The Metallicity Effect on Cepheid Absolute Magnitudes

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Comparing relative distance moduli of the Magellanic Clouds as determined from the Cepheid period-luminosity relations with corresponding values from the eclipsing binaries method, we determine the metallicity effect on Cepheid absolute brightness in $VIJHK_s$ bands. Within a very small uncertainty, which is dominated by the uncertainty on the mean metallicity difference between Cepheids in the LMC and SMC, we conclude that metallicity effects in all bands are consistent with a zero metallicity effect.

We present a very accurate determination of the effect of metallicity on Cepheid brightness from the Magellanic Clouds (MCs) Cepheids.

We used photometry in V and I bands and periods of pulsation from the OGLE III catalogue (Soszynski et al., 2008; Soszyński et al., 2010; Ulaczyk et al., 2013) and infrared J, H, and K_s data from the IRSF survey (Kato et al., 2007). From our sample, we removed Cepheids with periods longer than 100 days (LMC and SMC) and shorter than 2.5 days (SMC).

We found the observed (i.e. not corrected for extinction) period-luminosity relation for Cepheids in the LMC for each used band. Forcing slopes of these relations to the SMC P-L relations, we found zero points that we used to calculate the observed relative distance modulus of the MCs in the different bands (column 3 of Tab. 1).

The true relative distance modulus (i.e. corrected for extinction) can be expressed with the following formula:

$$\Delta(m-M)_0 = \Delta(m-M) - E(B-V) \times R_\lambda \tag{1}$$

where $(m-M)$ is the observed relative distance modulus, $E(B-V)$ is the difference between mean reddening towards SMC and LMC, and R_λ is the total to selective extinction ratio in a given band.

Assuming the reddening law of O'Donnell (1994), we calculated R_λ for our used bands. Fitting a line to Eq. 1 gives us the true relative distance modulus of the MCs and the difference between mean reddening towards the MCs. Our results are

0.481 ± 0.004 mag and -0.045 ± 0.003 mag for the true relative distance modulus and $E(B-V)$, respectively. Assuming the determined $E(B-V)$ value, we calculated the true relative distance modulus in each band from Eq. 1 (column 4 of Tab. 1).

According to Graczyk et al. (2014), the true relative distance modulus of the MCs amounts to 0.472 ± 0.026 mag. Distances determined based on late-type eclipsing binaries are practically independent of metallicity, so we compared our results with this value (column 5 of Tab. 1) to find the metallicity effect on Cepheid magnitudes.

From the literature we selected metallicity determinations of the Magellanic Clouds obtained with exactly the same technique for both Clouds to minimize systematic effects. Our calculated relative metallicity of the Clouds (SMC–LMC) amounts to -0.406 ± 0.048.

Assuming that the difference of the values of the relative distance modulus of the MCs, as determined from Cepheids and eclipsing binaries (column 5 of Tab. 1), is due to the mean metallicity difference of the Cepheids in these two galaxies, we found the metallicity effect on the Cepheid brightness, γ, by dividing values in the column 5 of Tab. 1 by the relative metallicity of the Clouds. The results are given in the last column of Tab. 1.

Table 1: Metallicity effect on Cepheid P-L relations in $VIJHK_s$ bands

Filter	R_λ	$\Delta(m-M)$	$\Delta(m-M)_0^{cep}$	$\Delta(m-M)_0^{cep-ecl}$	γ
V	3.143	0.340 ± 0.017	0.481 ± 0.017	0.009 ± 0.031	-0.022 ± 0.076
I	1.814	0.393 ± 0.012	0.478 ± 0.012	0.006 ± 0.029	-0.015 ± 0.071
J	0.874	0.449 ± 0.010	0.489 ± 0.010	0.017 ± 0.028	-0.042 ± 0.069
H	0.558	0.452 ± 0.009	0.477 ± 0.009	0.005 ± 0.028	-0.012 ± 0.069
K	0.366	0.463 ± 0.008	0.479 ± 0.009	0.007 ± 0.028	-0.017 ± 0.069

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