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

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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.

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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 identifier. When displaying information, BDB will automatically find all the entries with the internal identifier and will display the full set of parameters. If the parameter sets in different records intersect, the user will see all the available values for each parameter (they will be listed in square brackets). Sometimes it is necessary to associate a single entry in the catalogue with several different objects. For example, a separate table can represent links to data sources, wherein each source can provide data for several objects. To represent this information in the query results, such entries are linked through a special field [References], which can contain an arbitrary number of internal identifiers.

External identifiers are used to link entries from different catalogues. Each external identifier represents one of the dozens of identification systems used in astronomy. BDB includes identifiers of the following systems: ADS, Bayer, CCDM, DM, Flamsteed, GCVS, HD, HIP, IDS, IGR (INTEGRAL Gamma-Ray Sources, http://www.cosmos.esa.int/web/integral), Name, SBC9 and WDS. Each object (system, pair or component) may have one or more external identifiers, and it often happens when more than one object have the same identifier in some identification system. This is due to the fact that at the moment of the identifier assignment, these objects were not resolved and observed as a single source of light. The user, making the request to BDB by the identifier, should get detailed information about the requested object. Accordingly, a problem of cross-ID should be solved in BDB, i.e., each object should be associated with a list of identifiers, ever assigned to it. However, in this process, physically separated object should not be connected, even if they have one or more common identifiers. To ensure these requirements, we have developed our own consistent system of identification, which is currently being tested. Basic principles of this system are given in Section 3.

2.2. BDB implementation

Implementing BDB, we have chosen a set of free, stable, well-documented and well-supported tools which allow us to speed up the development and make a portable code. Using high-level libraries and frameworks allowed us to focus on the architecture of the database. BDB is implemented in stackless Python (http://stackless.com/) language using the Nagare (http://www.nagare.org/) framework and Elixir (http://elixir.ematia.de/) —the declarative superstructure over the ORM SQLAlchemy (http://www.sqlalchemy.org/), the database management system (DBMS) is PostgreSQL (http://www.postgresql.org/). For the online requests addressed towards external services, the ZSI module (http://pywebsvcs.sf.net/) implementing the SOAP protocol (http://www.w3.org/TR/soap/) is used. BDB consists of two parts: the web application providing interaction with the user, and the daemon performing data processing while the catalogues are imported. The interaction between these parts is realized via data share system memcache.

The web application is divided into administrative and user parts. The administrative part is intended to add and remove the catalogues, to create and change the rules of their import, and to readjust some BDB parameters. The user part serves to search and represent the information contained in BDB.

To add a new catalogue, several steps should be done. First of all, one needs to download the files of the catalogue (in VizieR format), including the ReadMe file, to BDB server. It can be done in automatic mode (after indication of the catalogue name in VizieR, necessary files are downloaded from the VizieR ftp-server) or in manual mode, uploading zip-archive from local workstation (usually used for the non-VizieR catalogues that are preliminarily reformatted into VizieR-like format). The uploaded ReadMe file is automatically analysed, information is selected describing all catalogue files and written into the database. If there are some mistakes preventing correct recognition of the ReadMe file, the content can be corrected in the frame of the BDB administrative interface. After successful interpretation of the ReadMe file, the data files are extracted from the archive and uploaded into the database.

The content of the file is read line after line performing for each line a code is generated based on the set of rules (''rules of parsing'') established for this catalogue. The rules of parsing are individual for every separate file of each catalogue. The interface to create these rules includes several sections: section referring to data on Systems, section of data on Pairs, and two sections referring to the Component's (primary and secondary ones) data, as well as the section of General code performed at the start of the parsing stage, before and after the interpretation of each line. In the sections referring to Systems, Pairs and Components, there are fields where the code (in Python language) should be inserted to return the value to be saved in respective fields of the created entry (i.e. orbital period for the Pair, or stellar magnitude for the Component). To calculate some parameters, rather complex algorithms are used; for the sake of convenience, their realization may be referred to General code section, the result saved as a variable, and its name inserted into the respective field of parsing. The code performed once while the parsing starts is inserted (if necessary) into a special section for algorithms requiring initialization at the start.

Besides specific fields for the entries of various types, there are general fields. These are the field of internal identifier (see Section 3 for details) and the field of the flag. The expression in the flag field should return logical True if the interpretation of current line of the catalogue should result in creation of the entries of this type (System, Pair of Component), otherwise the expression in the field should return logical False. There is also a general field of References that may contain the array of lines (in Python notation) each of them should represent the internal identifier. If the References field is not empty all the entries generated at the parsing of this given line would have references to respective data of original catalogue (i.e. Comments, Notes, etc.). While the information is represented to the user, he will see not only the data of entries he required for but also all the lines of original catalogue these entries refer to. This scheme is used, for instance, to represent the Comments of the original catalogue.

After the rules are established, one may do test interpretation of selected number of lines of the catalogue file. This does not affect the database but displays the results of parsing to the screen, to check for correctness. If parsing mistakes are revealed, one can return to the rules of parsing forms to make necessary corrections. If test parsing was recognized as correct, all the file can be parsed. As parsing can take a rather long time for large catalogues, it is done in background mode while web interface reflects only the level of completeness and the remaining time for completing the process. The data are inserted into the database after the parsing was completed.

2.3. Data query and representation

Presently, BDB can be accessed interactively at http://bdb.inasan.ru via a web-interface. BDB data can be queried by identifier and by parameters. Batch mode query will become available in spring 2015.

Query by identifier allows the user to select object, using an identifier from the basic list already given previously in Section 2.1. While typing the ID, interactive hint is displayed, allowing user to write only a part of the identifier for searching (done by means of Ajax). The identifiers are resolved with BDB ID table. User is also allowed to choose [Misc] (Miscellaneous) from the list and type another stellar identifier. In this case, if the submitted identifier is not found in BDB ID's, the Strasbourg astronomical Data Center

(CDS) service Sesame is addressed via SOAP protocol to resolve it (http://cds.u-strasbg.fr/cgi-bin/Sesame). Among the results found by Sesame, the ID contained in BDB is selected. The results of the request to Sesame are being cached. When the identifier is received, the following procedure is performed:

1. BDB finds all the entries (systems, pairs and components) referring to this identifier. Selected entries are included into the list (here and farther only the elements missing in the list are added to it).
2. For each selected entry, the entries with the same internal identifier are found and included in the list (as it was described, each object in BDB can be referred to several entries having the same internal identifier).
3. If the discovered entry is referred to the systems, all the pairs referring to it are included to the list. For the pair, both its components are included as well as the system it refers to. For the component, its parental pair is included.
4. The list of external identifiers to which the previously found entries refer is compiled.

These listed stages are repeated as a cycle for all the found identifiers, until the list being formed stops increasing.

It is a rather time-consuming process. To overcome this problem we compile an identification list of binaries, containing identifications of components, pairs, and systems in different catalogues. When the list is included in BDB, the database search will be based on the identification list data only, and the information will be retrieved from the original catalogues, using identifiers found in the list.

When the list of found entries is completed, the main result page is displayed. This page represents visualization for the queried system via Google Sky (http://www.google.com/sky/) selected due to convenience of use in Ajax environment, efficiency, reliability and flexibility. Other sky map services, such as AladinLite might be implemented in the future. List of identifiers for all involved systems, pairs and components are also displayed. Components of visual binaries are represented by circles. Clicking circles on the image or entity names in the list, one can select/deselect them for displaying and further analysis. For each object, all known BDB identifiers are represented, as well as the identifiers received via Sesame request. These requests are being done in a background mode, so the respective information is represented in the course of its receipt. The values of data fields are represented for each object as they are known from original catalogues.

The user can select objects of interest at the visualization diagram using the mouse. While one or more objects are marked, one can also select one or more catalogues for further analysis and press the [Next] button. The resulting page contains fundamental parameters of the selected entities listed in the selected catalogues, along with the relevant catalogues ReadMe data.

The query by parameters is another mode of request to BDB data. The user can select one or several request criteria, for instance, setting limits for orbital periods and stellar magnitudes, and selecting evolutionary stage of stars of interest for him. As the criterion is set, maximum and minimum values available in the database are automatically represented as a hint. For non-numerical criteria, such as evolutionary class, observational type, spectral type, the user can select one or several among possible options. Thus, one may wish to exclude binaries that are not physical ones (optical binaries) from consideration by selecting all available observational types except "Optical".

As soon as you click the [Search] button on the desktop, the table is represented including all the identifiers of the found objects (as clickable links) as well as the values for all non-empty fields of relevant entries. The objects are sorted up in the order of increase of the values in the fields of request. The user can receive the data on any object as if he worked with request by identifier (described above) by clicking on identifier link.

By default, only the first 100 objects of the found set are represented, but the user can see the further results clicking the [Next] button. The content of the table can be received via the link [download as text file] (columns being aligned by position). We plan to make possible getting data file in XML-VOTable and csv-formats.

2.4. Comparison with other databases

BDB purpose is to provide simultaneous access to catalogued data on binary stars of all types. One of the major problems solved in the frame of BDB project was to provide correct identification of the components of binary and multiple stars and link data of various catalogues with relevant stars. This makes a real difference for the binary investigator with other relevant astronomical databases.

SIMBAD: Due to its general character, the SIMBAD astronomical database is not specifically intended to describe binary stars. There are no parameters of binaries (e.g., period, eccentricity, etc.) among the search criteria, not all objects are included, there are confusions in designations of systems and components.

VizieR: catalogues should be pre-selected for search, not all important catalogues of binaries are included, there are confusions in designations.

Multiple Star Catalog (Tokovinin (1997), http://www.ctio.noao.edu/~atokovin/stars/, VizieR On-line Data Catalog J/A+AS/124/75) contains only objects with Keplerian orbits, stable during several revolutions, altogether 1359 stellar systems of multiplicity 3 to 7, identification set for search is poorer.

Catalogues and databases of particular types of binaries provide information on that type of binaries only. Besides that they are not free from identification errors. The system CCDM (=WDS) 04078 + 6220 consisting of 22 components and its representation in basic catalogues and in SIMBAD can serve an example. The result of cross-identification check is as follows:

- ADS: 1 misprint
- IDS: 3 misprints
- HD: 1 confusion
- WDS: 2 corrections
- CCDM: no error is found
- DM3 (http://www.usno.navy.mil/USNO/astrometry/optical-IR-prod/wds/dm3): 6 corrections (2 pairs × 3 bands)
- SB9: 1 correction
- Simbad: 4 corrections.

None of these databases allows adequate visualization which can be crucial for a binary/multiple system investigator to make certain conclusions about components and parameters.

3. Solving cross-identification problem for binary and multiple stars

The catalogues of binaries of various observational types use different designation schemes. That is why we have introduced a unique and consistent system for object designations in BDB. The designation of components/subcomponents of a binary/multiple system is still problematic, and a satisfactory solution is being sought, resulting in the scheme described below.

3.1. Self-consistent identification system for objects in binary and multiple stars: BSDB

The scheme should meet the following requirements:

- Designation is stable with respect to discovery of new distant components.
- Designation is stable with respect to discovery of new components of resolved binaries.
- A particular name always represents one object only.
- A particular object is always represented by one name only.
- Compatibility with existing nomenclatures, if possible.

According to these requirements, we construct a unique identifier for each object. All original identifiers of that object found in the published sources will be associated with that identifier. To compile a unique designation for objects in the resulting list, we follow the "IAU Specifications concerning designations for astronomical radiation sources outside the Solar system" recommending to use the standard equinox of J2000.0 (i.e., IRCS position or FK5-based, Julian equinox 2000.0 system) or the old standard equinox of B1950.0 (i.e., Bessel–Newcomb FK4-based, Besselian equinox 1950.0 system) for equatorial coordinate-based designations. "BSDB" (Binary Star DataBase) abbreviation is used as an acronym. As precise enough equatorial coordinates are provided in almost all input catalogues, a coordinate-based designation can be formed. Also, we add a specifier to distinguish systems, pairs and components ("s", "p" and "c", respectively). The reasons to introduce these three categories of objects are described in Section 2.2. Some parameters can pertain to a "system", while other parameters can describe a "component". Some other parameters (e.g., orbital elements) characterize a "pair" (note that a component of a "pair" is not always a single star).

It should be noted that the maximum number of components in a hierarchical multiple system, N, depends on the number of hierarchy levels and can be estimated. Surdin (2001) showed that the number of levels in hierarchical stellar systems is limited by the tidal action of regular gravitational field of the Galaxy and stochastic encounters with giant molecular clouds, and can reach values of 8 or 9, depending on mass and orbital parameters of the components. It can produce, in a case of maximum dense "packing" of components in the system, hierarchical systems with $N = 256$–512. This limit is purely theoretical, and actually one can hardly hope to meet hierarchical system of such density. However, there are high multiplicity systems, mainly non-hierarchical or combined, listed in the catalogues, primarily in the WDS (currently 11 WDS systems have from 30 up to more than 100 components) and obviously, this number will increase. That is why we have decided to use numerals to identify components on the upper level of hierarchy. For other levels we use capital letters A, B, etc.

To form the designation, we take equatorial coordinates for the standard equinox of J2000.0 from the catalogues. Coordinates given in the catalogues are precise enough to specify them in the form of HHMMSS.ss+DDMMSS.s or HHMMSS.ss−DDMMSS.s. An example of the designation is as follows: let BSDB J000144.48+590527.1:s designates a triple system consisting of a close pair and remote component. A close pair in that system can be designated as BSDB J000144.48+590527.1:p1A–1B (note that we use the minus sign as a separator to indicate components of a pair), while components can have BSDB J000144.48+590527.1:c1A and BSDB J000144.48+590527.1:c1B designations. A remote component would be designated as BSDB J000144.48+590527.1:c2 and would make, together with the BSDB J000144.48+590527.1:p1A–1B, a pair BSDB J000144.48+590527.1:p1–2. Note that there is no component '1' in the list. It is because '1' is not a star in this system but a pair of stars (1A–1B) and, respectively, is described by the parameters typical for pair (say, orbital period) and not for component. The coordinate part of a designation does not vary within the system (in spite of the fact that the components can differ in coordinates).

Indicating component designation we in general follow WDS notation, but we substitute upper level letters for digits and digits for upper level letters. Thus, we introduce BSDB J043306.62+240954.9:p1BA–1BB for the pair WDS 04331+2410 Ab1,2. The proposed system is extended to other types of binaries. Note that the principal catalogue of photometric (eclipsing) binaries, GCVS, has the same coordinate precision as WDS and CCDM, and the principal catalogue of spectroscopic binaries, SB9, is even more precise (here coordinates shall be truncated – not rounded – to form a designation).

Let us consider if the scheme is stable towards possible new discoveries. Due to principles chosen to determine a System, there is no chance that we would need to change a "Component" or a "Pair" to a "System". Systems always remain systems, and pairs remain pairs. However, it is very realistic to expect that in the future, some "Components" would be resolved and become "Pairs".

A newly discovered distant component will be designated by the next vacant digit. The solution of a component in two subcomponents will lead to an appearance of two new designations for the subcomponents, with letters A and B in two subsequent positions (e.g., subcomponents 2BA and 2BB will appear when a component 2B is resolved). In the latter case the resolved component designation (BSDB Jxxxxxx.xx+xxxxxx.x:c2B) will be moved to the "outdated BSDB name" column, and a new designation for the pair (BSDB Jxxxxxx.xx+xxxxxx.x:p2BA−2BB) will be constructed. Simultaneously, in BDB, all "old" information will remain available for the requests; the new information about the components and parameters of a new pair will be added from the catalogues where it is found.

The principles underlying BSDB identifier compilation do satisfy the "IAU Specifications concerning designations for astronomical radiation sources outside the solar system" (unlike, say, similarly coordinate-based WDS and CCDM names). It is not planned to change BSDB notation for the systems ever, even if the coordinates of a star would change with time due to proper motion.

3.2. Identification list of binaries

To provide the BSDB number for all binary systems included in BDB, we are working to appoint BSDB identifiers to binary and multiple stars of every observational type. For this purpose, we are compiling the general catalogue of identifications of binaries, preliminarily named Identification List of Binaries, ILB. The ILB should include BSDB identifications for all binary systems inserted in the catalogues up to date, as well as leave such possibility open for the coming binary lists/catalogues/surveys.

Most representative catalogues of binary systems (from wide to close pairs) are gradually connected to ILB. If an object is encountered for the first time, a unique BSDB identifier is attributed to it. Objects that already exist in the previously investigated catalogues are appended to the corresponding ILB entries. New objects (pairs, components), included in stellar systems already existing in ILB, lead to adjustments of the relevant sections of the catalogue. Cross-ID problems are solved in this stage, and, to do it properly, all available information (positional, photometric and sometimes already contained in catalogues cross-identification) is taken into account.

Once all cross-identification within the ILB is performed, the search algorithm will be significantly simplified: the search will be carried out only by BSDB-identifiers, and no runtime-checking of cross-identification mistakes will be required. Caching the results of queries will also be possible, indexing them by BSDB-identifiers results, as BSDB identification system guaranteed consistency within BDB. All this will allow us to speed up the search process by orders of magnitude, and will substantially reduce the response time of BDB.

Catalog ILB will be constantly updated, it will be not only the basis for BDB, but can also serve for other applications. It can be considered as the analogue of the CSI catalogue (Ochsenbein (1983), VizieR On-line Data Catalog: V/26) for binary and multiple stars.

4. BDB and IVOA standards

At some point, it seemed that modern astronomy stands at the borders of new discoveries. The opportunities of the discoveries are provided by modern information technologies, as well as political and technical international cooperation. However, towards the realization of the IVO, a number of pitfalls significantly slow its development. There is a number of objective and subjective obstacles to introduce such a potentially valuable tool. In particular, in order to effectively use the IVO tools, one needs to be an expert in the field of standards, supported by IVO. On the other hand, the ideas of Virtual Observatory are successfully put into practice only in certain areas, characterized by the homogeneity of observations and data, and stalled in areas with complex relationships between objects and observations. Binary stars are just an example of such a complex area for implementation of the IVO ideas. This is due to heterogeneity of observational types and observational data, the complexity of cross-identification of objects, the lack of a unique designation scheme, and so forth.

Initially BDB was conceived and implemented out of the context of IVO standards, although according to its destination, the database, of course, should be integrated in the IVO, and the authors' goal from the very beginning has been to make BDB VO-accessible.

BDB is organized to use certain IVO services. VizieR is the source where the majority of BDB catalogues is automatically downloaded from, and VizieR catalogue format is established as a "golden standard" within BDB so that non-VizieR catalogues are re-formatted into it to be downloaded and parsed. SESAME name resolver is addressed to if the user sends a request for an object named in miscellaneous format. We will also make runtime-queries to other databases (as we do it now for Sesame name-resolver).

BDB primary and already accessed purpose is to be user-friendly with the end-user analysing numerical and graphic data on individual or selected binaries manually. However, authors are also working to provide smooth interaction of the IVO users and services with the database. The batch mode request is going to be available soon. We definitely will implement VO ConeSearch protocol (Williams et al., 2011) and VOTable (Ochsenbein et al., 2013) output format. VOTable implies the use of UCDs (Derrière et al., 2011); UCDs to characterize some data specific to binary star need to be added to the present UCD controlled vocabulary (Preite Martinez et al., 2011). BDB will be referenced in VO Registry (Benson et al., 2011). When batch mode is provided, a web service will be set up which will follow the Universal Worker Service (UWS) pattern (Harrison and Rixon, 2011). It is planned also to implement TAP (Table Access Protocol) service (Dowler et al., 2011) in BDB.

5. Conclusions

There is a real need today for a construction of a data source and tool for different types of binary systems in the frame of the IVO project. BDB aims to fill up the gap.

The fully operational version of the database is available at http://bdb.inasan.ru. Simultaneously, BDB is developing both in size (including new catalogues) and in depth (adding new features improving usability and promoting integration of the IVO standards). Currently 14 catalogues are included in BDB which principally cover all observational types of binaries, and the database reached certain temporary volume limit. Before we have general index including all the cross-identification, rejection of false cross identifications is going in real time and significantly slows down the response to requests. To solve problems of identification and cross-identification of binary systems, BSDB designation scheme is constructed and an identification list of binaries is being compiled. As soon as the primary version of the ILB is integrated in BDB, it will serve as BDB general index, the processing of requests shall become quick, and more catalogues will be downloaded and parsed into the database. This, together with the features providing VO accessibility, is expected before the middle of 2015.

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