Variable binaries and variables in binaries in the Binary star DataBase

Dana Kovaleva, Oleg Malkov and Pavel Kaygorodov

Institute of Astronomy, Russian Academy of Sciences, Moscow 119017, Russia; dana@inasan.ru

Received 2018 April 28; accepted 2018 June 6

Abstract The Binary star DataBase (BDB, http://bdb.inasan.ru) combines data from catalogs of binary and multiple stars of all observational types. There is a number of ways for variable stars to form or to be a part of binary or multiple systems. We describe how such stars are represented in the database.

Key words: astronomical data bases — stars: binaries: general — stars: variables: general

1 INTRODUCTION

Binary stars are very numerous, and binarity rate increases from $\sim 20\%$ for M-dwarfs up to $\sim 60\% - 70\%$ for A- and earlier spectral type stars (Duchêne & Kraus 2013). Also, in many cases (probably as often as 1/4, according to Tokovinin 2014) after thorough investigation, binaries prove to be multiples. Information on properties of the population of binary and multiple stars has significant influence on studies of stellar formation and of Galaxy evolution (Bate 2015; Kouwenhoven et al. 2009; Weidner et al. 2009; Malkov & Zinnecker 2001; Piskunov & Mal’Kov 1991). Binaries exhibit many astrophysical phenomena of extreme interest, such as novae, type I supernovae (SNe Ia), Wolf-Rayet stars, and X-ray and symbiotic binaries; later stages of evolution of close binaries involve formation of compact objects, such as neutron stars and black holes, including recently discovered events related to their merging (Abbott et al. 2017; Lipunov et al. 2017; Abbott et al. 2016; van den Heuvel & Lorimer 1996; Tutukov & Yungelson 1994, 1993). Moreover, gravitational interaction between components in binary and multiple stars allows us to directly determine physical characteristics of the system and its components, including dynamical mass. This provides calibration of a number of relations between observed and physical parameters applied to single stars (Kraus et al. 2015; Horch et al. 2015; Malkov 2007; Benedict et al. 2006; Malkov et al. 1997), and enables tests of models of stellar evolution (see, for instance, Higl & Weiss 2017; Stassun et al. 2014; Vos et al. 2012; Kovaleva 2002).

Binaries are observed by various methods resulting in separate datasets named observational types (Malkov et al. 2017) (e.g. eclipsing, visual, spectroscopic, etc.). A binary star belongs to a certain observational type according to what observational technique was used to observe its duplicity. One binary may belong to one, two or more observational types, as soon as they overlap in spaces of physical and observational parameters (Kovaleva 2015). Usually, catalogs and databases address one or a few selected observational types. Combining their information may be problematic because of a number of problems. This includes insufficient or indefinite indentifiers, as well as non-homogeneous data which can characterize either a component, a pair or a system in total.

The purpose of the Binary star DataBase (BDB, http://bdb.inasan.ru) is to combine data from various catalogs and databases on binary and multiple stars, allowing a user to obtain complete information about a certain star, or about a set of binaries with pre-defined characteristics. This requires accurate cross-identification and establishment of proper relations between data and objects in binaries and multiples (Kovaleva et al. 2015b; Kaygorodov et al. 2012). The task is solved with an index catalog of binary and multiple stars, Identification List of Binaries (ILB, Malkov et al. 2016). This catalog implements a specially developed scheme based on three categories of object: System, Pair and Component (Kovaleva et al. 2015a).

The term “variable stars” refers to numerous and diverse sets of stars, having in common only photometric variability caused by a variety of astrophysical processes. If a binary star is observed as a variable, or a variable star is observed in a binary or multiple system, this often multiplies available astronomical information. BDB includes a number of catalogs having data on variable stars of dif-
ferent types, or focusing on variable binaries. In this paper, we discuss integration of these catalogs in BDB and related issues.

There are three types of relations between variables and binary (multiple) stars: (i) one or more components of a binary may vary its brightness by being a pulsator, a spotted star or an erupting star; (ii) the brightness of a pair may vary because of its orbital movement (e.g. eclipsing binaries); (iii) the binarity may cause physical variability (e.g. cataclysmic binaries). Though these types are not mutually exclusive (see a detailed discussion in Samus 2005), it is convenient to start discussing them separately. The primary catalog for all variable stars in BDB is the General Catalogue of Variable Stars (GCVS, Samus’ et al. 2017), however there are also catalogs in BDB addressing different observational types separately.

Section 2 discusses binary stars with variable components, Section 3 deals mainly with catalogs of eclipsing binaries and Section 4 contains information on catalogs of intrinsic binary variables. Section 5 discusses some issues relating to overlapping observational types and classes of variability, and Section 6 summarizes the results.

2 VARIABLE STARS IN BINARY AND MULTIPLE SYSTEMS IN BDB

In this section, we address cases when one or more components in a binary or multiple star system are intrinsic variables. The catalogs of such systems containing a few hundred stars were compiled by Baize (1962), Perova (1963) and Baize & Petit (1989). Regrettfully, none of these catalogs is available in electronic form, so they can be used for referral but are not integrated in the BDB thus far. The data on 171 classical Cepheids in binary and multiple systems from the “Binary stars among Galactic classical Cepheids” database (Szabados 2003) have been integrated in BDB, and a special flag (in Observational Type field) was assigned to all stars from that dataset. For the other types of intrinsic variable stars in binaries, no special catalogs are available except the “Candidates for Binaries with an RR Lyrae Component” (Liška et al. 2016), which will not be integrated in BDB until the candidates are confirmed.

A catalog of UV Ceti type flare stars in binary systems was constructed by Tamazian & Malkov (2014). It contains information on 138 such binaries, and data on orbital elements are available for 31 of them.

Some major catalogs contain information on variable components of binaries in text files in the form of comments. In BDB, we work on reading data on properties of binaries from text files. The success strongly depends on whether authors use formal phrases to describe the structure of a system. We obtain part of the information on stellar types from text comments (Notes) that are part of the Washington Visual Double Star Catalog (WDS, Mason et al. 2016).

In particular, 73 binary and multiple systems from this catalog are marked to contain pulsators like Cepheid or RR Lyr cases, though one should note that not necessarily all of these systems are physical (due to principles related to the way this catalog was constructed). On the contrary, information on intrinsic variability of the components of systems listed in the Multiple Star Catalog (MSC, Tokovinin 2018) and in The Ninth Catalogue of Spectroscopic Binary Orbits (SB9, Pourbaix et al. 2004) definitely refers to physical binaries. GCVS contains valuable information on variables having components in comments, though this information relates mainly to variable stars, and we do not use it in BDB so far. If a binary system is found in GCVS, we mark this system as one containing an intrinsic (pulsating, eruptive, spotted, etc.) variable, based on the GCVS variability type. However, the BDB information about different types of intrinsic variability is certainly very incomplete. We introduce “intrinsic variable inside” type only if a star has a GCVS identifier in some of the catalogs of binaries and GCVS provides information concerning relevant variability type.

Figures 1–4 below show the screenshots of (some part of) BDB representation for a remarkable multiple system BSDB J194448.73+291552.8:s including a classical Cepheid, SU Cyg. One of the components (BSDB J194448.73+291552.8:c1B) of the spectroscopic binary with an orbital period of ~549 d, SBC9 1172 = BSDB J194448.73+291552.8:p1A-1B, is a Cepheid, while another component itself is a close spectroscopic binary, SBC9 2142 = BSDB J194448.73+291552.8:p1AA-p1Ab, having orbital period of ~4.7 d. The wider pair can be resolved interferometrically. Three more distant visual components of yet unknown physical connection are situated at angular separations of ~25′′, ~71′′ and ~75′′, respectively.

Combined with parallax $\varpi = 1.52 \pm 0.27$ mas (Gaia DR1 TGAS, Lindegren et al. 2016) or $\varpi = 1.1695 \pm 0.0516$ mas (Gaia DR2, Lindegren et al. 2018), this does not favor expectations of orbital motion. On the other hand, based on Gaia DR2 parallaxes for these remote components ($1.2351 \pm 0.0278, 1.9440 \pm 0.0246, 1.1280 \pm 0.0345$ mas), at least two of them are situated rather close to SU Cyg in space, and at least one of them, the one with $\varpi = 1.1280 \pm 0.0345$ mas, has similar proper motion. Anyway, the system is quite interesting and promis-
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Welcome to

The Binary Star Database

Binary star databases (BDBs) are a database of binary/multiple systems of various observational types. BDBs contain data on eclipsing and non-eclipsing binaries, including multi-systems at multiple epochs for more than 20 billion stars in a variety of published catalogues and databases.

Fig. 1 Result of request on “SU Cyg” in BDB. This multiple system includes a Cepheid. Yellow background indicates lines of text referring to the requester identifier, and other (white) lines provide information on other objects in the same system.

Fig. 2 Result of request on “SU Cyg” in BDB, which lists identifiers and part of the data on pairs. The “Show selected data” button in the upper part of the figure (just below the visualization figure on the real screen) leads to lines of original data from the catalogs for objects displayed on the yellow background.

Fig. 3 One part of the result from a request on “SU Cyg” in BDB, second level (after the “Show selected data” button is pressed). Original data are from catalogs.
ing, thanks to an admirable combination of multiplicity and variability.

3 ECLIPSING BINARY CATALOGS

Eclipsing binaries form the most populated observational type of binaries, and hundreds of thousands of such stars have already been discovered in our Galaxy and in the Magellanic Clouds. The increase in the number of known eclipsing binaries during recent decades is thanks to projects searching for brightness variability (ASAS, Paczyński et al. 2006) due, in particular, to gravitational microlensing or exoplanet transit (OGLE, Soszyński et al. 2016; Kepler, Kirk et al. 2016). Numerous eclipsing binaries discovered in the course of such projects cannot, as a rule, be individually investigated and classified. In the meantime, the recent version of GCVS (Samus’ et al. 2017) includes more than 10,000 eclipsing variables having sufficiently complete data.

Eclipsing binaries can be very different both morphologically and physically. There is a number of catalogs devoted to some subclasses of these stars in BDB. Compared to other observational types of stars, catalogs devoted to reliably classified eclipsing binaries contain more physical information on the systems and components. In particular, a large volume of physical data was obtained by Prof. M. A. Svechnikov and his colleagues in their investigation of lightcurves of eclipsing variable stars (Perevozkina & Svechnikov 2004; Surkova & Svechnikov 2004; Dryomova et al. 2005; Svechnikov & Bessonova 1984; Bondarenko & Perevozkina 1996; Polushina 2011; Svechnikov & Kuznetsova 2004).

The Catalogue of Eclipsing Variables (CEV, Avvakumova et al. 2013; Malkov et al. 2006) contains the most complete data on eclipsing variables of known morphological types. It combines data from GCVS tables and text remarks with data from other bibliographic sources and observations, using an author’s original scheme of lightcurve processing to determine the physical type of a binary and its characteristics.

The gap between a number of discovered eclipsing binaries and possibilities for individual investigation of every star to obtain its physical characteristics make automatization of lightcurves classification extremely advantageous (see, for instance, Modak et al. 2018; Armstrong et al. 2016; Avvakumova & Malkov 2014; Malkov et al. 2008). It is expected that as one of the results of the Gaia mission, several million eclipsing binaries will be discovered (Süveges et al. 2017; Kochoska et al. 2017).

So far, extensive lists of recently discovered eclipsing binaries were not included into BDB, due both to their underclassification and low probability that they may intersect with any other catalogs. However, recent progress in automated classification of lightcurves, systematic investigations of eclipsing binaries discovered in large surveys with different techniques (Soszyński et al. 2016; Kozłowski et al. 2016; Parihar et al. 2009), objects observed in more than one survey (Drake et al. 2014; Muraveva et al. 2014; Schaffenroth et al. 2013), and many objects of interest among these eclipsing binaries (see, e.g., eclipsing binaries with a Cepheid component, Pilecki et al. 2016; Udalski et al. 2015; spectroscopically resolved eclipsing binaries Maceroni & Montalbán 2004;
Kozłowski et al. 2016) motivate us to start preparing for integration of extensive lists of eclipsing binary stars, discovered in surveys, into the ILB.

4 Catalogs of Intrinsic Binary Variable Stars

In GCVS, there is a number of classes of physically variable stars with variability caused by their binarity. Let us name them intrinsic binary variable stars.

Currently about 2000 cataclysmic variable stars are known. In addition to GCVS, two main (overlapping) catalogs for this observational type are those by Ritter & Kolb (2011) (which was regularly updated until 2016) and by Downes et al. (2005). The data on these binaries are highly non-uniform, but usually include orbital characteristics (period, inclination limitations), morphological type of a variable and relative characteristics of the components.

Some binaries demonstrate variability out of the optical range. In BDB, there are data on about 300 X-ray binaries (partly included in the already mentioned catalog by Ritter & Kolb 2011). Other data sources for these objects are the Catalogue of Galactic Low-Mass X-Ray Binaries (LMXB, Liu et al. 2007), and Catalog of Galactic High-Mass X-Ray Binaries (HMXB, Liu et al. 2006). In addition, there are more than 200 radio pulsars discovered in binary systems. These objects were identified with optical sources for their integration into ILB and, therefore, into the database (Malkov et al. 2015).

We do not yet include data on the classes of binaries discovered at the stage when they actually cease being binary, like SNe Ia and gravitational wave binaries.

There is a group of variable binaries for which brightness varies with stellar or orbital rotation. Simultaneously, this variability critically depends also on their binarity: these are ellipsoidal, reflecting and spotted binaries (Samus et al. 2005). GCVS is the main source of data for these stars in BDB.

5 Conclusions

Variable stars with different physical and observational natures are represented in BDB by data from a number of catalogs. As part of binary or multiple systems, intrinsic variable stars can provide more interesting data than single ones. Intrinsic binary variable stars are among the most popular astrophysical laboratories. Eclipsing binary stars form the most populated and rapidly increasing class of variable binaries. Only a smaller, well-studied part of them from the GCVS catalog is presented in BDB thus far. These stars allow determination of astrophysical data if their physical nature is properly classified. Automated classification of lightcurves of eclipsing binaries is an important challenge at present and in the near future.

When this paper was almost completed, the Second Data Release of the Gaia mission (Gaia Collaboration et al. 2016) had just been published. Although, contrary to earlier plans, this data release does not include catalogs of non-single stars, it contains extensive new information on variable stars. We work on BDB and its index catalog, ILB, to compile data from present and forthcoming large catalogs to benefit investigations of binary stars, including variable binaries and variables in binaries.

Acknowledgements This work was partly supported by the Russian Foundation of Basic Researches, projects 16–07–1162 and 18–02–00890. The support by Fundamental Research Support Program 28 by the Russian Acad. Sci. is acknowledged. This research has made use of the VizieR catalog access tool, CDS, Strasbourg, France. This work has also made use of data from the European Space Agency (ESA) mission Gaia (https://www.cosmos.esa.int/gaia), processed by the Gaia Data Processing and Analysis Consortium (DPAC, https://www.cosmos.esa.int/web/gaia/dpac/consortium).

Funding for the DPAC has been provided by national institutions, in particular the institutions participating in the Gaia Multilateral Agreement.

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