THE INFRARED DISTANCE SCALE: THE GALAXY AND THE MAGELLANIC CLOUDS

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Abstract. The advantages of using near-infrared photometry of Cepheids to determine distances to nearby galaxies are now well known. In this paper we summarize the current state of the infrared period-luminosity (P-L) relations for the Galaxy, the LMC, and the SMC and present composite P-L relations derived from all available photometry. We give distance moduli for the LMC and SMC based on these data and briefly report on the status of other work in progress.

Introduction

Magellanic Cloud Cepheids have always played a central role in our understanding of Cepheids and the determination of cepheid P-L relations. It is particularly important to examine the behaviour of these P-L relations in the infrared, as the Cepheid-based Local Group distance scale is best determined at these wavelengths.

We present P-L relations determined from intensity-mean JHK magnitudes of 40 LMC and 28 SMC Cepheids. At present we have multiple observations for three-quarters of the LMC Cepheids and one-third of the SMC Cepheids. Variables which are now known to be optical doubles, overtone pulsators, and those lacking a published ephemeris, were excluded from the sample. The individual observations will be published at a later date.

Reduction

To transform random-phase observations to intensity-mean average magnitudes, we adopt the procedure described in Welch et al. (1984). The recent ephemerides of van Genderen (1983a) were used where possible. Predicted lightcurves for each Cepheid were examined visually for goodness-of-fit. Significant phase adjustments were necessary for 50% of the LMC sample and 10% of the SMC sample. The vast majority of adjustments resulted in mean magnitudes differing by less than 0.03 mag from those derived from uncorrected curves. In 10% of the combined sample, an amplitude adjustment was also necessary. Particularly noteworthy is HV 2883 in the LMC, whose infrared amplitude is twice that predicted from the scaling relations of Welch et al. (1984).

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Period- Luminosity Relations

The observational P-L relations derived from our data are as follows:

LMC		SMC	
J	= 16.14 − 2.96 log P ±0.04 ±0.03	J	= 16.70 − 3.09 log P ±0.07 ±0.04
H	= 15.87 − 3.04 log P ±0.04 ±0.03	H	= 16.45 − 3.19 log P ±0.07 ±0.05
K	= 15.80 − 3.06 log P ±0.04 ±0.03	K	= 16.50 − 3.28 log P ±0.10 ±0.06

The largest source of error in using these same data to derive LMC and SMC distance moduli is the uncertainty in the galactic P-L zero-points. Unfortunately, the final distance moduli are sensitive to the choice of galactic calibrators and Hyades modulus. We justify our choice of calibrators in a paper on the improved calibration of the galactic near-infrared P-L relations (in preparation). In this work we use the calibrators EV Sct, CF Cas, CV Mon, V Cen, V367 Sct, U Sgr, DL Cas, S Nor, and RS Pup.

Adopting the galactic calibration data of Caldwell (1983), the distance of RS Pup from Havlen (1972), and the ratios of total-to-selective absorption from McGonegal et al. (1983), the apparent distance moduli to the LMC and SMC can be determined using the method described in McAlary et al. (1983). Briefly, the apparent moduli for both the LMC and SMC are solved for by assuming a common slope for the P-L relations in all three galaxies. We present the results of these calculations in Table 1. The composite H P-L relation is displayed in Figure 1. We have assigned an uncertainty of 0.2 mag to all galactic cepheid distance moduli.

Table 1

Composite P-L Relations and Apparent Distance Moduli for the LMC and SMC

Filter	Zero-point	Slope	(m−M) mag LMC	(m−M) mag SMC
J	−2.41 ±0.07	−3.00 ±0.02	18.60 ±0.07	18.97 ±0.07
H	−2.56 ±0.07	−3.08 ±0.02	18.49 ±0.07	18.86 ±0.07
K	−2.62 ±0.07	−3.10 ±0.03	18.48 ±0.07	18.84 ±0.07

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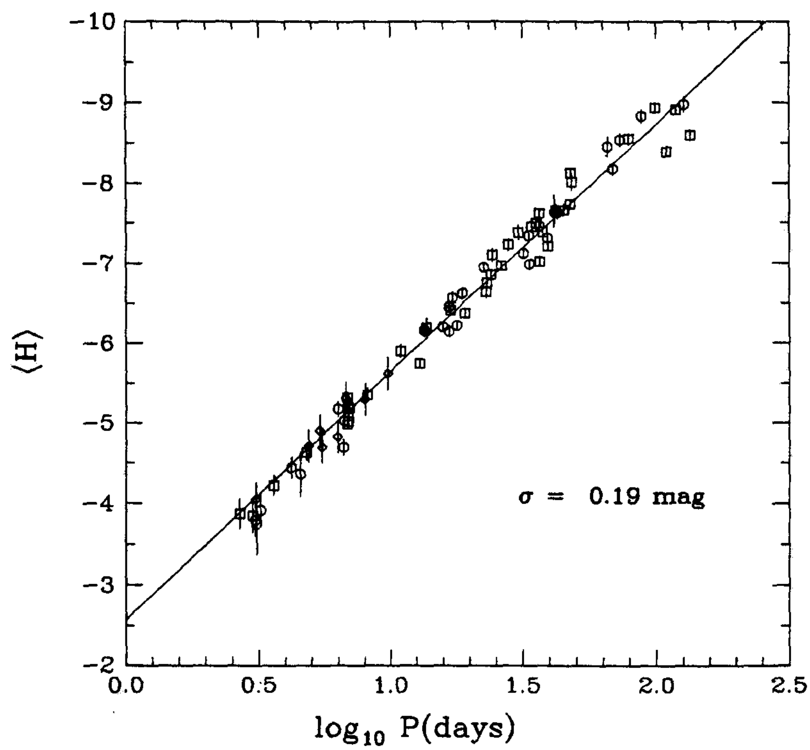
Fig. 1 The composite H P-L relation for the galactic calibrators, the LMC, and the SMC. Symbols are as follows: diamonds - galactic calibrators, squares - LMC, circles - SMC.



We adopt the average reddenings found by van Genderen (1983b): E(B-V)= 0.14 mag for the LMC and 0.11 mag for the SMC. The J, H, and K absorptions for the LMC are then 0.12, 0.07, and 0.04 mag, respectively, and for the SMC, 0.09, 0.06, and 0.03 mag, respectively. We obtain a true distance modulus of 18.45 for the LMC and 18.83 mag for the SMC.

Discussion

Welch and Madore (1984) and Feast (1984) have both presented H-band P-L relations. Feast's report of the unpublished work of Laney and Stobie cites a common slope of -3.34 for the LMC and SMC P-L relations. The SAAO work encompasses a smaller number of stars and a shorter baseline in log P, but uses more complete lightcurves. The slope difference may be accounted for by the exclusion of the 100-day Cepheids from the SAAO work. Welch and Madore (1984) reported observational H-band P-L relations for the LMC and SMC which differ only marginally from those reported here (as a result of more data, phasing and amplitude corrections, and a slightly different sample).

The standard deviation of one point about the observational and composite P-L relations is only ±0.2 mag. It is clear from Figure 1 that this width is very nearly constant for the entire range of observed periods.

Conclusions

The composite P-L relations reported above clearly illustrate the numerous advantages of infrared photometry for distance scale work. There is a great deal of information yet to be gleaned from these data.

Important applications of these new P-L relations are:

1) The recalibration of the Local Group distance scale.
2) The possible depth and structure of the SMC.
3) Constraints on the slope of the period-radius relation resulting from the slope of the infrared P-L relations.
4) The determination of infrared period-color relations, using more complete photometry.

Work on these problems is now in progress.

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