Setting the scene for Gaia and LAMOST
Proceedings IAU Symposium No. 298, 2013
S. Feltzing, G. Zhao, N. A. Walton & P. A. Whitelock, eds.

doi:10.1017/S1743921313006455

Gaia and variable stars

Laurent Eyer, Berry Holl and Nami Mowlavi

Department of Astronomy, Geneva University,
1290 Sauverny, Switzerland
email: laurent.eyer@unige.ch

Abstract. The study of variable phenomena (periodic, irregular or transient) provides a unique way to acquire knowledge about objects in our Universe. Currently, we are going through a rapid expansion of time-domain astrophysics. One reason for this expansion is the technological developments materialised in small to medium size observational projects such as HAT, OGLE, Catalina, PTF and upcoming very large projects such as Gaia or LSST.

In this article, we are focusing on the ESA cornerstone mission Gaia. This spacecraft will provide astrometric, photometric and spectroscopic measurements for one billion stars. Among the existing and planned multi-epoch projects Gaia is unique because it will provide exquisite astrometric measurements for all objects it observes. We provide a brief overview of the literature concerning this mission and its expected contribution to variability studies.

Keywords. space vehicles, astrometry, methods: statistical, techniques: radial velocities, techniques: photometric, stars: binaries: eclipsing, stars: variables

1. Introduction

The domain of variable stars will be deeply impacted by the Gaia mission. A general description of this topic has already been covered in several contributions (e.g., Eyer *et al.* 2009, 2011) and will therefore not be repeated here. Instead, we highlight a few points concerning Gaia and variable stars, and refer to other articles in the literature for more details.

First some basic aspects of Gaia and its operations are presented in Sect. 2. Signal processing of the photometric time series within the Data Processing and Analysis Consortium (DPAC) is then briefly presented in Sect. 3, after which a short discussion on variable stars is given in Sect. 4.

2. Gaia

We will start by describing a few basic concepts directly related to Gaia:

• The Gaia spacecraft has been built by EADS/Astrium and will be operated by the European Space Agency. At the time of writing, the satellite is soon to be transferred from Toulouse (France) to French Guiana where it will be launched by a Soyuz-Fregat rocket during the last trimester of 2013. The mission length is 5 years (with a possible one year extension).

• The currently expected end-of-mission performance can be found on the Gaia webpage (http://www.rssd.esa.int/Gaia), as well as in de Bruijne 2012, Eyer *et al.* 2012b and Vallenari (these proceedings).

• The data reduction will be done by the Gaia DPAC. We refer to Mignard *et al.* 2008 for its detailed structure.

• The catalogue will be delivered in several releases, the content of which is presented in Vallenari (these proceedings) and Eyer *et al.* 2013 (see references therein).

• A comparison of astrometric and photometric performance between Gaia and LSST is given in Eyer *et al.* 2012a. These two major surveys are completing each other very well.

3. Signal processing of the photometric time series within the DPAC consortium

The Gaia catalogue will include a part dedicated to variable objects, which will be prepared by the DPAC variability processing and analyses Coordination Unit 7 (CU7 for short). This group is composed of 70 active members across Europe and has an associated Data Processing Center located in Geneva. Within CU7 there is a vast effort across Europe to be able to detect, characterize and classify the variable objects that Gaia will observe. The catalogue products are variability properties and classification of the variable objects (variable stars and quasars).

Due to the particular scanning law motion of Gaia the number of observation epochs varies as a function of position on the sky. Over the 5 year nominal mission this number of epochs will be between 40 and 250, with the most scarcely sampled positions lying within 45 deg of the ecliptic plane. However, the semi-regular sampling of Gaia makes it performant for detection of periodic objects (Eyer & Mignard 2005). The performance is dropping when strict periodicity is not holding, see Distefano *et al.* 2012.

The developed CU7 software pipeline has been tested on real or simulated data. For example, the automatic classification of Hipparcos variable objects into 26 types using several algorithms has been studied by Dubath *et al.* 2011. In their article, the method of Random Forest obtained remarkable good results. Similar conclusions were obtained independently by Richards *et al.* 2011. A second study focusing on the 'unsolved' part of the Hipparcos variable star catalogue was done by Rimoldini *et al.* 2012.

In addition to the official variable catalogue releases information about variability, there will be an alert system for objects that require rapid action (to avoid loss of science). This photometric alert system is run at the Institute of Astronomy in Cambridge under the responsibility of the photometric processing Coordination Unit and is presented in Wyrzykowski *et al.* 2012.

4. Variable stars with Gaia

A general review of variable stars was given in Eyer & Mowlavi 2008. Gaia will lead to an impressive improvement of most diagrams that were presented in this review. For example, the period-amplitude and Hertzsprung-Russell diagrams will benefit from the large number of stars and from the accurate distances provided by Gaia. In some diagrams that are populated by only hundreds or thousands of objects, Gaia will populate them with millions of objects. On one hand observational properties of most variability types will be characterized precisely, and on the other hand these large numbers will allow to discover extremely rare objects. Gaia will also be an unprecedented gold mine for pointing out potentially interesting variable objects and trigger follow-up studies.

We proceed by highlighting some specific groups of objects:

• Standard Candles: A general review can be found in Eyer *et al.* 2012b with estimated numbers within the different classes of standard candles. However, we should note that some surface brightness asymmetries in giants and supergiants may perturb the parallactic measurements, e.g. Sacuto *et al.* 2011.

• The impact of Gaia on binary stars can be found in Eyer *et al.* 2012a and Eyer *et al.* 2013. In the latter study new estimations of the number of binaries were given.

These estimates were obtained thanks to simulations based on the Besançon Galactic Model (Robin *et al.* 2012). Within DPAC, the foreseen automated treatments of eclipsing binaries is based on a "Wilson-Devinney" type code to obtain the physical properties of binaires (see Siopis & Sadowski 2012).

• A review on exo-planets to be detected by Gaia has been presented in Sozzetti (2011), this concern principally the astrometric signal of such systems. Studies on the number of systems with planetary transits to be detected, as well as the methodology to detect them, have been published in Tingley (2011), Dzigan & Zucker (2012, 2013), and Voss *et al.* (2013).

References

de Bruijne, J. H. J. 2012, *Astrophysics and Space Science*, 341, 31
Distefano, E., Lanzafame, A. C., Lanza, A. F., *et al.* 2012, *MNRAS*, 421, 2774
Dubath, P., Rimoldini, L., Süveges, M., *et al.* 2011, *MNRAS*, 414, 2602
Dzigan, Y. & Zucker, S. 2012, *ApJL*, 753, L1
Dzigan, Y. & Zucker, S. 2013, *MNRAS*, 428, 3641
Eyer, L. & Mignard, F. 2005, *MNRAS*, 361, 1136
Eyer, L. & Mowlavi, N. 2008, *Journal of Physics Conference Series*, 118, 012010
Eyer, L., Mowlavi, N., Varadi, M., *et al.* 2009, SF2A-2009: Proceedings of the Annual meeting of the French Society of Astronomy and Astrophysics, 45
Eyer, L., Suveges, M., Dubath, P., *et al.* 2011, *EAS Publications Series*, 45, 161
Eyer, L., Dubath, P., Mowlavi, N., *et al.* 2012, *IAU Symposium*, 282, 33
Eyer, L., Palaversa, L., Mowlavi, N., *et al.* 2012, *Astrophysics and Space Science*, 341, 207
Eyer, L., Holl, B., Pourbaix, D., *et al.* 2013, *Central European Astrophysical Bulletin*, 37, 115
Mignard, F., Bailer-Jones, C., Bastian, U., *et al.* 2008, *IAU Symposium*, 248, 224
Richards, J. W., Starr, D. L., Butler, N. R., *et al.* 2011, *ApJ*, 733, 10
Rimoldini, L., Dubath, P., Süveges, M., *et al.* 2012, *MNRAS*, 427, 2917
Robin, A. C., Luri, X., Reylé, C., *et al.* 2012, *A&A*, 543, A100
Sacuto, S., Jorissen, A., Cruzalèbes, P., *et al.* 2011, Why Galaxies Care about AGB Stars II: Shining Examples and Common Inhabitants, 445, 171
Siopis, C. & Sadowski, G. 2012, Orbital Couples: Pas de Deux in the Solar System and the Milky Way, 59
Sozzetti, A. 2011, *EAS Publications Series*, 45, 273
Tingley, B. 2011, *A&A*, 529, A6
Voss, H., Jordi, C., Fabricius, C., *et al.* 2013, Highlights of Spanish Astrophysics VII, 738
Wyrzykowski, L., Hodgkin, S., Blogorodnova, N., Koposov, S., & Burgon, R. 2012, arXiv:1210.5007

Discussion

Birgitta Nordström: How and when will you alert the community about SN detections?

Laurent Eyer: The supernovae detection is dealt within the photometric alert system coordinated by S. Hodgking and L. Wyrzykowski (Cambridge University). After a trial period, the alerts will be published through regular alert channels as quickly as possible. The estimated number of Supernovae reaches 6,000 over 5 years, with one third being before the maximum.

Birgitta Nordström: You talked only about visual binaries, but what about spectroscopic binaries?

Laurent Eyer: s Some numbers have been estimated from (small scale) simulated Gaia data containing visual, spectroscopic and eclipsing binaries, which have been rescaled to the full Gaia sample. These numbers can be found in Eyer *et al.* 2013. For the spectroscopic binaries these estimations reach 8 million (of which 59% will be SB2).

Nicolas Martin: How far or how faint can you reliably classify an RR Lyrae star?

Laurent Eyer: I remind that in principle the G-band photometry is very good, even at the faint limit of the Gaia survey (G=20) the estimated uncertainty is only about 0.02 mag. As RR Lyrae stars have large amplitudes, especially RRac, we just have to detect their variability and obtain correct variability attributes to assure a correct classification. An RR Lyrae of mean magnitude 19.5 should be detected and classified very reliably. However, some miss-classification of RRc type with eclipsing binaries may occur.

Jorge Melendez: What about preliminary data releases on variability? It would be important to have a quick ($\sim$1 year) whole sky data release with magnitude, σ (scatter) and Δmag (total variation).

Laurent Eyer: For the moment what is in place is a scenario with a total of 5 releases. We should insist on the word "scenario". In particular the precise content in each release is not defined yet. In my opinion, it is indeed important to release data as soon as the estimations of the errors are reliable and 'reasonable'. For the moment the global variability catalogue is planned to become available as part of the 4th release. Note that due to the scanning law the sampling on the sky after one year of observations is still very inhomogeneous, and the proposed variability map will be difficult to construct for the whole sky (some positions will be observed at only 5-10 epochs). However, our goal is to be able to add variability attributes and classes in earlier releases.