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PHOTOMETRY AND VARIABILITY OF DOUBLE STARS
(Invited Paper)

R. L. Walker

U.S. Naval Observatory Flagstaff, Arizona

RESUMEN

Se discuten ciertos tópicos de fotometría de estrellas dobles así como programas observacionales actuales y nuevas técnicas de observación. Se describe un catálogo revisado de binarias visuales con una o más componentes variables.

ABSTRACT

Selected topics of double star photometry are discussed together with current observational programs and new observing techniques. A revised catalog of visual binaries with one or more variable components is described.

I. INTRODUCTION

This paper is in two parts. The first is in the nature of a review dealing with the photometry of visual binary stars. It is not the purpose here to provide a comprehensive survey of double star photometry, since the subject is too broad for such an approach. Rather, a few selected topics will be discussed. The second part of this paper describes a revised catalog of visual binaries with one or more variable components. It is the author's conclusion that photometry is a valuable, but neglected, means of discovering multiple systems among known double stars.

II. PHOTOMETRY OF DOUBLE STARS

Photometry of double stars can be divided into three categories. The first category is Δm photometry, which is a measure of the difference of magnitude between the members of the system. The second is wide-star photometry, where the separations are greater than 3.0 arcsec and the observations can be made independently for each component. The last category is integrated photometry where the members of the system are closer than 1.5 arcsec and cannot be separated by a conventional photometer.

III. THE MEASUREMENT OF MAGNITUDE DIFFERENCES

Determinations of Δm are important for their contribution to understanding the physical properties of stars, in which the field of double star astronomy plays a vital role. For many years, visual observers have estimated magnitude differences in the course of making astrometric measures. At best, the visual estimates have an error of ± 0.1 magnitude up to $\Delta m = 0.5$ magnitude; beyond 0.5 mag the error increases drastically. In addition, the errors increase with the separation of the pair, with the atmospheric turbulence, and for extremely bright or faint pairs.

Concerning the errors in estimation of Δm, the large range in the personal equations of the observers is striking. As Baize (1962) has pointed out, a first-rate observer such as Burnham had a propensity to minimize the brightness of the faint companions, thus overestimating the magnitude differ-

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TABLE 1

INSTRUMENTAL DETERMINATIONS OF MAGNITUDES AND MAGNITUDE DIFFERENCES

Date	Author	Stars	Method	m.e.
1879–1913	Pickering, et. al.	800	Double image	±0.08
1907	Müller, G. & Kempf	150	Zöllner	—
1907	Stebbins	107	Double image	±0.08
1920	Hertzsprung	167	Photovisual	±0.03
1935	Kuiper	500	Grating	±0.14
1939–1952	Muller, P.	400	Double image	±0.04
1943	Detre	206	Wedge	±0.10
1944–1948	Wallenquist	2900	Wedge	±0.20
1946	Kooreman	157	Photovisual	±0.03
1948	Miczaika	827	Zöllner	±0.06
1950–1966	Eggen	523	Photoelectric	±0.02
1950	Luyten	12	Photovisual	±0.06
1950	Wallenquist	180	Photoelectric	±0.03
1953	Hopmann	535	Double image	±0.08
1953	Johnson	40	Photoelectric	±0.02
1953–1969	Strand	1024	Photovisual	±0.07
1956–1957	Wiet-Knudsen	360	Photovisual	—
1958	Pettit	153	Wedge	—
1962	Wayman	56	Photoelectric	±0.02
1964	Tolbert	94	Photoelectric	±0.02
1966	Häggkvist	72	Photoelectric	±0.02
1966	van Herk	115	Double image	±0.07
1969–1971	Landolt	50	Photoelectric	±0.02
1969	Worley	94	Double image	±0.05
1970	Alexander	24	Photoelectric	±0.02
1970	Lindenblad	1	Grating	±0.05
1971	Lutz	28	Photoelectric	±0.02
1973	Walker	40	Photoelectric	±0.02
1975	Franz	200	P. E. Scanner	±0.05

ence, while others reversed this tendency. In the past some observers were content with reproducing the estimates of magnitude differences in the catalogs, while the writer has noticed that other observers habitually record intensity differences with a seeming lack of awareness of the Pogson scale. Fortunately, some observers have noted the magnitudes with great care and thus have furnished us with valuable information. Among these are Struve, Doolittle, van den Bos, Finsen, Couteau, and Worley.

Instrumental measurements of magnitude differences were begun by Pickering in 1879. Table 1 is a list of observers of magnitudes and magnitude differences, and a description of their programs. Surveys of Δm programs have been discussed in the catalogs of Wallenquist (1954) and Wierzbinski (1969) and references not found in their catalogs are given in the bibliography of this paper. The mean errors in this table are representative of the internal errors of the various programs and methods employed. For example, the errors are large in the case of Kuiper's program where pairs had large magnitude differences. At present, photovisual measures, such as those by Strand (1969), provide the most substantial contribution to Δm observations.

IV. PHOTOMETRY OF WIDE DOUBLE STARS

Photoelectric photometry of wide double stars is possible with any moderate sized telescope having a good drive. Unfortunately, there are few cases where orbital parameters are available to combine with the photometric observations. However, the work by Johnson (1953), and Eggen (1963) has demon-

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strated that the photometry of wide double stars will aid us in interpreting formation and evolutionary processes in these systems.

Breckinridge and Kron (1964) obtained red and infrared photometry of double stars. They dealt with the aperture problems in double star photometry, and devised observing techniques and calibration procedures which should be applied to all future photometry of double stars.

V. INTEGRATED PHOTOMETRY OF DOUBLE STARS

The last category deals with measurements of the combined light from the members of binary systems. Using integrated measures and accurate values of Δm, we have valuable data to improve both the mass-luminosity relation and dynamical parallaxes. Heintz (1969) has reminded us that in the Baize-Romani relationship, for dynamical parallaxes, the total magnitude enters much more critically than Δm.

Smak (1967) made an interesting study obtaining integrated photometry of sixty visual binaries with good orbits. He was looking for subdwarfs in binary configurations and argued that they would be identified by UV excess greater than +0.15 mag for spectral types F0-G5. His results were negative, but he did find evidence to support a correlation between orbital eccentricity and UV excess.

VI. NEW TECHNIQUES AND EQUIPMENT FOR DOUBLE STAR PHOTOMETRY

Our goal for the future must be to measure the individual components in all systems separately and with improved accuracy. New equipment has been developed and improved techniques are being devised for multiple star photometry. Rakos (1965) developed an area scanning photometer that was perfected by Franz (1966) and has been used for double star photometry since 1965. Franz is presently working on a modification of his equipment that will reduce the mean "close" separation he now measures from 3.0 to 1.0 arcsec. He has discovered 20 variables from a program of 200 stars. About a dozen of the program stars are under intense observation. Notable among these are UV Aurigae, a carbon-Mira star, and CE Cass, a double Cepheid.

The technique of rapid photometry during lunar occulations (Nather and Evans 1970) has led to new close double star discoveries. At the same time this productive technique is providing us with accurate relative photometry of double stars. N. M. White at Lowell Observatory, in cooperation with D. S. Evans, F. C. Fekel and colleagues at McDonald Observatory, have made over 1000 occultation observations of double stars.

Electronic camera techniques have been applied to double stars and accurate magnitude differences have been provided by Laques (1971) and his colleagues in France. In the United States, the Kron electronic camera has been applied to the photometry and astrometry of close binaries by Ables, Walker, and Hewitt (1970). Hewitt is presently continuing this work at the Flagstaff Station of the Naval Observatory with double stars that are on the parallax program there. The separations of these stars range from 1.5 to 6.0 arcsec.

The interferometric technique of Wickes and Dicke 1973) is past the development stage. In a recent publication, Wickes (1975) has presented values of magnitudes as well as astrometric quantities for nine double stars.

VII. AN OBSERVING PROGRAM

At the conclusion of Colloquium No. 18 at Sproul Observatory, members of IAU Commission 26 passed the following resolution: "Emphasis should be given to the need for photoelectric observations of binary systems". In an effort to fulfill this request, the author has developed a program to obtain UBV observations of binary systems. The program is intended to provide integrated photometry of binary systems, to provide absolute magnitudes of variable star types, and to discover multiple systems by means of identifying eclipsing binaries. There are approximately 1000 stars on the program, most of which were taken from the Orbit Catalog (Finsen and Worley 1970). To this list have been added systems with new orbits appearing in the "Circulaire d'Information" edited by P. Muller. Many of the systems

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on the program are believed to contain variable components. To date, over 2000 UBV observations have been obtained for 260 systems and six variable stars have been identified. The types of variations for three of these have not been determined, but the other, ADS 1963A (Walker 1973), is a W Ursae Majoris system.

VIII. THE DOUBLE STAR-VARIABLE CATALOG

Photometry has led to the discovery of numerous variable stars which are members of known double stars. Plaut (1934) published a list of double stars of which one component was a variable and for many years this served as a valuable finding list for observational astronomers. Baize (1962) revised this list and his catalog was noteworthy for the substantial increase in stars suspected of variation. Perova (1963) added still more stars in a similar revision. Twelve years have passed and there are sufficient discoveries to justify another revision of the catalog. Table 2 lists the contents of the aformentioned catalogs.

TABLE 2

CONTENTS OF DOUBLE STAR-VARIABLE CATALOGS

		Variables Known	Suspected Variables	Variables Double
Plaut	(1934)	105	19	
Baize	(1962)	160	182	
Perova	(1963)	190	223	
Revised	(1975)	519	367	33

The third column of Table 2 is of particular interest. Van den Bergh (see bibliography) compiled a similar list several years ago and remarked on the large number of RW Aurigae types. This is not surprising in view of the fact that these stars usually occur in physical groups (T associations). Kukarkin (1962) has stated that many of these variables are doubles and a list of RW Aurigae types should be examined for duplicity.

One method that will increase our knowledge of the statistics of multiple systems is to identify the number of eclipsing binaries in double systems. The Gliese Catalog of Nearby Stars (Gliese 1969) lists 330 double stars. Of these, eighteen systems contain known variables. Two (11%) are eclipsing binaries and 14 (78%) are flare stars. The high number of flare stars is not too surprising when one considers that most of the stars near the sun are red dwarfs.

Table 3 presents the percentages of types of variables in the new catalog. The percentages differ from those found in the Gliese catalog due to selection effects.

TABLE 3

PERCENTAGES OF VARIABLE TYPES IN THE REVISED CATALOG

Pulsating variables	48%
Eruptive variables	15%
Eclipsing binaries	37%

IX. CONCLUSIONS

We can look forward to improvement of our knowledge about the number of multiple stars from photometric discoveries. The photometric program described above reached only to $-30°$ declination. Southern hemisphere observations will be needed. Colleagues are invited to submit stars for the observing program and additions to the revised "Double Star-Variable Catalog."

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DISCUSSION

King: In photometry of close pairs, is direct photography being used? Sensitometric study of overlapping star images can produce good results.

Walker: This method has been applied at various times, but I am not aware of a current long-term program.

Strand: Did I understand you to say that Δm, the magnitude difference between the components of a double star, was a measure of the division of masses between the components? This is only so to a first approximation for main-sequence stars.

Abt: Are you including in your catalog only physical systems, or do you include systems for which there are insufficient data to tell whether they are optical or physical systems?

Walker: I have tried to assure that only physical systems are in the catalog, i.e., I use orbital motion, common proper motion, computed intrinsic separation, or Aitken's criterion. When in doubt I do include systems with insufficient data. In these cases the catalog will serve as a finding list.

Evans: Are you including possible unresolved duplicity in Cepheids and also Z Cam and U Gem stars?

Walker: Yes. There are about 20 Cepheids in the catalog. The eruptive variables such as the SS Cyg, Z Cam, and U Gem stars are included if a companion is known. There are about 40 eruptive variables in my catalog. Our definitions of "unresolved" may differ, though. Visual observers can separate pairs to 0.15 arcsec, sometimes to 0.10 arcsec.

Worley: I noted that you quoted the 1954 Δm catalog compiled by Wallenquist. Are you aware that there is a much later catalog of Δm estimates by Wierzbinski?

Walker: No, I am not. Thank you.

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