we face in preparing to use Gaia to search for transient pheonomena at optical wavelengths.

Keywords. space missions: Gaia, supernovae: general, gravitational lensing, novae

1. Where, how and when?

Gaiawill be launched in ESA/Kourou (French Guyana) from a Soyuz-Fregat rocket in 2013 June. Deployment will be at the L2 Lagrange Point, with the first community release of alerts expected in mid-2014 (internal verification will begin in early 2014). The mission is scheduled to last until 2018–2019.

2. What telescopes will Gaia have?

Gaia will be equipped with two 1.45×0.5m primary mirrors, forming two fields of view separated by $106^\circ\!.5$. The light from the two mirrors will be imaged onto a single focal plane. Gaia's Astrometric Field detectors will reach to $V = 20$.

3. What instruments will Gaia have?

Each object traverses through the focal plane (4.4 sec per CCD); see Fig. 1.
SM: Objects will be detected by Sky Mapper CCDs, and allocated windows for the remaining detectors.
AF: Source positions and G-band magnitudes are to be measured in the Astrometric Field CCDs (plate scale $\sim 0''\!.04 \times 0''\!.1$).
BP/RP: Low-dispersion spectrophotometry at 330–680 nm and 640–1000 nm), in 120 samples.
RVS: Intermediate-dispersion spectroscopy (R∼11,500) at 847–874 nm (around the Calcium Infrared triplet) to $V < 17$ mag.

‡ name pronunciation: *Woo-cash Vi-zhi-kov-ski*

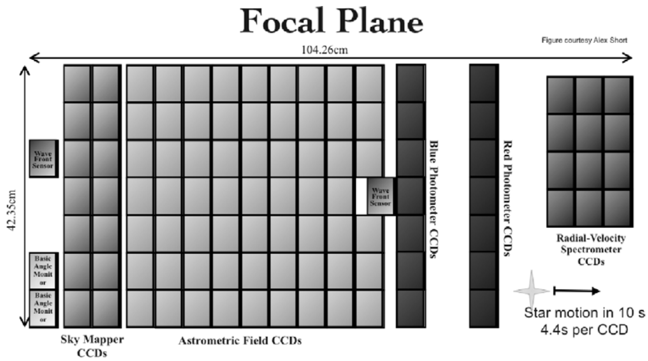

Figure 1. Focal plane of Gaia.

4. What is the data latency?

Gaia will be visible from the Earth for only 8 h a day. All the data from the previous 24 h will be downlinked during a contact. After initial data processing, alerts will be issued during a period from a couple of hours to 48 hours after the observation.

5. What is downloaded?

Most of the sky is empty. Gaia will only transmit small windows around stars that are detected at each transit on the Star Mapper CCDs, plus associated data.

6. How does the scanning law allow for full sky coverage?

Gaia has a pre-defined plan for scanning the sky. The spin axis will be maintained at 45° from the Sun, with a period of 6 h. Details are explained in Fig. 2.

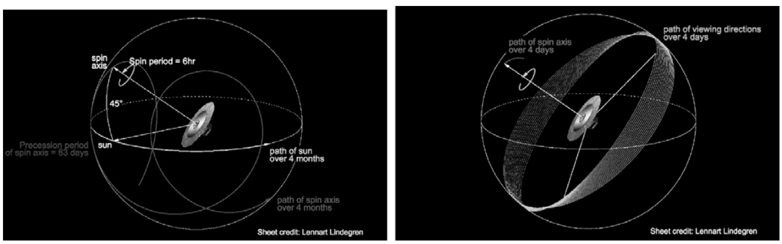

Figure 2. Nominal Scanning Law principles for the Gaia satellite.

7. What is the typical sampling?

On average, each object will be observed 80 times, though at the Ecliptic nodes objects will be scanned > 200 times. Observations will occur in pairs (two FOVs), separated by $\sim$2 hours. The separation between pairs will be between 6 hours and $\sim$30 days.

8. What is the precision of the instantaneous photometry and astrometry?

In a single observation (transit), the photometry will reach millimagnitude precision at $G = 14$, and 1% at $G = 19$. The astrometric precision will be in the range 20–80 μas at $G = 8$–15 (Fig. 3 explains the effects of gating), falling to 600 μas at $G = 19$. That level of astrometric precision will only be reached later into the mission.

9. How will anomalies be detected?

Using simple recipes:
1. By comparing the most recent observation with available historic data, and

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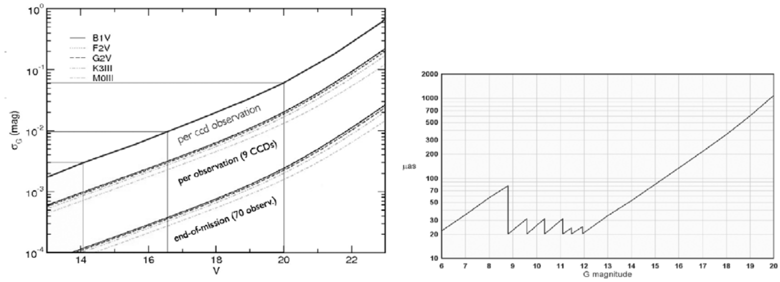

Figure 3. Precision of instantaneous photometry and astrometry of Gaia.

2. inspecting for unexpected changes.
3. No history? New transient!

10. How will the anomalies be classified?

1. From the light-curve,
2. from low-dispersion BP/RP spectroscopy, or
3. by cross-matching with archival data.

11. How will the BP/RP spectra be used?

Self-Organizing Maps (Wyrzykowski & Belokurov 2008) built from low-dispersion spectra can confirm a non-stellar nature, classify supernova types, measure supernova ages and possibly even constrain the redshift.

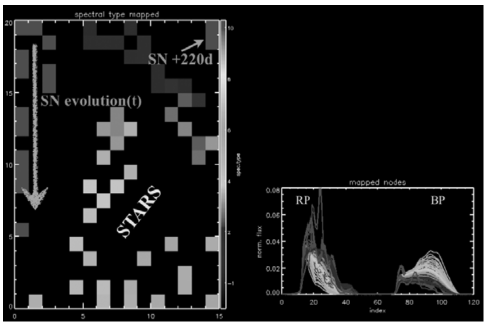

Figure 4. A Self-Organizing Map (left) can distinguish between different spectral types of stars and supernova at different epochs, as built from synthetic Gaia BP/RP spectra (right).

12. How will alerts be disseminated?

Through `skyalert.org`, email, www server, Twitter, iPhone app, etc.

13. What will an alert contain?

The coordinates, a small cut-out image from the SM, the Gaia light curve, a low-resolution spectrum at the trigger, the classification results, and the cross-matching results.

14. What will the main triggers be?

Supernovæ, classical novæ, dwarf novae, microlensing events, Be stars, GRB afterglows, M-dwarf flares, R CrB-type stars, FU Ori-type stars, asteroids—and surprises.

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15. How many supernovæ will Gaia detect during 5 years?

6000 SNe are expected down to $G = 19$. About 2000 should be detected before the maximum (Belokurov & Evans 2002).

16. How many Microlensing Events will Gaia detect?

1000+ events (mostly long $t_E > 30$ d) are expected to be detected photometrically, mainly in the Galactic bulge and plane. Astrometric centroid motion will be detectable in real time (for larger deviations of about 100 μas) in on-going events, and alerts may be triggered to obtain complementary photometry (Belokurov and Evans 2003).

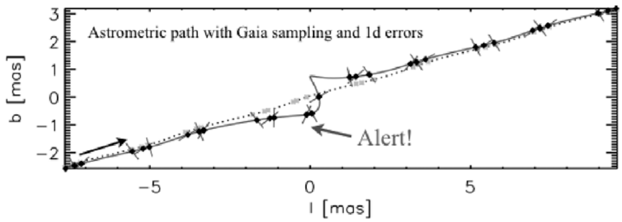

Figure 5. Trajectory of a source due to proper motion and centroid shift during a microlensing event.

17. Will Gaia alert on GRB optical counterparts?

Gaia's sampling and data latency are not appropriate, but detections of 1–2 bright, on-axis afterglows and 5–15 orphan afterglows can be expected (Japelj & Gomboc 2011).

18. How many asteroids is Gaia expected to see?

About 250,000 asteroids (mostly known ones). Alerts on new asteroids and NEO candidates will be based on unsuccessful star matching.

19. What about known anomalous objects?

Such objects can be added to the **Watch List**. Every time Gaia observes them, their data will become available for inspection.

20. How can I get involved now?

Through telescope time: prepare for Gaia Alerts, register at `skyalert.org`, set-up your alerts for SNe, CVs, blazars, etc. on CRTS stream (Drake *et al.* 2009), follow-up the alerts, and contact us with your data!
Through scientific interests: suggest what would be worth detecting and raising an alert; propose detection algorithms and classification techniques; suggest interesting known targets to be observed.

References

Belokurov, V. A. & Evans, N. W. 2002, *MNRAS* 331, 649
Belokurov, V. A. & Evans, N. W. 2003, *MNRAS* 341, 569
Drake, A. J., *et al.* 2009, *ApJ* 696, 870
Japelj, J. & Gomboc, A. 2011, *PASP* 123, 1034
Wyrzykowski, Ł. & Belokurov, V. 2008, *AIPC* 1082, 201

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