Why Galaxies Care About AGB Stars: A Continuing Challenge through Cosmic Time
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Observations of the Ultraviolet-Bright Star Barnard 29 in the Globular Cluster M13 (NGC 6205)

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Abstract. We have analyzed *FUSE*, COS, GHRS, and Keck/HIRES spectra of the UV-bright star Barnard 29 in M13. Fits to the star's optical spectrum yield $T_{\rm eff} = 20,000 \pm 100$ K and $\log g = 3.00 \pm 0.01$. Using modern stellar-atmosphere models, we are able to reproduce the complex shape of the Balmer Hα feature. We derive photospheric abundances of He, C, N, O, Mg, Al, Si, P, S, Cl, Ar, Ti, Cr, Fe, Ni, and Ge. Barnard 29 exhibits an abundance pattern typical of the first-generation stars in M13, enhanced in oxygen and depleted in aluminum. We see no evidence of significant chemical evolution since the star left the RGB; in particular, it did not undergo third dredge-up. Previous workers found that the star's FUV spectra yield an iron abundance about 0.5 dex lower than its optical spectrum, but the iron abundances derived from all of our spectra are consistent with one another and with the cluster value. We attribute this difference to our use of model atmospheres without microturbulence. By comparing our best-fit model with the star's optical magnitudes, we derive a mass $M_*/M_\odot = 0.40 - 0.49$ and luminosity $\log L_*/L_\odot = 3.20 - 3.29$, depending on the cluster distance. Comparison with stellar-evolution models suggests that Barnard 29 evolved from a ZAHB star of mass $M_*/M_\odot \sim 0.50$, placing it near the boundary between the extreme and blue horizontal branches.

Keywords. stars: abundances — stars: atmospheres — stars: individual (NGC 6205 ZNG1) — ultraviolet: stars

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The most luminous object in Messier 13 (NGC 6205) is the famous star Barnard 29. It is a UV-bright star, brighter than the horizontal branch and bluer than the red-giant branch. Some UV-bright stars are post-AGB stars, evolving from the asymptotic giant branch (AGB) to the white-dwarf cooling curve at high luminosity; others are AGB-manqué stars, evolving directly from the extreme horizontal branch (EHB) at lower luminosity.

We analyze archival spectra of Barnard 29 obtained with *FUSE*, with COS and GHRS aboard *HST*, and with the Keck HIRES. We derive stellar parameters $T_{\rm eff} = 20,000 \pm 100$ K, $\log g = 3.00 \pm 0.01$, and $\log N({\rm He})/N({\rm H}) = -0.89 \pm 0.01$. The star's photospheric abundances are plotted in Fig. 1. Our FUV results are roughly consistent with the optical values (where available) and with each other, though the scatter is sometimes greater than the error bars. Our optical results are consistent with those of Thompson *et al.* (2007), which are also shown. Preferred values are plotted as stars.

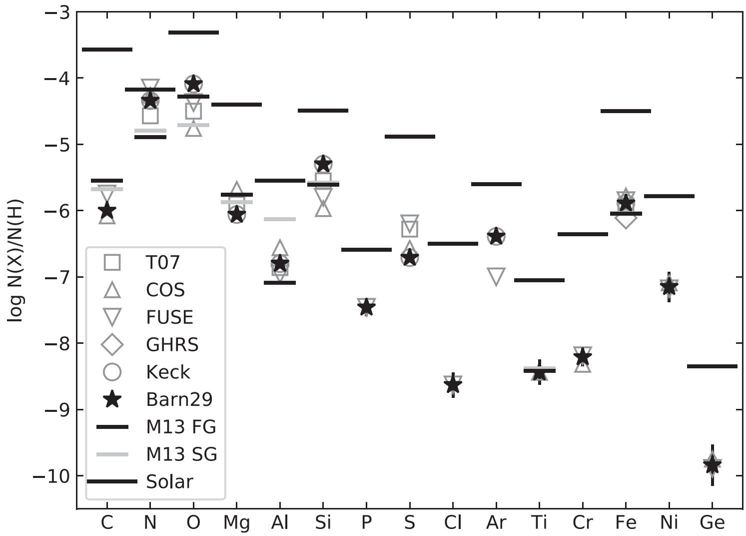

Figure 1. Photospheric abundances of Barnard 29 (stars), the solar photosphere (long black lines), and the first-generation (FG, short black lines) and second-generation (SG, short grey lines) stars in M13. Open squares are from fits to the star's optical spectrum by Thompson *et al.* 2007. Other symbols are from fits to the COS, *FUSE*, GHRS, and Keck spectra, as indicated.

We independently derive the iron abundance of Barnard 29 from its Keck, *FUSE*, COS, and GHRS spectra. As shown in Fig. 1, our values are consistent with one another and with the cluster iron abundance ($\log N(\mathrm{Fe})/N(\mathrm{H}) = -6.05$; Mészáros *et al.* 2015). Previous authors have found that the iron abundance derived from the star's far-ultraviolet spectrum is roughly 0.5 dex lower than that derived from optical data, which is consistent with the cluster mean (Moehler *et al.* 1998, Thompson *et al.* 2007). Moehler *et al.* adopt the microturbulent velocity $\xi = 10$ km s^{-1} derived by Conlon *et al.* (1994). All of our models were computed with a value $\xi = 0$ km s^{-1}, which yields line profiles that better reproduce the HIRES spectrum. Computing models with $\xi = 10$ km s^{-1} and re-fitting the GHRS spectrum yields a best-fit iron abundance $\log N(\mathrm{Fe})/N(\mathrm{H}) = -6.74 \pm 0.11$, matching the Moehler *et al.* result.

Galactic globular clusters host multiple stellar populations. First-generation (FG) stars display abundances typical of halo field stars, while second-generation (SG) stars, which may have multiple subpopulations, are enriched in Na and Al and depleted in O and Mg. Models suggest that the second generation is formed from gas polluted by material expelled by massive stars of the first generation. Mészáros *et al.* (2015) identified two stellar populations on the RGB of M13. FG stars (short black lines in Fig. 1) are richer in oxygen and poorer in aluminum than SG stars (short grey lines). Barnard 29 is clearly a FG star, richer in oxygen and poorer in aluminum. The star is slightly enhanced in nitrogen; otherwise, its abundances appear to have changed little since it left the RGB. In particular, its low carbon abundance ($N_C/N_O = 0.01$) indicates that the star did not undergo third dredge-up.

References

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