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Globular clusters seen by Gaia

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Abstract. We present a simulation of twelve globular clusters with different concentration, distance, and background population, whose properties are transformed into Gaia observables with the help of the lates Gaia science performances prescriptions. We adopt simplified crowding receipts, based on five years of simulations performed by DPAC (Data Processing and Analysis Consortium) scientists, to explore the effect of crowding and to give a basic idea of what will be made possible by Gaia in the filed of Galactic globular clusters observations.

Key words. Space vehicles: instruments — Galaxy: globular clusters — Methods: miscellaneous

1. Introduction

Gaia is a cornerstone ESA astrometric mission which is going to be launched in October 2013. It will provide 6D position and velocity information on Galactic stars, solar system objects, unresolved galaxies, with exquisite quality and additional astrophysical information such as E(B–V), astrophysical parameters, object classification, chemical tagging, for objects down to V$\simeq$20 mag. A deep discussion about the Gaia expected scientific harvest can be found in many papers (see e.g., Mignard 2005).

Gaia will certainly be able to provide interesting data for globular clusters as well, but crowding is the great unknown, its knowledge deciding whether we will be able to pierce through the central regions or be limited to the external parts. With all Gaia scientistists busy in pre-launch activities, we attempt here to use the results of 5–10 years of stellar blending simulations with GIBIS (Babusiaux 2005) to derive simplified receipts, and to give a basic idea on what will be made possible by Gaia in the field of Galactic globular clusters observations.

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2. Simulations

Two clusters were simulated with the Mcluster code (Küpper et al. 2011) — including the prescriptions by Hurley et al. (2000) — differing only in their concentration parameter, one having c=1.0 and r_h=5 pc and the other c=2.5 and r_h=4 pc. Both clusters were spherical, non-rotating, and did not include binaries. The underlying stellar population was old (12 Gyr), metal-poor (Z=0.003), and the other cluster properties were rather typical of the av-

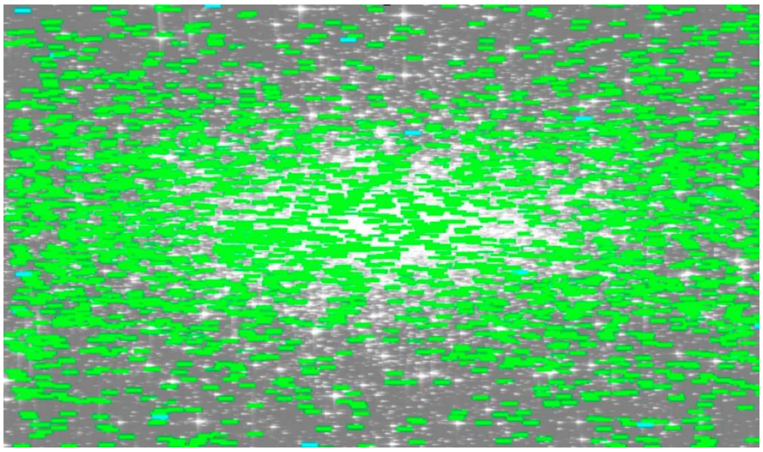

Fig. 1. A GIBIS (Babusiaux 2005) simulation computed by G. Giuffrida (2012, private communication) of a globular cluster observed through the Gaia spectro-photometers. Each star has a cygnus-like shape, and green rectangles are the windows assigned to bright stars (G≤20 mag) by the on-board detection algorithm. The 750 000 windows limit imposes that no new window is assigned to a new star (entering from the left) until one of the presently assigned windows is freed by a star transiting out of the field (from the right side). More crowded regions have a higher probability of having a window assigned, thus, the cluster center has more windows assigned than the two external regions above and below it. This is rather unusual compared to typical ground-based observations of crowded regions, and has implications for the completeness levels of the photometry (courtesy of G. Giuffrida).

erage Milky Way globular clusters (for example: M_V=–7.6 mag, M_{tot}=3.6 10^5 $M_\odot$, Kroupa IMF). Each cluster was projected at three distances (5, 10, 15 kpc) and onto two backgrounds, simulated with the Besançon model in a halo direction (l=150,b=80) and a crowded bulge field (l=5,b=5). Thus, in total, we simulated twelve clusters with different combinations of concentration, distance, and background crowding.

We transformed the simulated properties of each star into Gaia observables and their uncertainties (injecting Gaussian noise) using the latest version of the Gaia science performances[1] and related published transformations (e.g., Jordi et al. 2010; Kordopatis et al. 2011).

3. Gaia and crowding

Gaia is a complex instrument, with a large focal plane hosting three instruments and many CCDs read in TDI (Time Delayed Integration) mode, as described in many Gaia technical documents (but see also Cacciari 2011; Jordi 2011; Pancino 2012). Crowding thus has an impact which deserves in depth studies to be fully understood. Many groups used the various Gaia simulators to better understand crowding both for deblending and for image reconstrunction. Here we use their work to derive simplified receipts that can be used in our simulations of globular clusters. In particular, we classify blends as follows:

Hard blends (or classical blends). They occur when two or more stars are closer than the FWHM in the astrometric field (AF) of Gaia (≃0.53”); they could in principle be deblended using information owing to the different orientation of each Gaia transit, and to the radial velocity variations in the radial velocity spectrometer (RVS), but not having sufficient technical literature, for the moment we just flagged these cases in our simulations; we will treat them at a later stage.

Blends. Blends occur when two or more stars are closer than the short side of the readout window assigned in the AF and in the

[1] `http://www.rssd.esa.int`

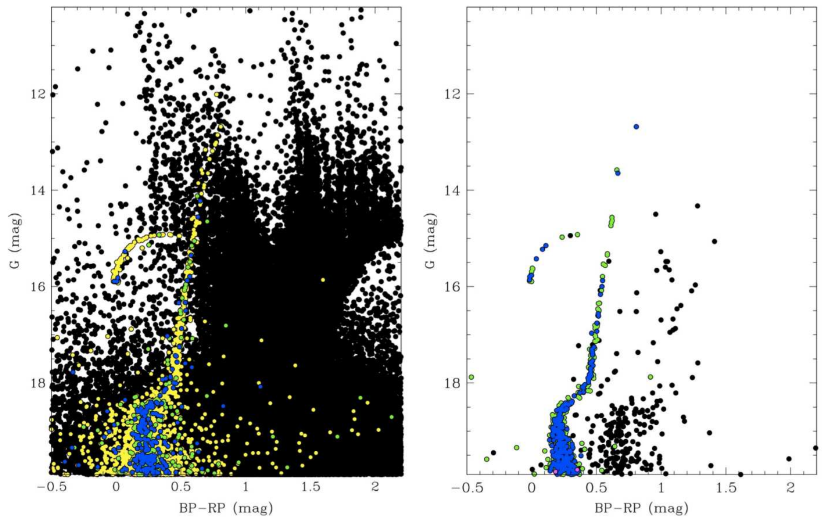

Fig. 2. The color-magnitude diagram in Gaia colors in an area of 0.7×0.7 deg around the simulated "difficult" cluster (see text). Black symbols in both panels refer to field stars, yellow symbols to deblended stars (see text for a description), green symbols to decontaminated stars, and blue symbols to clean stars. The left panel shows the full catalogue, while the righ panel shows only bona-fide cluster members selected by proper motions and distance from the cluster center; in this panel two cluster stars were accidentally rejected and are colored in magenta, while only a handful of the otherwise dominating field population remain after the selection. The number of well measured member stars is small, but they all have space quality measurements (of the order of a mmag precision and a few % calibration for the bright stars).

BP/RP instruments (Blue and Red spectro-Photometers), which is 2.12". In this case, the stars will always be assigned the same window (thus be compressed to one single 1D spectrum before ground transmission), no matter the orientation on the sky. However, the spectra will overlap differently for different orientations in the sky, and will have different radial velocities, measurable on RVS (for V<17 mag). All these effects can be modeled and the stars will effectively be deblended with residuals of ≃3–5% according to a test made by G. Giuffrida with GIBIS (Babusiaux 2005). The test was made without taking into account CTI (Charge transfer inefficiencies), however, so we degraded the Gaia science performances of (de)blended stars by 10%, proportionally to the flux contamination.

Contaminated stars. When two stars are not blended, but are closer than the long side of the assigned window (3.54" in BP/RP), they will be assigned the same window in some transit and separarate windows in some other transits, depending on the orientation of the Gaia scan direction on the sky. Thus they will be easier to disentangle than blends. However, bright stars (V≤15 mag) will have enough flux outside their windows to contaminate neighbouring stars so a variable "size" depending on their magnitude needs to be defined (Marrese, 2008, private communication) to take this into account. In general, various experiments on two stars in isolation showed that they can be decontaminated with residuals better than 1–3%. We conservatively degraded the Gaia science performances of (de)contaminated stars by 5%, proportionally to the flux contamination.

4. Results and conclusions

In general, as was largely expected, we see that crowding has a large effect on the central areas of clusters, generally making Gaia per-

Table 1. Systemic properties of two clusters (see text)

Property	Easy cluster	Difficult cluster	true (input) value
# of stars	16838	3513	—
μ_{RA}	–4998.7pm0.8 μas/yr	–4993±3 μas/yr	–5000 μas/yr
μ_{Dec}	–5000.2pm0.7 μas/yr	-4994±3 μas/yr	–5000 μas/yr
π	199.7±0.7 μas	101.2±1.4 μas	200/100 μas
D	5.007±0.007 kpc	9.997±0.017 kpc	5/10 kpc

formances rather poor (for a space telescope) inside the half-light radius of a cluster. Also, Gaia does not go very deep (V<20 mag) and thus clusters farther than 15 kps are not sampled down to their turnoff point. However, for those stars that are measured, Gaia grants:

- an excellent membership probability assessment using its superb proper motions and — for the bright stars — the RVS radial velocities; most samples obtained by Gaia will suffer from very low field contamination even in the most crowded environments; see Figure 2 for a difficult case diagram, cleaned with proper motions;
- space-quality photometry (see Figure 2), with mmag precision down to approximately 16–17 mag at least, and a photometric calibration of a few percent accuracy at most, for a number of stars ranging from a few hundred (for the difficult clusters) to a few tens of thousands (for a few tens of clusters);
- exquisite proper motions for the above stars, with μas/yr errors, at least down to 16–17 mag (or ≃300 μas/yr down to 20 mag), and parallaxes with similar errors, complemented by 1–10 km/s radial velocities for stars down to V≃17 mag;
- statistical distances and systemic proper motions with unprecedented accuracy (see Table 1, where the easy cluster has c=1.0, d=5 kpc, and halo-like background; the difficult cluster has c=2.5, d=10 kpc, and bulge-like backgound and is also shown in Figure 2)[2].

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[2] The distances in this paper are based only on parallaxes, but of course there will be many RR Lyrae in globular clusters as well.