Principal Component Analysis of Cepheid Variable Stars

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Background

Cepheid variable stars are important in measuring distances to galaxies. They obey a period-luminosity (PL) relationship, which can be used to estimate their distance using the inverse square law of brightness. This relationship has a large amount of scatter, and requires corrections for interstellar reddening.[1]

We use principal component analysis (PCA) to separate the light curves (LCs) of a population of stars into a number of principal LCs, with associated principal-scores (PCs). Adding the first or second PC to the PL relationship results in the new period-luminosity principal-component (PLPC) relationship. This relationship has much less scatter, and the PCs can be obtained without reddening corrections.[2]

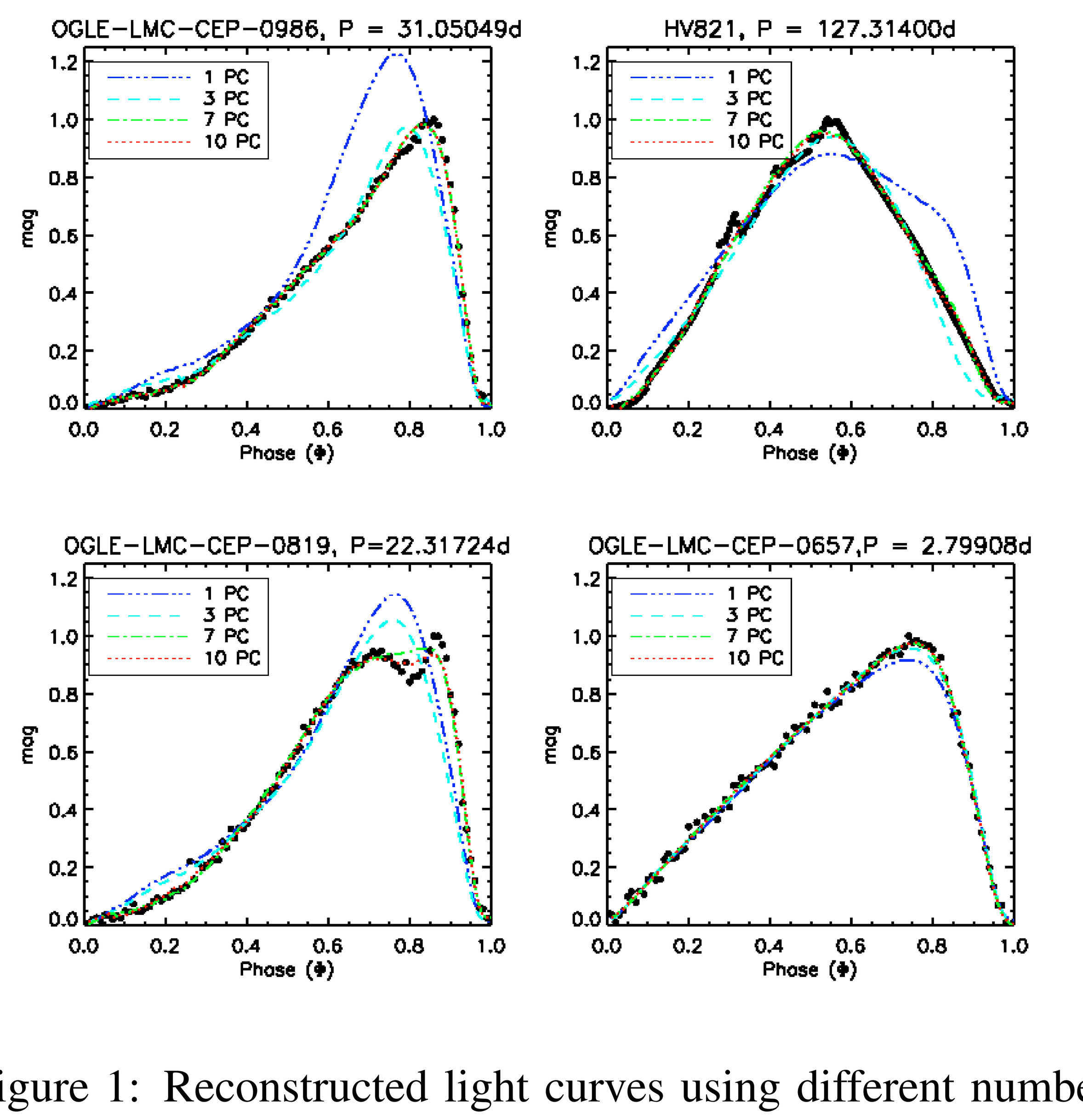

Figure 1: Reconstructed light curves using different numbers of principal scores. Observed points are in black.[2]

Principal Component Analysis

Traditionally, Fourier analysis (FA) has been used to interpolate LCs. FA has the advantage of working on unevenly spaced data points, but the disadvantage of assuming that the basis LCs are sinusoidal. PCA, on the other hand, has the advantage of allowing the data to determine the basis LCs, but the disadvantage of requiring evenly spaced points. Due to this, the data are preprocessed first using FA.[1]

PCA on a set of cepheids of the same type and distance outputs a set of eigenvectors, which can reconstruct the LC of any given star by a linear combination using that star's PCs as the weight coefficients. PCA outputs as many eigenvectors as there are points used for each star, but the eigenvectors can be sorted in order of significance, allowing us to ignore the majority of them. Reconstructed LCs are shown in Figure 1, and the first two principal-scores are shown as a function of period in Figure 2.[2]

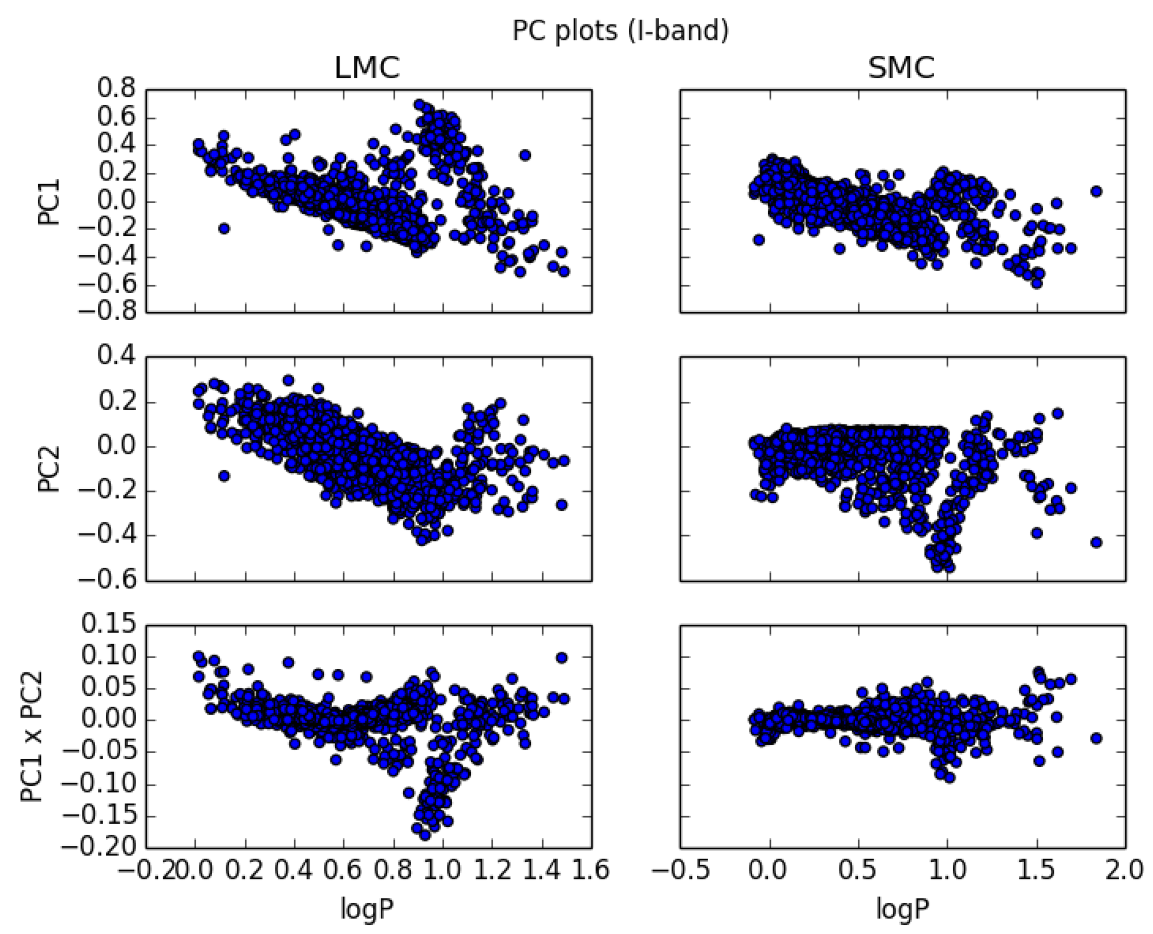

Figure 2: Principal scores plotted against period for fundamental mode cepheids in the LMC and SMC.

PLPC Relationship

We have modified the PL relationship by adding an extra parameter, principal scores. We model luminosity as a linear function with both period and a PC as independent variables. Doing so creates the new PLPC relationship, shown for the first two principal scores (PC1 and PC2) in Figure 3. The scatter is reduced significantly. We are still working to understand the implications and applications of this relationship.

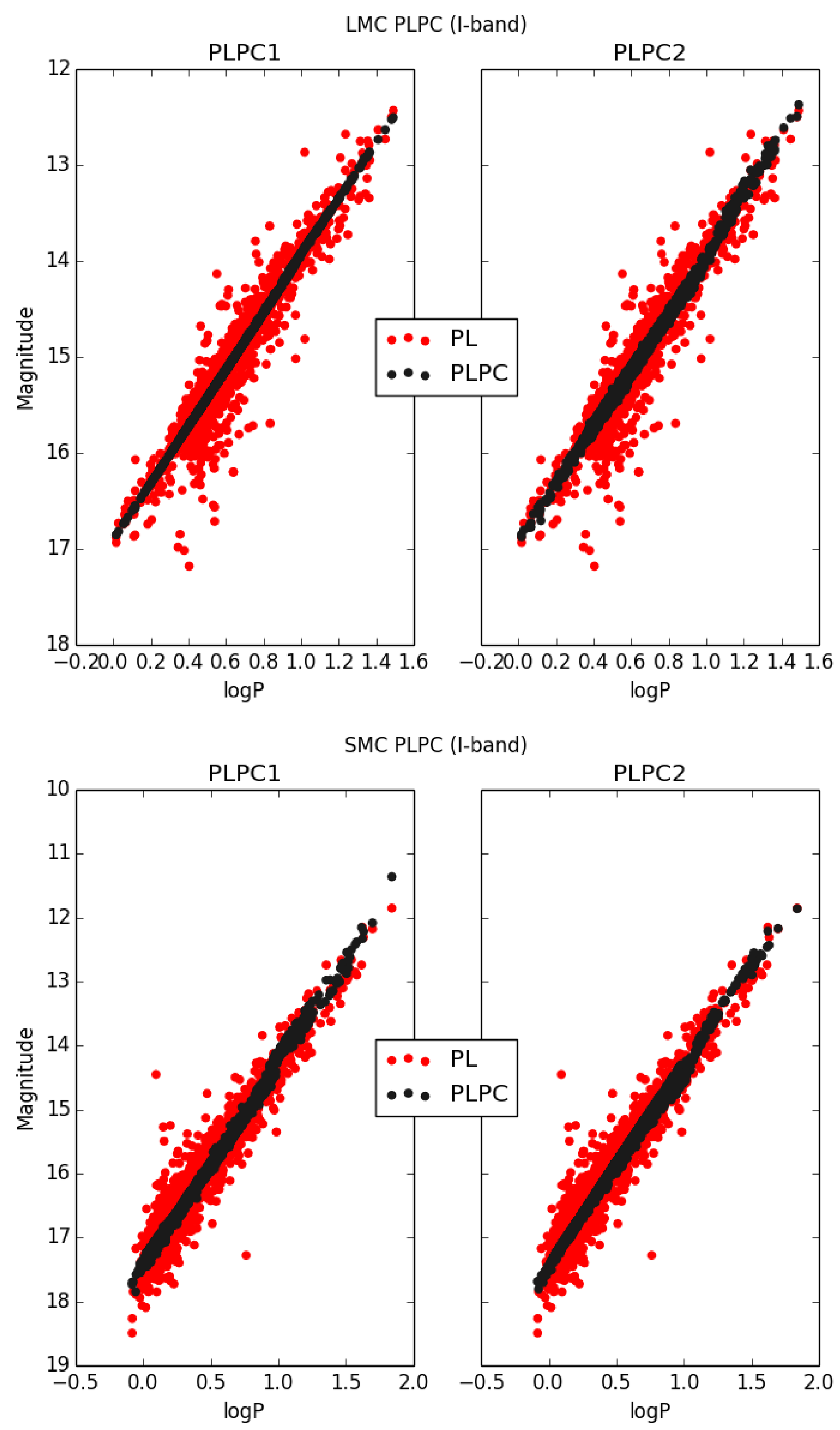

Figure 3: Period-luminosity and period-luminosity principal-component relationships for fundamental mode cepheids from the LMC and SMC.

References

[1] Kanbur, S., et al., 2002, MNRAS, 329, 126
[2] Deb, S. & Singh, H. P. 2009, A&A, 507, 1729