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# MULTICOLOUR PERIOD–LUMINOSITY RELATION FOR CLASSICAL CEPHEIDS

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Nine Cepheids in seven Galactic open clusters are used to derive consistent period–luminosity relations in the *BVRI* (Johnson), $(RI)_c$ (Kron–Cousins), and *JHK* (CIT) bands. The scatter of the PL relation decreases with the effective wavelength of the filter and is equal to only 0.05 mag for the K band. The distance modulus of the Large Magellanic Cloud is estimated at $18.25 \pm 0.05$ mag, in good agreement with the value inferred from RR Lyrae variables and the expansion parallax of SN 1987 A.

KEY WORDS Cepheids, PL relation, LMC, distance modulus

## 1 PERIOD–LUMINOSITY RELATIONS

To derive consistent multicolour – $BVRI(RI)_cJHK$ – period–luminosity relations for Galactic classical Cepheids we used nine secure Cepheid members of seven open clusters (not stellar associations or complexes – see Berdnikov and Efremov, 1985). Intensity-mean $BVRI$ (Johnson), $(RI)_c$ (Kron–Cousins) magnitudes for these stars are based on all published photoelectric measurements available in our Cepheid data bank (Berdnikov, 1995) and those for $JHK$ (CIT) are taken from Berdnikov *et al.* (1996). We adopted the periods of Cepheids from the fourth edition of the *General Catalogue of Variable Stars* (Kholopov *et al.*, 1985–1987). We determined the distances of open clusters by fitting their main sequences to the ZAMS of Kholopov (1980) with allowance for evolutionary effects (isochrones by Maeder and Meynet (1991) were used) and the colour excesses, from $U - B$ and $B - V$ colours of blue member stars. To allow for interstellar extinction, $A_\lambda = R_\lambda \times E_{B-V}$, we assumed $E_{B-V}$ to be equal to the mean colour excess of the blue stars of the corresponding cluster and adopted the following total-to-selective extinction ratios, $R_\lambda$:

$$A_B : A_V : A_{\rm rc} : A_R : A_{\rm Ic} : A_I : A_J : A_H : A_K : E_{(B-V)} =$$
$$4.260 : 3.260 : 2.590 : 2.325 : 1.863 : 1.495 : 0.772 : 0.469 : 0.274 : 1$$

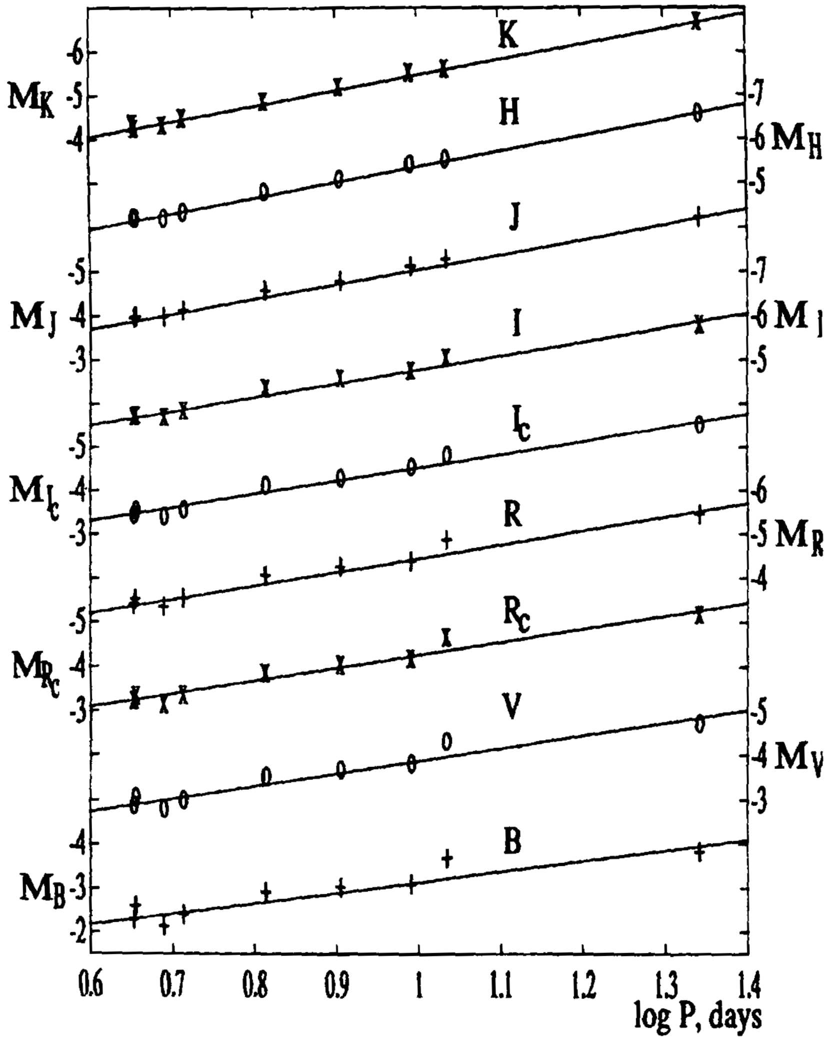


**Figure 1** Multicolour period-luminosity diagrams for Galactic Cepheids. Solid lines correspond to linear PL relations (1) (see text).

taken either from Berdnikov *et al.* (1996) ($BVRIJHK$) or calculated from $R_\lambda$ for $BVI$ (Johnson) using the known relations between $(V - R)$ and $(V - R)_c$ and between $(R - I)$ and $(R - I)_c$ (Landolt, 1983).

Figure 1 shows the log $P - \langle M_\lambda \rangle$ diagrams for $BVRI$ (Johnson), $(RI)_c$ (Kron-Cousins), and $JHK$ (CIT) bands and the corresponding linear PL relations:

$$\langle M_\lambda \rangle = a_\lambda + b_\lambda\,(\log P - 1). \qquad (1)$$

Figure 2 shows the zero point, $a_\lambda$, slope, $b_\lambda$, and the dispersion, $\sigma$, as a function of the effective wavelength, $\lambda_{\rm eff}$, of the filter compared with similar relations for the

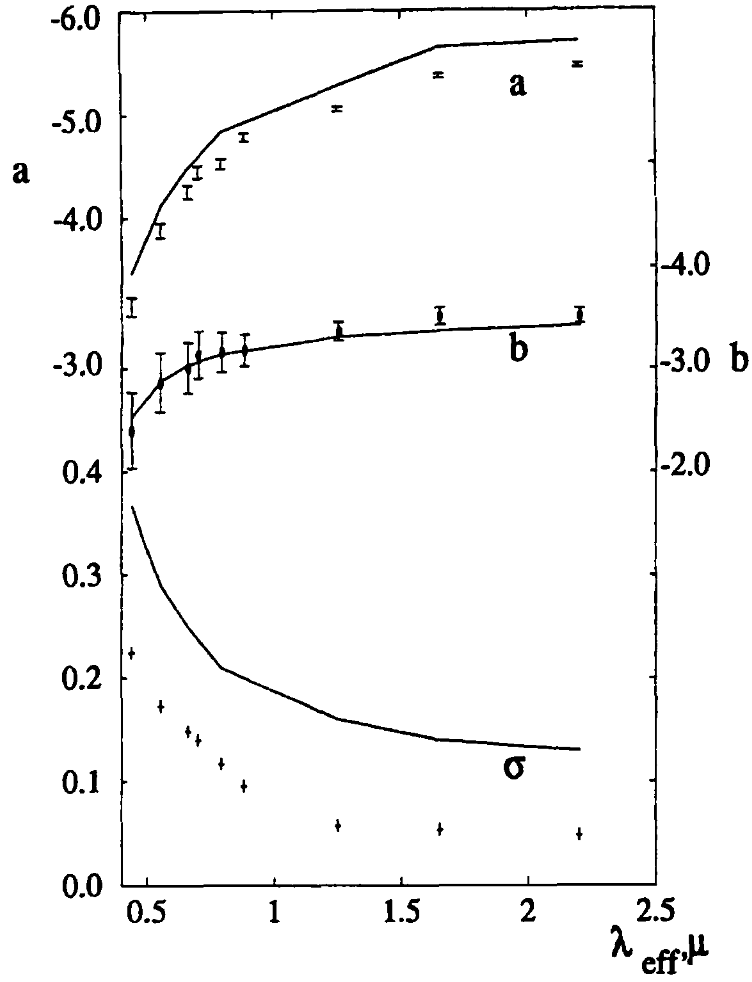


**Figure 2** The zero point, $a$; slope, $b$, and dispersion, $\sigma$, of the PL relation as a function of the effective wavelength of the photometric passband, $\lambda_{eff}$.

Large Magellanic Cloud (LMC) Cepheids (Madore and Freedman, 1991). As evident from Figure 2, the slope of the PL relation, $b_\lambda$, increases and dispersion, $\sigma_{M_\lambda}$, decreases with the wavelength of the filter.

Our slopes, $b\lambda$, are consistent with those of the corresponding PL relations for the LMC Cepheids (Madore and Freedman, 1991). However, the dispersions of our $JHK$ PL relations are significantly smaller than those of the corresponding relations in the LMC which might be due to the fact that we derived our $\langle J\rangle$, $\langle H\rangle$, and $\langle K\rangle$ intensity-mean magnitudes mostly from well-defined light curves. Furthermore, the assumption of Madore and Freedman (1991) that all LMC Cepheids have the same colour excess, $E_{(B-V)} = 0.10$ mag, could be an additional source of scatter on their observed PL diagrams.

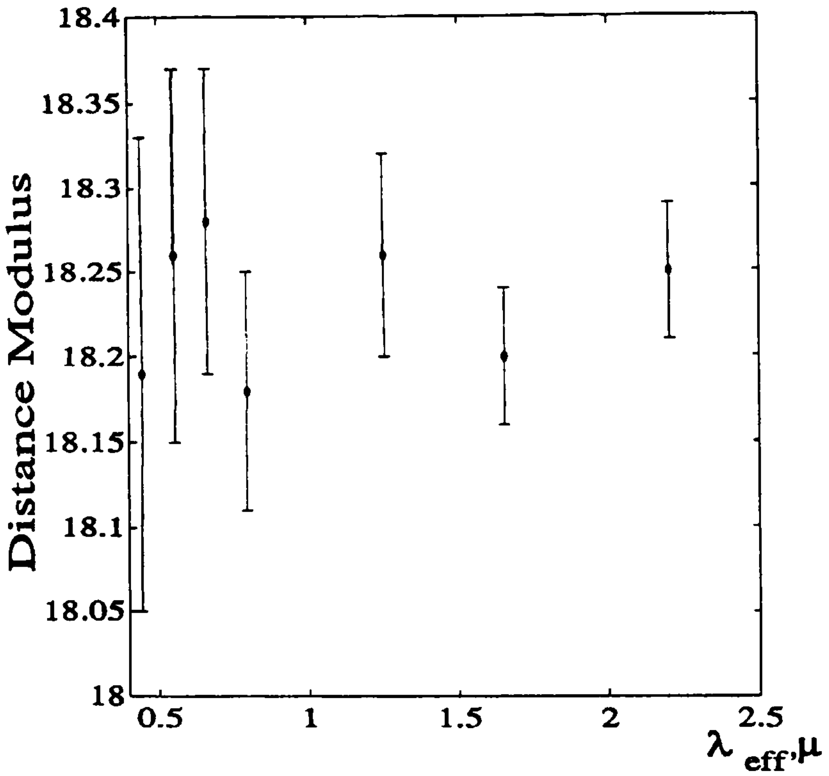


**Figure 3** The distance modulus of the LMC inferred from the Cepheid PL relation as a function of the effective wavelength of the photometric passband, $\lambda_{\rm eff}$.

## 2 THE DISTANCE MODULUS OF THE LMC

We estimated the distance modulus of the LMC by comparing the zero points of our PL relations with those for the LMC Cepheids (Madore and Freedman, 1991).

Figure 3 shows the LMC distance modulus thus inferred from log $P - \langle M_\lambda \rangle$ diagrams for $BVRI$ $(RI)_c$, and $JHK$ (CIT) PL relations as a function of the effective wavelength, $\lambda_{\rm eff}$.

The distance modulus of the LMC is most accurately inferred from infrared (JHK) PL relations – $DM$(LMC) $= 18.25 \pm 0.05$ mag – in excellent agreement with the values $18.28 \pm 0.13$ and $18.23 \pm 0.04$ mag – based on statistical-parallax (Layden *et al.*, 1996) and Baade–Wesselink (Carney *et al.*, 1992) absolute-magnitude calibrations for RR Lyrae variables, respectively (van den Bergh, 1995) and with $DM$(LMC) $= 18.29 \pm 0.09$ mag given by the infrared PL relation for semi-regular variable red supergiants (Dambis, 1993). Our result is also consistent with the expansion parallax of SN 1987 A ($\leq 18.37 \pm 0.04$ mag, see Gould, 1995).

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