The Hidden Potential of VVV RR Lyrae Light Curves

Gergely Hajdu[1·2·3], Márcio Catelan[1·3], István Dékány[2] and Eva K. Grebel[2]

1. Instituto de Astrofísica, Pontificia Universidad Católica de Chile, Av. Vicuña Mackenna 4860, 782-0436 Macul, Santiago, Chile
2. Astronomisches Rechen-Institut, Zentrum für Astronomie der Universität Heidelberg, Mönchofstrasse 12-14, 69120 Heidelberg, Germany
3. Millennium Institute of Astrophysics, Santiago, Chile

We introduce a new method of determining the average magnitudes of RR Lyrae variables: in the K_S-band, based on robust fitting of principal components from a high-quality training sample; in the J-band, using the amplitudes of the K_S principal components to approximate the J-band light-curve shape in each pulsation phase. Furthermore, it has been found that the metallicity of individual RR Lyrae variables can be inferred from the K_S-band light curves.

1 Introduction

The Vista Variables in the Vía Láctea (VVV) and VVV-X surveys (Minniti et al., 2010) are providing us with a treasure trove of stellar variability towards the Galactic bulge and disk, with the RR Lyrae variables being one of the most important distance and stellar population tracers. Unfortunately, multiple problems plague their characterization in the available data: small amplitudes (< 0.5 mag); relatively high light-curve scatter and high fraction of outliers for some stars; few measurements in the J-band. To realize their full potential, we develop an alternative to the traditional Fourier-based light curve fitting by utilizing prior information on the light-curve shapes in the K_S-band.

2 Near-IR RR Lyrae Light Curves

We collected high-quality K_S-band light curves for 101 RR Lyrae variables from the literature. After normalizing and aligning these light curves by the minima, we performed principal component analysis (PCA). The first four components capture 99.8% of the total variance of the training set. By utilizing these first four principal components (PCs) as basis vectors, we can determine the light-curve shapes, and hence the average magnitudes of variables in the VVV survey, even in cases where traditional Fourier-fitting would fail (e.g. top left panel of Figure 1).

Unfortunately, VVV J observations are scarce, hence they cannot be fit the same way as the K_S band to determine the mean J magnitudes of the variables. Therefore, their J-band light-curve shapes need to be approximated. We found that this can be achieved by estimating the deviation of the light curves from the average magnitude in each pulsation phase, as a linear combination of the four PC

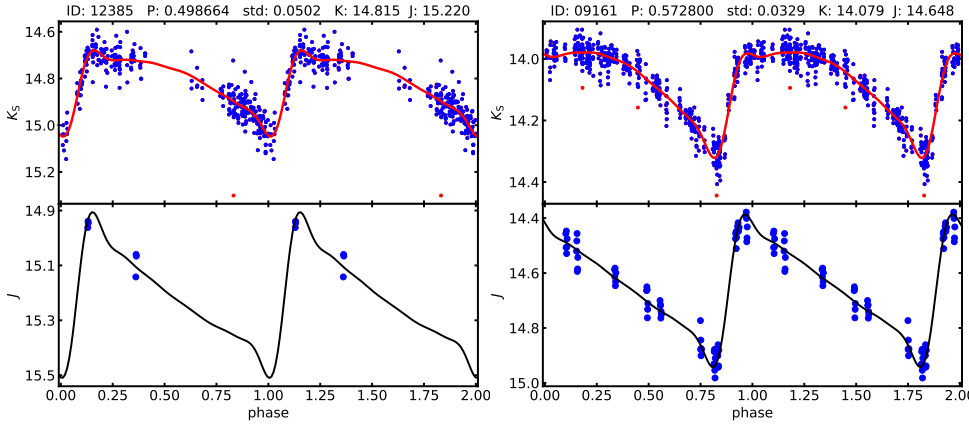

Fig. 1: *Top:* The K_S-band light curves are fit with the first four PCs of our PCA. *Bottom:* The J-band mean magnitudes are determined using the J-band light-curve shape, approximated from the K_S fit amplitudes. Note the quality of the J light-curve shape prediction for the variable on the right, which has an unusually large amount of J observations.

amplitudes determined from the fit of the K_S-band light curves. The bottom panels of Fig. 1 illustrate our J-band light-curve shape predictions.

3 Metallicity Estimates

The metallicity of RR Lyrae variables can be estimated based on their light-curve shape parameters in the optical wavelengths. We evaluated whether the same could be done in the K_S-band utilizing our fits. We had selected a subsample of ~ 6200 stable RR Lyrae variables with both I and K_S-band light-curves from the OGLE (Soszyński et al., 2014) and VVV (Minniti et al., 2010) surveys. The metallicities of these stars were estimated using eq. 3 of Smolec (2005).

By utilizing neural network regression, we found that it is possible to estimate the metallicities of RR Lyrae variables in this training set to an accuracy of ~ 0.2 dex by considering the pulsation period and the four principal component amplitudes of the K_S-band fits as independent variables.

These fitting and metallicity estimation methods will be used to realize the hidden potential of RR Lyrae stars as probes of the old population of the Galactic bulge and disk, as covered by the VVV survey.

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Conference dinner in the Wieliczka Salt Mine, Jan Haluszka Chamber. From left to right: Katrien Kolenberg, Jesper Storm, Vincent Hocdé, Nicolas Nardetto, Simon Borgniet and Lorenzo Rimoldini.

Conference dinner, from left to right: Lucy Del Carmen Mocarquer Lazen, Jan Lub, Alexandre Gallenne, Pierre Kervella, Dante Minniti and Joyce Pullen Urzúa.