THE FREQUENCY OF CEPHEID BINARIES

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Abstract: We summarize the methods now available to detect the presence of companions to Cepheids, and then we analyze the results of the application of the recent photometric method proposed by Fernie (1980). If applied to the set of VBLUW observations of southern Cepheids carried out by Pel (1976), this method gives a frequency of about 25°/$_o$, which is consistent with the more recent spectroscopic determinations (Gieren, 1981). The importance of the IUE satellite to directly observe the U flux emitted by the B-companion is emphasized.

It is known that a 3-9 $M_\odot$ star will cross the instability strip several times, and that classical cepheids are at their second-third crossing. If the star is a member of a binary system, the critical orbital period of the binary, in order to have the primary to cross the instability strip two times, is of the order of 200 days (Lloyd Evans, 1968). Therefore, it is difficult to resolve them directly, with photometric or spectroscopic observations. Nevertheless, it is important to know their number, in order to have a statistical test of evolutionary calculations for binary systems: in fact Cepheids evolve from B-stars, which, are well known to show a very high incidence in binary systems (Petrie, 1963; Abt and Levy, 1978). For long time the incidence of binaries among cepheids was thought to be no more than 5°/$_o$ (Abt, 1959), but this number has increased in the course of the years: 15°/$_o$ according to Lloyd Evans (1968); somewhat more according to Madore (1977) and Pel (1978), and up to 35°/$_o$ according to Madore and Fernie (1980). Many methods have been proposed to detect the binary cepheids. The first one of wide applicability is the one by Lloyd Evans (1968), based on the search of variable systemic velocities. However, good quality radial velocity curves are very rare, and only in recent years the method is being profitably used (Gieren, 1981). Direct spectroscopic

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evidence of a composite spectrum in the visible has been possible only in a few cases (Lloyd Evans, 1968) while the detection of the UV emission of blue companions to cepheids has begun with the IUE satellite (Eichendorf, 1981; Mariska et al., 1980), but has not yet been widely applied. Photometric methods, based on the opening of the colour-colour loops (Madore, 1977) or on the amplitude ratios among various filters (Fernie, 1979), are more suited to measure the frequency of Cepheid binaries, but cannot be used to ascertain without doubts the binary nature of individual cepheids.

Recently, Fernie (1980) has proposed a new photometric method, based on the measure of the shift between the light and colour curve (from now on, we will use only the U-V as colour curve). The basis of the method is the following: if the cepheid has a B-companion (from evolutionary considerations, these should be the most frequent ones), the phase of minimum light $\varphi^{min}(V)$, is unaffected, but $\varphi^{min}(U-V)$ will be altered, because the colour of the system is changed and, in practice, it will be shifted towards earlier phases, with a shift depending on the luminosity of the B-star (cf.Fernie, 1980). This method has already been applied by Madore and Fernie (1980) to UBV photometry. This photometric system, in my opinion, is not well suited for such a study, because of the low quality of U observations. As a matter of fact, the VBLUW photometry of southern Cepheids carried out by Pel (1976) is, on the contrary, especially suitable for this purpose. In order to apply Fernie's method to VBLUW photometry, one needs, first of all, a calibration of the phase shift

$$\delta\varphi = \varphi^{min}(V) - \varphi^{min}(U-V)$$

in terms of the magnitude difference between the cepheid and the B-companion. This has been done by Russo et al. (1981), who have also computed the parameter $\delta\varphi$ for 88 cepheids taken from Pel (1976) and with good quality U data. This parameter has been computed by fitting Fourier series to the U and U-V curves. The resulting distribution of $\delta\varphi$ is shown in Figure 1.

It can be see that the distribution is both skewed and displaced from zero with a maximum at about $\delta\varphi = 0.04$. If we assume that the non-gaussian part of the distribution is due to cepheids with possible companions, than we can estimate the percentage of binary cepheids to be 25 (±3)°/₀ of the total. However, it is not simple to judge if an individual cepheid with high $\delta\varphi$ is in the tail of the gaussian distribution, or if it belongs to the non-gaussian part, i.e., if it can safely be considered as having a companion. Moreover, we can in this way detect only cepheids with B-companions, which are the most frequent ones, but not the only ones.

Another interesting question arises from the consideration of the

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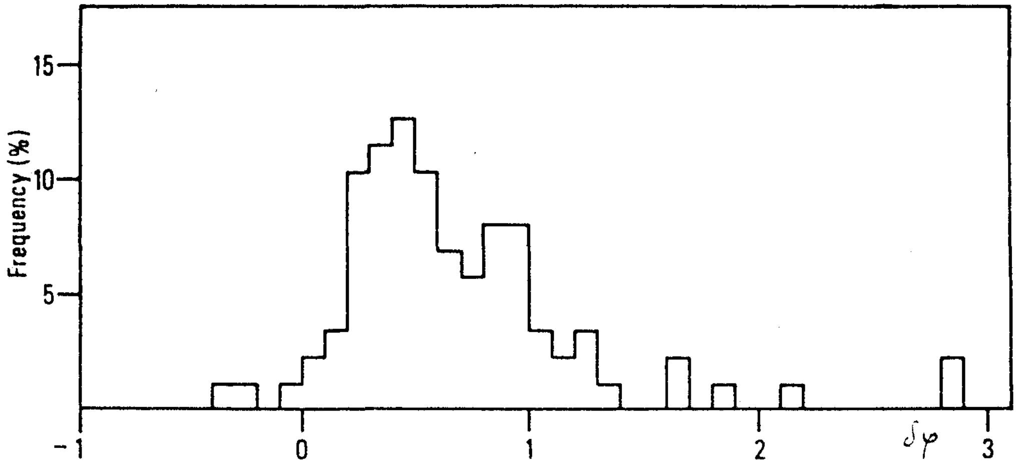

Figure 1: The distribution of $\delta\varphi$ values for 88 cepheids.

separation between the cepheid and its companion. From Kepler's third low, assuming a period of two hundred days, and a total mass of 20 $M_{\odot}$, we obtain a separation of the order of one a. u.. With a radius of $\sim 50\ R_{\odot}$ for the cepheid and $\sim 3\ R_{\odot}$ for the main sequence B-companion, the double system, although obviously detached, is a close binary system. This means that one should study the proximity effects on the cepheid due to the presence of the companion, and which should have consequences on the pulsation itself, like the pumping of non-radial oscillations and double mode phenomena.

In conclusion, we can say that:

- the percentage of galactic cepheids which have blue companion is estimated by different authors to be about 25°/₀, and seems well based;
- the identification of these binary systems is at the beginning, and only a few cases have been ascertained; in this purpose, the IUE satellite (and future UV satellite) can give a substantial contribution;
- the physics of such systems has not yet been explored, and many interesting phenomena will be faced in the near future.

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References

Abt, H.A.: 1959, Astrophys. J. 130, 769
Abt, H.A. and Levy, S.G.: 1978, Astrophys. J. Suppl. 36, 241
Eichendorf, W., Heck, A., Isserstedt, J., Lub, J., Pakull, M., Reipurth, B., and van Genderen, A.M.: 1981, Astron. Astrophys. 93, L5-L6
Fernie, J.D.: 1979, Publ. Astron. Soc. Pac. 91, 67
Fernie, J.D.: 1980, Astron. Astrophys. 87, 227
Gieren, W.: 1981, Astrophys. J., submitted
Lloyd Evans, T.: 1981, Mon. Not. Roy. Astron. Soc. 141, 109
Madore, B.F.: 1977, Mon. Not. Roy. Astron. Soc. 178, 505
Madore, B.F. and Fernie, J.D.: 1980, Pub. Astron. Soc. Pac. 92, 315
Mariska, J.T., Doschek, G.A., and Feldman, U.: 1980, Astrophys. J. Lett. 238, L87-L90
Petrie, R.M.: 1963, in Basic Astronomical Data, p. 64 (Univ. of Chicago Press)
Pel, J.W.: 1976, Astron. Astrophys. Suppl. 24, 413
Pel, J.W.: 1978, Astron. Astrophys. 62, 75
Russo, G. Sollazzo, C., and Coppola, M.: 1981, Astron. Astrophys, in press

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