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# Databases of Interest to Double– and Multiple–Star Observers

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**ABSTRACT:** A large collection of machine–readable catalogs containing data for various types of double– and multiple–star systems has become available over the last decade or so. These catalogs can be divided logically into general compilations of multiple–star data for visual systems and other collections of information for particular classes of binaries, such as cataclysmic, eclipsing, interferometric, spectroscopic, etc. A few large databases containing double– and multiple–star data have also become accessible over the last few years. This paper gives a general overview of some of the more important machine–readable catalogs and databases available, and includes a brief description of the information that each contains. The potential for what can become available in the near future, just by incorporating current information into a system providing full data retrieval, is also discussed.

## 1. INTRODUCTION

The development of high–capacity storage media and high–speed computer networks in recent years has revolutionized our access to the large volumes of data characteristic of astronomy. The study of double and multiple stars, which has produced large quantities of observations necessary for future studies, stands to be among the disciplines most affected by the computer revolution. The cataloging of visual double–star observations, begun around the turn of the twentieth century by Innes (1899) and Burnham (1906), and continued by Aitken (1932) and Jeffers *et al.* (1963), continues today by C. E. Worley at the U.S. Naval Observatory, where a comprehensive database of all known observations is maintained.

In addition, many specialized catalogs of double– and multiple–star data have become available in machine–readable form. These catalogs, which are available through the worldwide network of astronomical data centers, have made an extensive amount of information easily accessible to astronomers needing it for future research.

This paper presents a general overview of catalogs and databases of double and multiple stars presently available in machine–readable form. In additon to general compilations of data for visual systems, a number of specialized catalogs dealing with particular types of binary systems is described. Together, these catalogs and databases comprise a comprehensive collection of valuable information to assist researchers in future studies of stellar duplicity and the astrophysics of multiple–star systems.

## 2. CATALOGS AND DATABASES

Although the terms "catalog" and "database" are often used interchangeably, there are important differences that should be considered. While a catalog generally consists of a collection of data of a particular type for a wide variety of

objects, or for a specific class of objects, a database is usually much larger and contains many different kinds of information gathered from a large number of catalogs. Also, although catalogs may be accessible for browsing and processing by computer, databases are specifically designed to allow the retrieval of information for particular objects or groups of objects. Thus, individual catalogs generally evolve into databases following the merging of the specialized information that each catalog contains. These differences will become more apparent during the ensuing discussions. The following sections describe many of the double- and multiple-star catalogs currently accessible in machine-readable form. Specific types of astronomical data available for double and multiple stars are then covered, followed by a short section on databases containing information for such stars.

## 3. DOUBLE- AND MULTIPLE-STAR CATALOGS

### 3.1. Common Proper-Motion Stars

Surveys of double and multiple stars displaying common proper motion (CPM) are useful for the detection of physical binary systems, especially those in the solar neighborhood. CPM stars have generally been found in large surveys by blinking Schmidt plates. The extensive work of Luyten over the last 50 years has resulted in the compilation of a catalogy of CPM stars, the machine-readable version of which was prepared by Halbwachs (1987). The compiled catalog contains 6210 components of 6121 CPM systems detected during the course of Luyten's Palomar proper-motion survey.

CPM stars can also be detected by the computer searching of astrometric catalogs, as has been done for the AGK3 by Halbwachs (1986). This work resulted in a machine-readable catalog of 439 systems, of which 84% are expected to be physically associated.

### 3.2. Visual Double and Multiple Stars

As pointed out in Section 1, the cataloging of data for visual binaries has a long history. In addition to classical visual sytems, this area includes systems that have been resolved in more recent times using the techniques of lunar occultations and interferometry, which have resulted in the resolution of many systems that were previously only known as spectroscopic and eclipsing. Thus, modern observational techniques have transformed many such systems from purely spectroscopic and eclipsing into visual binaries.

The most comprehensive and up-to-date catalogs of visual systems are those maintained at the U.S. Naval Observatory by C. E. Worley and G. G. Douglass. The *Washington Catalog of Visual Double Stars* (WDS, Worley & Douglass 1984) contains a summary of all observations of visual double and multiple stars known to the compilers; it is the successor to the Lick *Index Catalogue* (Jeffers *et al.* 1963) and is based on a similar compilation of all individual observations (WDSOBS) that is currently maintained as a set of 48 files on the USNO IBM 4381 computer. This catalog is an invaluable resource for all observers of double and multiple stars and will eventually become available in machine-readable form following its completion. For all visual (including interferometric) observations, the WDSOBS contains an epoch of observation,

position angle and separation, estimated magnitudes (if reported), original reference, and various codes. The first and last observations provide a summary record for each system that, when extracted from WDSOBS, comprise the WDS described above.

More specialized and detailed catalogs of visual binaries include those that list orbits for physical systems. The *Fourth Catalog of Orbits of Visual Binary Stars* (Worley & Heintz 1983) is a comprehensive compilation of 928 orbits for 847 systems.

Many close binary sytems have been discovered by occultation and interferometric techniques. Although the former only gives vector separations from individual observations, multiple observations from sites having significant separations along the lunar limb can be used to determine actual separations and position angles. Most occultation observations providing quantitative data were made during a long–standing, high–speed photoelectric program coordinated at the University of Texas by D. S. Evans, who compiled the resulting data from his own and others' observations into a catalog (Evans 1983). For each observation, the compilation gives a determined vector separation, position angle, lunar limb slope (which can distort the resulting Fresnel diffraction pattern), magnitude differences of the components, and duplicity grade (no duplicity to certain duplicity). The combined catalog reports observations of 224 stars.

A comprehensive compilation of interferometric observations has been assembled by McAlister & Hartkopf (1988). This catalog contains all known modern interferometric measurements, including the visual interferometry results from early observations at Mount Wilson by Anderson and Merrill. Although these interferometric results are included in the WDSOBS catalog of Worley, the separate CHARA catalog is valuable because the results of negative detections are given as well, thus providng a wealth of reference material for future studies. The catalog includes measurements of 1588 resolved systems and 1681 stars that were not resolved. The results of this extensive compilation are currently being entered into the fifth edition of the Bright Star Catalogue (Hoffleit & Warren 1992) to serve as reference material for future studies of the brighter stars.

### 3.3. Spectroscopic and Eclipsing Systems

Comprehensive catalogs of spectroscopic binaries have been available in printed form for many years, beginning with the compilation of Campbell & Curtis (1905). The most recent machine–readable catalogs are those of Batten *et al.* (1989) and Pédoussaut *et al.* (1988). These catalogs are complementary in that the latter series is a complete bibliographic catalog of all publications concerning spectroscopic binaries, while the former contains a critical assessment of the available orbital elements. Another complementary catalog of SB orbital elements is that of Kraitcheva *et al.* (1980), which contains systems from the previous edition of the DAO and Complémentaire catalogs, along with updated information and additional astrophysical parameters such as component masses, mass ratios, semiaxes of orbits, and orbital angular momenta. This catalog now needs to be updated based on the latest editions of the catalogs above.

Another catalog of astrophysical parameters of close double stars includes photometric and spectroscopic orbital elements for eclipsing sytems (Svechnikov & Bessonova 1984). Photometric and absolute elements are given in separate

files and discussions of the elements are included in an extensive file of remarks. Other machine–readable catalogs of eclipsing binaries are those of Brancewicz & Dworak (1980), giving basic parameters (period, spectroscopic parallax, physical separation, luminosities and effective temperatures, masses, etc. ) computed via an iterative method for deriving geometric and physical parameters for eclipsing components, and a compilation of data for Algol–type candidates (Budding 1984), which contains astrophysical and orbital parameters for 414 systems.

### 3.4. Active Binaries

The category of active systems includes catyclysmic, interacting, and chromospherically active stars.

The most long–standing of catalogs in this category is the *Finding List for Observers of Eclipsing Variables* of Wood *et al.* (1980), which actually began its life as a catalog of eclipsing variables. The first edition of the *Finding List ...* was produced by the well–known astronomer R. S. Dugan (1934) with extensive help from Charlotte E. Moore, who conducted most of the literature search while she was at Princeton. Subsequent editions were produced by N. L. Pierce, by F. B. Wood, and by Koch, Sobieski, & Wood. The fifth edition, the first to become available in machine–readable form, has been extended to cover X–ray binaries and certain eruptive variables, even if eclipses are not certain to occur. In addition to basic data on positions, magnitudes, spectral types, orbital parameters, and extensive cross identifications to alternate designations, detailed notes concerning each system are given in a separate file. Also included in the printed version of the catalog are a section containing several extragalactic systems and a cross–identification list by constellation designations, but these are not in the machine–readable catalog. The catalog contains 3564 systems.

A closely related catalog is one by Ritter (1990) that contains various types of eruptive systems. The compilation includes astronomical and astrophysical data for 168 cataclysmic binaries, 36 low–mass X–ray binaries, and 28 related objects.

Finally, a catalog of chromospherically active binary stars, including RS CVn, BY Dra, and other binaries showing strong Ca II H and K lines, has been compiled by Strassmeier *et al.* (1988). In additon to the 168 systems in the main catalog, a list of 37 candidate stars having similar characteristics is included. The catalog contains separate files listing photometric and spectroscopic parameters, and positional and kinematic (space motions) information. There is also extensive cross referencing and copious notes are included.

## 4. DATA FOR DOUBLE AND MULTIPLE STARS

In addition to the specialized catalogs discussed above, there are several general compilations that contain astrophysical data for binary systems, general information for double and multiple stars, and specific types of data.

### 4.1. General Compilations

These catalogs contain astrophysical parameters for a variety of binary systems or reference data for a large number of double and multiple stars. The catalog

of Lindroos (1985) resulted from an attempt to calibrate the four–color and H$\beta$ photometric systems to derive astrophysical parameters for visual doubles with early–type primaries. The compilation of Popper (1980) was assembled as part of the preparation of a review article on stellar masses. Both compilations contain a large amount of information on fundamental stellar parameters as derived from observations and analyses of binary systems.

General catalogs that contain reference information for double and multiple systems include the *Bright Star Catalogue* (Hoffleit 1982) and its *Supplement* (Hoffleit *et al.* 1983). As mentioned previously, the new fifth edition of the former catalog (Hoffleit & Warren 1992) will contain speckle interferometric data as well.

### 4.2. Photometry

Catalogs of photoelectric photometry on the two most widely used photometric systems are available in machine–readable form. The catalog of Olsen (1982) compiles data on the four–color and H$\beta$ systems for 398 members of visual multiples, while a catalog of UBV data (Wallenquist 1981) contains 1064 sytems. These catalogs consist of observations made exclusively by their authors rather than data compiled from the general literature. Worley (1992, private communication) has compiled a catalog of magnitude differences for a large number of visual binaries, but this catalog is not yet available as a distributable machine–readable file.

### 4.3. Spectroscopy

MK classifications for members of visual double and multiple systems are available in the catalogs of Abt (1981) and Corbally (1984). The former catalog gives MK types for 864 members of visual multiples, while the latter lists components of 170 close visual binaries classified on the MK system.

### 4.4. Cross Identifications

Catalogs of alternate designations provide a valuable resource for the compiler of information about all types of stars, since various identifiers have been used in the literature throughout the history of astronomy. A cross index of ADS and IDS designations was compiled by Jung *et al.* (1973). This work was extended by Roman (1987) to include the WDS, ADS, HD, and DM identifiers. The latter catalog contains files ordered by each designation to allow for simplified information retrieval.

## 5. DATABASES

As discussed in Section 2, databases generally comprise information from a large number of individual catalogs that has been assembled into a system that allows easy retrieval of information about specific objects or groups of objects. Although a number of online databases has become accessible to the astronomical community over the last several years, such as the Einstein system at the Center for Astrophysics, the EXOSAT at ESTEC (Noordwijk) and NASA/GSFC, and NED (NASA Extragalactic Database) at IPAC (Infrared Processing and

Analysis Center, Pasadena), only the oldest online retrieval system (SIMBAD, Set of Identifications, Measurements, and Bibliography for Astronomical Data, Centre de Donnees Astronomiques, Strasbourg) contains a significant amount of information for double and multiple stars. Even SIMBAD contains only cross identifications and component designations for multiple systems and is incomplete in these areas. SIMBAD will only become a valuable tool for double– and multiple–star observers following the integration of observational data into the system, as has already been done with photometric and spectroscopic data, for example. Upon completion of the observational catalog (WDSOBS) work at the U.S. Naval Observatory, it is hoped that at least the complete data file can be incorporated into SIMBAD. Following the merging of observations and the incorporation of many of the specialized catalogs described in this paper, SIMBAD will become an indispensable tool to all researchers dealing with double and multiple stars. Thus, we have much to look forward to in the coming years.

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## 7. DISCUSSION

**POPPER:** Your list contains catalogs primarily of two types: lists of observations and lists of orbits derived from the observations, primarily orbits of visual binaries by Worley and others and orbits of spectroscopic binaries by Batten and his collaborators. Included in your list is at least one item of a third category, namely my list of stellar masses, radii, etc. , drawn from material contained in other catalogs and references. In my opinion, this list of derived results does not belong in your compilation. But, if it is to be included, more modern listings should be added, in particular those of Harmanec (*Bull. Ast. Inst. Czech.*) and Andersen (*Astr. Astp. Reviews*).

**WARREN:** I have included only those catalogs currently available in machine readable form, which the lists of Harmanec and Andersen are not. The data from your review article were computerized by Malkov (*CDS Bull.* No. 37, p. 175, 1989), who could, perhaps, update your compilation with information from the newer lists. This is appropriate work for the ADC, but only if they are supported well enough to retain the services of experts who can knowledgeably update such data.

**HEINTZ:** The handling of derivative catalogs has received careful attention in IAU Commission 5. Data centers cannot piecemeal update catalogs on their own authority; that has to be done by specialists. And since the astronomical community cannot fulltime work on updating catalogs, such compilations just take longer, although this may be deplorable with respect to rapid access by users.

**WARREN:** I agree, except in casees where the data centers employ astronomers who can either do the specialized updating or collaborate with specialists to perform the work. The latter case is more realistic most of the time, and this is an example of why the data centers should be supported to provide such personnel and services. Unfortunately, there seems to be a trend toward full automation, and if no specialists are available at the data centers, much of this type of work will simply never be done.

**SINACHOUPOULOS:** Our colleague Lindroos unfortunately had to leave astronomy since his field of interest (visual double stars) is not supported by the astronomical establishment of Sweden.

**WARREN:** This problem is also prevalent in the area of cataloging. In fact, at the Buenos Aires General Assembly, a resolution was submitted by Commission 5 (Documentation and Astronomical Data) and passed by the GA urging institutions to support long-term cataloging projects, which provide valuable data to astronomers who need them but do not have the time, inclination, and support to compile them for personal use.

**FEKEL:** Just a comment that an updated version of the Strassmeier *et al.* 1988 catalog of chromospherically active binary stars should be available in less than one year.

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