Catalogue of variable stars in open cluster fields

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Abstract: Knowledge of the variable star contents in open clusters is a significant advantage in their study. Analysing the variability of cluster members and field stars also allows us to study the characteristics of stars and clusters together. This catalogue of variable stars in open cluster fields is the first step in supporting such studies. We present a homogeneous catalogue of known variable stars in open cluster regions with up to two times the given cluster radius. This gives basic information about the distribution of variable stars in cluster fields for the complete sky. The compilation is based on the newest Gaia DR3 and the VSX catalogue.

Introduction

Star clusters are essential astrophysical laboratories for forming and evolving individual stars (members) and the Milky Way as a global galaxy.

The advantage of studying cluster members, such as variable stars, is the knowledge of the distance (especially important for very distant clusters not observed by Gaia), age (within a range of a few Myrs), and metallicity.

The observed variabilities of stars cover a wide range of amplitudes and time scales. The detection depends not only on the data's quality but also on the time base.

In 2012, we presented our first catalogue of variable stars in open clusters (Zejda et al. 2012). It contained 18 065 variables of all types. Since then, space-based missions such as Gaia, Kepler, and TESS and ground-based surveys such as MASCARA, KELT, and ZTF have significantly increased our knowledge. The achieved amplitudes decreased, whereas the Gaia mission significantly improved open cluster parameters and membership probability determinations.

In this poster, we present the results from the match of the latest catalogues for variable stars and open clusters.

Open Clusters

Since the release of astrometric and photometric Gaia data, new open clusters and moving groups' inflation has set in. Although the data quality is excellent, there are still several numerical limitations for structural characterisations of open clusters and the membership determination (Piecka & Paunzen 2021).

Determining the classical cluster parameters (age, reddening, metallicity, and distance) and mean astrometric open clusters parameters has posed a challenge for almost 100 years. The situation did not improve in the Gaia era because the different algorithms yielded different results (Dias et al. 2021). Especially for newly discovered aggregates, classical cluster parameters are, in general, not available.

Variable stars

Variable stars are divided into two general categories:

- *Intrinsic variable*s in which internal physical changes, such as pulsations or eruptions, are the driving mechanism
- *Extrinsic variables* in which the flux fluctuates due to eclipses or stellar rotation

The further classification is rather complex; originally, it was based on a star's light curve, amplitude, and periodicity (or lack thereof). All astrophysical theories, including stellar formation and evolution, can be tested with variable stars.

Matching routine

For the matching, we used the variable star catalogue AAVSO International Variable Star Index (VSX; version 2023-01-09), including 2 235 851 objects and a newly compiled open cluster catalogue with 8921 entries (Paunzen et al. 2023).

The routine itself is described in Prišegen et al. (2021). It is based on Gaia DR3 positional, proper motion, and parallax information. Furthermore, we used the colour-magnitude diagram of the Gaia photometry to check the location of the individual variable stars according to their host clusters isochrone. This approach proved to be very efficient and successful. It is programmed so that new data releases can be immediately processed.

Type	Clear	Uncertain	Unclear	Total
Eruptive	999	385	7	1391
Pulsating	11897	1276	736	13909
Rotating	4110	122	36	4268
Cataclysmic	22	38	1	61
Eclipsing	5432	227	263	5922
X-ray sources	27	2	0	29
Unclear, others	4903	876	237	6016

Table 1.: The statistics of detected variable stars as members of open clusters. The first column contains the number of stars with precise classification of variability type, and a sign denotes the second column numbers of stars with uncertain classification ":". The third column numbers of unclearly classified stars are noted by a sign "|".

Results

Almost one hundred classes and subclasses of variability are given in the General Catalog of Variable Stars (GCVS). However, new types and new divisions of variable stars still appear. The VSX very often uses "new definitions" of variability types taken from original papers, especially when describing the results of a survey. Here, we used the original GCVS division into the following categories of variable stars:

- Eruptive
- Pulsating
- Rotating
- Cataclysmic variables
- Eclipsing binary systems
- Intense variable X-ray sources
- Others

The group of new variability types was dissolved into the previous seven groups according to the main characteristics of the objects according to variable star designation in VSX.

The final results are presented in Table 1. All data will be also available in WEBDA[1]. Not surprisingly, the most numerous group of variables are pulsating stars. These objects can be used to find period-luminosity-metallicity correlations, for example. Also, their pulsational spectra can be used to correlate models, including age and metallicity.

The variety of eclipsing binaries will allow to calibrate evolutionary paths much more precisely using the astrophysical parameters of both components. Again, the metallicity can be taken into account during this procedure.

We found very interesting cataclysmic variables and X-ray sources in open clusters of different ages that need further investigation. Some of them were not identified of being members of a star cluster, yet.

In the near future, we will have access to even more precise photometric and astrometric data from the ground and space. This will further strengthen the results based on variable stars of open clusters. There is also room for hope that our current knowledge can be extended to extragalactic systems.

[1] http://webda.physics.muni.cz

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