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THE OOSTERHOFF PERIOD GROUPS AND MULTIPLE POPULATIONS IN GLOBULAR CLUSTERS

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ABSTRACT

One of the long-standing problems in modern astronomy is the curious division of globular clusters (GCs) into two groups, according to the mean period ($\langle P_{\rm ab}\rangle$) of type ab RR Lyrae variables. In light of the recent discovery of multiple populations in GCs, we suggest a new model explaining the origin of the Sandage period-shift and the difference in mean period of type ab RR Lyrae variables between the two Oosterhoff groups. In our models, the instability strip in the metal-poor group II clusters, such as M15, is populated by second generation stars (G2) with enhanced helium and CNO abundances, while the RR Lyraes in the relatively metal-rich group I clusters like M3 are mostly produced by first generation stars (G1) without these enhancements. This population shift within the instability strip with metallicity can create the observed period-shift between the two groups, since both helium and CNO abundances play a role in increasing the period of RR Lyrae variables. The presence of more metal-rich clusters having Oosterhoff-intermediate characteristics, such as NGC 1851, as well as of most metal-rich clusters having RR Lyraes with the longest periods (group III) can also be reproduced, as more helium-rich third and later generations of stars (G3) penetrate into the instability strip with further increase in metallicity. Therefore, although there are systems where the suggested population shift cannot be a viable explanation, for the most general cases, our models predict that RR Lyraes are produced mostly by G1, G2, and G3, respectively, for the Oosterhoff groups I, II, and III.

Key words: Galaxy: formation – globular clusters: general – globular clusters: individual (M15, M3, NGC 6441) – stars: horizontal-branch – stars: variables: RR Lyrae

1. POPULATION-SHIFT WITHIN THE INSTABILITY STRIP

Photometry of M15 shows three distinct subgroups on the HB: RR Lyraes, blue HB, and the blue tail (Buonanno et al., 1985). In our modeling of M15, most, if not all, RR Lyraes in M15 are assumed to be produced by the second generation stars (G2) with chemical compositions favorable to produce RR Lyraes with longer periods. Both theories and observations suggest G2 would be somewhat enhanced in both helium and CNO abundances, preferably in metal-poor GCs (Ventura & D'Antona, 2009; Decressin et al., 2009). We assign more helium-rich third and later generations of stars (hereafter collectively G3) for the progenitors of EBHB. Therefore, in our models, G1, G2, and G3 are placed on the HB as follows:

- G1: Blue HB ([Fe/H]=-2.2, age=12.5Gyr, $\eta = 0.42$)
- G2: RR Lyraes (He & CNO enhanced, ~ 1 Gyr younger than G1)
- G3 and later generations : Extreme Blue HB (Super He-rich)

Interestingly, when this model is shifted redward by increasing metallicity, HB morphologies similar to M3 and NGC 6441 are obtained, and the instability strip becomes progressively populated by G1 and, G3, respectively. This population-shift within the instability strip with metallicity can create the observed period-shift between the Oosterhoff groups. Details of this study can be found in Jang et al. (2014).

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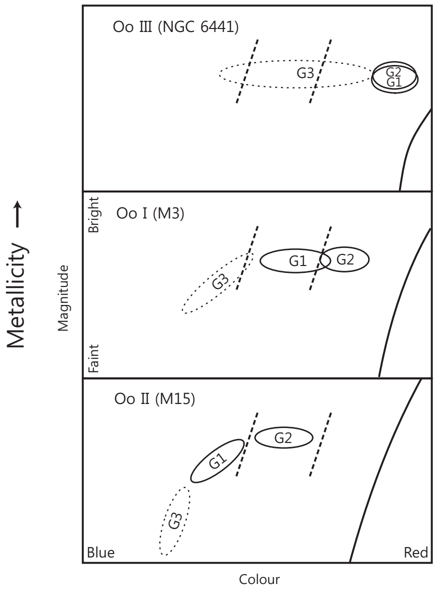

Figure 1. Schematic diagram illustrating the "population shift" within the instability strip (thick dashed lines) with increasing metallicity. For the most general case, most of the RR Lyraes are produced by G1, G2 (helium & CNO enhanced), and G3 (most helium-rich), respectively, for the Oosterhoff groups I, II, and III (adopted from Jang et al., 2014).

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