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THE DETECTION OF STELLAR SYSTEMS BY LUNAR OCCULTATIONS

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RESUMEN

Se describen algunos ejemplos de la resolución de estrellas múltiples muy cercanas, mediante el método de ocultaciones lunares. De esta manera se muestran tanto el poder, como algunas de las limitaciones de esta técnica.

ABSTRACT

A few examples of the resolution of very close multiple stars by the method of lunar occultation are described. In this way both the power and some of the limitations of this technique may be demonstrated.

The suggestion of using lunar occultations of stars to measure angular diameters and to resolve very close binaries appeared in the literature at least as early as 1909 (MacMahon 1909). However, only in the last five years has this method been used in a systematic way such that a significant number of discoveries and resolutions of very close systems (angular separations less than 0.050 seconds of arc) have been made.

A sketch of the geometry of a double star occultation by the moon is shown in Figure 1. What is actually measured is the projection of the angular separation on the velocity vector of the moon at the position angle of occultation.

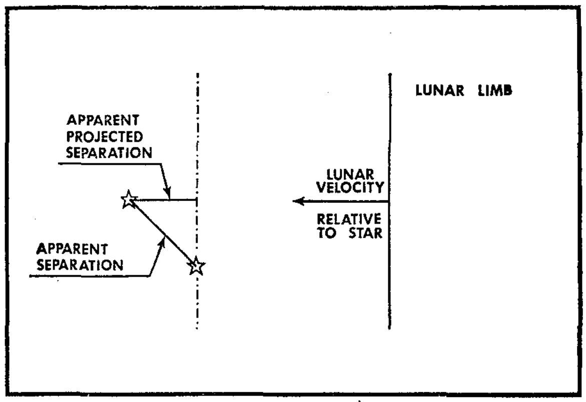

Fig. 1. The geometry of a lunar occultation of a binary. The measured time difference of occultation yields the apparent projected separation.

An observation consists of a one-to-two millisecond-per-integration record of the intensity fluctuations as the two stars are sequentially occulted by the moon. The projected angular separation is the product of the observed time difference of the occultation of the two stars and the lunar velocity at the position angle of contact. A magnitude difference is also determined; in fact, if simultaneous two-color observations are made, a color index for each component can be determined provided integrated photometry of the system exists.

An example of a double star observation is shown in Figure 2. Light intensity observed through a Johnson V passband is plotted against time with the entire trace being only about 0.15 seconds of time. This particular star, BS2304, has never previously been recognized as a double, although it is quite bright and has been observed spectroscopically several times. It is an A2Vn; that is, it has broad lines for the spectral type. (Cowley, Cowley, Jaschek, and Jaschek 1969). From the occultation trace, we have determined the visual magnitude difference ΔV to be 0.64 mag $\pm$ 0.04 and the projected separation to be 0.052 $\pm$ 0.0005 arcsec in position angle 123°.4.

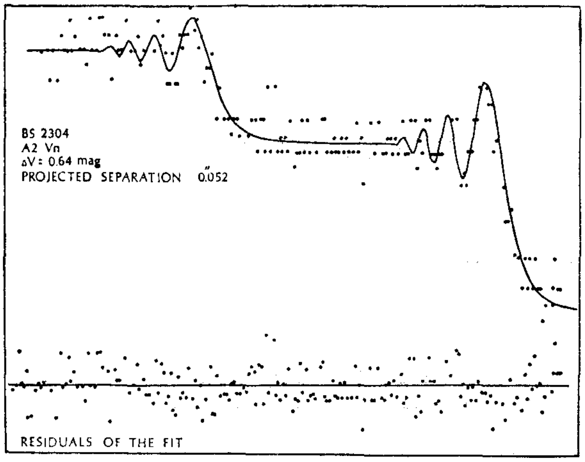

FIG. 2. A fit to an observed occultation of BS2304 with residuals plotted. Intensity is plotted against time.

In order to remove the projection effect on the angular separation, observations from two sites are required. The location of the sites must be such that a significantly different position angle of the occultation is observed. The geometry is sketched in Figure 3. Given Δ, the difference in the observed position angle at the two sites, and S_1 and S_2, the projected angular separation observed at the two sites, the angular separation, A, can be calculated.

An intensity-versus-time (0.002 seconds per integration) trace of the occultation of Tau Capricorni is shown in Figure 4. The first line is the observed trace, below which are shown the model, the fitted model, and the residuals.

This is a known binary with a class 4 (premature calculation) orbit (Finsen and Worley 1970). This star was also observed at McDonald Observatory by the University of Texas group. By combining the results of the two observations, one gets the results

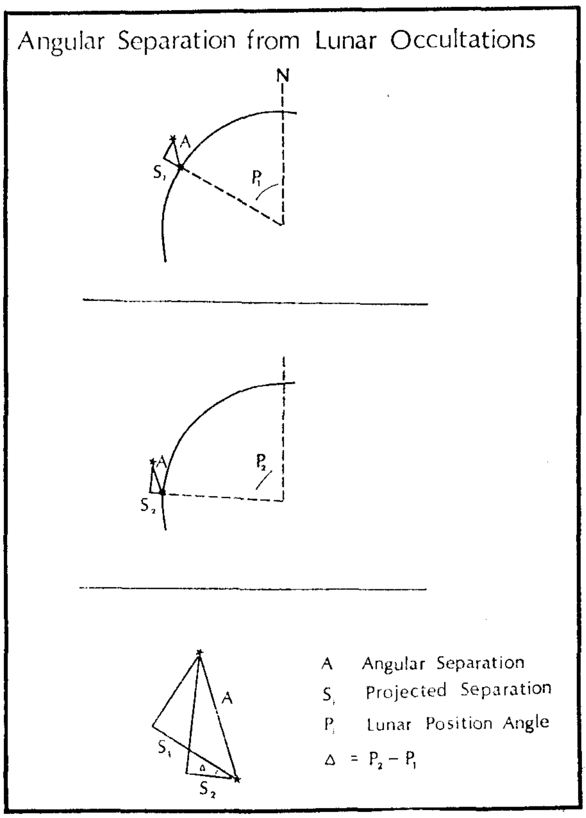

FIG 3. The geometry of a two-site lunar occultation observation of a binary. If Δ is large enough, then A, the angular separation, can be determinel.

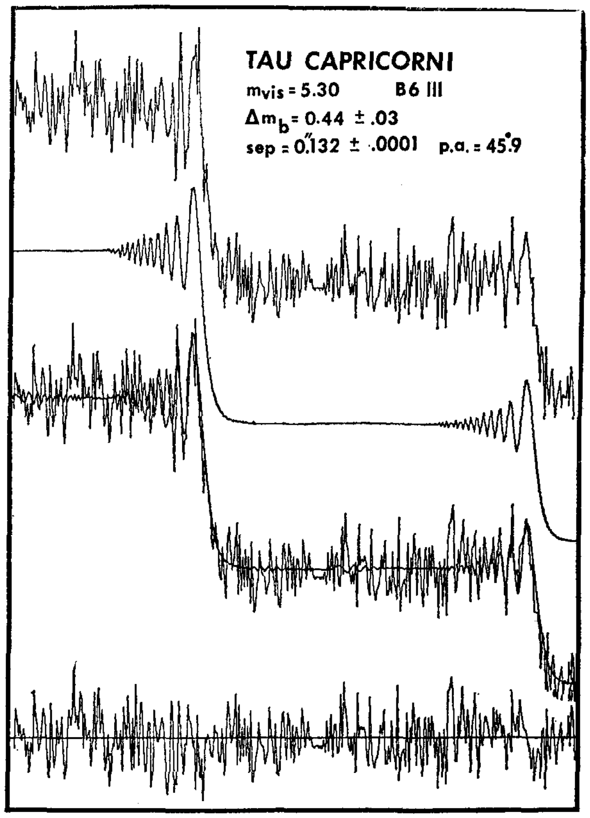

FIG. 4. A fit to an observed occultation of Tau Capricorni. From top to bottom, the observed pattern, the model, the fit, and the residuals are displayed.

TABLE 1

TAU CAPRICORNI			
	TEXAS		LOWELL
P. A.	64°.7		45°.9
SEP.	0".257 ± 0.0002		0".132 ± 0.0001
	ΔM_{BLUE} 0.42 ± 0.05		ΔM_B = 0.44 ± .03
	ΔM_{RED} 0.4 ± 0.2		
	PREDICTED (HEINTZ)		DERIVED (OCCULTATION)
A	0".23		0".352
P.A.	112°.3		113°.9

given in Table 1. From the occultations and using the geometry indicated in Figure 3, we derive an angular separation of 0.352 arcsec in position angle 113°.9, as compared with the uncertain orbital prediction of 0.23 arcsec in position angle 112°.3.

The spectroscopic binary BS3222 (Hoffleit 1964) is shown resolved in Figure 5. The format is the same as before, with 0.001 second time resolution. Although very noisy, the fit indicates a magnitude difference of 0.96 ± 0.04 in the Strömgren *y* passband. If the assumption is made that the lunar surface is perpendicular to the lunar radius at the point of occultation, then the separation is 0.0095 arcsec at position angle 72°.5. However, the observed speed of occultation was faster than predicted and can be interpreted as a slope of 7° at the point of occultation. When this is considered, the projected separation becomes 0.011 arcsec in position angle 79°.5.

As an indication of both the power and the limits of the occultation technique, Figure 6 shows a recent occultation of Iota Librae. This star is an A0p star with enhanced silicon features (Cowley *et al.* 1969) and three known fainter companions. The primary itself has been noted as having a variable radial velocity.

Because the two-color (Strömgren *y* and *b*) observations showed very good signal-to-noise ratio (only the *b* trace is shown) and the trace apparently indicated a single star, an angular diameter fit was made. The least-squares best fit of both traces implied an angular diameter of about 0.002 arcsec with an uncertainty slightly less than a millisecond of arc. However, the expected angular diameter for this star is about 0.0005 arcsec. Although this may indicate the limit of resolution in this case, I attempted a model fit assuming two stars, with the following result, which is also given in Figure 6. The companion if real, would be 1.57 magnitudes fainter in *y* and 2.77 magnitudes in *b*, giving a color index of about +1.2 in *b-y*. The separation would be

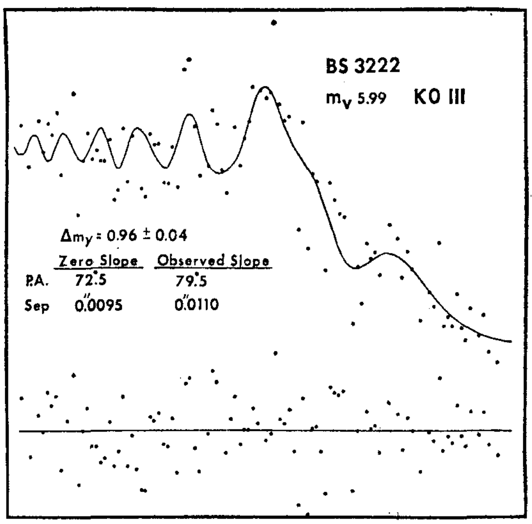

FIG. 5. A fit to an observed occultation of the spectroscopic binary BS3222.

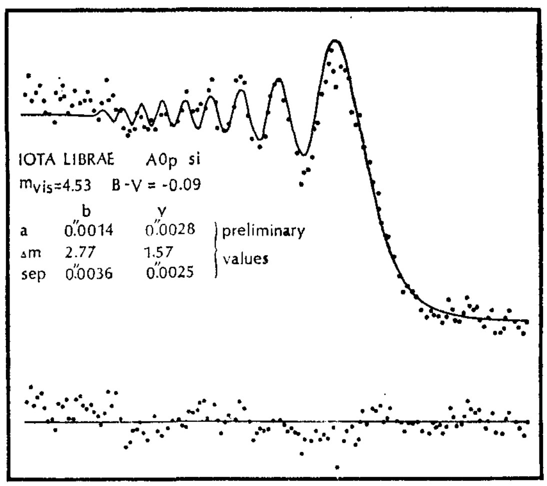

FIG. 6 A preliminary fit to an observed occultation of Iota Librae.

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0.003 arcsec. Whether this is the correct interpretation or not is certainly debatable. There is not enough information to draw a conclusion, except that the patterns appear not to be point-source patterns. It is possible that other lunar occultation observations of this star were made and that the combined data may clear up the ambiguities.

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DISCUSSION

Abt: I understand that attempts to discover occultation companions by spectroscopic techniques have often been unsuccessful. Do you have any comments on this?

White: One should probably take each case separately because there are many situations where a double star might not be recognized spectroscopically but would show up in an occultation observation. For example, an occultation observation thrives on relatively large magnitude differences, does not depend at all on relative radial velocities, and the spectral types could be very different or exactly the same and not affect the discovery probability. In addition, broad-lined components or hot and cool stars are equally likely to be discovered. All these characteristics present problems to the spectroscopist in observing double stars.

Franz: Will you attempt to analyze the Tau Capricorni observations simultaneously for both a diameter and duplicity?

White: I do not plan to at present. I would like to point out that by increasing the number of parameters governing the model it becomes easier to fit spurious observational effects.