Morphology of the Large and Small Magellanic Clouds using fundamental mode Cepheids

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Introduction

Classical Cepheids are a class of variable stars, which can be used as standard candles for extragalactic distance measurements. Their use as standard candles dates back to Henrietta Leavitt's discovery, in 1908, that there was a correlation between the period of oscillation and brightness of certain types of variable stars in the Small Magellanic Cloud, which has been dubbed the period-luminosity relation [3]. This relation can be used to determine the absolute brightness of a star, and from that its distance can be determined [1].

With stars' distances determined, their positions can be mapped out in 3D space. We have used this to map out the structure of the Large and Small Magellanic Clouds – two satellite galaxies of the Milky Way – using fundamental mode Cepheids [2].

Data

The data were taken from the third phase of the Optical Gravitational Lensing Experiment (OGLE-III) in Chile, which observed the two Magellanic Clouds in the I- and V- optical bands [5]. Only fundamental mode Cepheids observed in both the I- and V- bands were used. Reddening corrections were made using the V-band extinction values provided by Zaritsky [6].

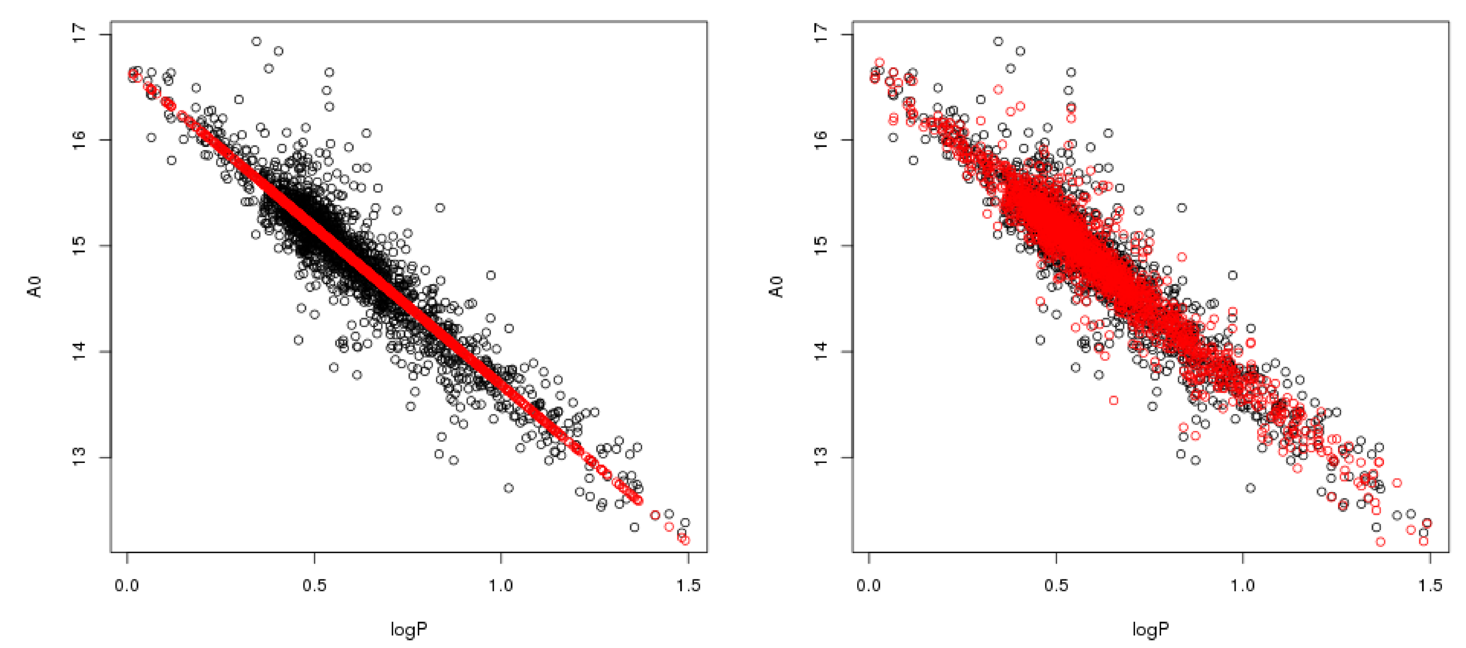

Figure 1: Period-Luminosity (left) and Period-Luminosity-Color (right) Relations for the LMC using I-band magnitudes.

Period–Luminosity Relations

There is a correlation between a Cepheid's period of oscillation, and its luminosity. However, the correlation is not perfect, and much effort has been made to find another variable which completes the picture. Photometric color, or the brightness difference between the light in two filters (e.g. $V - I$) has been largely successful at this [4]. We have attempted to find another variable which gives a stronger correlation, including light curve amplitude ratios and principal components, but to no avail.

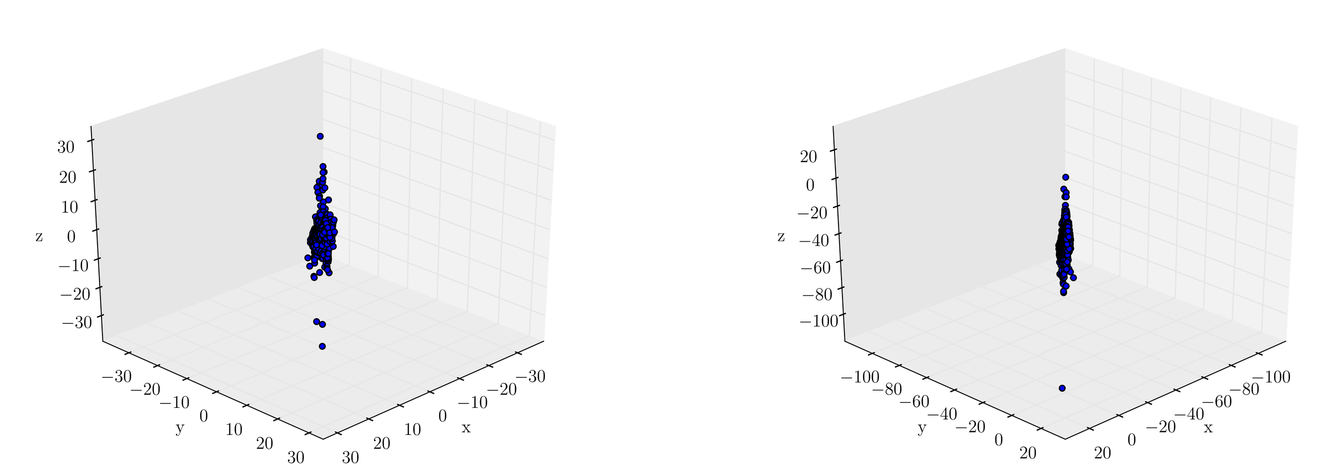

Figure 2: Cartesian coordinates of LMC (left) and SMC (right) Cepheids.

Galactic Structure

We mapped out the positions of individual stars using distances obtained through the PLC relation, along with their positions in the sky. These were transformed into cartesian coordinates using

$$\begin{aligned} x &= -D \sin(\alpha - \alpha_0) \cos\delta, \\ y &= D \sin\delta \cos\delta_0 - D \sin\delta_0 \cos(\alpha - \alpha_0) \cos\delta \\ z &= D_0 - D \sin\delta \sin\delta_0 - D \cos\delta_0 \cos\alpha - \alpha_0 \cos\delta \end{aligned}$$

In order to determine the angular orientation of the galaxies, two models were used: a plane and a triaxial ellipsoid. Through simulated galaxies, the ellipsoid was found to be most reliable. The axes of the triaxial ellipsoid were found by constructing an inertia tensor, $\mathbf{I}$, which takes the form

$$\mathbf{I} = \begin{bmatrix} I_{xx} & I_{xy} & I_{xz} \\ I_{yx} & I_{yy} & I_{yz} \\ I_{zx} & I_{zy} & I_{zz} \end{bmatrix}; \; I_{\alpha\beta} = \begin{cases} \sum_{\gamma \neq \alpha} \operatorname{cov}(\gamma, \gamma), & \text{if } \alpha = \beta \\ -\operatorname{cov}(\alpha, \beta), & \text{if } \alpha \neq \beta \end{cases}$$

The eigenvalues (λ_i) of this tensor can be used to find the lengths of the principal axes (S_i), using $S_i = \sqrt{\frac{5}{2}(\lambda_j + \lambda_k - \lambda_i)}$, and the eigenvectors give the orientation of the axes [2]. Before we can confidently determine these angles, we need to remove stars which are not part of, but in front of or behind the two galaxies.

References

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