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RR Lyrae Stars and Anomalous Cepheids in the Draco Dwarf Spheroidal Galaxy

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Abstract. We present new results on RR Lyrae stars and anomalous Cepheids in the Draco dwarf spheroidal galaxy. We have increased the number of double-mode RR Lyrae stars and found three new anomalous Cepheids. With period-magnitude and period-amplitude diagrams, we discuss the Oosterhoff classification of Draco. Contradictory results were found in that Draco appears to contain both Oosterhoff I and II type RR Lyrae populations.

1. Introduction

The Draco dwarf spheriodal galaxy was first extensively studied by Baade & Swope (1961), who identified 260 variable stars in their survey, determining periods and photographic B light curves of 138 variables. Goranskij (1982) and Nemec (1985) reanalyzed the Baade & Swope observations, finding 10 double-mode RR Lyraes (RRd). In this current survey of Draco, we present our photometric results of 268 RR Lyraes and 8 anomalous Cepheids.

The Draco dwarf spheroidal galaxy is a metal poor system with an $\langle[\mathrm{Fe/H}]\rangle \sim -2.0$ (Mateo, 1998). Draco has a well populated red horizontal branch (HB). However, compared to a metal poor globular cluster such as M15, Draco has a sparsely populated blue horizontal branch.

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2. Observations and reduction

The data were obtained from two sources: the 1.0m telescope at the United States Naval Observatory (USNO) - Flagstaff station and the 2.3m telescope at the Wyoming Infrared Observatory (WIRO). The observations spanned over two years, from June 1993 to July 1995. There were between 40 to 60 observations in V and I.

The images were reduced using the standard IRAF CCD reduction packages while the photometry was done with the stand alone versions of DAOPHOT II and ALLFRAME (Stetson, 1987, 1994). To find the periods, two methods were utilized: a date compensated discrete Fourier transform supplemented by phase dispersion minimization (Stellingwerf, 1978).

3. Results

We have increased the number of RRd stars from the original 10 to at least 26. Prior to this work, five anomalous Cepheids were known to be in the Draco dwarf galaxy, and to this number we have added three more.

In the period-magnitude diagram, Fig. 1, a clear separation between the ab and cd type RR Lyraes is shown. Nemec (1988) proposed that two period-luminosity (P-L) relationships exist depending on the pulsational mode (fundamental or first overtone) of anomalous Cepheids for five dwarf spheroidal galaxies. Three of the newly discovered anomalous Cepheids of Draco fall close to Nemec's fundamental mode P-L relation, but it is not clear if the Draco Cepheids fall along two distinct P-L relations.

A period-amplitude diagram for Draco RR Lyraes is presented in Figure 2. Here we have overlaid the Oosterhoff I (M3) and Oosterhoff II (ω Centauri) trend lines for RRab stars (Clement & Rowe, 2000). The Draco RRab stars appear to mostly fall along or are close to the Oosterhoff I line. In comparison, galactic globular clusters that are more metal poor than [Fe/H] = -1.7 are classified as Oosterhoff II.

Lee et al. (1990) provide a plausible explanation for this contradiction in Oosterhoff classification in Draco. RR Lyraes in Oosterhoff II globular clusters are originally on the blue horizontal branch and evolve away from their zero-age horizontal branch positions. As they evolve, the stars become brighter and redder. According to Ritter's relation, as the star gets brighter, the period becomes longer. Since Draco has a sparsely populated blue horizontal branch, this is not the best description for this system. If the Draco RRab stars are not as evolved as those in a metal poor globular cluster, then these stars are fainter, have shorter periods, and hence fall closer to the Oosterhoff I trend line.

However, the RRc and RRd stars of Draco have periods similar to those found in Oosterhoff II globular clusters. Only one RRd star was found to be similar to Oosterhoff I globular cluster RRd stars. Some c-type RR Lyraes are also like Oosterhoff I stars, but a majority of them are Oosterhoff II. Detailed modeling for different evolutionary scenarios is needed to see how difficult it is to explain the different Oosterhoff properties of RRab and RRcd stars.

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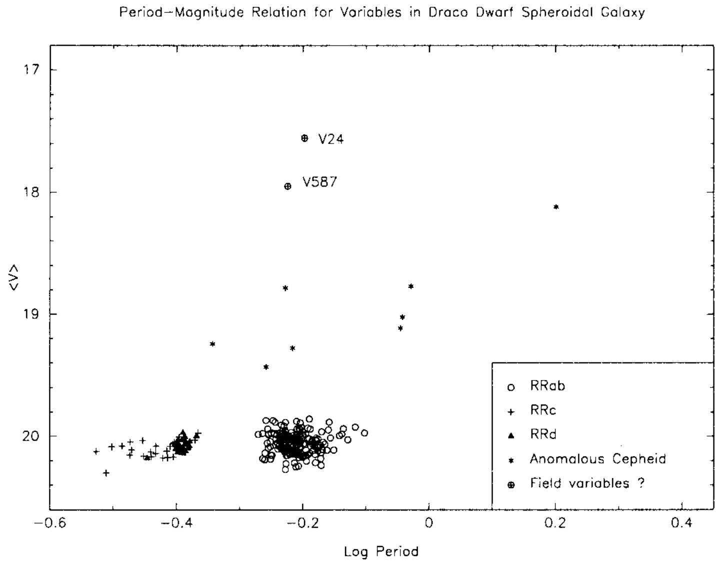

Figure 1. Period-magnitude diagram for RR Lyraes and anomalous Cepheids in Draco. Included are two possible field variable stars, labeled V24 and V587.

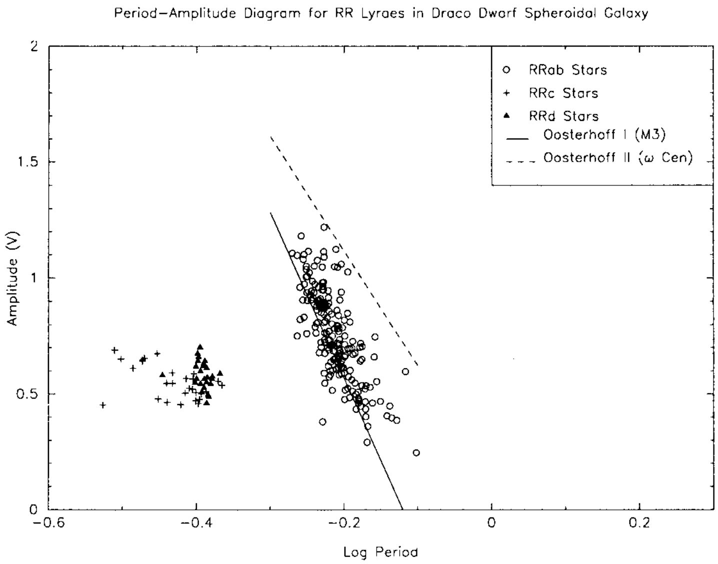

Figure 2. Period-amplitude diagram for Draco RR Lyraes.

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4. Future work

In this paper we presented our results from V band photometry only. V and I colors are being determined. We will also be investigating the prevalence of the Blazhko effect among the RR Lyraes in Draco and the radial distributions of the variable stars.

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Discussion

D. Laney : Could the peculiar distribution of RR Lyrae stars with respect to Oosterhoff I and II be explained by an age distribution different from that found in typical Oosterhoff I and II globular clusters?

K. Kinemuchi : Grillmair et al. (1998) discuss a lack of multiple main sequence turnoffs; thus no multiple star formation episodes. From their analysis, there is no large age distribution in Draco.

G. Kovács : The P-A diagram may not necessarily be the best way to estimate cluster metallicity. For RRab stars, there is a much better correlation with P and ϕ_{31}. Also, amplitudes might be affected in the case of crowded field photometry. Concerning the latter effect, do you have an estimation on the severity of crowding in the case of your data set?

K. Kinemuchi : Draco is not a very compact object, so crowding does not usually become an issue. We do have problems with near neighbors, but almost all of that is taken care of with our photometry programs. We have not yet looked into the ϕ_{31} values of our RRab light curves.

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