Baltic Astronomy, vol. 15, 77–80, 2006.

A SPECTROSCOPIC SEARCH FOR NEW SDB STARS FROM THE GALEX SURVEY

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Received 2005 August 1

Abstract. We have recently initiated a systematic search for the UV-bright, subdwarf B (sdB) stars in the Milky Way. The sdB stars are core He-burning stars with very thin H envelopes and are known to be immediate progenitors of white dwarfs, but their formation mechanism is still enigmatic. For instance, it is not clear whether such objects are born as single stars or can form only in binary systems. The number ratio of sdB stars in each Galactic stellar population (i.e., thin disk, thick disk and halo) may give a clue to which of the suggested formation mechanisms dominates: the binary scenario or the RGB-peel-off scheme. This approach was hampered by the lack of identified sdB stars belonging to the thin disk and halo. Thus, it is of primary importance to find new sdB stars that are faint (halo) and lie at lower Galactic latitudes (thin disk). In this contribution, we will describe the motivation and plan for our spectroscopic survey and preliminary results based on pilot observations for 34 sdB star candidates from the GALEX All-sky Imaging Survey.

Key words: stars: early-type – stars: subdwarfs – surveys

1. INTRODUCTION

The UV bright, hot subdwarf B (sdB) stars are considered to be core He-burning stars of 0.5 $M_{\odot}$ with very thin H envelopes of $M_{\rm env} \leq 0.02 M_{\odot}$ (Heber 1986). In the Galactic field, they are characterized by H-dominated atmospheres with $T_{\rm eff} \approx 24\,000$–$30\,000$ K and $\log g > 5$. Their counterparts in globular clusters are generally recognized to be extended horizontal-branch (EHB) stars found as the faint and blue tail of the horizontal-branch (HB) in clusters such as NGC 6752 and M 13. These observations suggest that the UV-bright stars might be populous enough to account for much of the UV uptrun phenomenon observed in elliptical galaxies and spiral galaxy bulges (Greggio & Renzini 1990; O'Connell 1999; Yi et al. 1999). The sdB stars are known to be immediate progenitors of low mass white dwarfs (WDs), although they consist of only a small fraction of whole sample of WD progenitors (Saffer et al. 1994). In their past, sdB stars must have experienced a core He flash and substantial mass-loss during or after the red giant branch (RGB) phase. But, it is still a mystery how the mass-loss mechanism in the sdB star's progenitor manages to remove all but a tiny fraction of the H envelope exactly at the same time when the He core has attained the canonical sdB mass of 0.5 $M_{\odot}$ required for the He flash. This project aims to study the sdB population in the Galaxy, which may shed light on their still enigmatic formation process.

2. WHY LOOK FOR "NEW" SDB STARS?

Major formation channels of sdB stars can be divided into two scenarios: (1) single sdB stars are created from the enhancement of stellar wind near the RGB tip which strips off the H envelope (D'Cruz et al. 1996), and (2) sdB stars are formed from close binary evolution with strong mass transfer by a companion (Mengel et al. 1976). Previous observational results are not in contradiction with either scenario (Maxted et al. 2001; Altmann et al. 2004). The RGB-peel-off models predict a depletion of the HB stars in the middle temperature range (HBA stars) as metallicity increases, while stars at the hot and cold ends of HB (sdB and Red HB stars) should be abundant at all metallicities. Thus, as proposed by Altmann et al. (2004), the number ratio of sdB stars in each stellar population may provide a clue to answer which formation mechanism can be dominating. If the binary scenario is the most significant process, the number ratio of sdB stars in the thin disk, thick disk and halo would be similar to that of other evolved, low-mass stars. In the RGB-peel-off scheme, sdB stars would be more dominant over HBA stars in the thin disk. Unlike the known case of HBA stars (e.g., Altmann & de Boer 2000), this approach was hampered by the lack of identified sdB stars belonging to the thin disk and halo. Therefore, it is particularly important to increase the number of identified sdB stars with faint magnitudes (halo) and at lower Galactic latitudes (thin disk), and GALEX can provide useful targets for it.

It has lately been confirmed that large He abundance variations (ΔY) among stars can not only naturally reproduce the EHB stars in ω Cen, but can also explain the large spread of FUV magnitude for the EHB stars in NGC 2808 (Lee et al. 2005). They have suggested He abundance being a third parameter which influences HB morphology of such clusters, other than metallicity and age. Spectroscopic distances of these field sdB stars will be derived from stellar radii and angular diameters: the former is based on the surface gravity measured from the spectra and a canonical mass of 0.5 $M_{\odot}$, and the latter is obtained from comparing model atmosphere flux with dereddened NUV photometry. We then expect to be able to determine absolute $M_{\rm FUV}$ of sdB stars at an accuracy of 0.2 magnitude owing to the spectroscopic distances and GALEX FUV photometry, and thus reasonable ΔY among the sdB stars by the comparison of, if any, observed $M_{\rm FUV}$ spread and the predictions derived from isochrones. This would permit us to systematically obtain ΔY of sdB stars as a function of stellar population in order to study the global third parameter effect of the Galaxy.

It has been known that sdO stars have a larger scale height (≥ 1.0 kpc, Thejll et al. 1994) than sdB stars (~ 0.5 kpc, Villeneuve et al. 1995), which is inconsistent

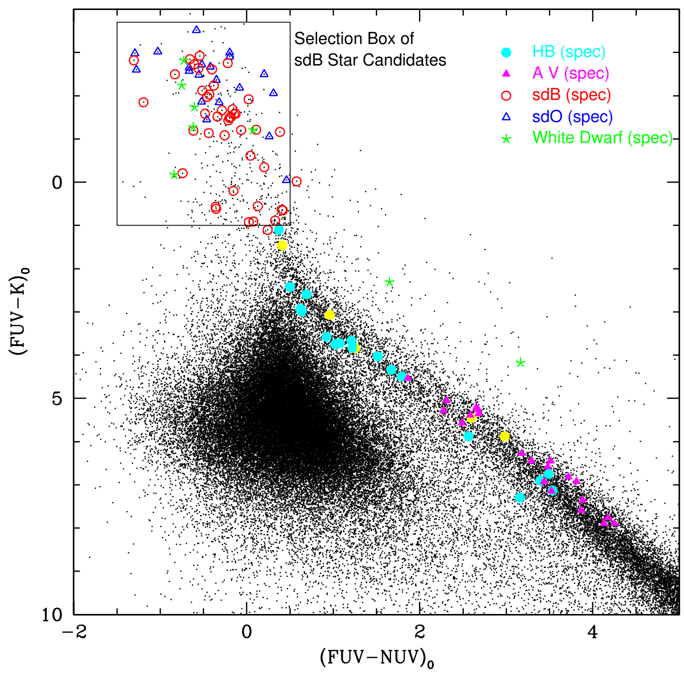

Fig. 1. GALEX AIS objects from about 1000 fields in GR1, also matched in 2MASS. Spectroscopically known sdB/O, WD, HB and A V stars are marked by different symbols. The sdB and sdO stars are clearly separated.

with an evolutionary connection between sdB and sdO stars. But, a larger scale height of 0.9 kpc has recently been obtained including "fainter" (but still $B \leq 16$) sdB stars (Altmann et al. 2004). This implies that a correct scale height can only be obtained with a sample without limiting magnitude bias.

3. CANDIDATE SELECTION

The public GALEX Release (GR1) of All-sky Imaging Survey (AIS) data was made in 2004 December. We performed cross-matching of the GALEX and 2MASS catalogs for some 3000 AIS fields (~3500 deg^2). As seen in Figure 1, two-color diagram efficiently separates sdB/O stars because the FUV–NUV color provides relatively long temperature baseline (spectral type) for hot stars, while the FUV–K_S color is useful for classification between stellar and non-stellar objects. Our empirical comparison with spectroscopically known sdB/O stars agrees well with the above expectation. It should be pointed out that replacing 2MASS K_S with SDSS i or USNO-B I gives a similar result, so our sdB candidate stars should reach apparent magnitude NUV ≈ 20 ($B \approx 20$), four magnitudes fainter than for the Palomar Green survey (Green et al. 1986) which was one of the most extensive surveys for sdB star in the past. Using this method, we have selected a sample of some 1000 sdB star candidates over a range of depths and sky-coverages.

4. OBSERVATIONS, RESULTS AND PLANS

We have performed pilot spectroscopic observations for 34 sdB star candidates with the KPNO 2.1 m telescope and GoldCam, McDonald 2.7 m telescope and LCS and Lick 3.0 m telescope and KAST between 2004 June and 2005 May. Based on the visual inspection of spectra and measurements of $D_{0.2}$ (average width of Hγ and Hδ lines at 20% below continuum) and R_c (average depth of Hγ and Hδ lines) employed in Beers et al. (1992), the medium-resolution (1–3 Å) spectroscopy has revealed that the sample consists of 14 sdB, 5 narrow-lined B, 8 WD, 4 HBB with He lines and 3 normal B stars. Based on the preliminary detection rate of sdB stars (14/34) and the number of our sdB star candidates ($N \geq 1000$), we expect to "newly" confirm more than 400 *bona fide* sdB stars in the halo and thin disk as well as in the thick disk. In the future, more sophisticated methods will be employed to determine stellar parameters (log g, $T_{\rm eff}$, and He abundance) accurately. Using observing time awarded at the CTIO 4.0 m, KPNO 2.1 m and Lick 3.0 m telescopes, we plan to complete a spectroscopic survey of some 1000 sdB star candidates by early 2006. Radial velocities determined from our spectroscopy, combined with proper motions from astrometric surveys such as UCAC2 (Zacharias et al. 2004), USNO-B (Monet et al. 2003) and future space missions (Gaia and SIM), will provide us with full space motions and thus allow us to assign population membership for the sdB stars. Indeed, this huge data set of GALEX sdB stars, which reach the entire UV visible Milky Way, will eventually help us broaden our understanding about their formation/evolution mechanism and Galactic structure.

ACKNOWLEDGMENTS. We are grateful to the referee, Sabine Moehler, for her careful review of the paper and a number of thoughtful suggestions. We gratefully acknowledge support for this work from NASA grant GALEX GI 04-0000-0096. J. R. and Y.-W. L. appreciate partial support by the Korean Ministry of Science and Technology through the Creative Research Initiative Program.

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