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ORIGINAL ARTICLE

A Bayesian approach to calibrating period-luminosity relations of RR Lyrae stars in the mid-infrared

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Abstract A Bayesian approach to calibrating period-luminosity (PL) relations has substantial benefits over generic least-squares fits. In particular, the Bayesian approach takes into account the full prior distribution of the model parameters, such as the *a priori* distances, and refits these parameters as part of the process of settling on the most highly-constrained final fit. Additionally, the Bayesian approach can naturally ingest data from multiple wavebands and simultaneously fit the parameters of PL relations for each waveband in a procedure that constrains the parameter posterior distributions so as to minimize the scatter of the final fits appropriately in all wavebands. Here we describe the generalized approach to Bayesian model fitting and then specialize to a detailed description of applying Bayesian linear model fitting to the mid-infrared PL relations of RR Lyrae variable stars. For this example application we quantify the improvement afforded by using a Bayesian model fit. We also compare distances previously predicted in our example application to recently published parallax distances measured with the Hubble Space Telescope and find their agreement to be a vindication of our methodology. Our intent with this article is to spread awareness of the benefits and applicability of this Bayesian approach and encourage future PL relation investigations to consider employing this powerful analysis method.

Keywords Statistical methods · RR Lyrae · Distance scale

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1 Introduction

The period-luminosity (PL) relations of pulsating variable stars—typically variables of types RR Lyrae (RRL), Cepheid, and Mira—are invaluable tools for constructing the rung of the distance ladder that connects the Milky Way to other nearby galaxies, extending to ~ 5 Mpc. Recent applications of this distance measurement technique using Cepheids have successfully mated Cepheid distances to SNe Ia host galaxies and constrained the Hubble Constant, H_0, to 3.3 % (Riess et al. 2011). The authors have recently derived mid-infrared PL relations for RRL variables (Klein et al. 2011), and demonstrated their potential to serve as important distance indicators for the Large Magellanic Cloud. Additionally, continuing studies of Miras (Whitelock et al. 2008) confirm their potential to provide accurate distances even beyond the reach of Cepheids.

The accuracy and precision of any distance measurement made using the PL relation of a variable star, or any population of variable stars within a distant system, is dominated by the uncertainty of the locally calibrated PL relation. The general method is to fit a PL relation to the variables for which trigonometric parallax measurements are available (Feast and Catchpole 1997). For more than the past decade only *Hipparcos* (Perryman and ESA 1997) could provide these required local distance measurements to a significantly large sample of local stars with the accuracy necessary. More recently, the *Hubble Space Telescope*