Extragalactic Star Clusters
IAU Symposium Series, Vol. 207, 2002
Doug Geisler, Eva K. Grebel, and Dante Minniti, eds.

The Hβ Index As a Chronometer of Extragalactic Globular Cluster Systems

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Abstract. For the first time, we have taken into account the detailed systematic variation of horizontal-branch (HB) morphology with age and metallicity in our population synthesis models and they result that the integrated Hβ index is significantly affected by the presence of blue HB stars. As a matter of fact, due to the systematic HB morphology variation, it is found that Hβ does not monotonically decrease as metallicity increases at given ages, but shows a kind of wavy feature. According to our models, a systematic difference between the globular cluster system in the Milky Way Galaxy and that in NGC 1399 in the Hβ vs. Mg_2 plane is explained if globular cluster systems in giant elliptical galaxies are a couple of billion years older, in the mean, than the Galactic counterpart.

1. Introduction

For distant stellar populations, one relies upon the integrated colors or spectra to investigate their ages and metallicities since individual stars are not resolved. Here, we specifically focus on the Hβ index, which is widely used as an age indicator. Most of the previous works (e.g., Worthey 1994), however, have been done on the basis that stars near the main-sequence turnoff (MSTO) region are the most dominant sources for the integrated strength of Hβ. Consequently, without meticulous consideration for stars beyond the red giant branch, they claimed that the strength of Hβ depends on the location of the MSTO, which in turn depends on the age at a given metallicity. Several investigators, however, have cast some doubt upon the sensitivity of the Hβ index given the presence of other warm stars, especially blue horizontal-branch (HB) stars (e.g., Burstein et al. 1984; Jorgensen 1997).

On the observational side, it was barely possible to obtain low signal-to-noise (S/N) spectra of globular clusters in systems outside the Local Group (e.g., Mould et al. 1990). These spectra have been useful only for kinematic information. With the advent of 10 m-class telescopes, however, Kissler-Patig et al. (1998) and Cohen, Blakeslee, & Ryzhov (1998) have successfully obtained relatively high S/N spectra that provide the reliable line index calibration for globular clusters in NGC 1399 and M87, the central giant elliptical galaxies in Fornax and Virgo clusters.

https://doi.org/10.1017/S0074180900224674 Published online by Cambridge University Press

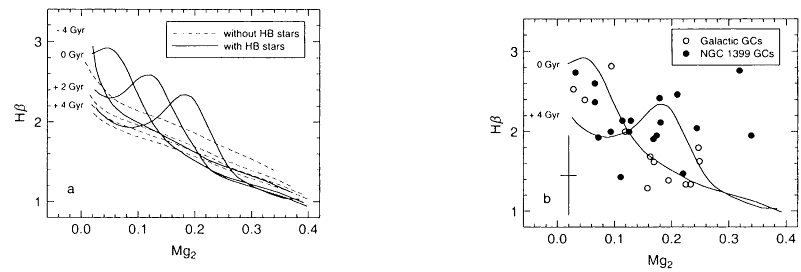

Figure 1. (a) Effect of HB stars on the strength of Hβ as predicted from our models. (b) The comparison of Galactic globular clusters with those in NGC 1399. Observational errors are displayed for clusters in NGC 1399. Note that the overall distributions of the globular cluster system in NGC 1399 is different from that in the Milky Way Galaxy, indicating that giant elliptical galaxies may contain globular clusters that are a couple of billion years older, in the mean, than those in the Milky Way.

2. Populations Models with Horizontal-Branch Stars

For our population models, the Yale Isochrones (Demarque et al. 1996), rescaled for α-element enhancement (Salaris, Chieffi, & Straniero 1993), and the HB evolutionary tracks by Yi, Demarque, & Kim (1997) have been used. The Salpeter (1955) initial mass function is adopted for the relative number of stars along the isochrones. For the conversion from theoretical quantities to observable quantities, we have taken the most recently compiled stellar library of Lejeune, Cuisinier, & Buser (1998) in order to cover the largest possible ranges in stellar parameters such as metallicity, temperature, and gravity. The detailed calculation method of spectral index is presented in Lee, Yoon, & Lee (2000).

In Figure 1a, the variations of Hβ strength as a function of metallicity (Mg_2) are plotted at given ages. Here, $\Delta t = 0$ Gyr corresponds the recently favored mean age of Galactic globular clusters ($\sim$ 12 Gyr) in the light of new distance scale as suggested by HIPPARCOS (e.g., Chaboyer et al. 1998). Note that, unlike the models without HB stars (*dashed lines*), distinct "wavy" features appear in our models with HB stars (*solid lines*). It is found that the strength of Hβ does not simply decrease with either increasing age or increasing metallicity once HB stars are included in the models. Now it is evident that the blue HB stars around $(B - V)_o \sim 0$ are the key contributors for the strength of Hβ. The differences in Hβ strengths between the models with and without HB stars are as much as 0.75 Å at the peak. In addition, it should be noted that the peak of the Hβ enhancement moves to higher metallicity as age gets older.

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3. Comparison with Observations

Having confirmed that the detailed modeling of HB is crucial in the use of Hβ index as an age indicator, Figure 1b compares our results with observations of globular cluster systems in the Milky Way and in NGC 1399. It is important to note here that all of these observations were carried out at the Keck telescope with the identical instrumental configuration, the Low Resolution Imaging Spectrograph (LRIS, Oke, de Zeeuw, & Nemec 1995). Despite the still large observational uncertainties, it is inferred from Figure 1b that the NGC 1399 globular cluster system is perhaps systematically a couple of billion years older, in the mean, than the Galactic counterpart.

It is of considerable interest, in this respect, to find that a similar age difference is inferred from the "metal-poor HB solution" of the UV upturn phenomenon of local giant elliptical galaxies (Park & Lee 1997; Yi et al. 1999). If our age estimation is confirmed to be correct, this would indicate that the star formation in denser environments has proceeded much more rapidly and efficiently, so that the initial epoch of star formation in more massive (and denser) systems occurred a couple of billion years earlier than that of the Milky Way (see also Lee 1992).

Acknowledgments. Hyun-chul Lee would like to thank the organizers, especially Eva, Doug, & Knut, of this beautiful symposium for their hospitality and for providing financial support.

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