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Oosterhoff properties of RR Lyrae stars in the NSVS database

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Abstract. We present results from a sample of bright field RR Lyrae stars found in the Northern Sky Variability Survey (NSVS). These stars span a region of 5 kpc centered around the Sun, which probes the thick disk and inner halo Galactic components. From the photometric data available from NSVS, we have calculated the periods, amplitudes, mean magnitudes, Fourier decomposition parameters, and photometric metallicities. From these parameters, we discuss our findings regarding the Oosterhoff dichotomy and the scale heights of the field RR Lyrae population.

Key words. Stars: RR Lyrae – Stars: Oosterhoff Dichotomy – Galaxy: Galactic structure

1. Introduction

Large databases of variable stars are useful by-products from many surveys of the Milky Way Galaxy. For example, the OGLE and MACHO surveys provided information of RR Lyrae stars (RRLs) near the Galactic bulge, while surveys from SDSS, QUEST, and others found RRL that probe the outer halo of the Galaxy. The RRLs of this work, mostly of Bailey ab-type (RRab), come from the Northern Sky Variability Survey (NSVS) (Wozniak et al. 2004), which probe the thick disk and inner halo components of the Galaxy in the solar neighborhood.

Oosterhoff (1939) divided Galactic globular clusters into two groups based on the properties of their RRLs. Catelan (2004) reviews the current status of the Oosterhoff group phenomenon. Here we discuss the Oosterhoff group types of field RRab stars in the NSVS database. We also discuss the scale height of the RRL disk component.

2. Data Acquisition and Reduction

The NSVS database is comprised of data obtained from a year of observations done by the first generation Robotic Optical Transient Search Experiment (ROTSE-I) (Akerlof et al. 2000). Although this telescope was originally designed to find the optical counterparts of gamma ray bursters, a survey of the northern sky as seen from Los Alamos, New Mexico, was also produced. The survey is all sky down to $\delta \sim -30°$. An important consideration is that the ROTSE-I telescope did not use a filter, although the peak sensitivity is closest to that of Cousins R.

To compensate for the filterless observations, calibration relations were developed for the RRLs. Parameters such as amplitude, mean magnitude, and the Fourier decomposition phase parameter, ϕ_{31}, were scaled to values in Johnson V. These calibration relations are presented in Kinemuchi et al. (2005).

We selected 1193 RRab candidates from the NSVS database using several criteria based on period, amplitude, 2MASS color, number of observations, and a limiting magnitude of $V = 14$. Most of the NSVS RRab candidates are not found in the General Catalog of Variable Stars (GCVS) Kholopov et al. (1996). Due to crowding, the NSVS database is incomplete close to the Galactic plane.

We derived periods and light curves for all 1193 RRab stars. Photometric metallicities were determined for 589 confirmed RRab stars that were brighter than $\langle V \rangle = 14$ and that had well determined light curves. For the photometric metallicities, we used two empirical methods: 1) a relation that used period and the Fourier decomposition phase parameter, ϕ_{31} (Jurcsik & Kovacs 1996), and 2) a relation using the log period and amplitude (Sandage 2004). We also determined distances to all the RRab stars in our sample by using a luminosity-metallicity relation (Cacciari & Clementini 2003). Reddening corrections were obtained from the Schlegel et al. (1998) maps, assuming $A_V = 3.1E(B-V)$.

3. Results

We determined the periods for 1193 RRab stars via the Supersmoother routine (Reimann 1994). The average period of this distribution was $\langle P_{ab} \rangle = 0.563 \pm 0.01$ days, a value close to that of Oosterhoff I type globular clusters. Although the period histogram indicates that an Oosterhoff I population is dominant it also has a larger range in period than is found among pure Oosterhoff I systems. Because of the absence of shorter period RRab stars far from the plane, the mean period increases from $\langle P_{ab} \rangle = 0.557$ day for $|Z| < 2$ kpc to $\langle P_{ab} \rangle = 0.580$ day for $2 < |Z| < 5$ kpc.

Figure 1 shows our Bailey, or period-amplitude, diagram of the NSVS RRab stars. Here, the amplitudes were scaled from the ROTSE amplitudes to their equivalent in V. In the Bailey diagram, we overplotted the Oosterhoff trend lines from Clement & Rowe (2000). Their trend line for Oosterhoff I is based on the RRLs of M3, whereas the Oosterhoff II relation was determined from RRLs of ω Cen. In our plot, we found that indeed, most of the stars appear clustered about the Oosterhoff I trend line, however some are found near the Oosterhoff II line.

The dotted line in Figure 1 is an arbitrary separation of the Oosterhoff I and II groups. Among Galactic globular clusters, the division between Oosterhoff I and II clusters comes near $[Fe/H] = -1.7$. Our dividing line in Figure 1 does not have the slope expected of $[Fe/H] = -1.7$ RRab stars according to Sandage (2004)'s calibration. Cacciari et al. (2005) noted that the more evolved RRab in M3 may not fall on the typical Oosterhoff I locus in the Bailey diagram. The Oosterhoff I trend line in Cacciari et al. (2005) is similar to that of Clement & Rowe (2000), but has a shallower slope at larger amplitudes. Exactly which dividing line is adopted does not change our result that a significant Oosterhoff II population is shown in Figure 1 in addition to the dominant Oosterhoff I component.

We have identified a group of metal-rich RRab stars with $[Fe/H] > -1$ in our sample. In Figure 1, they are mostly contained in the quadrilateral box in the plot. All of these stars were carefully screened to eliminate possible Bailey c-type RRLs or other short period variables. These metal-rich stars indicate a continuation of the RRL properties with metallicity for the Oosterhoff I group.

3.1. Metal-rich Group

We focus our attention on the metal-rich group of 70 stars. Figure 2 shows the metallicity distribution of the RRab stars with their Z distance. Note that the metal-rich stars (identified

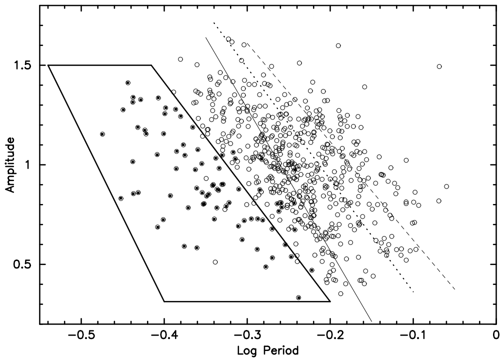

Fig. 1. Bailey diagram for the NSVS RRab stars. The trend lines are from Clement & Rowe (2000). The solid line is the relation for Oosterhoff I while the dashed line is for Oosterhoff II. The dotted line is an arbitrary division of Oosterhoff types I and II. The box contains most of the metal-rich ($[Fe/H] > -1$) RRab stars (filled circles).

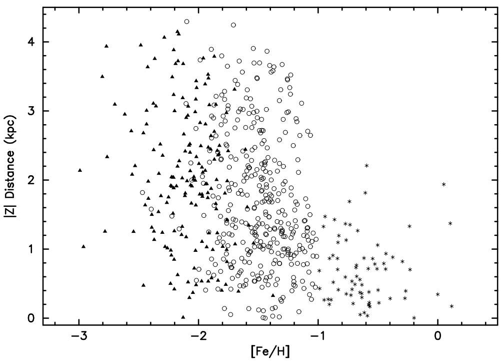

Fig. 2. Metallicity distribution of the NSVS RRab stars with respect to the distance from the Galactic plane (Z distance) in kpc. The filled triangles are the Oosterhoff II stars, the open circles Oosterhoff I stars, and the asterisks are the metal-rich RRab stars with [Fe/H] > -1.

by the asterisks) are found mostly close to the Galactic plane, compared to those stars found in the Oosterhoff I and II groups (open circles and filled triangles, respectively). Due to these metal-rich stars' location in the Galaxy, we identify this group as our thick disk sample.

3.2. *Scale Height of the Thick Disk Component*

The scale height for the thick disk component was calculated from the metal-rich RRab stars. We used the method of determining the density of stars as a function of Z distance. We did two calculations with 6 stars per $|Z|$ bin and 10 stars per $|Z|$ bin. For both cases, we obtained rather short scale heights, compared to the canonical value of $\sim$ 1 kpc. For the 6 stars per bin case, our resultant scale height was 0.34 ± 0.06 kpc, whereas for 10 stars per $|Z|$ bin, the height was 0.44 ± 0.13 kpc.

Our derivation of the thick disk scale height is dependent on our choice of $M_V - [Fe/H]$ relation. However, if we are to expect a scale height solution of 1 kpc from our sample of metal-rich RRabs, the brightness would have to increase by the implausible amount of 1.79 magnitudes!

The metal-rich RRab stars clearly belong to a disk population. However, a scale height of 0.4 kpc is smaller than the $\sim$ 1 kpc expected of a thick disk population. Plausible changes in the adopted luminosity-metallicity relation and application of correction factors modeling the detection efficiency do not change the scale heights significantly. However, the solution is dominated by the stars closest to the Plane. If

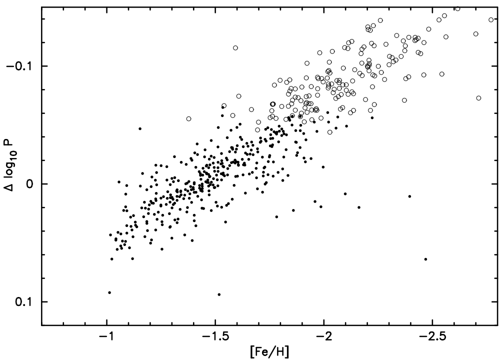

Fig. 3. Reproduction of Suntzeff et al. (1991)'s figure 8b, but with NSVS RRab stars. Only those stars classified as Oosterhoff I (filled circles) and Oosterhoff II (open circles) from Figure 1 are plotted; none of the metal-rich stars are included. Note there is not a clear break between the two groups.

the metal-rich RRab stars within 0.4 kpc of the Plane are removed, the scale height for the remaining metal-rich stars becomes 1.5 ± 0.4 kpc.

Our best explanation for these results is that the metal-rich RRab sample contains both an old thin disk and a thick disk component. Others have also raised this possibility. Layden (1995) noted that, in his sample of RRab stars with spectroscopically determined metallicities, the scale height appears to decrease with increasing metallicity. However, at this time, we do not have the full kinematic description of these metal-rich RRab stars in our sample. With the kinematic information, we should be able to separate the old thin disk and thick disk stars within our sample.

3.3. The Oosterhoff Dichotomy in the NSVS

Suntzeff et al. (1991) found a clear separation between field stars of Oosterhoff type I and II, using a sample of RRab stars with spectroscopically determined metallicities. In their figure 8b, they plot the period shift, $\Delta LogP$, against metallicity, and find a gap at $\Delta LogP \sim -0.03$. We reproduce this plot with our sample of Oosterhoff I and II stars. In Figure 3, we do not see the clear gap that Suntzeff et al. did with their sample of field stars. We caution, however, that there may be more scatter in our photometrically determined metallicities than in the Suntzeff et al. (1991) spectroscopic values. We note that the Bailey diagram for RRab stars identified in the QUEST survey (Vivas & Zinn 2003) does not show a clear separation between Oosterhoff I and II stars.

4. Summary

We identified 1193 candidate RRab stars in the magnitude limited NSVS database, most of which are not listed in the GCVS. Periods, amplitudes, mean magnitudes, and distances were determined for all these stars, which were brighter than $\langle V \rangle = 14$. For a subset of 589 RRab stars, we determined photometric metallicities. This solar neighborhood RRab sample contains a metal-rich disk population, a dominant Oosterhoff I population, and a significant Oosterhoff II population. Scale height determinations for RRab stars with $[Fe/H] > -1$ suggest that the disk population contains both an old thin disk and a thick disk component.

Future work will include supplementing the photometric data for this RRab sample with kinematic data. We will need spectroscopic observations to obtain radial velocities, as well as for ΔS metallicities. The NSVS database is also being used to study multiple mode RR Lyrae stars and to investigate the RRc population in the solar neighborhood.

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References

Akerlof, C. et al. 2000, AJ, 119, 1901
Cacciari, C. & Clementini, G. 2003, Lecture Notes in Physics, 635, 105
Cacciari, C., Corwin, T.M., & Carney, B.W. 2005, AJ, 129, 267 2005,
Catelan, M. 2004, Variable Stars in the Local Group, 310, 113
Clement, C.M. & Rowe, J. 2000, AJ, 120, 2579
Jurcsik, J. & Kovacs, G. 1996, A&A, 312, 111
Kinemuchi, K. et al. 2005, in preparation
Kholopov, P.N. et al. 1996, Vizier On-Line Catalog
Layden, A.C. 1995, AJ, 110, 2288
Oosterhoff, P.T. 1939, The Observatory, 62, 104.
Reimann, J.D. 1994, Ph.D Thesis
Sandage, A. 2004, AJ, 128, 858
Schlegel, D.J. et al. 1998, ApJ, 500, 525
Suntzeff, N., Kinman, T, & Kraft, R. 1991, ApJ, 367, 528
Vivas, A. K. & Zinn, R. 2003, MSAIt, 74, 928
Wozniak, P. R. et al. 2004, AJ, 127, 2436