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IS CALCIUM II TRIPLET A GOOD METALLICITY INDICATOR OF GLOBULAR CLUSTERS IN EARLY-TYPE GALAXIES?

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ABSTRACT

We present population synthesis models for the calcium II triplet (CaT), currently the most popular metallicity indicator, based on high-resolution empirical spectral energy distributions (SEDs). Our new CaT models, based on empirical SEDs, show a linear correlation below [Fe/H] ∼ –0.5, but the linear relation breaks down in the metal–rich regime by converging to the same equivalent width. This relation shows good agreement with the observed CaT of globular clusters (GCs) in NGC 1407 and the Milky Way. However, a model based on theoretical SEDs does not show this feature of the CaT and fails to reproduce observed GCs in the metal–rich regime. This linear relation may cause inaccurate metallicity determination for metal–rich stellar populations. We have also confirmed that the effect of horizontal-branch stars on the CaT is almost negligible in models based on both empirical and theoretical SEDs. Our new empirical model may explain the difference between the color distributions and CaT distributions of GCs in various early-type galaxies. Based on our model, we claim that the CaT is not a good metallicity indicator for simple stellar populations in the metal–rich regime.

Key words: galaxies: star clusters: general – globular clusters: general – stars: abundances – stars: evolution – stars: horizontal-branch

1. CONSTRUCTION OF CALCIUM II TRIPLET MODEL

We have adopted Cenarro et al. (2001a,b, 2002) and INDO-US (Valdes et al., 2004) empirical spectral energy distribution (SED) libraries to reproduce the calcium II triplet (CaT) models of simple stellar populations. We applied the same input physics and stellar parameters used in Chung et al. (2013a,b). Figure 1 shows our model results with globular clusters (GCs) in NGC 1407 and the Milky Way. Our models show good fits to the observations, converging to 8 Å in the metal–rich regime. These shapes for the CaT–metallicity relations are very similar to the empirical CaT predictions of Vazdekis et al. (2003). However, our model based on theoretical SEDs (Munari et al., 2005) does not converge in the metal-rich regime. This may be because of the poor calibration of the Munari et al. (2005) library in the metal–rich regime. We have also confirmed the negligible effect of horizontal branch stars on the strength of the CaT (see blue lines in Figure 1).

2. IMPLICATIONS OF NEW CAT-METALLICITY RELATIONS

Our new CaT–metallicity relation does not increase with increasing metallicity in the metal–rich regime. This means that, if our relation is close to the "true" relation, the metallicity determined only from the observed CaT is very insecure for metal–rich stellar populations. In this regard, our new relation may give an explanation for the CaT distributions of GCs in early-type galaxies. We have performed the projection test (Yoon et al., 2006; Kim et al., 2013) for the metallicity distribution function (MDF) of GCs in early-type galaxies using our new CaT–metallicity relations. Figure 2 shows the result of the projection test, and our simple assumption of a Gaussian MDF reproduces the CaT distribution of GCs in early-type galaxies without any fine tuning. The converging shape of the CaT–metallicity relation makes metal–rich GCs stack around 8 Å and makes the CaT distribution of GCs skewed Gaussians.

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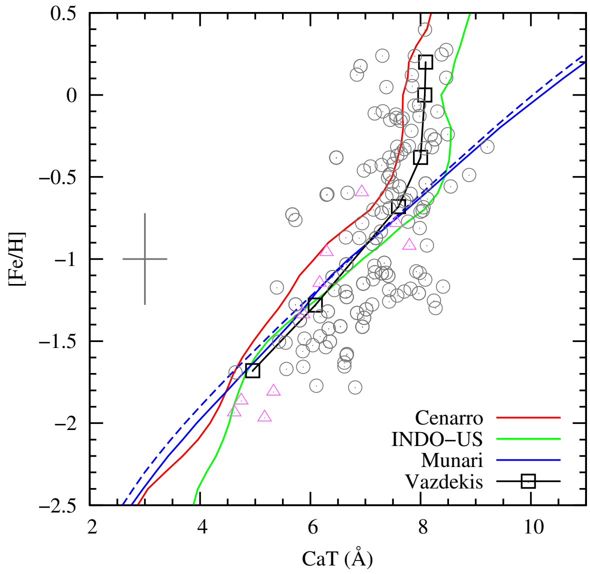

Figure 1. The comparison of CaT models with GCs in NGC 1407 and the Milky Way. Grey circles and magenta triangles are GCs in NGC 1407 and the Milky Way, respectively (Foster et al., 2010). Red and green lines are evolutionary population synthesis model based on the Cenarro and INDO-US empirical library, respectively. The black line with squares is the CaT prediction of Vazdekis et al. (2003). The model based on the theoretical spectral library (Munari et al., 2005) is displayed in blue lines. Solid and dashed blue lines indicate the model with and without horizontal branch stars. The age of all models is 12 Gyr. Our model based on the empirical library shows good agreements with the observed GCs.

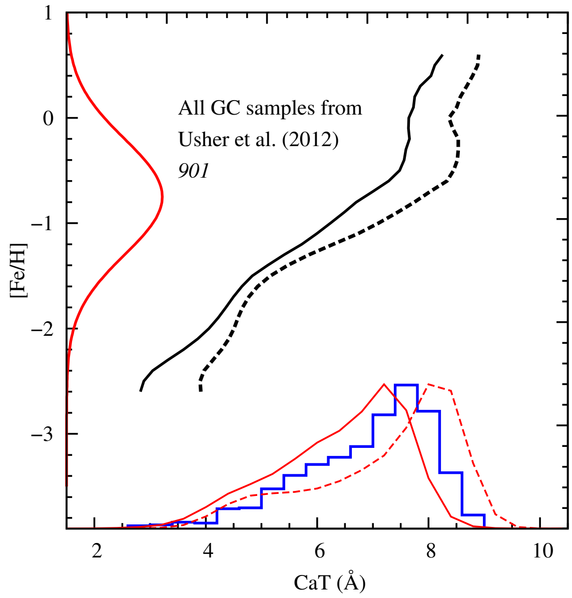

Figure 2. The projection test using new CaT–metallicity relations. Solid and dashed lines are models based on Cenarro and INDO-US empirical library, respectively. The blue histogram is 901 observed GCs in Usher et al. (2012). We assume a Gaussian MDF which has a mean value of [Fe/H] ~ -0.75 with $\sigma_{[\mathrm{Fe/H}]} = 0.55$. The line types of projected distributions follow the model used for the simulations. Our model shows good agreements with the observation.

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