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Gaia observations of naked-eye stars: status update

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Abstract. ESA's Gaia space astrometry mission is performing an all-sky survey of stellar objects. At the beginning of the nominal mission in July 2014, an operation scheme was adopted that enabled Gaia to routinely acquire observations of all stars brighter than the original limit of G∼6, i.e. the naked-eye stars. We present the current status and extent of those observations.

Keywords. space vehicles: instruments, catalogs, astrometry, stars: distances

1. Gaia's bright limit

In the Gaia focal plane, the SkyMapper CCDs (SM1 and SM2) identify the the star-like sources that Gaia will observe. Data of stars not identified in the SkyMapper are not downlinked, thus are lost. The original Gaia bright limit of $G \simeq 6$ was improved to $G \simeq 3$ by tuning the onboard parameters of the SkyMapper star detection algorithm (Sahlmann *et al.* 2016b; Martín-Fleitas *et al.* 2014). For the 230 stars brighter than $G=3$, we are pursuing two solutions in order to observe them as well:

Forced SkyMapper Imaging: This consists of forcing the acquisition of full-frame SkyMapper images and is in operation since the beginning of Gaia's nominal mission.

Virtual Object Synchronisation: This uses Virtual Objects whose associated CCD windows are placed at defined locations. They usually fall on 'empty' regions of the sky and, for instance, serve to estimate the sky background. The idea of Virtual Object synchronised observations is to predict the focal plane crossing of a very bright star and to place a Virtual Object window on top of it. The method has been successfully tested and its implementation for the brightest 50 stars (G<1.75) is underway.

2. Very bright star science cases

Very bright stars with magnitudes $G < 6$, i.e. the ∼6000 stars observable with the naked eye, are among the best studied astronomical objects. Securing Gaia data for those stars is a unique science opportunity, in particular in what concerns astrometry because no other current or planned observatory can obtain global astrometry at sub-milliarcsecond level of this stellar sample. Science cases include but are not limited to:

- Parallaxes and proper motions about 10 times more precise than from Hipparcos, e.g. of bright massive stars that are fundamental anchor points for stellar astrophysics.
- Orbit constraints for very bright binary stars (at least 25% of the sample).

- Discover new exoplanets, in particular around very bright A and F stars.
- Accurate masses of known exoplanets discovered by radial-velocity monitoring. This will for instance include GJ 676A whose astrometric orbit caused by planet b was already determined from the combination of ground-based astrometry and radial velocities (Sahlmann *et al.* 2016a). Gaia naked-eye star observations can make similar work possible for tens of known exoplanets.

3. Forced SkyMapper Imaging

At every predicted passage of a very bright star, Gaia records 5 seconds of SkyMapper full-frame data. The PSF core saturates and a nominal model does not reproduce the high spatial frequencies, but the images measuring ∼5'×6' contain plenty of astrometric information. The data are non-nominal and treated with an off-line pipeline (Sahlmann *et al.* 2016b; Gaia Collaboration *et al.* 2016b,a). This method has been in operation since October 2014. Its disadvantages are that only SkyMapper data are collected, which have a fixed integration time (CCD gating) and they are undersampled by a factor of two (∼0.1"× 0.3" effective pixel size) compared to the astrometric field CCD data. The more powerful solution of virtual object synchronisation can mitigate this.

The technique of forced SkyMapper imaging is also applied to capture images of extremely dense fields (to mitigate effects of crowding) and of events when stars are observed close to Jupiter's limb (for scene reconnaissance).

4. Virtual Object Synchronisation

Because Gaia is spinning and precessing, this method relies on accurate temporal (∼9 ms) and spatial (∼1") predictions of very bright star passages in the Gaia focal plane. These prediction capabilities were demonstrated in several tests reaching ∼70% success rates (defined as capture of the stellar core). Using improved prediction models we aim at >90% success rate. The critical advantage of this method is that it gives access to SkyMapper, astrometric field, and spectro-photometric data of extremely bright stars.

In summary, there is no bright limit for Gaia astrometric observations, however core saturation poses challenges both for naturally detected stars ($G < 6$) and in the forced SkyMapper images. Virtual object synchronisation may mitigate some of those problems for the 50 stars brighter than G=1.75.

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