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FIRST THOUGHTS ABOUT VARIABLE STAR ANALYSIS

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Abstract. The *Gaia* mission characteristics permit to estimate its impact on the variable star research. During its five-year operation *Gaia* will produce about 100 photometric measurements in each passband of the *Sloan* system for about 1 billion stars. Thanks to our knowledge of the *Hipparcos* data and the similarities between these two missions, we can forecast that *Gaia* will detect tens of millions of new variable stars.

Key words: stars: variables, photometry – orbiting observatories: Gaia

1. INTRODUCTION

The first step of variable star analysis is to study the time series of individual measurements per object for obtaining and to reduce them to mean magnitudes, light curves, intrinsic dispersions, noises, periods, epochs, light curves, etc. The ability to obtain this information depends on the signal parameters (amplitude, shape) and the measurement and reduction procedures in the satellite (time sampling, number of measurements, noise). The accurate estimation of the noise and the ability to identify outlying values are two crucial prerequisites for variable star analysis. Therefore, precise calibration procedures are needed, e.g. the control of star extraction in crowded fields, controlled ageing effects, etc.

2. ESTIMATION OF THE NUMBER OF VARIABLE STARS

We binned the star population measured by *Gaia*, and applied the fraction of variable stars found in the *Hipparcos* analysis for the same population and the same magnitude precision. The model inputs are the following:

- The errors of individual measurements. In our estimation we adopted their magnitude dependence from Høg et al. (1998) for the G magnitude and an error of 0.01 mag for $V \leq 17$). The saturation affects only a small number of bright stars and is not taken into account.
- The star population. We have used the starcount model ($N(M_V)$, $N(m_V)$ as a function of V–I) given by Torra et al. (1999). The total number of stars with $V \leq 20$ mag is 912 millions.
- The variability detection threshold for the foreseen *Gaia* time sampling and noise distribution as a function of magnitude (established from *Hipparcos* results.

With this model, we estimate 26 million variable stars, among them 7 million periodic variables.

Some comments can be added:

- The *Gaia* star sample will differ from the *Hipparcos* sample by the presence of more numerous red dwarf stars. Red dwarfs generally are variable with pseudo-periodic variations of several days (BY Draconis stars). A large fraction of them can be detected with *Gaia*.
- Because the *Hipparcos* survey is magnitude limited, sample biases are present when estimating the fraction of variables (for example, in the cases of EB or EW eclipsing binaries).
- The *Gaia* time sampling will be semi-regular and will introduce aliasing frequencies when doing period search. This sampling will lower the ability to detect certain periods. In the *Hipparcos* database, the performance of the period search algorithms usually dropped when periods were close to 15 days (cf. Eyer et al 1994).
- GAIA will also produce time series for stars in the Magellanic Clouds and for the active galactic nuclei.

A second estimation of the amount of variable stars can be inferred from the micro-lensing surveys. In Tables 1 and 2 we show a compilation of some results. *Gaia* should be better than these

Table 1. Statistics of the OGLE experiment (Udalski et al. 1994, 1995a,b, 1998).

Number of stars	Periodic	Eclipsing	Pulsating
38390	0.55 %	0.30 %	0.08 %
142198	0.56 %	0.33 %	0.05 %
144629	0.45 %	0.24 %	0.04 %

Table 2. Statistics of the MACHO experiment (Cook 1997).

Number of stars	Variable	Periodic
LMC 9×10^6	0.41 %	0.26 %
Bulge 12×10^6	0.32 %	0.12 %

Table 3. As a comparison: statistics of the *Hipparcos* mission (Eyer 1998).

Number of stars	Variable	Periodic	Eclipsing	Pulsating
118204	7.0 %	2.3 %	0.7 %	1.0 %

experiments because its precision is higher. Table 3 shows the results of the analysis of the *Hipparcos* results. A simple extrapolation of the OGLE experiment for *Gaia* gives 5 million periodic variable stars, which is in a fair agreement with the *Hipparcos* data.

3. AUTOMATED ANALYSIS

For the *Hipparcos* database, the Geneva variable star analysis has classified 60 % of the program stars as "not detected as variables", the complementary 40 % needed the subsequent analysis. Trends and outlying values have been detected, suspected variables were flagged, periodic and unsolved variable stars were listed in the ESA SP-1200 catalogues. They represent 7 % of the total number of stars. Since the number of variable stars, measured by *Gaia*, will be four orders higher, less interactive approaches should be developed. Since it is important to inspect the individual stars, a rapid access to the individual time series is definitely needed. The *Gaia* variable star analysis should certainly be iterative with high quality control procedures. Specific methods should be developed for the search of micro-lensing events.

4. SCIENTIFIC INTEREST

The scientific return of massive variability searches is very valuable and diverse (Paczyński 1997). Consequently, the *Gaia* mission will have a great impact on variable star research. It will not only permit a global description of stellar variability in terms of physical parameters (temperature, gravity, metallicity) but also will allow progress on such fundamental issues like the universality of the Cepheid period-luminosity relation. *Gaia* will have implications on asteroseismology (Favata 1999), on the study of Long Period Variables (Barthès 1999), eclipsing systems (Giménez 1998), etc.

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