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BINARY POPULATION SYNTHESIS, SDB STARS AND THE UV UPTURN

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Abstract. We aim to use the methods of binary population synthesis (BPS) to study the ultraviolet upturn (UVX) in the spectra of giant elliptical galaxies with emphasis being placed on those binary channels which could lead to the formation of stars that can account for it. This project will combine Sukyoung Yi's single star population synthesis methodology with that of Zhanwen Han's binary population synthesis methods in order to provide a more coherent study of the origin of the UV upturn, the focus being on sdB stars as the possible source of the UV upturn. The primary approach of the project will be to explore the UV upturn, with sdBs included, for several different metallicities in order to examine the UVX in composite populations.

Key words: stars: hot subdwarfs – stars: binaries: general – galaxies: elliptical – galaxies: stellar content

1. THE UV UPTURN (UVX)

At present, a moderate consensus suggests that low-mass core helium burning stars, which are in the HB phase of their evolution, serve as the strongest candidates for sources of the UVX in stellar populations. The UVX is characterized by a high increase in rest-frame UV flux (in the range of $\lambda \sim 1000$–2500 Å) in the spectra of elliptical (E) galaxies, S0 galaxies and in the bulges of spiral galaxies.

2. UVX HYPOTHESES

Most population synthesis studies of the UVX, including those of Yi (1997, 1998), assume that it arises from the evolution of single HB stars. However, others, such as Han and Podsiadlowski (HP), having conducted an extensive binary population synthesis study of the origin of sdB stars (Han et al. 2002, 2003) formed via binary channels, note that sdB stars could help account for a significant portion of UV radiation in galaxies; in fact, HP have also conducted an extensive study of the UVX at solar metallicity. In the single star scenario, two hypotheses make contradictory claims as to how the UVX originates from low-mass HB stars. The metal-rich hypothesis (Yi et al. 1997, 1998) claims that the UVX originates in metal-rich stars characterized by a high He abundance, and, hence, high mass-loss. In contrast, the metal-poor hypothesis (Park & Lee 1997) claims that the UVX is the natural consequence of the oldest, metal-poor stars in a GE having evolved into the HB phase of their lives. In the binary scenario, the UVX originates from EHB stars in the form of sdBs which result from several different types of binary evolution channels: (1) common envelope (CE) ejection; (2) RLOF in one binary component and (3) merger of two WDs.

3. INPUT MODELS

EPS models for single star evolution are here combined with the products of binary population synthesis models to produce a combined population synthesis. The EPS models and methods employed are those of Sukyoung Yi and Seok-Jin Yoon. In these, data from the Y^2 isochrones and realistic synthetic HB constructions have been reduced and processed into synthetic CMD and SED models by Seok-Jin Yoon. The sdB models are products of Han (1995) binary population synthesis code, which uses an input grid generated by an updated version of Eggleton's original stellar evolution code (Eggleton 1971, 1972, 1973). The spectral library employed is that assembled by Lejeune et al. (1997). Tables 1 and 2 list the model input parameters.

Table 1. General input parameters.

Stellar population:	10^7 single stars; 10^7 binaries
IMF:	Miller-Scalo
Age range:	1 − 20 Gyr
Metallicity:	$Z = 0.02$ (single abundance population)
Stellar mass range:	$0.1\,M_\odot < m < 100\,M_\odot$
Binary input parameters:	
Binary fraction:	67%
Flat distribution in q:	$n(q) = 1$
Critical mass ratio:	$q_{\rm crit} = 1.5$
Reimers mass-loss coefficient:	$\eta = 0.25$
Common ejection frequency:	$\alpha_{\rm CE} = 0.75$
Thermal energy conversion efficiency:	$\alpha_{\rm TH} = 0.75$

Table 2. Model input parameters.

Parameter	Yi	Han
Convective core overshoot:	$0.20H_p$	$0.25H_p$
Mixing length parameter (l/H_p)	1.7431	2.0
Helium abundance (Y):	0.27	0.28
He enrichment parameter ($\Delta Y/\Delta Z$):	2.0	2.0

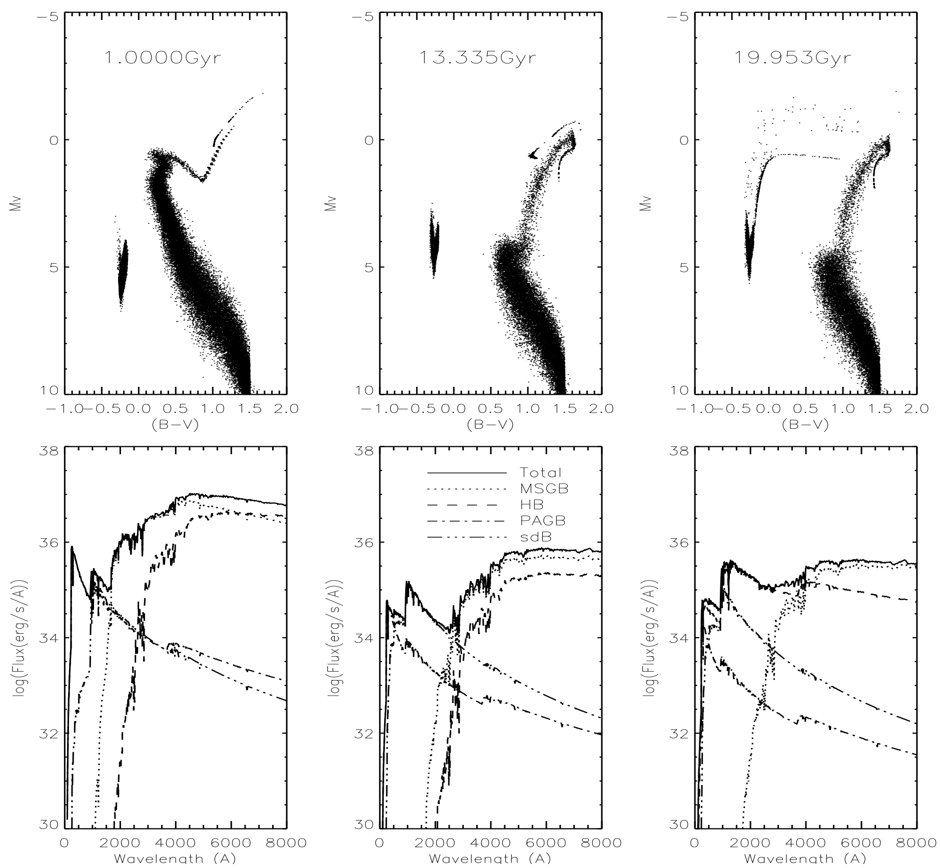

Fig. 1. Time evolution of the SSP as shown in the given CMDs and SEDs.

4. PRELIMINARY RESULTS

As a prelude to studying the UVX in composite systems (GEs), the first step of this inquiry has been to examine the UVX in a simple stellar population (SSP) for a single abundance of $Z = 0.02$. Both single and binary stars have been included in the population synthesis study. Figure 1 shows the CMD and SED time evolution of the population, respectively, for the given ages. With sdBs included, the total FUV flux decreases with increasing age until the trend is reversed by a contribution from single HB stars for late ages. The corresponding color evolution of *1500–V* with redshift z is given in Figure 2 (the solid line) along with two other models for composite systems obtained by Yi et Yoon (Lee et al. 2005). As seen, there is an increase of *1500–V* for the redshift range $0.0 < z < 0.2$ in contrast to that suggested by the other two models and empirical data points of NGC 1399 and Abell 2670. Incidentally, the cosmological parameters are $\Omega = 0.15$, $\Lambda = 0.85$, $z_F = 4.9$ and $H_o = 64.0$.

5. SUMMARY AND FUTURE PROSPECTS

Since the parameter space over which this study has been conducted is very limited ($Z = 0.02$ and $\eta = 0.25$), the results presented here are inconclusive in regard to the UVX hypotheses discussed earlier. Interestingly though, the given SSP does exhibit a UVX due to the presence of sdBs at early ages and later. However, the downward trend in *1500–V* for lower redshifts is not reversed, which differs from an increase in *1500–V* near low redshifts in GEs. The difference in results can stem from the fact that the SSP is a single abundance population whereas giant elliptical galaxies are composite metal-rich systems. Much is still to be learned from a study of Population II and super-solar stellar populations. Both abundance domains are the primary aims of this project in the future through an adaptation of Han's BPS code for different metallicities, mass-loss prescriptions and binary input parameters to see how the UV contribution from sdBs is affected.

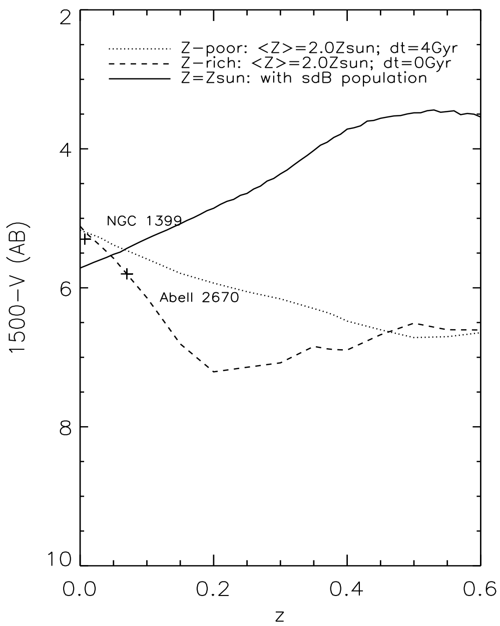

Fig. 2. Evolution of *1500–V* with z. Data points for NGC 1399 and Abell 2670 are from the GALEX survey (Lee et al. 2005).

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