CEPHEID COMPANIONS AND THE MASSES OF CEPHEIDS

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ABSTRACT

We have observed in the ultraviolet the hot companions of the Cepheids SV Per, RW Cam, SY Nor and KN Cen. The study of the absolute and relative intensities reveals that all, except the companion for KN Cen are evolved stars which should fit on almost the same mass track as the Cepheid. We find however that with generally accepted reddening values the companions of at least SV Per and RW Cam are too faint. Either the Cepheid loops are more luminous than presently calculated or the reddening is larger than presently accepted.

We have obtained low resolution short wavelengths IUE spectra for the hot companions of the population I cepheids SV Per, RW Cam, SY Nor and KN Cen. The ultraviolet fluxes of the companions are lower than expected.

The true energy distribution of the companions can only be obtained after correction for interstellar extinction. The correction depends on the color excess and on the ultraviolet extinction law. We have used Seaton's average galactic extinction law.

Generally we can say the lower the assumed value for E(B-V) the lower will be the true stellar flux and the lower will be the luminosity of the star which matches the observed flux. For small E(B-V) we find that the companion has to be a main sequence star, for larger E(B-V) the companions is found to be a giant or even supergiant. The overall fit of the energy distribution and the limits for the visual magnitude must help us to decide which of the possibilities is the correct one.

For a given E(B-V) the absolute flux at 1350 Å determines a relation between T_{eff} and R. The observed relation between R and T_{eff} for main sequence stars or for average giants gives another relation between R and T_{eff}. For a given E(B-V) the R and T_{eff} can thus be determined uniquely either for main sequence stars or for average giants.

A. Maeder and A. Renzini (eds.), Observational Tests of the Stellar Evolution Theory, 449–452.

The final value of E(B-V) and thereby T and R is determined from the best fit of the overall observed energy-distribution with model energy distributions as seen in Figure 1.

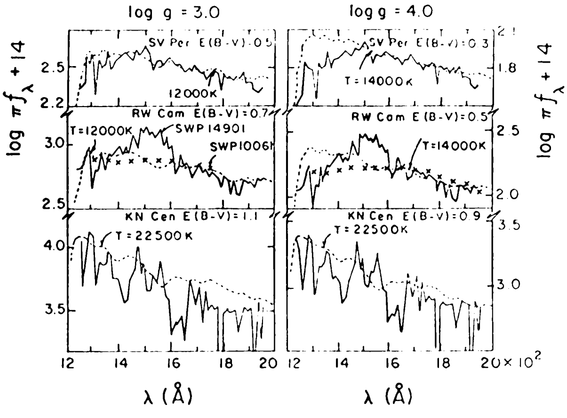

Figure 1 shows a comparison between observed and theoretical energy distributions for giant companions. Also shown is the similar comparison for main sequence companions.

The fit is much better for giant stars. For main sequence stars we also derive too small a flux for the companion in the optical region. We conclude that the companions must be giants.

In the T_{eff}, L diagram the cepheids and the companions should fit on one isochrone. Figure 2 shows that this is not the case for SV Per, RY Nor and especially RW Cam.

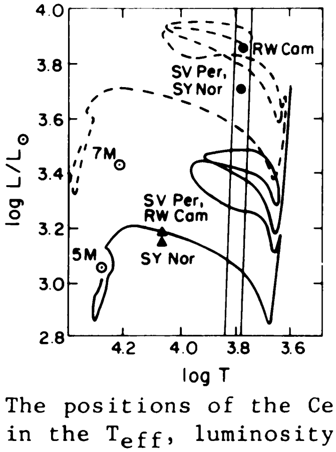

Figure 2. The positions of the Cepheids and their giant companions in the T_{eff}, luminosity diagram. Also shown are evolutionary tracks for different masses according to Becker, Iben and Tuggle 1977.

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It appears that the cepheids are too luminous for this. We see basically two possibilities to resolve this discrepancy:

a) The cepheids have indeed lower masses and the loops occur at higher luminosities than calculated so far, or

b) we have used the wrong relation R(T) and therefore perhaps too small a value for E(B-V).

The reddenings required for the best overall fit temperatures are given in Table 1, where we also give the measured values for E(B-V). The required values appear rather high, though not completely out of the range of previously determined values.

TABLE 1. Measured and required values for the color excess E(B-V)

Star	E(<B>-<V>)[1] measured best value	E(<B>-<V>) range	E(B-V) giants	E(B-V) required T=12000K	E(B-V) required T=13000K
SV Per	0.37	0.32-0.65	0.45	0.53	0.55
RW Cam	0.53	0.53-1.03	0.66	0.79	0.82

[1]According to Dean, Warren and Cousins 1978.

Whether possibility a) or b) is the correct answer to our problem must be decided by accurate determinations of E(B-V).

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DISCUSSION

Frogel: Are there any Cepheids with red companions?

Böhm-Vitense: Yes, but we only considered Cepheids with blue companions which can be observed in the UV where the intensity of the Cepheid proper is very small. Red companions are hard to observe unless they are red giants of large luminosity. Red main sequence stars could not be seen.

Lloyd Evans: A study using infra-red photometry of suspected cases of Cepheids with red companions gave no convincing detections. However, the observational test is harder than with hot companions, because the colour difference is smaller.

Conti: How sensitive are the conclusions to the adoption of a standard UV extinction law? Savage and associates have just published studies showing substantial variations from place to place in the Galaxy. Even within a cluster, the UV extinction seems to vary, as compared to E(B-V).

Böhm-Vitense: In order to put the companions on the evolutionary track required by the Cepheid with accepted E(B-V) values we would need to increase the UV extinction to values larger than observed anywhere in the galaxy. The largest observed extinction (ξ Oph) will not do it. I do not know whether it would be possible that the Cepheids have some unusual circumstellar extinction.

Lynas-Gray: Did you use the Kurucz (1979, Astrophys. J. Suppl. 40, 1) model atmospheres?

Böhm-Vitense: Yes.

Waelkens: Did all the Cepheids that showed peculiar loops in the colour-colour diagrams and that you studied turn out to have blue companions on your ultraviolet spectra? If not, how can the loops be explained?

Böhm-Vitense: Not all the Cepheids with open loops in the two colour diagram do have observable blue companions. For none of the population II Cepheids with open loops did we see a blue companion. The open loops appear to be intrinsic. Several population I Cepheids with small open loops also do not have observable blue companions.