EVOLVED STARS IN THE HALO OF OUR GALAXY FROM THE PALOMAR-GREEN SURVEY

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ABSTRACT: We present high-resolution spectroscopic observations of early-type stars, drawn from a complete sample of targets from the Palomar-Green Survey. Qualitatively, the metal-line spectra are sharp and are therefore indicative of extremely low projected rotational velocities. As such the objects are characterized as members of an old, evolved population (for example, blue horizontal branch or post-asymptotic giant branch). Quantitatively, the CNO abundances from model atmospheric analyses suggest the presence of nucleosynthesis dredge-up products in the stellar photospheres. By careful choice of Pop I galactic disk B-type stars we have computed differential abundances between the targets and their main-sequence analogues. With one exception, they all have [Fe/H] abundances consistent with their progenitor objects being metal deficient. Some conclusions are drawn as to the previous evolution (red giant branch, horizontal branch or asymptotic giant branch) of the stars. A full description of these data will appear in the Astrophysical Journal.

1. BACKGROUND:

There has been some controversy surrounding the nature and origin of faint blue stars observed at high galactic latitudes. In recent years, we have undertaken high-resolution spectroscopy of such B-type objects and, while there remains a small number of stars that are most certainly young (core hydrogen burning) at large distances from the galactic disk, it has become increasingly clear that low-mass stars in hot stages of post-main-sequence evolution are a serious source of contamination to samples of apparently young, blue objects defined via low-resolution spectroscopy.

In an effort to resolve the uncertainties concerning the evolutionary status of all these objects, we have instigated a wide-field survey exploiting the Palomar-Green survey (Green et al. 1986) of ultraviolet excess objects, covering some 10% of the sky. Employing a two-pass filter approach, we have identified complete magnitude-limited samples from photographic photometry; subsequent low-resolution spectroscopy eliminated high gravity sub-dwarfs, finally yielding complete lists of lower gravity stellar objects for high-resolution follow-up. Echelle spectroscopy of the PG targets was obtained using the WHT 4.2-m and Mayall 4.0-m telescopes, at a resolution of ~ 0.1 - 0.2 Å over the wavelength range 3900 - 5000 Å. Bright, Pop I B-type comparison stars were observed using the 0.9-m could feed telescope at Kitt Peak.
Fig. 1. Examples of the spectra obtained for the Palomar-Green stars and bright, normal Pop I B-type objects respectively. This spectral region, bluewards of Hβ, contains stellar absorption features due to C II, N II and O II.

2. MODEL-ATMOSPHERE ANALYSES

Line-blanketed model-atmospheres of Kurucz (1991) together with LTE radiative transfer codes have been used to derive stellar atmospheric parameters and chemical compositions. Furthermore, a detailed differential abundance analysis has been performed relative to the grid of “normal” composition B-type stars. Here, we present a sample of apparently old, evolved low-mass stars and discuss their significance.

3. DISCUSSION OF INDIVIDUAL STARS

PG 0823+499: The star exhibits large C and N enhancements; the remaining metals indicating that the star is of Pop I origin. Its $T_{\text{eff}}$ log g place it well below the lowest mass post-AGB computations and above the ZAHB. The C, N and possible He enhancements are perhaps evidence that it has undergone significant enrichment of those elements during a core helium flash at the tip of the RGB during its evolution previous to becoming a BHB star.

PG 0832+676: This object shows only marginal evidence of abnormal CNO abundances, while there is a general heavy metal depletion of ~ 0.4 dex. It lies very close to the lowest mass post-AGB evolutionary track; however, the chemical composition and uncertainties in $T_{\text{eff}}$ log g do not allow us to distinguish between a post-AGB or post-BHB interpretation for this star.

PG 0833+699: The high surface gravity of this star effectively rules out a post-AGB interpretation. In addition, the CNO abundances show the remarkable pattern seen in PG 0823+499; however the heavy metal abundances do not clearly indicate the progenitor composition. It is interesting to note that S and Ar are less depleted than Fe. This star may therefore exhibit the “gas separation” effect observed in
some post-AGB candidates known to be in binary systems.

PG 0954+049, PG 1008+689: The gravities are once again too high for post-AGB objects, and the likelihood is that these stars are evolving off the BHB. The objects present somewhat discordant abundance patterns for Mg, P and Fe. Interestingly, a phosphorus enhancement is seen in the field BHB star Feige 86, where it seems likely that radiative levitation of phosphorus from deep layers has taken place. The helium depletions indicate that gravitational diffusion has occurred.

PG 1212+369: This star is an eclipsing binary system and has a mass determination \((m = 0.39 \pm 0.05\ M_\odot)\). This mass, and the atmospheric parameters derived here, are consistent with the interpretation that the object was once a low-mass, core helium burning star and is now post-BHB. Our abundance values once again indicate an old population origin for this star. The lack of a visible C II doublet at 4267 Å implies a large depletion in carbon.

PG 1213+456: No iron abundance was measured for this target; however the Mg and Si differential abundances imply a metal-weak population origin. The high surface gravity suggests the object is not in a post-AGB phase of evolution, while the severe C depletion makes the object quite distinct from the two candidate C-enriched BHB stars PG 0823+499 and PG 0833+699. However, this star is probably a post-BHB object.

PG 1224+672: This star is the hottest in the sample, with a high surface gravity \((\log g = 5.3)\). The star's atmosphere is clearly He and O depleted, and it is a subdwarf, lying at the high temperature limit of the extended horizontal branch.

PG 1243+275: The surface gravity for this star does not discriminate well between the possibility of a post-AGB or BHB star. The abundance information shows a large metal depletion for O, Mg, Si and Fe while N is possibly less depleted. Once again, this seems more akin to the sdB candidates discussed above than to the BHB stars.

Fig. 2. The positions of the program stars (solid squares) in the \(T_\text{eff} - \log g\) plane, where the theoretical tracks of the ZAMS (dotted lines), BHB (solid line), PAGB (dotted lines) and a \(M_\odot = 0.5\ M_\odot\) post-BHB helium shell burning star (dashed line) are indicated. Also shown are candidate post-AGB stars studied previously by us (crosses).
PG 1310+316, PG 1351+393: They appear to be "classic" BHB stars in that they are both extremely helium weak and they both have secure iron differential abundances that point to an old population. PG 1351+393 also shows the large phosphorus enhancement seen in, for example, PG 1008+68

PG 2301+259: Once more, the atmospheric parameters indicate a post-BHB nature for this star, and the He depletion is clearly seen. A large enhancement is observed for Cl and P; although a direct differential measurement is not available for either species. Similar trends have been observed in the BHB stars PHL 25 and PHL 1434.

Generally, all the stars show anomalous abundance patterns that can be explained in terms of post-main-sequence evolution. Given the effects of gravitational diffusion and radiative levitation (which are clearly seen in some of the stars) it is difficult to elucidate the progenitor metallicities, however it seems likely that with the possible exception of PG 0823+499, these stars belong to an old, metal weak population.

REFERENCES

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