Complementary Approaches to Double and Multiple Star Research,
IAU Colloquium 135, ASP Conference Series, Vol. 32, 1992
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Visual Double Star Catalogs — Past, Present, and Future

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ABSTRACT: **The first lists of visual double stars were published by Mayer and Herschel in the late 18th century, but only sporadic lists and catalogs appeared during most of the following century, until Burnham began the systematic collection of such data, which has continued to this day. This contribution discusses the evolution of the visual double star data base over the last centuries and suggests how the data might be ordered to serve future needs.**

Although the first modern discovery of a double star is attributed to Riccioli about 1650, more than a century passed before the astronomical world began to take notice of this class of object. Then, nearly simultaneously, C. Mayer (Bode 1781) and W. Herschel (1782), published the first catalogs of double stars. Both observers included not only their own discoveries, but also pairs which had been found casually by others. Mayer listed about 80 objects, while Herschel listed 269, claiming that 227 were of his own discovery. He also complained about the omission of many pairs in Mayer's list, as well as the inclusion of objects which he considered far too wide to constitude *bona fide* double stars. To be fair to Mayer, one must note that Herschel had better observing equipment, and that Mayer arranged his list in a more convenient way; by right ascension rather than the six classes dependent on separation used by Herschel.

However, Herschel was to influence double star astronomy greatly by his long–term interest, which led not only to the proof that some double stars were true binaries, but also to more lists of dicoveries, including 434 more doubles (Herschel 1785), followed by a final catalog (Herschel 1822) shortly before his death, which included 145 additional discoveries.

These first efforts were now to be superseded by the monumental work of F.G.W. Struve at Dorpat. In 1824 he received a telescope superior to any then extant, and immediately began a systematic survey of the heavens for double stars. First fruits of this survey were published as the *Catalogus Novus* (Struve 1827), which listed all his new discoveries, plus all other known systems where the separation did not exceed 32″ . Tabulated were 3,110 double and multiple systems. Charming additions to the volume included a page of finding charts and sketches of the Trapezium, δ Cyg, and ζ Her, as well as a large fold–out map plotting all the pairs. Struve next began the long task of obtaining accurate measures and positions for his pairs. In 1837 he published the enormous volume *Mensurae Micrometricae* (Struve 1837) containing his micrometer measures, which remains the most important double star publication of the Nineteenth Century. By modern standards the arrangement of the data seems strange, for Struve divided his pairs into eight classes arranged by separation, and further subdivided them into bright and faint pairs.

J. Herschel continued his father's discovery work, and contributed a large number of pairs, including a substantial portion in the southern skies. Unfortu-

nately, the J. Herschel pairs are generally wide and faint. Moreover, they were not accurately measured by micrometer, instead having only crude estimates of angle and separation. Posthumously, a catalog of 10,300 double stars compiled by J. Herschel (1874) was published. It proved of little use, however, as it listed no information beyond the name(s) of the pair, its position, and the precession.

Struve's work, and that of his son Otto, who found a further 547 pairs at Pulkovo, formed the base of much of the double star work done in the next fifty years. It appeared that the Herschels and Struves nearly had completed the discovery and tabulation of the visual doubles, and, although a relatively few chance discoveries continued to be made, most attention was directed towards the measurement of known pairs and the determination of orbits. As astronomical observation waxed in the middle and late nineteenth century, a number of books were published which contained lists of interesting double stars and measures thereof, but none were comprehensive. Among these were works by Smyth (1844), Flammarion (1878), and Crossley*et al.* (1879).

In the early 1870's arose an American amateur, S.W. Burnham, who was to have a profound influence on double star astronomy. Initially with his own six-inch refractor, but later exploiting the many great refractors being built in the United States at that time, Burnham began to discover many new pairs. He soon felt a need to begin a collection of double star literature in order to determine if his discoveries really were new pairs. In most cases, Burnham had to resort to "make pen copies of nearly everything required... secured by visiting the libraries of the Naval and other observatories." Later Burnham began to construct a pen manuscript, and this finally resulted in his *A General Catalogue of Double Stars* (Burnham 1906), which is generally known by its acronym BDS. Burnham imposed no separation or magnitude limits, but did limit his coverage to pairs north of $-31°$ declination. This resulted in 13,665 entries (a multiple system was given a single number). In the extensive notes accompanying the catalog, Burnham also listed many of the measures of each pair, and gave references to the remainder.

Following publication of this most important work, Burnham continued collection of double star data until 1912, at which point he turned over the material, plus his entire double star library, to E. Doolittle of the Flower Observatory. It was Doolittle who began transference of the data from manuscript to the form of a card catalog.

When Doolittle died in 1920, R. Aitken of the Lick Observatory inherited the card catalog. After bringing it up–to–date, Aitken began to prepare a new general catalog. This work, the New General Catalogue of Double Stars (Aitken 1932), commonly called the ADS, is justly famous. Aitken listed substantially all the measures made from the time of Burnham's catalog to 1927, along with extensive notes; total entries are slightly above 17,000. However, he did impose limits dependant on magnitude and separation, which resulted in omitting many objects tabulated by Burnham, and also was obliged to give only means for objects with many measures. Nevertheless, this catalog is justifiably famous for its style and authoritative contents, and some astronomers continue to list pairs by their "ADS" numbers, even though the newest data in the ADS is now more than 65 years old.

Serious astronomical exploration of the southern skies began much later

than that of the northern sky, and was for long at a low level of activity. This was true for double star astronomy as well, and it was not until 1899 that Innes (1899) issued his *Reference Catalog.* It listed all the pairs then known south of the celestial equator, many of which were discovered by northern observers, but totalled only 2,140 pairs. A second catalog, contemporaneous with the ADS, was published as the *Southern Double Star Catalogue* (SDS) by Innes in 1926–7 (Innes 1927).

Following the retirements of Aitken and Innes, the task of recording new pairs and collecting measures devolved on H.M. Jeffers at Lick Observatory, and W.H. van den Bos at Union Observatory. Of these two, van den Bos had the harder task, as he and associates at Johannesburg were very active observing, while Rossiter and colleagues at the Lamont–Hussey Observatory were discovering thousands of new pairs. By contrast, discovery and observation in the northern hemisphere had fallen into the doldrums due to the effects of depression and World War II.

In the meantime, progress in technology led to the proposal that the Lick manuscript archive be translated into punch–card format. Initially, this involved only the northern measures tabulated since 1927, but then was expanded to include new measures. At a later date, van den Bos agreed to the transfer of a copy of his manuscript catalog, and it too was punched. Thus, for the first time a comprehensive catalog covering both north and south was created. This punched card catalog, eventually totalling several hundred thousand cards, was unwieldy and presented storage problems; moreover, it was for a long period almost unuseable, as Lick Observatory lacked all punch card and computing facilities excepting a keypunch.

By the 1950's, the ADS and SDS were seriously out of date, and plans were laid to create a new, printed catalog. In form, the Index Catalogue of Visual Double Stars, 1961 (Jeffers *et al.* 1963), resembled Burnham's first volume. A single printed line, obtained from a punch card, represented each pair, so that if the object were multiple, multiple "pairs" were listed. When issued, the catalog contained 64,247 pairs, and received the acronym IDS. The increase in the number of observations now was such that no practical scheme could list them. Instead, only the dates, angles, and separations of the first and last reliable observations were tabulated. Basic positions for epoch 1900, with the centennial precession, were listed. This step backwards from the 1950 positions listed in ADS, was unfortunate in my opinion. Notes to the IDS contained little of astrophysical interest, and were mainly aimed to note synonymous names, durchmusterung identifications, and proper motions of other components.

The IDS was in fact published after the retirements of both Jeffers and van den Bos. While Lick continued to serve as a depository for a few years, it was evident that the work needed the continuity that only an active worker in the field of visual double stars could provide. Thus, in 1964 the decision was taken to move the work to the U.S. Naval Observatory. The cards were trucked to San Jose, and there turned into computer tapes, which I retrieved early in 1965. In Washington, these were once more turned into cards. There then began a long process of error detection and correction, which continues to this day. These errors are of every imaginable sort, ranging from mispunched cards to garbled references caused by the imperfect melding of the northern and southern projects. At the same time, my able colleague G. G. Douglass

embarked on the project of writing efficient software so that we could both use the data itself and also make it available to the astronomical public, and this effort likewise continues.

By informal agreement, the Naval Observatory also agreed to supply punch card copies of new data, as well as corrections, to the Greenwich, Lick, and Paris observatories. This was done in part to guarantee preservation, and in part as a convenience to those organizations. Eventually, changes in personnel, location, and technology, as well as our own budgetary constraints, made this infeasible. However, we have managed to fill hundreds of individual requests, some for quite extensive amounts of data, without ever imposing any charges, and this service remains intact today. Until recently, we generally sent listings, but with the rapid spread of e-mail, an increasing amount of our data transmission has been by this medium.

Nearly twenty years ago I began the long project to include all of the early observations in the data base. To be done properly, such a task requires that one extract the information from the original sources, which in turn implies that one needs a superb library. Fortunately, the Naval Observatory possesses such! So far, having required more than a thousand sources, I have been unable to find three in our library. At the present time, all of the "important" early series have been accessed, with the exception of the later observations of J.H. Madler, who presents special problems because he both failed to list his dates as Besselian fractions and took no means. Other short series also remain undone, and I can say only that I believe the job will be done by the date of my retirement.

In 1982 we were able to convert the card catalog to magnetic disk storage (and consequently to dump several tons of cards), and thereby to obtain almost instantaneous terminal access to any portion of the data base. This gave me the opportunity to begin a general revision and correction of the data aimed at the production of a new Index catalog, The Washington Visual Double Star Catalog, 1984.0 (Worley & Douglass 1984). This catalog has virtually the same format as the Index Catalogue. However, it omits some of the pairs listed earlier, because there is doubt of their reality. Nevertheless, it lists 73,610 pairs versus the 64,237 contained in the IDS. We concentrated on updating information on motion and additional measures. Of course, corrections were also incorporated. Few alterations were made to the magnitudes, spectral types, and proper motions. Like the BDS and ADS, it also lists the references from which the catalog was compiled, an omission from the IDS that we believe was a mistake. The WDS is available from the data centers in tape form, and is also available in the form of a CD-ROM recently issued by the Astronomical Data Center (1991).

Upon completion of the 1984 version of the WDS, we began immediately to construct a successor version, which is in near–final preparation. We first reformatted the data to make more efficient use of the 80-column space. We now list 2000 coordinates only, and do not indicate the precessions, since these are easily computable with modern means. We have alloted more space to magnitudes, so that we can give two–decimal values, and that for spectral types, where we now list MK types if available. We have eliminated the obsolete ADS numbers (we do maintain an ADS/WDS cross index, however, for anyone sufficiently distressed by this action). Other minor changes also have been made, mainly of a cosmetic nature. Another problem now being addressed is that of identification. Many pairs were never numbered by their discoverers, and are too faint

to appear in the durchmusterungs. Positions can be used, of course, but these too are uncertain in many cases. So I am gradually numbering all such objects. The Notes have been extensively revised, and this emphasis is continuing, as we strive to increase the scientific content. At present, I am engaged in making a comparison of all the Durchmusterung stars with the SIMBAD data base, from which much useful data has been obtained. My estimated time of completion of the new version of WDS is 1994. Table 1 summarizes the present state of the data base.

TABLE 1. Status of the Double Star Data Base, April 1992

(1) MEANS	
Data records added at Lick (pre-IDS)	164,095
Data records added at Lick (post-IDS)	14,847
Lick total	**178,942**
New data records added at USNO (pre-WDS)	73,177
Old data records added at USNO (pre-WDS)	133,641
New data records added at USNO (post-WDS)	30,069
Old data records added at USNO (post-WDS)	20,045
USNO total	**256,932**
(2) DOUBLE STARS	
IDS	64,237
WDS (1984)	73,610
WDS (1992	77,125

So it has been that, following the episodic collection of double star data in the 18th and 19th centuries, relative continuity began with Burnham, and has continued to this day. In fact, I believe that the double star data base represents the longest continuously maintained data base in astronomy. But what of the future? First, the accelerating developement of new instrumental technology is bound to result in many new discoveries of pairs. Hopefully, this will also result in continued observation of the astrophysically interesting ones. Considerable increases in the accuracy with which parallaxes (and mass ratios) can be determined will lead to many additional reliable masses, and our knowledge of the statistics of duplicity, and its profound implications for the star formation processes, should be greatly aided. Of course, there will continue to be a need for the archiving and dissemination of the astrometric data. It is hard to predict what form this will take, but I feel that our present 80-column card format will soon depart. Cross–indexing with other data bases is still very inadequate: for example, many thousands of known pairs are either missing entirely from SIMBAD, or are present without any notation that the object is in fact double. I am working on this problem, but it is painstakingly slow. Those applying new instruments and techniques to the detection and study of double stars also need to be reminded that firm calibrations are needed to tie the new data to that already existing, and that this has not been done in too many cases. (If they can not demonstrate that they can obtain acceptable results for well–known systems, how are we expected to believe their new and unique results?). Finally,

the visual double star data is greatly inhomogeneous, to such an extent that I believe any attempt to derive statistics from it is doomed to failure. A consistent magnitude scale would be a welcome first step in remedying this condition, and so I am encouraged to learn that such work is underway.

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3. DISCUSSION

FEKEL: What is the status of an updated version of your orbital elements catalog?

WORLEY: I maintain a list of all new orbits in the same format as used previously, but the orbits are ungraded for quality. I will return to this project following completion of the next edition of the WDS.

POVEDA: What is the present availability of the WDS? To what date is it available? Have the companions to Gliese's stars been included?

WORLEY: The 1984.0 version of the WDS is available from the data centers (Strasbourg, Goddard, etc. It is, along with the orbit catalog, also available on the CD-ROM recently issued by the Astronomical Data Center. The WDS aims to include all double stars for which a differential measure exists; therefore, it should include all the pairs listed by Gliese (but not discovered by him).

MATTEI: Is it possible to obtain information on a double star whose data have not yet been published in a catalog? How does one go about this?

WORLEY: You could try A&A Abstracts. In general, only published data are include in our data base, although there are some exceptions. We don't include vague comments such as "there is a faint companion about 15 arcsec away"; instead, we require a differential measure.

SINACHOPOULOS: What is a "data record" for you?

WORLEY: A data record is either an observational mean of individual measures (card–image), or a summary (index) record.

https://doi.org/10.1017/S0252921100006576 Published online by Cambridge University Press