IMPLEMENTATION OF VARIABLE STARS IN THE GALACTIC MODEL

I. GENERAL CONCEPT

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ABSTRACT

In this document, we present the plan for the integration of variable stars into the Besançon Galactic model used in the Gaia simulator. It is based on the knowledge of the fraction of variables within a certain stellar population for a given variability type (i.e. in a certain HR diagram region), and on a modelling which consists of a set of probability distributions of periods and amplitudes with an associated light curve model.

1. INTRODUCTION/OVERVIEW

In the framework of the Gaia Data Access and Analysis Study (GDAAS2), the Variable Star Working Group (VSWG) provided code dedicated to the photometric variability detection in September 2004. This code has been revised, and we are testing it.

The present status of the variability in the Galactic model is rudimentary. A star has a certain probability of being variable and then its characteristics consist of a discreet set of amplitudes and periods.

As we plan other developments, such as testing classification algorithms, we have to simulate many more variability types.

This document is the plan to have a more developed, though still somewhat simple, treatment of the variable stars in the Galactic model. However, the way the proposed methodology introduces the variable stars allows high complexity, that will converge with time to a realistic description of variability. The Galactic model that will be used for the Gaia Data Access and Analysis Study is the Besançon Galactic model.

The fact that we will be able to test the algorithms developed by the working group is not the only interest for introducing variable stars to the Galactic model. It will allow a more precise estimate to be made of the number of variable stars detectable by Gaia. Furthermore, such estimations compared to local counts would allow validation of the Galactic model or a revision of our knowledge on certain variable types.

2. FOUR MEETINGS

The discussion about the introduction of variable stars in the Galactic model was initiated at the Turin meeting in July 2004, an informal meeting then was held at Besançon in September 2004. Then, following the Gaia symposium, the VSWG had a meeting in Paris and this problem was presented. The consequence of these discussions was to define a strategy, and a call-for-work to the working group members, to assemble results and to produce a document (this one). The first results were presented in Leiden in January 2005.

3. THE VARIABILITY

We can see from Figure 1, that variability concerns many objects. Some are in the Solar system, some in the Galaxy and others are extra-galactic.

Asteroids are variable, because of their non-spherical shape and their intrinsic rotation. But these objects also have peculiarities for the Gaia data processing (they move across the fields of view), and thus they need special treatment which is the responsibility of the working groups dedicated to small solar system bodies.

Gamma ray bursts, microlensing events and cataclysmic variables are the responsibility of the Science Alert Working Group.

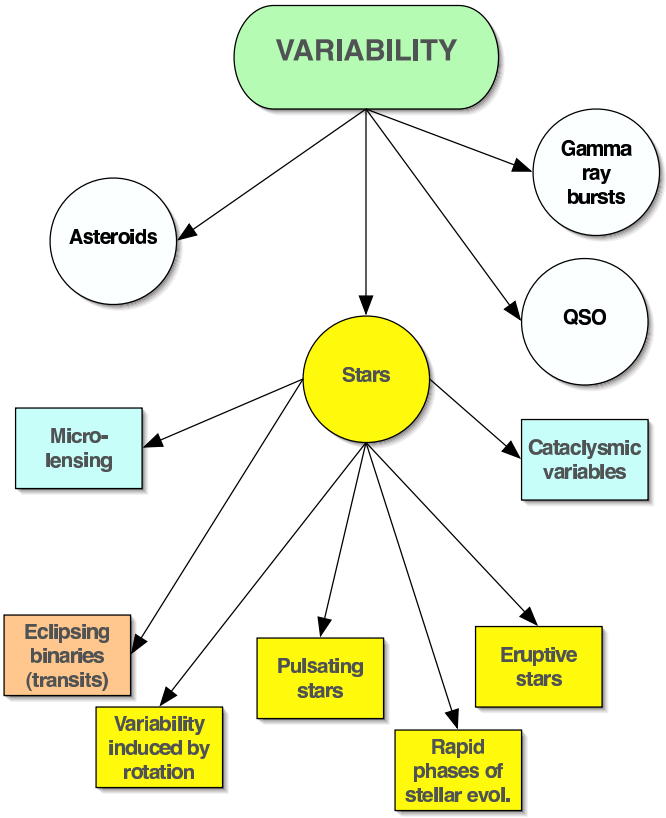

Figure 1. Global view of variability types

The QSO model will be introduced into GDAAS under the responsibility of the SWG.

At the Besançon meeting, it was learned that eclipsing binaries would be the responsibility of the Double Star Working Group, though it was not confirmed in the Leiden meeting, some coordination was felt necessary and an email was sent by F.Arenou and L.Eyer to the community interested in eclipsing binaries at the end of February 2005. However, from the VSWG there has been interest in modelling the variability for eclipsing systems. Since the estimations of the number of eclipsing binaries are very different (Eyer 2005), it can be asked if it would be worth doing this also from the side of the VSWG since the approach will probably be different.

What remains is the variability induced by rotation, pulsating stars and eruptive stars. An additional subject would be on the rapid phases of stellar evolution, but often these have a variability superimposed on other variability behaviours.

We should keep this more global picture in mind rather than the simplistic view of Figure 1, because in reality, when the observations will be taken, all the variability types will be present contaminating each other from the point of view of the analysis.

4. THE STRATEGY

In principle, the steps are simple. For each variable type we want to introduce to the Galactic model, the VSWG has to provide three pieces of information:

- The fraction of each variable type for a given region of the HR diagram. Thus we introduce a discretization of the HR diagram. It could be divided into spectral types and luminosity classes (as done by Eyer & Grenon (1997)) or in intervals of temperature and luminosity.
- A probability distribution of periods and amplitudes for periodic variables.
- A model of the light curve.

Obviously these points, especially the second and third, are deeply interconnected.

5. FRACTION OF VARIABLE STARS

A similar work was carried out for the 1999 Gaia Leiden meeting (Eyer 1999). The goal of the work was to estimate the number of variable stars of different types. It was based on the survey part of the Hipparcos catalogue and from the Galactic model of Barcelona.

The current work was distributed to the working group members who produced descriptions of each variable type depending on their specializations.

5.1. Variable Star Characteristics

There are very few published general descriptions of variability types available. There is the definition of the types contained within the GCVS (General Catalogue of Variable Stars), but this is very brief. The most recent description is the book edited by Sterken & Jaschek (1996). However, the descriptions are somewhat heterogeneous. This is why we initiated among the VSWG activities a task to generate uniform descriptions of variable types. As different authors tend to give different types of answers we produced a form of template. This work is still growing, on the side of the description items and also on the number of types described. For now, we have about 15 variable types (groups) which are described (carried out by 11 people). In order to have a comparison of the status of completion of these descriptions, we had in Hipparcos about 30 variable types (if we do not split the variable types into different subgroups). For the variable star characteristics it seems natural to add an item about the fraction of variables and about light curve modelling.

5.2. Work done for the fraction of variable stars

Up to now, nine people have sent responses, with nine variable star types covered. This covers mostly the pul-

sating variable stars. It is still to be seen if this work is sufficiently detailed to allow the information as it stands to be included in the Galactic model.

6. AMPLITUDE AND PERIOD PROBABILITY DISTRIBUTION FUNCTIONS AND LIGHT CURVE MODELLING

6.1. Amplitude and period distributions

Modelling the amplitude and period distributions by analytic functions may be quite difficult. What is proposed here is to model the distribution with numerical tables obtained from existing data, if the number of available stars is large enough. For example, using the stars from the catalogue of (Rodríguez et al. 2000) and applying some smoothing, the distribution shown in Figure 2 can be obtained. The generated tables are furnished in FITS format. In January, Dafydd Wyn Evans wrote code to draw randomly a period and amplitude from such a 2-D distribution and passed it to Annie Robin and Céline Reylé. This method can be used for the δ Scuti stars, Cepheids, RR Lyrae, SARV, SR and Mira stars. For several types, inter-comparisons can be made with samples from the Galaxy and the Magellanic clouds. In case the variables are unsufficiently known, a simple model can be made and a FITS table produced.

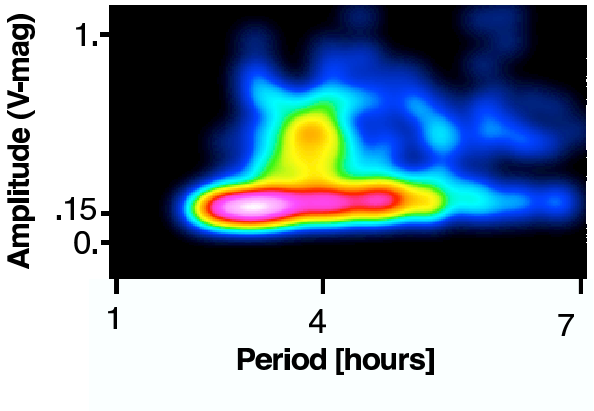

Figure 2. The smoothed distribution for the amplitude-period relation of δ Scuti stars from the catalogue of Rodríguez et al. (2000), the catalogue contains also SX Phe stars.

6.2. Light curve modelling

For the moment in the Barcelona Galactic model, which was the model originally used in the GDAAS simulations, there are two simple proposals:

1. Simple sinusoidal light curves
2. A proposal by F. Mignard to reproduce asymmetric light curves such as found for Cepheids, RR Lyrae or δ Scuti stars:

$$0.446 + 0.4598\sin(2\pi\nu t - 20.76)$$
$$+0.1561 * \sin(4\pi\nu t - 63.76)$$
$$+0.0730\sin(6\pi\nu t - 91.57)$$
$$+0.0390\sin(8\pi\nu t - 112.62)$$
$$+0.022\sin(10\pi\nu t - 129.47)$$

We plan to implement this scheme in the Besançon Galaxy model in the Gaia simulator. In addition, with the variability described here, it would be wise to add some random variability in addition to the instrumental and reduction noise as was done by the Barcelona group.

7. FUTURE WORK

We need to complete the work for the descriptions of the other neglected types. For the classical pulsating stars, we are not far from completion. Care will be needed in order to have homogeneity in these descriptions as well as having a similar level of elaboration. We also need to add **multi-periodicity** to our models. Finally, it is of extreme importance to introduce behaviours which are **semi-regular** and **irregular**. Except for having template curves, we have adopted no solution at present for the modelling of these behaviours.

There are also chromatic effects which should be introduced as well as radial velocity variations. There are also other variable types which deserve more attention. Stars where the variability is induced by rotation or eruptive stars. Very little effort has been spent up to now on these types.

8. ACKNOWLEDGEMENTS

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