REVIEW OF THE OCCULTATION TECHNIQUE FOR THE STUDY OF BINARIES

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The systematic search for stellar multiplicity by observations of lunar occultations began in 1969. David Evans will review a large portion of the data collected since then in the second paper of this session. Here we will outline the historical development of the technique and comment on its limitations, contributions to double star research, and future improvements.

Sir John Herschel (1865) may have been the first to suggest that "a double star, too close to be seen divided with any telescope, may yet be detected to be double by the mode of its disappearance." However, the visual discovery of duplicity by occultation is not sufficient, for the observations are not subject to analysis after the fact. The power of the occultation technique was realized more than 100 years after the suggestion, with the application of photomultipliers and electronic digital data handling. Whitford (1939) took the first step in using a cesium photo tube, oscilloscope, and moving film to record the occultations of Beta Capricorni and Upsilon Aquarii. The resolution of the spectroscopic binary Beta Capricorni was discussed, but he concluded his data were not able to resolve it, an observation which was later accomplished at several observatories and summarized by Evans and Fekel (1979). Whitford's technique met the requirements of time resolution and, in one form or another, was occasionally used during the next 25 years to determine stellar angular diameters, record timings, and even discover duplicity (e.g., Evans 1955; O'Keefe 1950 (discovered 228 B Aurigae to be double); Rakos 1964). Occultations have to be observed regularly at high time resolution to discover duplicity in any systematic fashion; therefore, there must be a means of recording in a usable fashion the large quantities of numbers. Between 1968 and 1970, photomultipliers, digital memories, and minicomputers were applied to the problem, as summarized in *Highlights of Astronomy* ("Joint Discussion on Photoelectric Observations of Stellar Occultations," edited by Deeming, 1971). More recently, microprocessors have been used for recording occultation data (White 1977a; Chen and Sandmann 1980).

With the solution of data acquisition and data reduction problems, there still remain some basic limitations to the technique. The obvious one is the requirement that the undiscovered multiple system be occulted by the Moon. However, the ±6° band centered on the celestial equator affords a significant sample of stellar types and even stellar clusters if observations are made on a regular basis. The fundamental limit to angular resolution is the signal-to-rms noise of the observations (Scheuer 1962). Telescope aperture size, filter bandpass, and integration times must be chosen so that they will produce the highest signal-to-rms noise ratio without themselves limiting the angular resolution (e.g., Ridgway 1977). And finally, a single occultation will allow the resolution of the separation along the velocity vector of the lunar edge at the point of occultation. This projected position angle (White 1977b; Nather and Evans 1971) will always be less than or equal to the true position angle. The determination of the latter requires two observations at sites separated enough to give significantly different projection angles.

Nevertheless, with medium-sized telescopes using standard modern photometric systems, the contributions of the lunar occultation technique for the study of double stars are unique and significant. Accurate magnitude differences of three to four and in several colors can be measured for systems with projected separations of about 1 second of arc to a few milliseconds of arc. Multiple systems are discovered in a systematic way with visual magnitude limits approaching 11 mag and with an angular resolution approaching 2 milliseconds of arc. Thus, occultation observations supplement other techniques by supplying magnitude and color differences not attainable by other means and by selecting stars for further study. In addition, known spectroscopic binaries have been resolved, yielding a complete solution to the system. By virtue of its unmatched high angular resolution capability, the impact of occultation discovery on double star statistics is particularly important.

The occultation technique is presently a viable tool for double star research, but there are improvements to be made. More effort needs to be directed toward improving observational techniques so that the best possible signal-to-rms noise ratio is attained for the existing conditions and to develop better reduction techniques. Wider baselines should be used regularly in multicolor observations; for example, 0.4, 0.7, and 1.0 microns would detect companions of greatly differing color indices. With inexpensive microprocessors, a network of amateur astronomers could be encouraged to make objective observations, increasing the chances of discovery of new double stars (Chen and Sandmann 1980). Two-dimensional detectors might eventually be used in conjunction with a prism or grating to record both the variation in color and time of the lunar occultation, thus opening many new possibilities for detecting faint, close companions.

High-speed observations of lunar occultations, despite the limitations, are proving to be an inexpensive and effective way to resolve, determine magnitude differences, and discover multiple stars that either could not or would be difficult to observe by any other current observational technique.

References

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DISCUSSION

BECKERS: Does the presence of mountains and their slopes on the edge of the Moon affect the interpretation of your measurements?

WHITE: This is a subject which has a long history of discussion, and it has evolved from theoretical to empirical. At times there is an effect. There is an advantage, of course, in multi-site observations, and also duplicate observations of the same object a few months later if possible.

CURRIE: One of the other advantages of the array is that one is able to cut back sky and moon background, by essentially having a much smaller aperture.

RAKOS: The photon noise problem will be improved by an array because the quantum efficiency is much higher than for the photomultiplier, but you need noise-free amplification in a very short time - a millisecond - and that is not easy to get now.

WHITE: That's why I say this is in the future, but it is interesting to contemplate, to be able to use the two dimensions, not in space, but in time and color.