THE DETECTION OF TRIPLE SYSTEMS THROUGH THE PRECESSION OF THE NODES EFFECT

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I. INTRODUCTION

This paper is a report on a new technique for detecting close triple stars and on a current observational project with some preliminary results, using this method. The goal of the project is to discover new triple systems where the ratio between the long and the short orbital period is small. A system will be called a close triple system if its short orbital period is of several days.

In most of the known triple stars (Fekel 1981), the period ratio is very large. This can be attributed to the fact that the wide orbit has been detected visually in most cases. In the few exceptions (e.g. λ Tau, Ebbighausen and Struve 1956), the wide orbit was discovered by detecting additional periodicity in the derived velocity of the close pair mass center γ As this small modulation is imposed on the large radial velocity variation associated with the orbit of the close pair, many triple systems could have escaped this kind of detection. Consequently, the present typical or averaged period ratio might be highly overestimated.

The period ratio in multiple stars in general is an important parameter for the theory of star formation (Bodenheimer 1978), and therefore the correct estimate for its typical value should be attained carefully. Moreover, if one could have in hand a large sample of the close triple systems, a detailed comparison with their evolutionary theory (Mazeh and Shaham 1978) might also be possible. Therefore, it could be useful if an efficient survey of the known spectroscopic binaries could nowadays be performed in order to detect possible close third companions.

II. THE NODAL PRECESSION EFFECT

The present method for detecting triple systems is based on the Nodal Precession of the binary plane caused by the third star. Due to the third star second order gravitational interaction with the close pair, the angular momentum of the binary $L_{1,2}$ precesses around the total angular momentum of the system L. As a result, the angle between $L_{1,2}$ and any direction which is relatively constant in space (but not coinciding with L) undergoes periodic changes as depicted in figure 1. These can lead to genuine, as well as apparent changes in the binary system. When the fixed direction is our line of

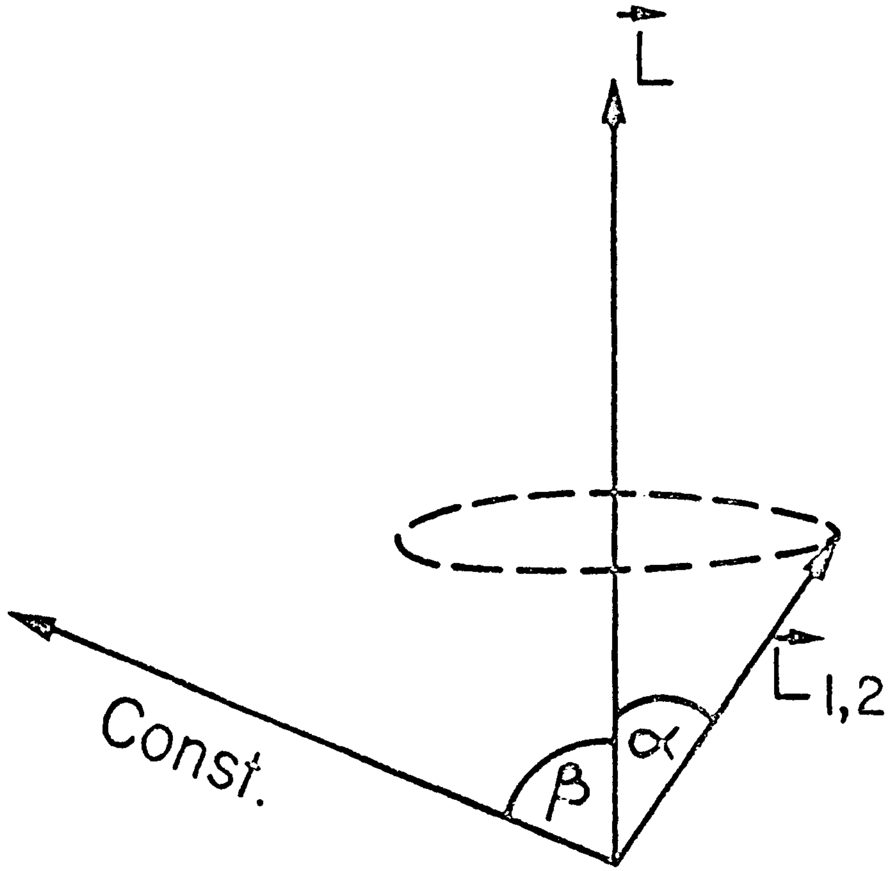

Fig. 1: The Precession of the Nodes Effect

sight, we have periodic changes in the inclination of the binary plane relative to us (Mazeh and Shaham 1976, Soderhjelam 1975). These bring about periodic variation in the amplitude of the radial velocity of the spectroscopic pair. Large enough variation of K should be detectable by remeasuring the radial velocity of the system in different phases of the precession period. Any change of K should be a hint for a possible companion to the binary system.

The amplitude of the inclination modulation depends strongly on the angle between the binary orbital plane and the orbital plane of the third star. The precession angle is zero if the three star motion is coplanar, and it might be very large when there is a large angle between the two planes of orbit. In a very recent study, Fekel (1981) found that at least a third of the known triple system have noncoplanar orbits. Although his sample includes only few systems with small period ratio, it is encouraging to find some evidence for noncoplanar mechanism in the star formation process.

One may expect to detect the precession effect in cases where the precession period T_{prec} is not too long. The Perturbation theory of Harrington (1968, 1969) yields

$$T_{prec} = \frac{m_1 + m_2}{m_3} \left(\frac{T_3}{T_{1,2}}\right)^2 \eta \qquad (1)$$

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where m_1 and m_2 are the masses of the close pair; m_3 is the mass of the third companion which orbits in the wide orbit; $T_{1,2}$ and T_3 are the short and the long periods, respectively; and η is a geometrical factor of order unity (see Mazeh and Shaham 1976; Soderhjelm 1975). Consider, therefore, as an example a case where

$$m_1 = m_2 = 1M_\odot \qquad m_3 = 0.2M_\odot \qquad T_{1,2} = 4 \text{ days} \qquad T_3 = 100 \text{ days}$$

The amplitude of the binary radial velocity variation is

$$K_1 = K_2 = 85\sin i_{1,2} \text{ km s}^{-1}$$

while the binary mass center will follow a modulation with

$$K_{1,2} \simeq 6 \sin i_3 \text{ km s}^{-1}$$

where $i_{1,2}$ is the binary inclination and i_3 is the orbital inclination of the third star. In such a system it was almost impossible to detect undeliberately some evidence for the third star in the composite spectrum of the system or to follow such small variation of γ induced by the third star. However, in a favorite configuration in space K_1 and K_2 might be changed during the precession period $T_{pres} \sim 50$yrs.

The orbital elements of many spectroscopic binaries has been known accurately for thirty years or more. Systems with no peculiarities have not been remeasured since then. We suggest here to check systematically all these spectroscopic binaries, to measure independently their present value of K_1, and to compare it with the old one. If the binary period itself is constant while K_1 is varying, the system is suspected to be a triple star. In a case of a double line spectroscopic binary, the precession effect will be such that

$$\frac{\Delta K_1}{K_1} = \frac{\Delta K_2}{K_2} \qquad (2)$$

where ΔK_1 and ΔK_2 are the variations of K_1 and K_2 respectively. Fulfillment of eq. (2) should serve as another indicator for the third star existence. To confirm the star multiplicity directly a system found in this survey should be followed carefully to detect either a small periodic variation of γ or some foot-prints of the third star in the composite spectrum of the system.

III. THE PRESENT PROJECT

29 stars out of the Batten et al. catalog (1978) have been chosen for the present project. The list includes systems where:

1) The stars are not earlier than F0;
2) The orbit quality (in the Batten et al. (1978) classification) is better than c;
3) The system is not eclipsing;
4) The star is north of -10°; and
5) The period is $2^d \leq P \leq 9^d$.

All of them, except for 2, have been currently measured with the CORAVEL machine at the observatory of Geneva (Baranne et al. 1979). For 18 of them, preliminary results for K can be derived. The results seem encouraging:

A. For 9 systems we got very good agreement ($\Delta K \lesssim 1$ km s^{-1}) between the new and the old value of K. In some, the difference is as low as 0.2 km s^{-1}.

B. For 6 systems, 1 km $s^{-1} \lesssim \Delta K \lesssim 4$ km s^{-1}, and further observations are needed in order to get better accuracy.

C. Three systems of which the results are brought in table 1, look very promising. Two of them are double line spectroscopic binaries and the fact that

$$\frac{\Delta K_1}{K_1} \simeq \frac{\Delta K_2}{K_2}$$

seems to make the detected variation above the 3σ confidential level. In one system -HD 144515 the difference is large, and $\Delta K/K$ = .32%. We would like to emphasize again that the results are preliminary and further observations are under way.

TABLE 1

Possible Close Triple Systems

Star	Old K (km/sec)	New K (km/sec)
HD 100018	76.2	72.7 ± .4
	84.5	81.9 ± .5
HD 109510	66.3	69.7 ± .5
	77.4	80.8 ± .7
HD 144515	38.1	50.2 ± .6

IV. CONCLUSIONS

We have shown that a new way for detecting low mass third companion of a confirmed spectroscopic binary can be applied nowadays. The preliminary results are encouraging, showing variations of the binary inclination over some tens of years in a few cases. Other systematic projects for early type stars, short period ($< 2^d$) spectroscopic binaries and southern stars would also be very useful.

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DISCUSSION

BATTEN: Values of K_1 and K_2 can depend on the dispersion used, and one should be cautious in interpreting old observations already published. Relative phasing of the two periodic motions in a triple system may also affect the values determined for K_1 and K_2, and this might be comparable with the effect you have described.

MAZEH: I agree with the first comment. The second refers to the motion of the center of mass of the binary around the center of mass of the system, and this might be too small to be detected in my case where I was limited to a low-mass third star. If the third star were massive, you would be able to detect the variable radial velocity of the binary system.

ABT: This question is related to Dr. Batten's. You quoted the errors in the new observations but not in the older data. Can you determine the errors in the old data from the scatter of the data about the computed curves?

MAZEH: If I take the published scatter, I get the three-sigma, but we must reanalyze the old data and reestimate their sigmas.

SCARFE: It is not possible to determine the total angular momentum even for a three-spectrum system from visual and spectroscopic data alone, since the longitude of the node in the short-period orbit is not known. This kind of observation would permit this determination, and this is useful for systems with substantial other information available.

POPPER: In computing the values of K obtained at different times, it is important to use the same value of eccentricity in the two cases. Another means of detecting a change in orbital plane could be the changing depth of eclipse in an eclipsing binary. One possible case may be IU Aur.

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