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Revision of the [Fe/H] – ϕ_{31} – P relationship for RRc variables

Siobahn Morgan

Department of Earth Science, University of Northern Iowa,
Cedar Falls Iowa, USA
email: siobahn.morgan@uni.edu

Abstract. The relationship derived by Morgan *et al.* (2007) for type-c RR Lyrae variables (RRc) between values of [Fe/H] – ϕ_{31} – P has been revised and expanded. New relationships are based upon Fourier coefficients of 163 RRc variables in 19 Galactic globular clusters using the metallicity scales of Harris (2010), Zinn & West (1984) and Carretta *et al.* (2009). This larger database includes more low-metallicity clusters ([Fe/H] < -2.0), and the best fitting relations are found to depend upon values of $\log P$ rather than P. The new relations are applied to various populations of RRc including Milky Way field variables, LMC globular clusters variables, ω Cen RRc, and RRc in various OGLE III databases.

Keywords. stars: abundances, stars: variables: other

1. Introduction

The use of Fourier coefficients for deriving physical characteristics of variable stars is well established in the literature. Morgan *et al.* (2007, MWW hereafter), provided a relationship between the ϕ_{31} coefficient and two metallicity scales for 106 type-c RR Lyrae (RRc) variables in Galactic globular clusters. The present study expands this number to 163 variables, with the inclusion of data from seven additional globular clusters. All variables were examined for well defined light curves with low values of uncertainty in the ϕ_{31} coefficient, whenever available. In addition, the metallicity scales used in the present study have been revised to include values from Carretta *et al.* (2009), the recently revised values from Harris (2010), and Zinn & West (1984). The cluster metallicity values from Carretta *et al.* (2009), and Harris (2010) are very similar, as would be expected, though there is a slight deviation in values in metal rich clusters.

2. Method and application

Following the method of MWW, the values for the Fourier coefficient ϕ_{31} were fit to second order functions of P, ϕ_{31} and [Fe/H], as well as to $\log P$. It is noteworthy that the best fitting relations were consistently found for $\log P$-based formulae rather than those based upon P. In general, the values obtained for [Fe/H] using the relations found here and those from MWW were consistent in value, with differences typically less than 0.005 dex for the newer metallicity scales, while the average difference for the relationships based upon the Zinn & West (1984) values were closer to 0.02 dex. For simplicity only the relationship based upon the Carretta *et al.* (2009) values, which is

$$[\mathrm{Fe/H}] = 4.86(\log P)^2 + 0.0183(\phi_{31})^2 - 0.820(\log P)\phi_{31} - 4.260, \tag{2.1}$$

will be discussed here.

Following the procedure outlined in MMW, the [Fe/H] – ϕ_{31} – log(P) relation given above was applied to a variety of RRc variables to test its viability. The first population examined were field RRc variables. There was general agreement between the values from the literature and those from Equation 2.1, with the values from Equation 2.1 being slightly more metal poor compared to values obtained via ΔS values or spectroscopy. The metallicity of RRc variables in ω Cen (NGC 5139) were also calculated using equation 2.1. A total of 67 RRc stars with well defined light curves resulted in an average [Fe/H] $= -1.64 \pm 0.26$, with a range of metallicity values between -2.29 and -1.04. These results agree well with the range of known stellar populations for the cluster.

Equation 2.1 was also applied to RRc located in five LMC globular clusters. The results were varied, with metallicity values from the literature and those based upon the Fourier relation of RRab stars from Jurcsik & Kovács (1996) comparable to the results from Equation 2.1 for two of the clusters, NGC 1466, and NGC 1841. For the other three clusters (Reticulum, NGC 1786, NGC 2257), some of the variables included as RRc may actually be RRe variables (second overtone pulsators) and those should therefore be excluded. Their exclusion does bring the average metallicities based upon equation 2.1 closer to the other methods of [Fe/H] determination for two of the clusters, however the metallicity values based on Equation 2.1 for RRc in Reticulum remain significantly different from values in the literature.

Variables in the OGLE III database were also examined, though without any special discriminator other than that used in the creation of the database (see Soszyński *et al.* (2009) for methods of variable classification). Variables of an uncertain nature, or those that are foreground objects were removed, and the I magnitude based values for the Fourier coefficients were transformed to the V system using the method of Morgan *et al.* (1998), before Equation 2.1 was applied. For both the LMC and SMC variables, the average value for [Fe/H] from Equation 2.1 is significantly below that found in other studies of RR Lyrae variables in these galaxies, with $\langle[\mathrm{Fe/H}]\rangle = -1.73 \pm 0.39$ for the LMC sample of 1974 variables, and $\langle[\mathrm{Fe/H}]\rangle = -2.18 \pm 0.35$ for the 47 SMC variables. The average metallicity for the Milky Way Bulge sample of 4423 RRc stars was -1.22 ± 0.41.

3. Conclusions

The original metallicity relations based upon Fourier coefficients of MWW have been revised to utilize current metallicity scales of various authors as well as Fourier coefficients derived from recent high quality photometry programs. The relations are found to provide results similar to those of MWW. As more high-precision photometry of variables becomes available, it is likely that various relations between physical characteristics and Fourier coefficients will be utilized frequently. As with any method, these relations should be continually examined for consistency and accuracy.

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