Session 6. Progress in Observing Techniques

OBSERVATIONAL PROCEDURES FOR VISUAL DOUBLE-STAR WORK

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When IAU Symposium No. 17, the most recent international conference on visual double stars to take place in the United States, was held in Berkeley in 1961, there was little discussion on observational techniques and no introductory remarks were presented on the subject. The reasons for this are obvious. The classical techniques of double-star observation, those that provided virtually all the data available on visual double stars, were too well known to require introduction or discussions; other methods, with the possible exception of early image tube and electronic camera experiments, did not exist.

Today, more than ten years later, most double-star work continues to be carried out by the same classical techniques. However, several methods have come into use or have recently been developed that are capable of contributing importantly to visual double-star research.

Limiting my remarks to methods of positional and photometric measurements, I shall first introduce, mostly by name only, the classical methods, largely for the sake of completeness and to pay tribute to their outstanding accomplishments. I shall then briefly discuss some aspects of recently developed techniques.

With the possible exception of meridian circle observations, visual micrometer measures of double stars must occupy the position of most successful and most enduring technique in observational stellar astronomy. This technique is as important and as productive now as it was when first used on a large scale by W. Struve in his great survey that began nearly 150 years ago and that resulted in the discovery of some 3000 pairs and the accumulation of about 10,000 measures whose accuracy was unprecedented then and rarely surpassed since. Visual micrometer measurement, either with the classical filar micrometer or with instruments of more recent design, such as the double-image micrometer, has virtually become synonymous with visual double-star research, and forms the exclusive basis for about 90 per cent of all orbits listed by Finsen and Worley (1970).

Rejuvenated by the use of encoders for automatic data acquisition and recording (Worley 1967), this technique will continue to play a leading role in the future of double-star research.

Second only to the visual micrometer method is the technique of multiple-exposure photography. While the first measurable images of a double star, namely Zeta UMa, were obtained on a wet collodium plate as early as 1857 by G. P. Bond, it was the work of Hertzsprung (1920) that marked the beginning and, in some respects, the ultimate development of this important observational procedure. Practiced during the past five decades intermittently at several observatories throughout the world, this method made its greatest contributions through programs carried out by Strand (1946) first here at the Sproul Observatory starting in 1938 and later at the Dearborn, Yerkes and Lowell Observatories (Strand 1954, 1957), and through the most extensive program of this type instituted by him at the U. S. Naval Observatory. This program alone, from its establishment in 1958 through the middle of 1970, has produced more than 7000 plates containing a total of more than 400,000 exposures of about 825 pairs. The quoted mean error of a published position is typically $\pm 0''.01$ to $\pm 0''.02$.

The third of the classical methods of double star observation is that of interferometry, a procedure so masterly described by Finsen (1971) during the first session of IAU Colloquium No. 5 at Nice in 1969, that I shall simply refer to the published proceedings for a complete evaluation of this demanding technique.

This applies similarly to the use of the classical methods of photographic astrometry for the discovery and investigation of double stars, work that has long been the central theme of research by van de Kamp and his associates here at the Sproul Observatory, and that has been the topic of presentations by Lippincott (1971) and by Strand (1971) at the Nice meeting.

Finally, I should mention the importance of proper motion surveys for the discovery and investigation of visual double stars, surveys such as the Lowell Survey carried out by Giclas, Burnham and Thomas (1971) and particularly the work carried out by Luyten (1967, 1971) in his Bruce and Palomar Schmidt Surveys and discussed by him at the IAU Double Star Colloquia at Uccle in 1966 and at Nice in 1969.

Turning now to a discussion of photometric procedures, I refer, for a summary of mostly visual methods of determining Δm's in double stars, to the introductory lecture given by Muller (1971) at the Nice Colloquium. At the same meeting, Strand (1969) presented a summary of his determination of photovisual magnitude differences from multiple-exposure plates. This investigation and several extensive series of photoelectric measures of magnitudes and colours of visual double-star components, notably the work by Eggen (1963, 1966), represent the most important contributions to the photometry of visual doubles in recent years. However, because of the use of conventional techniques, photoelectric photometry has been limited, with few exceptions, to pairs of separation larger than 10″, and no pair of separation smaller than 4″ had been observed, even with very large telescopes.

While it was, therefore, in the area of photometry that the need for more appropriate observing procedures was most apparent, it is interesting to note that the techniques recently adapted or newly developed for double-star research are all equally suited for photometric and positional work, and that, combined, they can cover the full range from subinterferometric separations to very wide pairs and from very bright objects to the faintest stars observable today by any technique at any telescope.

Perhaps the most exotic among these novel techniques is that of the discovery and measurement of double stars by lunar occultations, a method described by Nather and Evans (1971) at the Nice Colloquium and also the subject of a joint discussion at the XIVth General Assembly of the IAU at Brighton in 1970. This method, although affected by a few obvious and many subtle limitations and difficulties, has already demonstrated its ability to detect duplicity of pairs having separations as small as a few milliseconds of arc and to provide accurate photometric data for their components. Successful determination of the relative position of double star components will depend upon observation of the same events from two or more locations. To this end, active programs are now carried out or being initiated at several observatories in the United States, including the McDonald, Lowell and Mees Observatories.

Oldest among the "new" methods of double-star observations is the use of electronic cameras. Early experiments with the Lallemand camera were described already at the Berkeley Symposium by Rösch (1962) and results of more recent and more extensive use of the Lallemand electronic camera were presented and discussed by Laques (1971) at the Nice Colloquium.

In the United States, Kron and his associates have used the Kron electronic camera to explore its potential for double star research.

Other techniques, still largely unexplored, include work with vidicon tubes, whose usefulness for astronomical research is now being investigated by McCord and Westphal, and methods of photoelectric scanning now being developed by Fredrick and Villamediana and their associates at the Leander McCormick Observatory.

Finally, one technique now used routinely for astrometry and photometry of visual double stars, and one I am most familiar with, is the method of photoelectric area scanning, a procedure first introduced by Rakos (1965) and further developed by Høg (1971) and in my own own work at the Lowell Observatory. My program has, to date, produced about 4000 photometric and positional measures of more than 150 double stars, including more than 25 pairs with known orbital elements and several frequently observed objects containing at least one component of known intrinsic variability. The pairs observed have a median separation of about 4″, and several objects of separations as small as 1″.6 have been measured. The accuracy attainable for the positions derived from scanner observations is that obtained by the photographic multiple-exposure technique. Magnitude differences determined by scanning typically have a mean error of $\pm 0^{m}.03$, the same as that for magnitude differences obtained by conventional photoelectric techniques for wide pairs and better than the accuracy of Δm's determined by any other method.

One problem that is shared by several of the techniques just mentioned and that caused considerable discussion and controversy at the Nice Colloquium is that of finding a function that can correctly represent the observed profiles of star images. I have since investigated and completely solved this problem. The failure of Gaussian distributions, used in the early stages of this work, to give a satisfactory representation of observed image profiles, is demonstrated by the left half of figure 1 which shows, plotted as crosses, the observed data together with computed profiles obtained from Gauss-analysis and represented by solid lines. The systematic character of the deviations between observed and computed double star profiles can be seen upon simple inspection of these plots.

Efforts to find a better representation of the observed image profiles have led to the formulation of a novel distribution function which, for a single peak, has the form:

$$I = \frac{H}{1 + \left\{\frac{abs(x - A)}{B}\right\}^{P}},$$

where H is the height, A the peak location, and B the half-power width. P is a variable exponent of the form:

$$P = P_0\left\{1 + \frac{abs(x - A)}{C}\right\},$$

where P_0 is the power at the peak location A, and C determines the rate at which P changes as a function of x.

The right half of figure 1, showing the same image profiles previously discussed, demonstrates the high systematic accuracy of profile fitting with this new function. While the use of Gaussians often resulted in residuals larger than five per cent of the peak height of the profile, this function leaves residuals that are rarely larger than one per cent of the maximum height of the profile. It is with the use of this function that the more than 4000

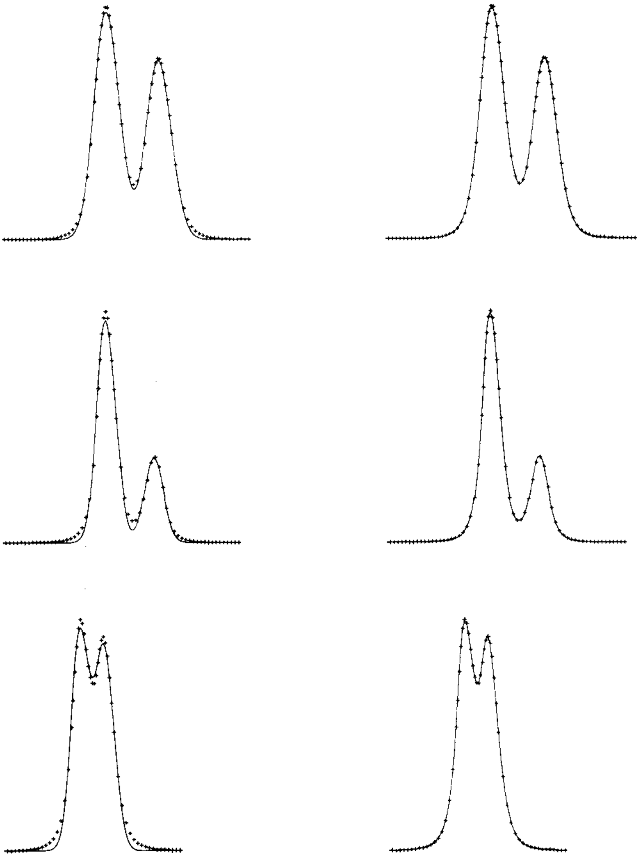

FIG. 1—Comparison of observed (crosses) and computed (solid lines) image profiles of visual double stars, the left side showing representation by Gaussian functions, the right side representation by functions of the type described in the text.

profiles of double star images have been analyzed and that the accuracy of positions and magnitude differences reported above has been attained.

In summarizing the present state of observational procedures, it is obvious that the long-established, classical techniques of observation will continue to dominate most investigations of the properties, particularly of the orbital parameters, of visual binaries. But it is equally obvious that new techniques already in use or yet to be developed will play a role of ever increasing importance in the study of both the orbital and the physical parameters of double stars.

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DISCUSSION

A TV technique now in the experimental stage at the Royal Observatory, Belgium, was described by Dommanget. Preliminary tests showed that with the 45-cm refractor equipped with 6× magnification a binary with 10^{m} components at a separation of 1″ to 2″ was easily observed on the screen, even while being registered by tape. Each image (exposure time 1/25 sec) can be studied separately thereafter. The camera was a Fernseh TV 720 with an ESB silicon tube and a XX9950 image intensifier. Some comments were given on the difference between SEC and ESB tubes, showing the superiority of the latter for double-star work, and on the observed synchronism of image deformations by atmospheric disturbances.

Laques gave a progress report on the Lallemand camera; no technical changes were indicated since the account at Nice in 1969. With a telescope of 1 m aperture and 30 m effective focal length, both ρ and θ are measured to an accuracy of about $0\overset{''}{.}01$. The separations range from about 2″ down to $0\overset{''}{.}35$, and the limiting magnitude is 10^{m}. Further results have been published (*Astron. and Astrophys.* **15**, 179, 1971). Plates are oriented by artificial marks, and each image is reduced separately because the seeing effects vary rapidly. UBV magnitudes are obtained to about $\pm 0\overset{m}{.}05$ using a wedge densitometer. The image overlap limits photometry to separations greater than 1″.

Franz believes that the integration over many images needed in order to get symmetrical images offsets the advantage of the short exposure times of the camera, and hence doubts the prospects for photometry of close pairs; there is no way to beat the seeing. He then discussed his mathematical representation of the profiles with Heintz. Since the function adopted matches the observations sufficiently well, no need is felt to modify the theory.

Franz and Walker mentioned the results obtained by Kron with his electronic camera. The minimum separation was $1''.1$. Very good seeing was required owing to the long integration time. The formal expression for the profiles varied with wavelength and also depended on the seeing (and did not fit Gaussians well with good seeing). The errors amounted to 3% in UBV, to $0''.03$ in the separation ρ, and to $0^\circ.1$ in position angle θ.

Villamediana described the linear-scanner image-tube technique with which he is now working at the Fan Mountain Observatory of the University of Virginia. The basic component is a rotating grating which yields a frequency-modulated output of the star images. The scanning technique has been modified, but no results are available as yet.

Worley mentioned the possibility of magnifying the photographic image, for instance by a Barlow lens. A scanning interferometer recently developed at Princeton may prove useful, particularly for large Δm differences. For better measuring efficiency, it is hoped that intermediate storage stages such as photographic plates can ultimately be eliminated.

In conclusion Strand remarked that he found these new developments exciting, but it was important that they should not be left in the experimental stage. They should soon be brought into actual productivity because of the urgent need for the observational data.

RESOLUTIONS

At the conclusion of its sessions, Colloquium No. 18 of the International Astronomical Union approved the following resolutions:

(1) that emphasis should be given to the need for photoelectric observations of binary systems

(2) that the development of new observing techniques should lead to the implementation of continuing observational programs

(3) that Commission 26 be requested to clarify the definition of dynamical parallaxes

(4) that the lack of programs in the southern hemisphere is noted with great concern, and that immediate steps be taken to remedy the grave situation.