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Relative Ages from Horizontal-Branch Morphology : Revisited

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Abstract. We present our recent revision of model constructions for the horizontal-branch (HB) morphology of globular clusters, which suggests the HB morphology is more sensitive to age compared to our earlier models. We also present our high precision CCD photometry for the classic second parameter pair M3 and M13. The relative age dating based on this photometry indicates that M13 is indeed older than M3 by 1.7 Gyr. This is consistent with the age difference predicted from our new models, which provides a further support that the HB morphology is a reliable age indicator in most population II stellar systems.

1. Introduction

Because the horizontal-branch (HB) stars in globular clusters are much brighter than main-sequence (MS) stars, the interpretation of HB morphology in terms of relative age differences would be of great value in the study of distant stellar populations where the MS turnoff is fainter than the detection limit. In this paper, we report our progress in the use of HB as a reliable age indicator.

2. New HB Population Models

Some seven years ago, Lee et al. (1994, hereafter LDZ) have concluded that age is the most natural candidate for the global second parameter, because other candidates can be ruled out from the observational evidence, while supporting evidence does exist for the age hypothesis. Although this conclusion is generally accepted in the community, there is still some debate about this issue (see Table 1 of Lee et al. 1999). Among others, critics are arguing that the relative age differences inferred from the MS turnoffs are often too small compared to the amounts predicted from the HB models for the several second parameter pairs, including the well-known M3 and M13 pair.

We found, however, several recent developments that can affect the relative age dating technique from HB morphology. First of all, there is now a reason to believe that the absolute age of the oldest Galactic globular clusters is reduced

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to about 12 Gyr, as suggested by the new Hipparcos distance calibration and other improvements in stellar models (Reid 1997; Gratton et al. 1997; Chaboyer et al. 1998). As LDZ already demonstrated in their paper, this has a strong impact on the relative age estimation from HB morphology. Also, it is now well established that α elements are enhanced in halo populations ([α/Fe] = 0.4). Finally, Reimers' (1975) empirical mass-loss law suggests more mass-loss at larger ages. The result of this effect was also presented in LDZ, but unfortunately the most widely used diagram (their Fig. 7) is the one based on fixed mass-loss. We found all of the above effects make the HB morphology more sensitive to age (see Lee & Yoon 2001 for details). Therefore, as illustrated in Figure 1, now the required age difference is much reduced compared to Figure 7 of LDZ. Now, only 1.1 Gyr of age difference, rather than 2 Gyr, is enough to explain the systematic shift of the HB morphology between the inner and outer halo clusters. Also, to within the observational uncertainty, an age difference of about 1.5–2 Gyr is now enough to explain the observed difference in HB morphology between the remote halo clusters (Pal 3, Pal 4, Pal 14, and Eridanus) and M3. These values are consistent with the recent relative age datings both from the HST and high-quality ground-based data.

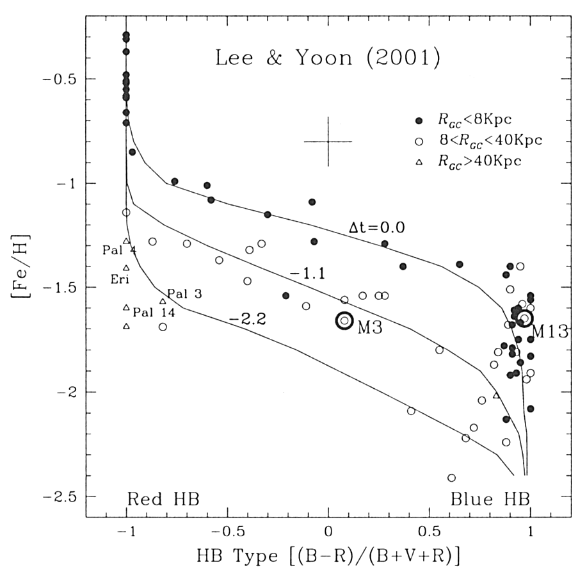

Figure 1. New HB population models are more sensitive to age compared to our earlier models. $\Delta t = 0$ corresponds to the mean age of the inner halo (R < 8 Kpc) clusters, and the relative ages are in Gyr.

3. The Case of M3 and M13

We obtained high quality color-magnitude data for the classic second parameter globular clusters M3 and M13. The clusters were observed during the same nights with the same instruments (MDM 2.4m), allowing us to determine ac-

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curate relative ages. From the color difference method between the turnoff and the base of the red giant-branch (RGB), we now confirm M13 is indeed 1.7±0.5 Gyr older than M3 (Fig. 2; see Rey et al. 2001 for details). This is consistent with the age difference predicted from our new HB models (see Fig. 1), which provides a further support that the HB morphology is a reliable age indicator in most population II stellar systems.

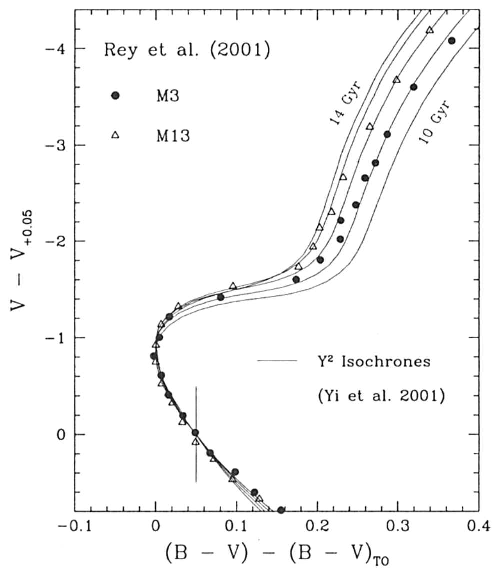

Figure 2. The fiducial sequence for M3 is compared with that for M13 following the prescription of VandenBerg et al. (1990). Note the separation between the two clusters' RGBs, indicating an age difference.

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