Characteristic Temperature of UV Upturn of Elliptical Galaxies

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Horizontal branch (HB) and post-HB stars are widely believed to be the main sources of the UV upturn phenomenon of luminous elliptical galaxies in recent population synthesis studies (Bressan et al. 1994, Dorman et al. 1995, & Yi et al. 1995). Since the magnitude of the UV flux from these highly evolved helium burning stars is sensitive to age, the UV upturn could be an independent age indicator for elliptical galaxies.

Characteristic temperature of the UV upturn ($T_{UV}$), being independent of the magnitude of the UV upturn, provides important constraints on the underlying physics of the population synthesis by telling us accurately about the mean temperature of the hot HB stars. The recent HUT UV observations (Brown et al. 1995) suggest that the UV spectra of 6 elliptical galaxies are best reproduced by stars of $T_{eff}$ (namely, $T_{UV}$) = 20000 - 23000 K.

The $T_{UV}$ primarily depends on the mean temperature of the hot HB stars, which is not trivial to derive unless full post-HB tracks are taken into account. For example, figure 1-(a) shows that a 14 Gyr old, metal-rich system has most of its HB and post-HB stars in the hot region of the CMD, assuming a gaussian mass dispersion on the HB. The black square on the red end of the HB would be the position of the HB if neither a mass dispersion nor a full evolutionary track is taken into account; this hypothetical galaxy would not produce any noticeable UV flux except for some from post-AGB stars. Even a small mass dispersion produces a significant UV flux because the temperature of the metal-rich, low-mass HB stars is very sensitive to the mass. It is clear that both a reasonable mass dispersion and full tracks are important especially for UV population synthesis. Even if both accurate tracks and a plausible mass dispersion are included, the $T_{UV}$ is sensitive to several other parameters, eg. chemical composition (eg. $\Delta Y/\Delta Z$) and the mass loss efficiency. There are more than one set of these parameters that produce a similar magnitude of UV upturn, hence, one should choose model parameters with sufficient justification (Yi et al. 1996).

We constructed population synthesis models assuming a gaussian mass dispersion with $\sigma_{M,ass}=0.06$, $\Delta Y/\Delta Z= 2 \& 3$, and a mass loss efficiency parameter $\eta=0.5$ in the Reimers' formula. The $\sigma_{M,ass}$ and $\eta$ are chosen to reproduce the HB morphology of Galactic globular clusters and the mass of RR Lyrae stars in them, and $\Delta Y/\Delta Z$ was deduced from the solar chemical composition. Note that none of these parameters have been empirically verified for metal-rich ([Fe/H] $\geq 0$) stars because of lack of nearby sample stars.

The flux ratio on figure 1-(b) is a direct function of $T_{eff}$ and $T_{UV}$. The ratios for the galaxies have been estimated from the figure 1 of Brown et al.(1995). Their $T_{UV}$s are approximately 20000 K, according to the flux ratio comparison. Since the largest model $T_{UV}$s (that is, the one for 25 Gyr old model) for [Fe/H]
Figure 1.  (a) A model CMD of 14 Gyr old, metal-rich galaxy. the black square on the red end of the HB would be the position of the HB stars if neither a mass dispersion on the HB nor full tracks are taken into account. Larger circles represent larger number of stars. (b) $T_{UV}$s for model galaxies are marked as ages (in Gyr) on the stellar $T_{eff}$-flux ratio relation for 3 metallicities (lines). A noticeable UV upturn starts to show at the smallest age on each line.

$T_{UV}$s = -1.5, 0.0, and +0.5 are about 21000, 18000, and 20000 K, respectively, all these models predict too low a $T_{UV}$ for NGC 3379 whose $T_{UV}$ is at least 21000 K, unless an implausibly large age is assumed. Besides, considering that the HUT spectra are similar to the solar-abundance stellar spectra in terms of line strength, the observed $T_{UV}$ range is clearly higher than expected for a solar-abundance model galaxy (dotted line on figure 1-(b)) by 1000 - 3000 K. The solar-abundance models barely reproduce the smallest flux ratio (of NGC 3115) even at the age of 25 Gyr.

A slightly higher mass loss efficiency for the metal-rich stars ([Fe/H] $\geq$ 0) would increase the model $T_{UV}$. Recent discovery of unexpectedly hot HB stars in NGC 6791 (Liebert et al. 1994) may support the hypothesis that more metal-rich stars experience a higher mass loss. The mass loss efficiency parameter $\eta$ plays the most important role in the UV population synthesis. A more extensive study will be carried out for various $\eta$ and HB mass dispersion assumptions.

References