LUNAR OCCULTATION TECHNIQUES IN INVESTIGATIONS OF BINARY STARS

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ABSTRACT

The paper discusses the possibility of direct measurement of angular separations and luminosity ratios of components of unresolved binary systems through observations of lunar occultations. A current program at Kavalur Observatory is described and some results presented.

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Information about binary systems are usually obtained from photometric or spectroscopic observations. Although it is possible to determine orbital characteristics of the system from light and velocity curves, certain ambiguities remain which cannot be eliminated without direct measurements of the angular dimensions. For most binary systems, these cannot be determined by any direct method, the separation being a tiny fraction of the seeing disc. Interferometry or speckle techniques can provide the required information in some cases, but these experiments call for sophisticated equipment with large light collectors. On the other hand, the familiar phenomenon of lunar occultation can provide a direct method requiring simple instrumentation to measure the parameters of some binary systems.

The phenomena of lunar occultations results in an undulating light curve at the moment when the moving edge occults the stellar disc. This is due to covering or uncovering of different Fresnel zones at the plane of lunar limb, in the wave front of the light from the occulted object. The shape of the monochromatic curve is basically the convolution of the single point Fresnel diffraction pattern with the strip distribution function across the object. The inherent capability of modern systems in recording very fast light variations without distortion makes it possible to use these records for determining the latter by a process of deconvolution.

The experiment consists of recording the occultation light curve with as high a time resolution as possible. Any telescope used in photometric programs is suitable for such observations. The recording system can be easily fabricated; employment of magnetic tape recorders or on-line microprocessors makes the task of recording easier. A system built in our laboratories (Bhattacharyya & Sundareswaran, 1977) incorporating an analog tape recorder is being employed in the cassegrain focus of the one metre telescope at Kavalur. A typical record is shown in Fig. 1.

When the star is a binary, the light curve shows its binary nature if the separation between the components is not too small. If the projected spacing in the direction of lunar limb movement is large compared to the width of Fresnel fringes, the light

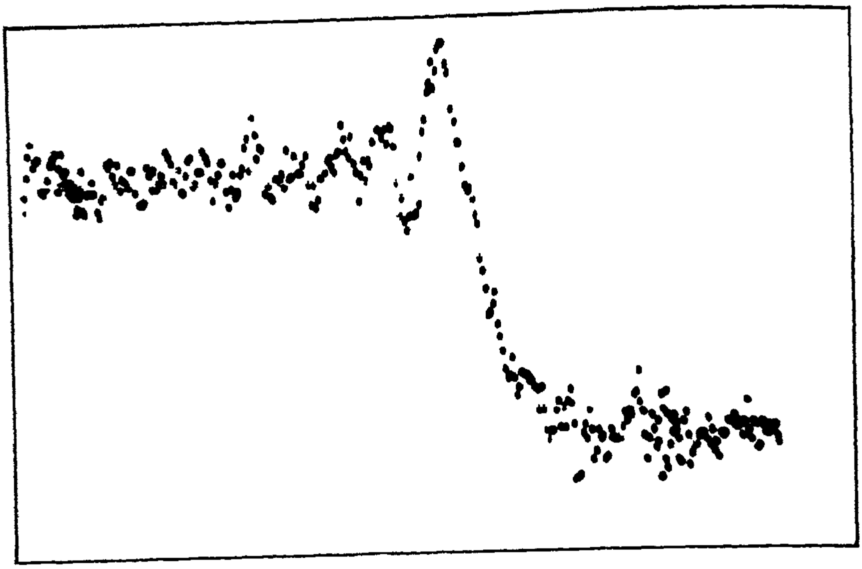

Fig. 1. An Occultation light curve

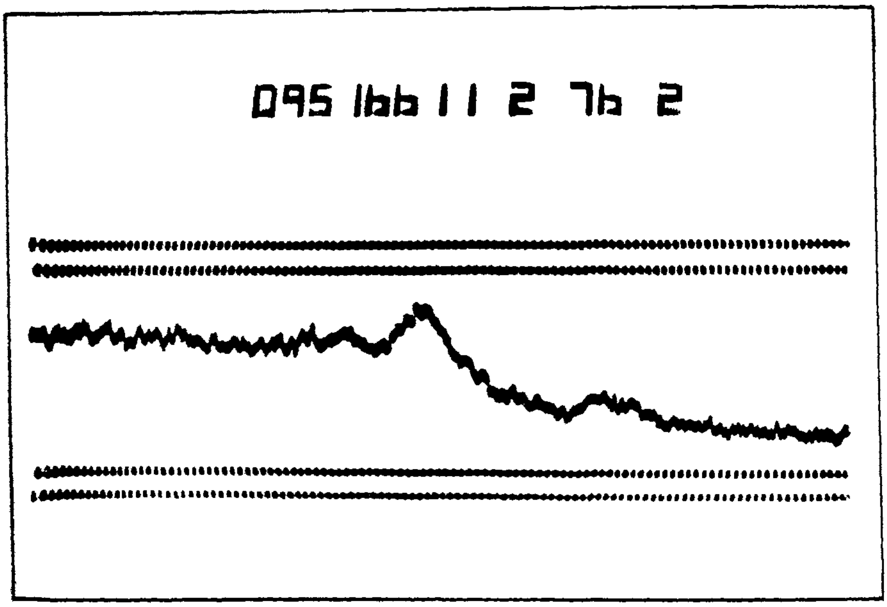

Fig. 2. An occultation curve due to a binary star

curve shows clearly separated two steps; but even for smaller separations, the presence of the companion can be seen. An example of occultation of such a system is shown in Fig 2. The separation of the two major of components of SAO 095116 recorded on February 11, 1976 was about one hundredth of an arc second at the moment of this occultation. This triple star system has also been measured through a series of occultations by the University of Texas group, where the separation and the orientation of the components are seen to follow a regular cyclic pattern (Africano et al., 1977). The method provides a direct measurement of the angular separation from which the inferred parameters of the system can be firmly established.

Still smaller separations also leave marks on the record from which the values can be found. The method followed is essentially the same as employed in determining stellar diameters from occultation curves (Nather & Mc Cants, 1970). From the spectroscopic information and the spectral response of the detector employed, the shape of the expected occultation curve for a point source is first calculated. The distortion introduced by finite diameter is then incorporated. Several models are made in which the star is given a set of diameters and the modified light curves computed; these are compared to the observed curve. The model showing the best fit is judged to represent the structure. Finer modifications like incorporation of the limb darkening etc are done and finally the effect of seeing noise in the determination is evaluated.

The problem of judging the best fit can be accomplished in several ways. We follow a method in which the correlation coefficient between the observed and theoretical series is maximised (Bhattacharyya et al., 1981). An example where the observed light curve is compared with a series of computed curves due to varying stellar disc diameters is shown in Fig. 3; the correlation coefficient between the observed light curve and the computed ones with slowly increasing diameters show a smooth maximum. The model with the diameter where the peak correlation is reached is judged to be the most appropriate one. Uncertainties are then determined from the noise in the record.

Extension of the method for determination of the structure of the binary system yields information about the separation between its components and their intensity ratios. The model series of light curves are computed for two components of varying intensity ratios and separations, and maximisation of correlation coefficients sought. The geometry of the occultation event figures in the computations where the orientation of the limb with the line joining the two stars is required to be determined. In determining this, the general shape of the light curve and the known orbital parameters of the binary system are made use of. From the optimum model, the consistency of the results are generally checked; and doubts about some of the ambiguous parameters like the inclination of the orbital plane can be resolved.

The fitting of such models with the light curve of the binary system alpha Virginis obtained in 1976 has shown the possiblities of the method of resolving very fine structures (Bhattacharyya et al, 1981). Some uncertainties due to lunar limb irregularities or heavy scintillations can be effectively estimated by multiple observations of the same event at two or more locations (Evans, 1970).

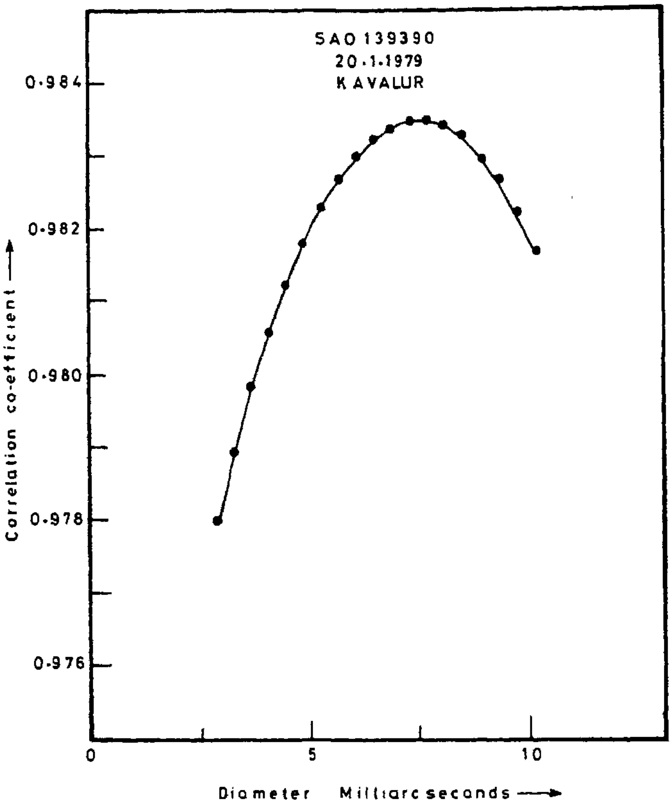

Fig. 3. Variation of correlation coefficient with changing diameters of model stellar discs.

The intrinsic accuracy of the determination of binary parameters by lunar occultation method is very high. The accuracy is capable of surpassing those of the Interferometric methods under favourable conditions. The basic advantage is created by the chance coincidence of celestial bodies, and even small telescopes at suitable geographic locations can obtain results matching those obtained by other sophisticated experiments.

REFERENCES

Africano, J.L., Evans, D.S., Fokel, F.C., and Montemayor, T.: 1977, Astron. J. *82* 631-639.

Bhattacharyya, J.C., and Sundareswaran, A.: Kodai. Obs. Bull. Ser. A. *2*, 69.

Bhattacharyya, J.C., Gokhale, M.H., and Namboodri, P.M.S.: (under preparation).

Evans, D.: 1970, Astron. J. *75*, 589.

Nather, R.E., and Mc Cants, J.: 1970, Astron. J. *75*, 963.

DISCUSSION:

A. Soemarjono:

Measurement of angular diameter (apparent) of stars.

1. What is the procedure of measurement?

2. The difference to the interferometric technique?

. Did you measure the correlation function of the optical field produced from the star at the observation baseline?

. Is your technique capable to measure the spectral density (and thus the temperature) of the star?

. Principally, how can you increase the signal-to-noise ratio? (Electrically or optically).

. What is the merit compared with the speckle technique (Labeyrie type interferometer).

1. The technique consists of the following steps

i) Record the light curve with a high speed recorder ($\sim$ 1 KHz response)

ii) Calculate occultation parameters viz. lunar limit speed, slope, distance etc.

iii) Compute Fresnel diffraction pattern due to a point source as applicable to the particular case. Information needed:

a) Wavelength of observation

b) Spectral response of filter-detector

c) Limb travel rate

d) Lunar distance

Note: If wide band filter is used integrated effect will have to be computed.

iv) Compare the distorted light curve by assuming different diameter, limb darkening etc.

v) Check the fit with the observed curve.

2. i) No.

ii) Basically yes; but, I am afraid, the sensitivity will be poor.

iii) By combining many informations. It is unsafe to tamper with bandwidth or filter. Larger telescopes (to a limit will help).

iv) Several advantages:

a. No large telescope needed.

b. Observation is simple.

c. Accuracy comparable to interferometry (Intensity).

d. Decided geographical location advantage.

Disadvantages:

a. Only stars in zodiacal belt measureable.

b. Phenomena transient (like total eclipse).

P.J. Edwards:

In New Zealand we have made frequent optical observations of lunar occultations. It is my experience that in the relatively few cases when the records are sufficiently clear to allow useful reductions for stellar diameter, the disagreement between the results from different observers usually exceeds the expected errors. Have you tried to reduce the errors due to non-gaussian scintillation noise by some technique – e.g. multicolour observations?

Answer:
Multicolour observations do help, but have not yet been employed by us. We have tried recording events from two adjacent telescopes mainly to circumvent uncertainties due to lunar limb irregularities.