ASTROMETRIC AND PHOTOMETRIC AREA-SCANNER MEASUREMENTS OF DOUBLE STARS

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ABSTRACT. Accurate magnitudes and colors of individual components of binaries are needed to provide valuable information on stellar evolution. Using an area scanner, accurate magnitudes, as well as good astrometric data, can be obtained for close pairs. A summary is given for the first major data set.

I. OBSERVING PROGRAM

Starting in 1973, an extensive program has been underway at the Institute for Astronomy, University of Vienna, to obtain area-scanner measurements of close visual binaries. The first major set of completed reductions encompasses about 250 pairs. Data were obtained with the 64-cm telescope at Mauna Kea and the 50- and 100-cm telescopes at ESO. Most stars were selected from the Finsen and Worley catalog (1970). The smallest separations were on the order of 0".8. The purpose of the program is to establish the first photoelectric sequence for the magnitude differences of close visual doubles in the Johnson UBV and Strömgren uvby systems. The instrument used for the measurements described here is the predecessor to the solid-state model described by K. D. Rakos. Descriptions of the area scanner appear elsewhere (cf. Rakos 1965, 1970; Franz 1967).

II. REDUCTION TECHNIQUES

Quality of area-scanner data depends on many factors, including seeing, telescope tracking errors, photon statistics, and the atmospheric spectral dispersion. Integrating two to four minutes provides the necessary accuracy; dead time is always compensated for before the profiles are analyzed. The one-dimensional scan can be described by

$$s(x) = f(x-p_1) + r \cdot f(x-p_2). \qquad (1)$$

Here, r is the brightness ratio between components, while p_1 and p_2 represent their positions. By far the best function to fit stellar profiles out of those tested (Jenkner 1974a) is the Franz function, a generalized Lorentz distribution, first used by O. G. Franz (1973) having the form

$$f(x) = \frac{H_i}{1 + \left(\frac{|x-A_i|}{B}\right)^{P'}} + K \; ; \; P' = P\left(1 + \frac{|x-A_i|}{C}\right). \quad i = 1,2 \qquad (2a,b)$$

The eight parameters can be found using an iterative least-squares method. The difference between the two A's gives the separation, while -2.5 log (H_1/H_2) gives the magnitude difference. Because of its superiority, this function was used in routine reductions (Jenkner 1973, 1974b).

Problems with asymmetry cannot be overcome using such symmetrical functions. The Fourier method introduced by Dicks and Van Rooyen (1973) can be used to overcome this difficulty. This method requires, however, simultaneous observations of both a single-star and the double-star profile, which is essentially achieved by using two perpendicular scanning slits (Rakos 1974). By incorporating both methods, Kreidl

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(1978) and Rakos showed that the parameters obtained from the least-squares fit could be used to construct a single-star profile to use in place of the lacking observed one in the Fourier method. This proved to be most fortunate, as most scans were obtained with a single slit. Table 1 shows direct comparisons of both reduction techniques. Astrometric quantities can also be calculated easily by using stars well observed by E. Hertzsprung (1920, 1964) utilizing the photographic multiexposure technique to provide calibration constants. In spite of the fact that temperature and other effects were not compensated for, errors are small, as is demonstrated in Table 2. Results are comparable with those achieved via the photographic multiexposure technique.

TABLE 1. Comparison of standard deviations from a least-squares fit to a Lorentz distribution (Franz function) and those from the Fourier transform method (Dicks and Van Rooyen).

Star	d"	F	N	T	Lorentz Distribution m	Lorentz Distribution σ	Fourier Transform m	Fourier Transform σ
ADS 13429	5.4	B	33	W	0.636	0.031	0.644	0.022
ADS 4682	6.4	B	6	Ch 1	0.04	0.20	0.02	0.02
ADS 14592	2.5	U	4	Ch 2	0.77	0.07	0.78	0.02
ADS 4260AB	10.8	B	5	Ch 1	1.40	0.07	1.34	0.06
ADS 9737	6.3	V	8	H	0.94	0.06	0.91	0.06
ADS 9979	6.5	V	7	H	1.10	0.06	1.07	0.03
ADS 9882	2.6	V	5	H	0.34	0.03	0.37	0.03
ADS 13403	3.3	V	3	H	2.29	0.05	2.17	0.02

d" = separation; F = filter; N = number of observations; T = telescope (W = Vienna 1.5 m, CH 1 = ESO 50 cm, CH 2 = ESO 100 cm, H = MKO 64 cm).

TABLE 2. Comparison of calculated and measured separations and position angles for ADS 8630. Calculated values are from Muller and Meyer "Troisième catalog d'éphémérides d'étoiles doubles."

Epoch	d (cat)	P_a (cat)	d (obs)	P_a (obs)	Telescope
1972.203	4".33	302°.8	4".43	302°.0	1.5-m Vienna
1973.456	4.32	301.2	4.35	301.2	64-cm MKO
1975.062	4.20	300.3	4.25	300.3	50-cm ESO
1975.071	4.22	300.1	4.25	300.2	100-cm ESO

III. RESULTS AND DISCUSSION

Photometric data were reduced to the standard Johnson and Strömgren systems. The combined magnitudes for about 135 binaries have been compiled so far. The standard deviation in V is $\sigma = 0.020 \pm 0.011$. Individual component brightnesses for about 200 pairs were determined; the mean difference between the Finsen and Worley catalog value for ΔV and ΔV observed was found to be $\overline{\Delta V} = -0.003 \pm 0.080$ for 42 stars. The accuracy of color differences can be checked by comparing $\Delta(B-V)$ with $\Delta(b-y)$, which yields a standard deviation of $0^m.051$ for one color.

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Distances and position angles were derived for about 175 pairs, with a mean error in position angle of $1\overset{\circ}{.}16$ and about $0\overset{''}{.}06$ for separation. Most errors were less than half of these values, but measurements where the component separation was about 7" or greater led to less accurate results due to fewer data points defining the profile. Frequent observations led to obviously better results; 30 observations of ADS 13429 yielded d = $5\overset{''}{.}704 \pm 0.022$. Again, the Fourier transform technique resulted in astrometric results almost always considerably more precise.

Finally, it can be said that the area scanner has made it possible to obtain accurate combined magnitudes, component magnitude differences, and astrometric data for a large number of double stars. Many of these objects are located in the southern hemisphere--a region largely ignored until recently. For relatively little observing time, high accuracy is obtainable on moderately sized telescopes. The reduction method is totally impersonal, and improved computing facilities will lead to a faster output of reduced data in the near future. Detailed numerical results of this first set of objects appear in the *Astronomy and Astrophysics Supplement Series* (Rakos *et al.* 1982).

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DISCUSSION

FREDRICK: In view of the discussion by Josties, is there a better way to get a scale calibration than by going to so-called standard stars?

KREIDL: From my experience calibrating these measurements, if one uses three or four Hertzsprung stars, you get an error for the position angle of only approximately two-tenths of a degree, and for distance, it is about one percent, or usually of the order of a couple of hundredths of an arcsecond. Also, if one takes stars that have very well-known orbits and compares scanner results with computed positions, you also get excellent agreement. I think the calibration errors introduced are considerably smaller than the inherent errors in the method itself.

McALISTER: Have you considered using some sort of prism/beam splitter arrangement to produce an artificial binary star of accurately known magnitude difference as an independent means for calibrating your photometry?

KREIDL: No. In comparing catalog values with ours, the agreement is quite good. For visual magnitudes, in the Johnson system, the average error for a single observation was 0.04 magnitude. The errors actually increase with larger separation, because there are fewer points defining the curves. I found no degradation of results as long as the magnitude differences were not larger than about 3.5, although we have effectively separated stars with magnitude differences greater than four.

FRANZ: Did you observe some of the objects repeatedly; and, if so, did you find variable stars unknown before?

KREIDL: Many of the stars were observed at two or three periods, sometimes over several years. Variability was detected in quite a few cases, with differences sometimes several tenths of a magnitude.