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INVITED REVIEW

Standard candles from the Gaia perspective

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Abstract The ESA Gaia mission will bring a new era to the domain of standard candles. Progresses in this domain will be achieved thanks to unprecedented astrometric precision, whole-sky coverage and the combination of photometric, spectrophotometric and spectroscopic measurements. The fundamental outcome of the mission will be the Gaia catalogue produced by the Gaia Data Analysis and Processing Consortium (DPAC), which will contain a variable source classification and specific properties for stars of specific variability types. We review what will be produced for Cepheids, RR Lyrae, Long Period Variable stars and eclipsing binaries.

Keywords Stars: distance · Stars: variables · Stars: binaries · Stars: statistics · Cosmology: distance scale · Space vehicles · Surveys · Catalogs

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1 Introduction

The subject of standard candles is a fundamental scientific case that will greatly benefit from the Gaia mission. In this respect Gaia is unique and this scientific subject will take advantage from all aspects of the mission. The astrometry will obviously provide a major contribution. However, other aspects of the Gaia measurements will contribute to this subject as well. The classical standard candles are RR Lyrae and Cepheid stars. But Gaia will also offer the possibility to exploit other classes of variable stars as standard candles. Examples of "non-classical" standard candles include Long Period Variables (LPVs) (Feast et al. 1989; Matsunaga et al. 2009), OGLE Small Amplitude Red Giants (OSARGs; Wray et al. 2004), eclipsing binaries (Paczyński 1997) and High Amplitude δ Scuti stars (McNamara 1997).

Certain types of stellar variability occur within specific mass and metallicity ranges and at given evolutionary stages. The size of the Gaia dataset will ensure that all these cases will be covered statistically. Gaia data will allow us to establish the fundamental astrophysical properties of these stars, in particular their luminosity, and thereby establish their usefulness as standard candles. They will also determine their cosmic scatter. Gaia will therefore be able to test the universality of many different standard candles.

The astrometric precision of the Hipparcos satellite has been exploited to its limit in the case of standard candles.

Standard candles like Cepheids or RR Lyrae can be considered "far" for Hipparcos precision. The statistical properties of distance, parallax and absolute magnitude are complex. Feast and Catchpole (1997) constrained the zero point of the period-luminosity relation with a subtle and sound method. However, their zero point has been subject to discussions. It is worth mentioning that the number of Cepheids retained for constraining their solution was only 26. The distance modulus of the Large Magellanic Cloud (LMC), obtained with the Hipparcos-derived zero-point is 18.7±0.10, which seems a bit too far compared to other standard estimates that are close to 18.5 (cf. Clementini et al. 2003).

Decades after the historical discovery of the Cepheid period-luminosity relation by Henrietta Leavitt, surveys towards the Magellanic Clouds such as OGLE, MACHO and EROS, provided a remarkable contribution to the subject of standard candles. Even if the distances to the Magellanic Clouds are not known precisely, they can be considered at a fixed distance with only moderate depth and therefore the difference in apparent magnitude can be interpreted as a difference in luminosity. This is why the Magellanic Clouds have offered such a high scientific potential. Gaia, as a whole-sky survey, will observe the Magellanic clouds, as well as the halo and the plane of the Galaxy (with parallaxes). The inter-comparison of different populations of standard candle classes with a single instrument will have an enourmous impact, since, for the first time, they can be calibrated to a homogeneous reference.

2 A quick review of the Gaia mission

In this section, we present properties of the Gaia mission that are relevant to standard candles.

Gaia is a spacecraft of the European Space Agency (ESA) that will be located at the Lagrangian L2 point, 1.5 million km away from Earth. It will observe about 1 billion objects with a magnitude between $V \simeq 6$ and 20 mag. The measurements gather astrometric, photometric, spectrophotometric and spectroscopic data. The length of the mission is 5 years with a possible one year extension. For a duration of 5 years, the average number of measurements will be about 70 per object (this number contains estimated dead-times). The launch is foreseen for 2013. There will be an alert system and intermediate data releases throughout the mission. The final results will be made available by 2020–2021.

A summary of performances can be found on the Gaia webpage (http://www.rssd.esa.int/Gaia) under Science Performances. The numbers displayed in Tables 1 and 2 are extracted from this webpage (as of October 2011).

The scanning law The Gaia scanning law has been designed in order to optimize the astrometric results of the mission. The Gaia satellite has two fields of view (FOV) of 0.7×0.7 deg^2 each. These two viewing directions are separated by an angle of 106.5 deg. The two FOV images are superposed on the same focal plane that consists of 106 CCDs, totaling nearly 1 billion pixels. As the satellite rotates around its axis with a period of 6 hours, the stars are sweeping through the focal plane. The CCDs are read in Time Delay Integration mode. The rotation axis of the satellite is precessing on a Sun-centered cone with an opening angle of 45 degrees and a precession period of 63 days. This constant angle of the rotation axis with respect to the Sun's position gives the peculiar dependency of the scanning law on ecliptic coordinates. The average number of transits (one passage through the FOV) is about 70 but varies between 40 and 250, depending on the sky position.

Properties of the scanning law have been presented by Eyer and Mignard (2005). Although there have been changes in satellite design, the conclusions of the study remain valid for the Astrometric Field (AF). The spectral window of Gaia sampling contains high peaks at high frequencies, limiting aliasing when compared to large scale ground-based surveys (see Eyer et al. 2009). The period recovery of periodic signals is very high even at relatively low signal to noise ratio (see Eyer and Mignard 2005). Handling of semi-regular or irregular variables might be difficult due to the sparsely sampled Gaia time series. Furthermore, the semi-regular or irregular variables may contaminate the samples of periodic objects. Particular cases such as double-

Table 1 Astrometric error for end-of-mission parallax as a function of spectral type and magnitude

	B1V	G2V	M6V
$V-I$	−0.22	0.75	3.85
Bright stars	$6<V<12$	$6<V<12$	$8<V<14$
	5–14 µas	5–14 µas	5–14 µas
$V=15$	26 µas	24 µas	9 µas
$V=20$	330 µas	290 µas	100 µas

Table 2 Radial velocity end-of-mission error as a function of spectral type and magnitude

Spectral type	V	Radial velocity error
B1V	7	1 km s^{-1}
	12	9 km s^{-1}
G2V	13	1 km s^{-1}
	16.5	13 km s^{-1}
K1III-MP (metal-poor)	13.5	1 km s^{-1}
	17	13 km s^{-1}

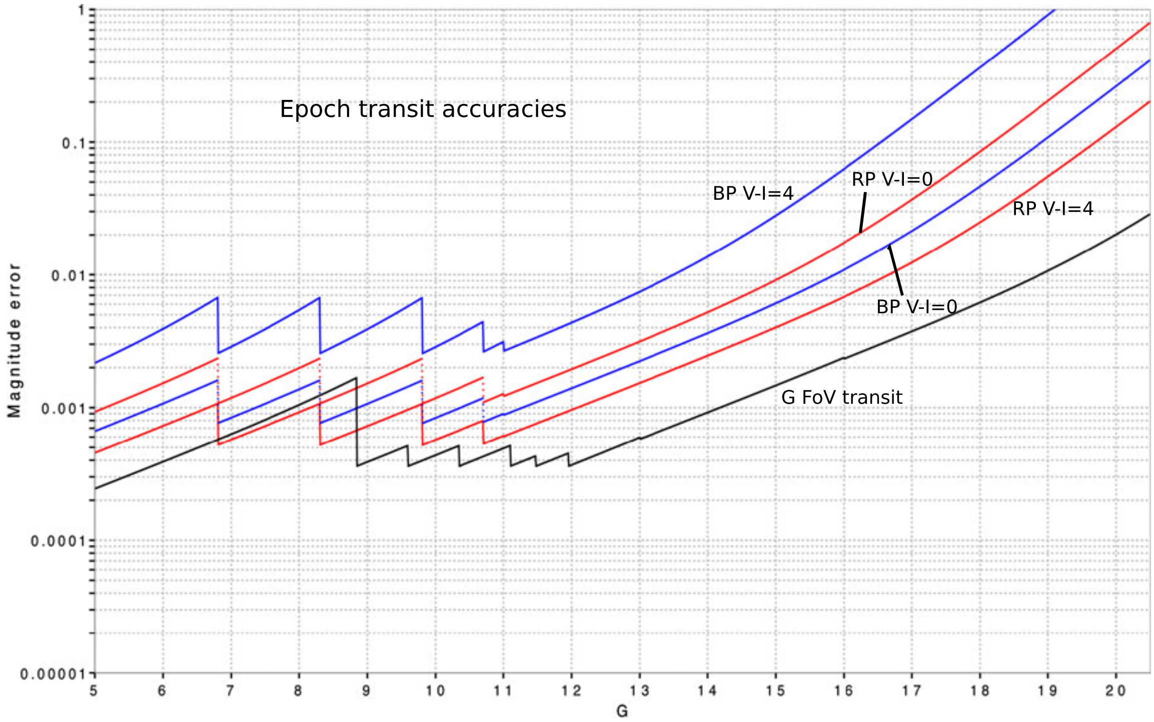

Fig. 1 Per transit photometric error in G band, integrated BP and RP as a function of G magnitude. The sawtooth structure at the bright magnitudes is a consequence of the gating system which allows observations of bright stars by limiting the exposed part of the CCD, thus reducing the integration time

mode Cepheids or Blazhko RR Lyrae stars will also require special analysis.

The astrometric performance The mission's success depends critically on the astrometric performance achieved. Therefore, performance estimations have been the subject of constant attention throughout the development of the spacecraft. The latest numbers available, re-evaluated during the critical design review in April 2011, are displayed in Table 1.

These numbers result from studies which have been recently quite stable; the current numbers are consistent with those obtained in the past few years. Globally, the performance is within the initial requirements with only some minor non-compliances.

The numbers shown in Table 1 represent estimated errors on parallax at the end of the mission. They should be multiplied by 0.8 and 0.5 in order to obtain errors for end-of-mission position proper motion (μas/year), respectively.

In theory, the performance improves with mission length L. The parallax and position errors scale as $L^{-0.5}$ while the proper motion error varies as $L^{-1.5}$. However, the astrometric solution of the first 18 months is likely to be affected by systematic errors. The goal of the consortium will be to search and correct for these errors through the subsequent iterations in such a way as to reach the expected accuracy at the end of the mission. As a consequence, the scaling of the different solutions produced during the mission may not strictly follow the above rules.

For a Cepheid located at 12 kpc with a 10 day period, a relative parallax error of 10% is expected assuming no extinction. The same relative error is reached for a 6 kpc Cepheid if the extinction is $A_V = 5$ mag. For Cepheids, Gaia will cover a significant fraction of the Galaxy with a very good precision.

The photometric and spectrophotometric performance The astrometric field is also producing a white light (called G-band) magnitude. As there is no filter, the bandpass is only limited by the optical properties of the system (reflectivity of the mirror, response of the CCDs, etc.). The wavelength coverage is from 330 to 1050 nm. The photometric G-band precision should be of very high quality, as it is the sum of the 9 CCD measurements over one FOV transit. The transit/epoch photometry accuracy as a function of the magnitude is given in Fig. 1. The lower limit of the calibration error is estimated to be at the level of 1 mmag. The per-CCD photometry will also be available and will allow detection of variability on very short time scales (tens of seconds).

Gaia performs also low resolution spectrophotometry. The Blue Photometer (BP) covers the wavelength range from 330 to 680 nm while the Red Photometer (RP) covers the range 640–1050 nm. The RP has red-enhanced CCDs so that longer wavelengths are reached. The requirements were

Table 3 Numbers of RR Lyrae stars, Cepheids, Long Period Variable stars, eclipsing binaries, known in the Galaxy, the LMC and SMC and predicted numbers in the Galaxy for the Gaia mission. For Hipparcos the numbers are taken from ESA (1997); the numbers from ASAS should be take with care (see Berdnikov et al. 2009, variable types have been selected with the "only" option) and are taken from the ASAS webpage as of May 2011, the estimates for Gaia are from Eyer and Cuypers (2000); The "other" line are other publications: Galactic Cepheids (Fernie et al. 1995), Gaia Cepheids (Windmark et al. 2011), Gaia eclipsing binaries (Dischler and Soederhjelm 2005; Zwitter 2002), OGLE-III SMC RR Lyrae stars (Soszyński et al. 2010b), OGLE-III LMC RR Lyrae stars (Soszyński et al. 2009a), OGLE-III bulge RR Lyrae stars (Soszyński et al. 2011), OGLE-III SMC Cepheids (Soszyński et al. 2010a), OGLE-III LMC Cepheids (Soszyński et al. 2008), EROS LMC LPV (Spano et al. 2011), OGLE-II SMC eclipsing binaries (Wyrzykowski et al. 2004), OGLE-III LMC eclipsing binaries (Graczyk et al. 2011)

		RR Lyrae	Cepheid	LPV	Eclipsing bin.
Known	Hipparcos	186	273	1,238	917
	ASAS	1,635	872	2,793	5,911
	Other	(bulge) 16,839	509		
Predicted	Eyer & Cuypers	(bulge) 15,000–40,000 (halo) 70,000	2,000–8,000	200,000	3,000,000
	Other		9,000		500,000; 7,000,000
LMC		24,906	3,361	37,047	26,121
SMC		2,475	4,630		1,351

not formulated in terms of acquiring desired astrophysical quantities, but in terms of photometric precision in pseudo-bands. The BP and RP spectra have each 60 samples. The photometric precision of the integrated or "mean" spectra are given in Fig. 1. However, again, these numbers should be seen as theoretical limits. The lower limit of the calibration error is estimated to be at the level of 10 to 30 mmag. It should be noted that the error estimations from the April 2011 review have larger errors for this lower limit. Finally, the Sky-Mapper (SM) CCDs will also produce photometric measurements. The mean number of transits in G, BP and RP is estimated to reach 70 over 5 years.

The Radial Velocity Spectrometer performance The Radial Velocity Spectrometer (RVS) is a near-infrared instrument with a resolution of 11,500 and spans the wavelength range from 847 to 874 nm, which covers the Calcium triplet. The RVS instrument will survey the whole-sky up to magnitude $V \sim 15$ or 17 (depending on the spectral type of the stars) with end-of-mission error levels from 1 to 10 $\mathrm{km\,s^{-1}}$, depending on the spectral type and magnitude, cf. Table 2. The number of measurements in the RVS will be about 40 per object over the 5 year mission. The number of transits for the RVS is reduced, since there are only 4 dedicated CCDs perpendicular to the scanning direction whereas the SM, G, BP, RP instruments have 7.

3 Standard candles

The knowledge about standard candles will benefit from all aspects of the Gaia mission: its astrometry, its photometry and spectrophotometry, as well as its spectrometric radial velocity measurements.

The astrometry will allow calibration of luminosities of the standard candles thanks to the Gaia parallaxes. For a given variability type, there exists an interplay between luminosity, distance (distribution within the Galaxy) and Gaia precision for the corresponding apparent magnitudes. However the number of standard candles of a given type with good and useful astrometry will increase by one to several orders of magnitude with respect to the present situation.

The Gaia multi-epoch photometry is also advantageous in the case of standard candles with large amplitudes. For these cases, light curves can be modeled and mean luminosities can be defined. Finally, with uniform and homogeneous photometric and spectrophotometric measurements of Gaia, calibrations of period-luminosity-color relations can be established.

Another less often mentioned benefit from astrometry is that Gaia will be able to determine the orbit of astrometric binary stars from their movement on the sky. With radial velocity measurements also from Gaia, the physical orbit can be determined (e.g. Zwahlen et al. 2004). This is another way to determine distances purely geometrically.

Furthermore Gaia will conduct a global survey, collecting photometry and spectrophotometry on a multi-epoch basis that will allow the detection of new objects in each standard candle category, e.g. new Cepheids, new RR Lyrae stars and eclipsing binary systems, see Table 3. Due to its diversity the impact of such a harvest is difficult to forecast. However, the physics driving the variability and instability, and in particular how metallicity affects the variability properties of a star will be systematically studied. Both aspects are essential for the calibration of standard candles using Gaia astrometry. In addition, we may find entirely new classes of standard candles within the Gaia data.

Spectrophotometry will also provide estimates of stellar parameters for the standard candles.

Radial velocity data that will be obtained for the most luminous objects will allow computation of physical parameters of single star pulsators, using the Baade-Wesselink method and orbital parameters of binary systems with the Wilson-Devinney-like code (see Sect. 4.3).

The detection of new standard candle objects and characterization of their astrophysical parameters will provide a wealth of data to test, on a statistical level, the universality of standard candle relations such as the period-luminosity-metallicity relation. Once calibrated to high accuracy with Gaia, standard candles can be used to extend studies of Galactic and extragalactic structure beyond the astrometric performance capabilities of Gaia. As examples, we mention tracing of the galactic bar using OSARGs (Wray et al. 2004), or the possibility to constrain the three-dimensional structure of the Large and Small Magellanic Clouds by using period-luminosity relations of pulsating red giants (Lah et al. 2005). Synergies of Gaia with other large surveys such as LSST are also easily envisioned. The RR Lyrae stars calibrated with Gaia can be used by LSST to fully characterize the halo of our Galaxy.

Different standard candles correspond to stars at different stages of evolution. If the evolutionary stages of standard candles are known, the formation history of the Galaxy can be traced (see e.g. Clementini 2011).

Another interesting application of standard candles is in mapping the distribution of the interstellar medium.

Despite many studies devoted to variable stars on one side and to populations of stars on the other side, not many studies have so far been devoted to the combination of both fields, i.e. the study of variable stars in relation to stellar populations. Here are two examples of questions showing the need for more studies in this domain. A basic question that arises when talking about variable stars in stellar populations concerns the fraction of stars that are expected to vary. The answer is not obvious, as attested by the difficulty to predict the number of variable objects expected to be observed in a specific survey, see Table 3. For example, the number of eclipsing binaries predicted to be detected by Gaia varies from 0.5 million (Dischler and Soederhjelm 2005) to 7 million (Zwitter 2002), which represents a factor of ten uncertainty. Moreover, it is not always possible to predict whether a star at a given location in the HR-diagram will pulsate or not. Stars are expected to pulsate in some specific areas of the HR-diagram, called instability strips, e.g. the "classical instability strip" is hosting Cepheids, RR Lyrae or δ Scuti stars. The identification of the borders of those instability strips has been a successful tool to better understand the pulsational mechanism and the parameters driving the photometric variability at the surface of the stars. The crucial role of convection and of its coupling with pulsation has, for example, been highlighted in explaining the red border of the Cepheid instability strip. It explains why stars located in the HR-diagram between the instability strip and the red giant branch do not pulsate. However, what remains unexplained is why some stars observed in the instability strip do not show the expected photometric variability. The comparison of certain types of variable stars in different known stellar populations, such as our Galaxy, open or globular clusters, or in the local group of galaxies, provides a useful way to learn about those variable stars as a function of different properties such as the metallicity. Open clusters, for example, are natural laboratories for this, as their member stars are assumed to share the same age, initial chemical abundances, distance and reddening. In this way, the already listed 2100 open clusters in the disk of our Galaxy (Dias et al. 2002), spanning a large interval in age and Galactocentric distances, have been used as an excellent tool to probe both the chemical and dynamical structure and the evolution of the Galactic disk. The variety of variable star content from one cluster to another, associated to the specific variability properties characterizing each phase of evolution, provides independent measurements for the physical parameters of open clusters. Yet, this connection is not well known so far. One difficulty is the determination of the membership of the cluster. Gaia will put the question of membership on solid ground (see van Leeuwen 2009 for what has been done with Hipparcos).

In Table 3 we review the number of discovered objects by different large scale surveys. The estimates by (Eyer and Cuypers 2000) are only for the Galaxy or some component of the Galaxy. The large uncertainty in these numbers shows that there are many unknowns in this domain. From Table 3, the optimist's view would be that Gaia will multiply by nearly 5 the number of Galactic RR Lyrae stars, by 10 the number of Galactic Cepheids, by nearly 40 the Galactic LPVs and by nearly 1000 the Galactic eclipsing binaries. To this table variables from the LMC and SMC are added. Due to the bright limit of Gaia at $V \sim 6$ mag, only few Cepheids will be missed (in the Hipparcos catalogue we found 22 stars for which the maximum light is brighter than 6).

A word on Supernovae: Gaia will have an alert system that will detect supernovae and other transient events. The estimated number of supernovae brighter than magnitude 19 is around 6,000. One third of these will be observed before their maximum. This subject is covered by Gilmore in this volume.

4 Gaia data processing and analysis consortium activities on standard candles

Software development is often underestimated in large scale projects. For Gaia, however, it was recognized early-on that the software development is a key element for its success.

Indeed, the Gaia data processing and analysis is a tremendous task, due to the large amount of raw data to be processed (in the order of 100 compressed Terabytes in 5 years), but even more so due to the complex and interwined relationships between astrometry, photometry, spectrophotometry and spectroscopy. In addition, since the targeted accuracy is higher than anything ever obtained before for so many stars, the processes have to be self-calibrating, going through a number of iterations, with each set of results providing inputs for the next run. This is most obvious for the astrometric global iterative solution. The global reference frame of sky positions will be built gradually, measuring/modeling parallaxes and proper motions, and eliminating deviating points such as multiple stars.

The task of the variability analysis and processing was given to the Coordination Unit 7 (CU7), where the work is decomposed into several steps.

Step 1: Variability detection The photometric (CU5) and spectroscopic (CU6) groups are in charge of detecting variable objects applying general-purpose algorithms, such as some statistical standard tests. The Special Variability Detection (within CU7) is defined to implement specific algorithms which take advantage of what we know about a particular type of variability. All variable objects are then stored into the Variability Database.

Step 2: Variability characterization Once variable object candidates are identified, their behavior is characterized. A number of *attributes* are computed to characterize the sources. Some of them reflect global stellar properties, such as mean color or absolute magnitude, whereas others describe some of the light curve features. A number of statistical parameters are derived from the magnitude distribution. Since we know that Gaia has a relatively good performance on periodic objects, a period search is carried out and the folded light curves are modeled with Fourier series. Many harmonics are fitted, but only those that are significant according to an F-test are kept. The number of harmonics is also limited if there are gaps in the time sampling to avoid non-physical large model excursions in regions devoid of measurements.

Step 3: Variability classification Once variables are identified and characterized, multiple classification methods are applied. We decompose this into three subtasks: supervised methods, clustering techniques, extractors (a specific variability type is selected using all the astrophysical knowledge). Automated and efficient variable star detection and classification are critical components of large-scale surveys. They are required both to study stellar population properties and to provide candidates for further detailed investigation of individual cases. Tests have been performed for supervised methods by using cleaned Hipparcos light curves to evaluate the ultimate performance of periodic (Dubath et al. 2011) and non-periodic (Rimoldini et al., in preparation) star classification schemes. The classification result associates a given variable star with a membership probability to a given class of variable stars.

Step 4: Specific object studies In the three first tasks, data for all objects are processed in a systematic way. In Specific Object Studies, specific algorithms are applied to objects as a function of their variability class. For example, the processing required at this stage for the periodic Cepheid stars is different from the one required for the usually rather erratic distant Active Galactic Nuclei. After the Specific Object Studies step, all available information about the variables has been extracted from the Gaia data and is available in the Variability Database.

We will be able to validate the automated classification, in this step, by analyzing the objects in greater details and studying the properties of sub-samples (sometimes manually). The Specific Object Studies step should also reevaluate the membership probability assigned by the automated classification.

We present what is foreseen for the Specific Object Studies of standard candles, namely in Sect. 4.1 for RR Lyrae stars and Cepheids, in Sect. 4.2 for Long Period Variables, in Sect. 4.3 for Eclipsing Binaries and in Sect. 4.4 for Supernovae.

Step 5: Global variability studies In the next step, the Global Variability Studies task will investigate larger-scale properties of variability, e.g. the period distribution for all Cepheids, a color-magnitude (or HR) diagram with isocontours of variability amplitude, etc. Given the large number of objects, special tools are in development in order to facilitate the evaluation and usage of the database content.

4.1 Cepheids and RR Lyrae stars

A good characterization of Cepheids and RR Lyrae stars is essential if those objects are to be used as standard candles. The automatic data processing implemented in the CU7 pipeline should first derive the period(s) and the Fourier decomposition parameters of the light curves, i.e.: the amplitude ratios and phase differences (see Leccia et al. 2011). These parameters allow the identification of the pulsation mode(s), fundamental or higher overtones. They will also be useful to **estimate** the metal abundance of those objects and their intrinsic colors.

Double-mode RR Lyrae variables will be detected and the period ratio fundamental/first overtone used to estimate the mass of the targets.

A significant sample of RR Lyrae (about 30%) are expected to be affected by the Blazhko effect, which is a modulation of the amplitude and/or phase of the periodic signal, that can lead to an erroneous determination of mean magnitude and stellar parameters. The detection of Blazhko RR Lyrae and the estimate of the Blazhko period (when possible) has been implemented in the CU7 processing chain.

For Cepheids, the pipeline will be able to distinguish between population I (Classical Cepheids) and population II objects (BL Her, W Vir classes) that obey different Period-Luminosity or Period-Luminosity-Color relations.

In this context, the question of binarity is also important. The presence of a companion leads to smaller photometric amplitudes and an altered mean luminosity compared to the light curves of single Cepheids (e.g. Klagyivik and Szabados 2009). This would lead to an erroneous distance estimate from the period-luminosity relation, if the effect of the companion is not taken into account.

Stellar parameters can be derived with the knowledge of multi-epoch radial velocities, measured by Gaia. The radii and the distances of Cepheids and RR Lyrae can be derived with the Baade-Wesselink (BW) method, with an error of a few % for bright objects and about 10% at V magnitudes of 13–14. The resulting quantities can be compared with the values obtained through Gaia astrometry, providing stringent constraints on the systematic errors affecting the method. In particular, it will be possible to fix the value of the "projection factor p", a proportionality constant between pulsational and radial velocities, which is the most important source of error for any version of the BW technique. This will allow to safely use the BW method for faint objects outside the Galaxy.

4.2 Long Period Variables

Long Period Variables (LPVs) constitute a class of red giant variables classically defined by the Mira stars and semi-regular variables. These variables are known to obey several nearly parallel period-luminosity relations related to the various pulsation modes. Miras are known to be fundamental pulsators, and variables with smaller amplitudes are typically first or second overtone pulsators. Their P-L relations have been identified from observations, thanks to large scale surveys initiated by MACHO (Wood et al. 1999), OGLE (Soszyński et al. 2009b), and EROS (see e.g., Spano et al. 2011). Unfortunately, the modeling of the pulsation of those red giants is difficult due to the coupling between pulsation and convection. The agreement between predicted and observed relations is quite good, but the impact of stellar parameters on the pulsation properties is still poorly understood. Large scale surveys with multi-epoch photometry of red giants in the Magellanic Clouds, the distances to which are known, have been the driving tool to study the P-L relations of LPVs.

By providing the distances to a large set of red giants in our Galaxy, Gaia will bring substantial additional data for those studies, widening the range of stellar parameters and relating the zero points of the relations to a direct measurement. It will also be possible to study various subgroups within the Milky Way and to place nearby and well-studied LPVs onto a distinct P-L relation. This study, however, requires the knowledge of the bolometric correction for each star, the value of which strongly depends on the atmospheric chemistry (O or C-rich, with or without dust). The O or C-rich nature of the star can be assessed from the relative strengths of the TiO and CN molecular bands around 7780 and 8120 Å, which fall within the spectral range of the RP spectrometer of Gaia (6500–10000 Å). First investigations to see whether the resolution and sensitivity of the spectrometer is sufficient to allow for a good distinction into O or C-rich stars led to promising results awaiting fine tuning once Gaia is in orbit.

Furthermore, special care has to be taken on a possible shift of the photo-center of red giants due to their large radii and the possibility of large scale and variable structures on their surface, e.g. as the result of convection. The impact on the astrometry of Betelgeuse in the Hipparcos H_p band, for example, is estimated to be of the order of 3.4 mas (Harper et al. 2008). This effect in Gaia is investigated by the Coordination Unit 4 in the Gaia Consortium.

4.3 Eclipsing binaries

Eclipsing binaries are traditionally sub-classified as EA, EB or EW types. EA, or Algol (β-Persei), types have the eclipses well defined in their light curves, with the possibility to identify the times of their beginning and their end in the folded light curve. EB, or β-Lyrae, types display a continuous variation of the light curve over an orbital cycle, preventing the identification of the eclipse times. EW, or W Ursae Majoris, types have similar depths of the primary and secondary eclipses.

Pojmanski (2002) suggested a classification based on the physical property of the binary, i.e. detached, semi-detached or contact binary. These three categories can theoretically be identified from the a_2 and a_4 parameters of the Fourier decomposition of the light curves in cosine series (Rucinski 1993; Pojmanski 2002).

The automated variability processing pipeline for Gaia will also characterize the geometry of the folded light curves of eclipsing binaries and estimate the duration of the eclipses and their depths and phases. A study is underway to explore the orbital parameters that can be estimated based solely on the geometrical characterization of the folded light curves in order to help the sub-classification. Initial guesses of some of the parameters may also be helpful for the computation of the full parameters of the binary system with a Wilson-Devinney-type code, a task in the hand of Coordination Unit 4 in the Gaia consortium.

4.4 Supernovae

The light curves of cataclysmic variables and supernovae will also be characterized by CU7 and the results will be made available in the Gaia catalogue of variable stars. Contrary to the alert system of CU5 whose purpose is to alert the scientific community as early as possible and hence is derived from basically calibrated data, the data analyzed by CU7 will consist of fully calibrated data that cover the light curve of supernovae over the entire duration available at the time of catalogue publication.

5 Conclusions

Gaia's scientific impact on standard candles will be remarkable. Clearly, there will be some limitations related to statistical aspects of the analysis: aliasing in the period search and the estimations of the circumstellar or interstellar extinction as well as the bolometric correction. However, Gaia will calibrate many standard candles and these will contribute to many different topics. In this article we touched on a few: testing the universality of standard candles, deriving statistical properties of different types of standard candles, searching for new standard candles, constraining stellar evolution through standard candles, improving the knowledge of the formation history of the Galaxy and extending Gaia's results to investigate Galactic structure. Some of the problems might be used to our advantage and some standard candles could be utilized to crosscheck Gaia's astrometry or even to establish extinction maps (Windmark et al. 2011).

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