SOME REMARKS CONCERNING THE ACCURACY OF PHOTOMETRIC REDDENINGS FOR CLASSICAL CEPHEIDS

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Considerable effort has been spent over the years in deriving colour excesses for classical Cepheids using their observed photometric indices. Various broad band, intermediate band, and narrow band systems have been used for this purpose, all with varying degrees of success. Reddenings derived in this manner are extremely useful, and most of the factors which limit their accuracy seem to be reasonably well known. Two others, which often tend to be overlooked but which are addressed here, are the presence of photometric companions to many Cepheids and the tendency to treat interstellar reddening in a prescriptive manner. The point is not necessarily to raise doubts about the validity of published photometric reddenings for classical Cepheids, but rather to examine the possibility that one can derive slightly more reliable colour excesses using the available observational data.

PHOTOMETRIC COMPANIONS

Many Cepheids, probably in excess of 25%, have been found to have unresolved companions in recent years, with blue companions encountered more frequently than red companions. The majority are probably physical, being late B or early A stars formed with the Cepheid, but, being of smaller mass, still residing close to the ZAMS in the H-R diagram. Such companions tend to be faint, and differences of 3^m or 4^m (or more) with respect to the Cepheid primary are not uncommon.

Fig. 1 plots the effect that a blue companion, chosen here to have the colours of an A0 star, has on the mean colours (in this case B-V and R-I) of a typical classical Cepheid with $P \simeq 5^d$. Fig. 1 is intended only for illustrative purposes, but it raises an interesting point, namely that blue companions 4^m or 5^m less luminous than the Cepheid can make the mean colours of the system $0^m.01$ to $0^m.02$ too blue in B-V. A photometric reddening for such a system using UBV colours would tend to be systematically too small by the same amount, and this can be as large as $0^m.05$ for a companion only 3^m fainter.

Similar problems exist for most systems centred on the blue end of the spectrum, although these can be reduced using near infrared photometry. The contamination in R-I, for example, is 3 or 4 times smaller than that in B-V in Fig. 1, although the magnitude range of R-I colours is only half that of B-V colours. In the case of a red companion, however, there may be no advantage gained from using near infrared photometry.

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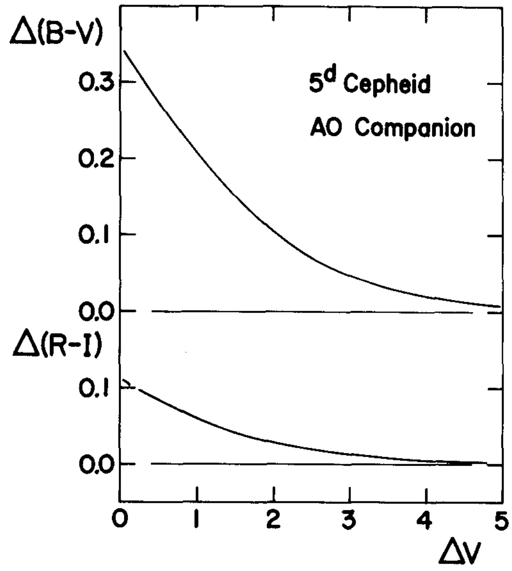
Figure 1.



Clearly there is considerable advantage in knowing if a Cepheid has a companion before one derives its photometric reddening. On the other hand, how reliable is a photometric reddening estimate when it is not known if the Cepheid has an unseen companion?

INTERSTELLAR REDDENING

So many theoretical studies have been done of interstellar reddening in the various photometric systems that one tends to overlook the observational results which are available. My own work has involved examining the reddening slope in the UBV system using the best available photometry and MK spectral types published for early-type stars in restricted regions of the galactic plane where the reddening varies by more than a magnitude in E(B-V). Regression fits made to the data for stars in 6 different regions lead to the conclusion that the curvature term in the reddening slope E(U-B)/E(B-V) is constant near +0.02, but the slope itself varies with location in the Galaxy over an extreme range from 0.62 to 0.80. The average slope is close to the canonical value of 0.72, but only in 1 of the 6 regions examined did the calculated slope actually fall within ±σ of this value. The

Table 1. Reddening Parameter Variations

E_{U-B}/E_{B-V}	E_{m_1}/E_{b-y}	E_{c_1}/E_{b-y}	E_{khg_2}/E_{b-y}
0.65	-0.38	0.13	-0.02
0.72	-0.35	0.18	-0.01
0.75	-0.33	0.20	-0.03
0.80	-0.31	0.23	-0.02
Feltz & McNamara	-0.35	0.20	+0.44

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interstellar reddening relation appears to vary throughout the Galaxy, and its exact form depends upon the region being examined. Since most photometric analyses of Cepheid reddenings assume that a constant interstellar reddening law is valid, this is bound to introduce some errors into the resulting values of colour excess.

Photometric indices most susceptible to reddening slope variations are those which involve colours in the violet portion of the spectrum, where the reddening law varies most. Table 1 lists for 4 different UBV colour excess ratios the corresponding results calculated for a few specific photometric colour excess ratios, namely those involving the Strömgren m_1 and c_1 indices, and the narrow band khg_2 index defined by McNamara et al. (1970). The Strömgren m_1 and c_1 indices involve violet and ultraviolet colours, respectively, and show distinct variations in reddening slope from the mean values assumed in most studies. The khg_2 index, however, was designed to be almost reddening-independent, and this is confirmed here.

The last line of Table 1 shows the reddening slopes used by Feltz & McNamara (1980) in their examination of photometric reddenings for 41 classical Cepheids using a mixture of Strömgren photometry, Hβ photometry, and khg_2 photometry. The Strömgren m_1 and c_1 indices are somewhat poorly suited for determining Cepheid reddenings, unless one is prepared to treat the reddening law for each Cepheid on an individual basis. Hβ photometry also seems to be ill-suited for this purpose, perhaps because of the magnitude of the scatter in published data. The khg_2 index, however, seems to be ideally suited to the problem, but it is surprising that Feltz & McNamara (1980) found it necessary to use a large reddening correction for what was designed to be a reddening-free index. This is likely to be an error on their part.

Table 2 lists space reddenings recently derived for 5 Cepheids (Turner 1984) using stars in their immediate vicinities which seem to be either physically related to the Cepheids or to lie at roughly the same distance. These reddenings have been combined with the b-y and khg_2 photometry of Feltz & McNamara (1980) for these variables, with the results plotted in Fig. 2. It should be evident from the plotted data that the khg_2 index is an excellent temperature indicator for most Cepheids since it correlates extremely well with unreddened b-y colour. There is a slight difference in this dependence between the declining

Table 2. Cepheid Space Reddenings

Cepheid	P^d	E_{B-V}	Origin of Space Reddening
SZ Tau	3.15	0.30	Nearby Coronal Members of NGC 1647
α UMi	3.97	0.01	Nearby Companion of Similar Distance
BB Sgr	6.64	0.30	Nearby Coronal Members of Cr 394
ζ Gem	10.15	0.04	Nearby Companion of Similar Distance
SV Vul	45.10	0.45	Nearby Members of Vul OB1 Subgroup

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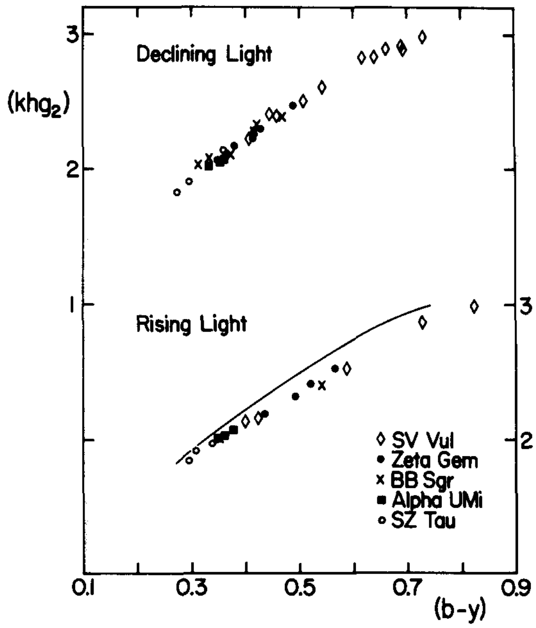
Figure 2.



light and rising light portions of the light curves, and blue companions do produce difficulties, as outlined by Feltz & McNamara. However, the khg_2 photometry of Feltz & McNamara (1980) appears to be a better indicator of Cepheid reddening than these authors realize. Regrettably, the reddenings derived by Feltz & McNamara from their data are seriously compromised by their adopted reddening corrections. In particular, their reddening estimates tend to be systematically too large, except perhaps for the least reddened Cepheids. Since the khg_2 photometry of Feltz & McNamara (1980) is itself otherwise ideally suited for the determination of photometric reddenings for Cepheids, one may hope that it will be possible to extend such photometry to additional Cepheids.

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