Coordinate Data and Identification of Stars in Astrophysical Catalogs

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Abstract

The aim of our paper is to compile high-precision positional star catalogs by combining extensive astrophysical data sets with the results of large astrometric surveys. The essential features required of the compiled catalogs are data reliability and unambiguity. There are cases where the commonly adopted accuracy of 1 arc sec in coordinates cannot ensure unambiguous identification of stars. Therefore methods of verification of catalogs have become increasingly important, which require a certain technique of unambiguous identification of objects. This paper reports the results of identification of stars in The Henry Draper Extension Charts catalog and in the catalogs of variable stars using the identification technique developed. Examples of the resolution of conflicts involving double and multiple stars in astrophysical catalogs are discussed.

Introduction.

The ever increasing amount of the data from various fields of both astrophysics and Galactic astronomy on the one hand, and the release of astrometric catalogs containing accurate coordinates for millions of stars (HIPPARCOS, TYCHO, USNO, UCAC, and 2MASS), on the other hand, provide good prerequisites for the creation of compiled catalogs for various purposes containing high-precision positions of the objects studied.

The principal requirement toward the catalogs compiled are reliability and unambiguity of the data. The ever increasing sizes of the catalogs impose increasingly stringent criteria. The currently generally adopted accuracy (1″ or better) has become insufficient, because it fails to guarantee unambiguous identification of objects, e.g., in the cases of close optical binaries or star clusters.

No data can be used by itself without invoking adequate processing algorithms, and therefore the development of a technique for reliable and unambiguous identification of objects has become a task of great importance and urgency. The form of the initial data prevented the use of automated identification procedures (Nesterov et al, 1995, Gulyaev and Ashimbaeva, 1997), making it necessary to perform manual identification of each object.
1 Technique of identification of stars in the HDEC catalog in the catalogs of variable stars.

In the process of our work we developed a set of rules for identification of objects. Like in the case of automatic identification we set a certain interval of permissible values.

The object usually must meet a number of criteria simultaneously:

1. We set certain coordinate tolerances (the minimal “box”, where identification is possible without loss of information; maximum size of the field studied whose increase would prevent the identification of the configuration);

2. Photometric indices (we set a magnitude interval);

3. Allowance for the proper motions;

4. Referencing the object to star configurations (the configuration of the identified object must strictly agree with that depicted in the published figure).

Too stringent requirements increase the risk of losing information about the object. Too loose requirements, on the other hand, increase the risk of getting too much unnecessary and erroneous information. Hence we need to optimize the criteria imposed. The final identification must be unambiguous even for very approximate input data (with coordinates known with errors of up to 1 arcmin or even more).

2 Determination of the coordinates of the stars of the Second Extension of the HD catalog.

The work on accurate identification of astronomical objects by assigning to them accurate coordinates adopted from mass astrometric catalogs began in 1990-ies. The results of the determination of the coordinates for HDEC stars can be found in (Nesterov et al. 1995). Here is a brief review of the subject history. The second extension of the HD catalog (Cannon A.J., Mayall M. W., 1949) was published in the form of 275 charts, and has therefore been almost totally neglected by the international research community. A number of researches attempted to convert the Second extension of the HD into a more convenient form: Bonnet (1978), Roman (1992), Röser et al. (1991). The latter authors measured the Cartesian coordinates for a total of 10 639 stars of the HDEC. The average position accuracy of these measurements was $0''.3$. This work demonstrated that it was possible in principle to convert HDEC data into a computer-readable form.

We identified each star manually, because automatic reduction was evidently out of question due to the form of the initial data. We identified stars by comparing the published chart to the image drawn by SimFOV program (A.A. Volchkov
and O.A. Volchkov), which visualizes the positions of stars from the reference catalog on a computer monitor. We used the GSC-AC catalog (Röser et al., 1995; Nesterov and Gulyaev, 1992) as our reference catalog. We assigned to each HDE star the best-matching GSC-AC star according to visual inspection.

We then compared the initial data set with the measurements of the Cartesian coordinates of HDEC stars made at Astronomische Recheninstitut (Heidelberg, Germany). As a result of additional comparison and checks we obtained a data set of very high quality.

In addition to single stars we also found 1783 multiple systems (or blends). A total of 503 variable stars make up a separate list.

Result. The HDEC star catalog is available from Strasbourg Data Center as catalog III/182. The result of the work on the HDEC catalog can be summarized as follows:

1. The second HD extension, which hitherto existed in the form of finding charts exclusively has been converted into a star catalog.

2. We determined precise (to within 0.5") positions for 86,933 HDEC stars; proper motions accurate to about 5 milliarcseconds/yr are given for more than 96% of all stars.

3 Creation of the astrometric catalog of variable stars.

Our next step was to determine the accurate coordinates for variable stars using the identification technique described above. Since 1994, we started compiling our catalog of positions and proper motions (Gulyaev and Ashimbaeva, 1997).

Our main source of data on variable stars was the Fourth edition of the General Catalog of Variable Stars (Kholopov et al., 1985-1988). The object coordinates given in this catalog were formally accurate to within 1" and 0.1" in $\alpha$ and $\delta$, respectively, although the actual situation proved to be much worse.

Again, stars of the General Catalog of Variable Stars (GCVS) were impossible to identify automatically due to the form of the data presented — only finding charts of different quality were available. We therefore identified stars using the technique already tested with HDEC. We compared each finding chart with the corresponding stellar field drawn on the computer monitor based on the data from the available reference catalog.

We cross identified variable stars with: (1) the PPM star catalog (Röser et al., 1993) for the brightest stars and (2) the first release of the GSC/AC catalog (Nesterov and Gulyaev, 1992), for the bulk of the stars.

Results. Table 1 summarizes the quantitative results of identification for the catalog considered.

The catalog compiled by 1997 had the form of a data set containing identifications with the PPM, GSC, and AC catalogs. Because of the death of A.P. Gulyaev in 1998 the work remained incomplete with no electronic version has been produced. We later reconstructed the catalog based on the available
**Table 1**: Results of identification  

| Description                                                                 | Value   |
|------------------------------------------------------------------------------|---------|
| Total number of stars in the GCVS including name lists nos. 67-72            | 31,081  |
| - stars with available finding charts                                       | 26,797  |
| Number of stars in the NSV catalog with identified finding charts           | 7,991   |
| Total number of finding charts examined                                      | 42,789  |
| Number of stars identified                                                   | 21,789  |
| Number of missing stars with identified finding charts                       | 12,257  |
| Number of GCVS stars whose finding charts could not be identified.           | 742     |

Identification files and numerous archive records (Ashimbaeva et al., 2004). In addition to the previously employed GSC and AC=4M catalogs we identified variable stars with the HIPPARCOS (The Hipparcos and Tycho Catalogues, 1997), TYCHO2 (Hog et al., 2000), NPM (Klemola et al., 1987), and A2.0 (Monet et al., 1998) catalogs. We greatly appreciate the invaluable assistance and advice offered by the members of the Division of Variable Stars of the Sternberg Astronomical Institute and especially by N.N. Samus.

The catalog is available at [http://astrometric.sai.msu.ru/lib_projects.01.html](http://astrometric.sai.msu.ru/lib_projects.01.html).

Here are a few comments concerning its contents.

Stars in the catalog are sorted by their names in accordance with the GCVS convention. NSV stars (Kularkin et al. 1982) are sorted by their numbers and listed after the GCVS stars. The accuracy of coordinates depends on the particular reference catalog employed and varies from 0.5″ for GSC to 0.0006″ for HIPPARCOS. The J2000.0 equatorial coordinates are given with the following accuracy: right ascensions — to within 0″.001 and declinations, to within 0″.01. The proper motions are given as in the corresponding source catalog, i.e., to 0″.00001/yr for the HIPPARCOS catalog and to 0″.001/yr for the Astrometric catalog. The coordinate epoch is given in the cases where no proper-motion data are available. For the convenience of identification we also give the number of the star according to the HIPPARCOS, NPM, Tycho2, or GSC catalog. We also give the photometric data (magnitude, magnitude interval) as provided by the reference catalogs used for identification (HIPPARCOS, NPM, Tycho2, GSC, AC, PPM, and A2.0).

**Results of the work.** We refined the coordinates for a total of 21,971 variable stars with the positional and proper-motion accuracy matching those of the astromeric reference catalogs.

### 4 Multiple systems in the HDEC.

We analyzed multiple stars among the HDEC objects. To this end, we used Aladin program of the Astronomical Data Center in Strasbourg ([http://aladin.u-strasbg.fr/](http://aladin.u-strasbg.fr/)).

Our analysis allowed us to: (1) refine the coordinates of each component in accordance with the data provided by the reference catalogs and measure the coordinates on the image; (2) identify all false measurements — in the cases where the star proved to be single or wrong coordinates were given for the
component; (3) determine the proper motions for a number of stars by analyzing the images taken at different epochs, and (4) sometimes find new components by comparing charts made at different wavelengths and for different epochs. The reduction of the entire data set yielded more than 4000 components. In addition to component identification errors we also revealed gross errors of the HDEC, which are inevitable in a large catalog.

We compared our catalog to other CDS catalogs in order to search for the available identifications for multiple stars of HDEC. Table 2 summarizes the results of this comparison.

### Table 2. Comparison of identification of multiple stars of the HDEC catalog.

| Catalog                                      | Identifications                                                                 |
|----------------------------------------------|---------------------------------------------------------------------------------|
| HIPPARCOS input catalog                      | 23 multiple stars of the HDEC catalog                                           |
| HIPPARCOS and TYCHO catalogs (they are now inseparable) | 822 multiple stars of the HDEC catalog                                          |
| TYCHO-2                                       | 1007 identifications by numbers, 14 stars of the catalog have CCDM component designations |
| TYCHO-3                                       | 350 identifications with different numbers including 21 double identifications. |
| Visual Double Stars in HIPPARCOS (Dommanget et al., 2000) | 17 multiple systems and 54 components                                           |
| The Tycho-2 Spectral Type Catalog             | Identification by coordinates (2"
 identification radius)? 135 objects. Identification by number (5"
 identification radius)- 102 stars.                                              |

We found a total of 319 single stars including 11 stars with proper motions; assigned coordinates to all components with an accuracy of 0.″1; assigned spectra to individual components in 1166 cases; found 611 double and eight triple and multiple blends; revealed errors in HDEC data records; found identification errors in the system of the Astrographic catalog, and compared our data with those of other catalogs of multiple systems.

### 5 Conclusions.

The aim of this work was to produce compiled catalogs containing high-precision coordinates of interesting objects, which have other data published in astrophysical catalogs such as HD and General Catalog of Variable Stars. As a result, we determined for the first time accurate coordinates and proper motions for objects of the Second Extension of HD and refined coordinates and proper motions for objects of the General Catalog of Variable Stars.

We developed a technique for nonautomatic identification of objects, which
facilitates and speeds up the process. We continued our work by analyzing complex cases of identification of multiple systems in the HDEC catalog. We found cases of false identification, revealed possible causes of such errors, and refined the coordinates of individual components.

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