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Binary star DataBase BDB development: Structure, algorithms, and VO standards implementation

D. Kovaleva [a], P. Kaygorodov [a], O. Malkov [a,b,*], B. Debray [c], E. Oblak [c,1]

[a] Institute of Astronomy of the Russian Academy of Sciences, 48 Pyatnitskaya Str., 119017 Moscow, Russia

[b] Faculty of Physics, Moscow State University, Moscow 119992, Russia

[c] Institut UTINAM, CNRS UMR 6213, Observatoire des Sciences de l'Univers THETA de Franche-Comté Bourgogne, Université de Franche-Comté, 41 bis Avenue de l'Observatoire, BP 1615, F-25010 Besançon, Cedex, France

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ABSTRACT

Description of the Binary star DataBase (BDB, http://bdb.inasan.ru), the world's principal database of binary and multiple systems of all observational types, is presented in the paper. BDB contains data on physical and positional parameters of 240,000 components of 110,000 systems of multiplicity 2 and more, belonging to various observational types: visual, spectroscopic, eclipsing, etc. Information on these types of binaries is obtained from heterogeneous sources of data—astronomical catalogues and surveys. BDB provides a tool for effective managing of the catalogues of binary stars into the IVO. Organization of the information is based on the careful cross-identification of the objects. BDB can be queried by star identifier, coordinates, and other parameters. To solve the problem of cross-identification which for binary and multiple stars is much more complicated than for single stars, a new consistent scheme for identification of objects in binary and multiple stars, BSDB (Binary Star DataBase), is developed and implemented. The list of all binary and multiple stars cross-identifiers (preliminarily named Identification List of Binaries, ILB) is being created and will be used to improve BDB request processing. IVO standards implementation into BDB is discussed.

1. Introduction: BDB and what it gives to astronomical community

A lot of effort and resources were invested in the design and content of International Virtual Observatory (IVO), and to benefit one needs to dispose simple tools to work with existing data. Currently there is a need to integrate a tool for an effective managing of the catalogues of binary stars into the IVO, and BDB provides such a tool.

Astronomical databases and catalogues serve as major data sources as part of the International Virtual Observatory. So, VizieR (Ochsenbein et al., 2000; Landais and Ochsenbein, 2012, http://vizier.u-strasbg.fr/) catalogue service provides access to catalogued data published in astronomical journals, SIMBAD astronomical database (Wenger et al., 2000, 2007, http://simbad.u-strasbg.fr/simbad/) provides data for astronomical objects outside the solar system, and NED (Mazzarella and NED Team, 2007, http://ned.ipac.caltech.edu/) is a comprehensive database for extragalactic objects. Various databases/catalogues serve as data sources for binary stars of different observational types, examples are WDS (Mason et al., 2001, http://ad.usno.navy.mil/wds/, VizieR On-line Data Catalog: B/wds) and CCDM (Dommanget and Nys, 2002; VizieR On-line Data Catalog: I/274) for visual binaries, ORB6 (http://ad.usno.navy.mil/wds/orb6.html) and OARMAC (http://www.usc.es/astro/catalog.htm) for orbital binaries, INT4 (http://ad.usno.navy.mil/wds/int4.html) for interferometric binaries, SB9 (http://sb9.astro.ulb.ac.be/, VizieR On-line Data Catalog: B/sb9) for spectroscopic binaries, CEV (http://www.inasan.rssi.ru/~malkov/CEV/, VizieR On-line Data Catalog: J/AN/334/860) for eclipsing binaries, Downes et al. (2001–2006) (http://archive.stsci.edu/prepds/cvcat/, VizieR On-line Data Catalog: V/123A) and Ritter and Kolb (2003–2014) (VizieR On-line Data Catalog: B/cb) for cataclysmic binaries, etc. However, there was no database synthesizing the various categories, and the Binary and multiple stars DataBase (BDB), presented in this paper, aims to fill this gap.

* Corresponding author at: Institute of Astronomy of the Russian Academy of Sciences, 48 Pyatnitskaya Str., 119017 Moscow, Russia. Tel.: +7 495 951 79 93; fax: +7 495 951 55 57.

E-mail address: malkov@inasan.ru (O. Malkov).

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The Binary and multiple stars DataBase BDB (http://bdb.inasan.ru) is being developed as the world's main source of data on binary and multiple systems of all observable types (visual, spectroscopic, eclipsing, etc.) and includes physical, photometric and positional data. Information about these types of binary is included in BDB from heterogeneous data sources: astronomical catalogues and surveys. The history and initial purposes of BDB creation project are described in Oblak et al. (2002, 2004), and Malkov et al. (2009). At present, the database is moved from Besançon Observatory where it was started, to the Institute of Astronomy of the Russian Acad. Sci., significantly reconstructed and renovated, as one of activities in the frame of Russian Virtual Observatory (RVO, Dluzhnevskaya and Malkov, 2005; Malkov et al., 2006, http://www.inasan.rssi.ru/eng/rvo/) project. Main BDB objectives and ideas of BDB management were discussed by Malkov et al. (2009, 2011, 2013) and Kaygorodov et al. (2012). Current version of BDB contains astrometric, photometric, spectroscopic and other data on some 240,000 components of 110,000 systems of multiplicity 2 and more, which can be queried by object name, coordinates and various criteria.

Designing BDB, we take into account and rely on experience of well-known and widely used astronomical databases such as SIMBAD and VizieR but incorporate a set of catalogues not included in VizieR. We will also provide links to other binary star databases from BDB. The list of principal data sources for binaries of different types to be included in BDB has been described in Malkov et al. (2011). A supplementary list of catalogues (published mainly in 2006–2010) to be integrated in BDB was presented in Kaygorodov et al. (2012). The catalogues are included ≪as is≫, the data are completely available to the user as they were in the catalogue. However, when we find errors/misprints in original catalogues (both in identification, format, and observational data) we correct them (when possible) and inform authors and/or VizieR service. The origin of information, presented as a result of a BDB query, is clearly indicated.

Organization of the information is based on the careful cross-identification of the objects in the frame of supported set of basic BDB identifiers. We have found a number of component cross-identification problems occurring in original catalogues, and with the algorithms included into BDB we are able to find and solve such problems automatically. We have developed and used a new consistent scheme of designations of binary/multiple stars that allows establishment of proper links between objects and data from different sources.

The development of BDB is impossible in isolation from the real scientific problems, such as investigation of characteristics of the binary stars population of the Galaxy, determination of the masses and other physical parameters of the stars, statistical study of binary evolutionary scenarios, study of variations of multiplicity fraction of the stars of different spectral classes. As the creators and developers of database are binary investigators themselves, the additional tools required for specific typical tasks, as well as utilities serving more effective interaction of BDB with the world archives of astronomical data and tools of the International Virtual Observatory, are on the way to be created.

In Section 2 we describe how BDB is structured and implemented, how it works for the user and what is special about BDB, Section 3 explains how we solve the problem of cross-identification of objects in binaries and multiples, and Section 4 deals specifically with BDB features related with the VO, existing and planned.

2. How BDB works

2.1. BDB structure

BDB contains information on binary and multiple stars. Multiple stars may either represent mini-clusters of gravitationally connected objects, or a hierarchy of pairs where each pair element may be either a single star or another (possibly hierarchical) pair, or a system of several pairs and single stars. One of the main problems in data extraction is that pairs and components in various catalogues may be identified differently. For instance, in one catalogue an object may be presented as a single star while in another one this same object is a pair. Moreover, the hierarchy of the objects in a given system may be different in various catalogues. We made it our principle not to filter or change the content of the catalogues included into BDB. The database should represent controversy of the catalogues if it happens and pass all data to the user in order he draws his/her own conclusions.

To establish the structure providing correct links between objects and data, we introduce in BDB three categories of objects: System, Pair and Component. This approach is originated by the fact that each of these categories has its own set of observational data. Mass, radius, temperature, luminosity, etc. are Component's characteristics (same set of astrophysical parameters as a single star might have). The Pair consists of two gravitationally linked objects (any of them may also happen to be a pair). This category is characterized by another set of parameters: relative position of pair members at celestial sphere (for visual binaries), orbital parameters (rotational period, orbital eccentricity, etc. — for orbital and part of spectroscopic binaries), total magnitude (for photometrically unresolved) and joint spectrum (for spectroscopically unresolved binaries). The observers of binaries usually deal with the pairs, and this is the information mainly included into catalogues of binaries. Some data can be prescribed to different categories: say, the coordinates, magnitudes, spectra, colours, etc. can refer to each Component in a case of resolved binary, and to a Pair if the binary is unresolved. Finally, the System does not contain specific data fields but is used for linking the pairs belonging to it. The system in our scheme is a merely technical notion that can refer to a set of physically bounded stars or even to a set of optically close ones. The only reason for a set of stars to be named a "system" in BDB is to be designated by the same identifier in one of basic catalogues of binary and multiple stars. Systems may be hierarchical or non-hierarchical, or combined.

The Pair refers to the parental System and can refer to one (in the case of astrometric pairs) or, normally, to two Components. Similarly to the System, the Reference does not contain specific data fields but can be referred to by the System, Pair, Component entries via [References] field.

In the course of data import, each catalogue line results in one or several entries of described types. The values placed into the fields of created entries, are calculated according to the algorithms developed separately for each parsed catalogue. Each entry contains reference to the initial catalogue and the line from where the data were taken. This information is available for the user interacting with BDB. Apart from the data, the database also keeps metadata with information about the catalogues, their file structure, as well as rules of parsing for each of them.

For each object, as many entries are created in BDB as there are references to the object in the various catalogues. A catalogue may contain several entries for one object, possibly in different data files.

To link the entries, internal identifiers are used within one catalogue and external ones are used to keep connection between different catalogues. Internal identifiers can be constructed in an arbitrary way (they are never shown to BDB user), and their main requirement is the following — each object within a catalogue must have one and only one unique identifier. If an object appears more than once in a catalogue (e.g., part of the parameters are represented in one table of the catalogue, and another part – in the other table), then several entries are constructed (in each entry only a part of the fields is filled) having a common internal