The origin and evolution of the halo PN BoBn1

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Galactic halo planetary nebulae (PNe) are interesting objects as they provide direct insight into the final evolution of old, low-mass halo stars, and they are able to convey important information for the study of lowmass star evolution and the early chemical conditions of the Galaxy. About 14 objects have been identifend as halo members from their location and kinematics since the PN K 648 was discovered in the globular cluster M 15. However, in extremely metal-poor and C- and N-rich ([C, N/O]> 0, [Ar/H]< −2) halo PNe, there are unresolved issues on chemical abundances and evolution time scales. BoBn 1 (PN G108.4-76.1) is one of the C- and N-rich and extremely metal-poor halo PNe ([C, N/O]> 1, [Ar/H]= −2.22 ± 0.09, [Fe/H]= −2.39 ± 0.14; this work).

We have performed a comprehensive chemical abundance analysis of the extremely metal-poor halo PN BoBn 1 based on *IUE* archive data, Subaru/HDS spectra, VLT/UVES archive data, and *Spitzer*/IRS spectra[1]. We have detected over 600 lines in total and calculated ionic and elemental abundances of 13 elements using detected optical recombination lines and collisionally excited lines. In the optical high-dispersion spectra, we detected emission lines of fluorine and *s*-process elements such as rubidium, krypton, xenon, and barium. The amounts of [F/H], [Kr/H], and [Xe/H] suggest that BoBn 1 is the most F-rich among F-detected PNe and is a heavy *s*-process element rich PN. The enhancement of C, N, and heavy *s*-process element is comparable to carbon and *s*-process enhanced metal-poor (CEMP-*s*) stars with [Fe/H] > −2.5 [2]. This suggests that BoBn1 shares a similar origin an evolutionary history with CEMP-*s* stars.

We built photo-ionization model using non-LTE theoretical stellar atmosphere models to check consistency between elemental abundances derived by empirical methods and from the model and to investigate the properties of the central star, ionized nebula, and dust in a self-consistent way to fit the IR wavelength region. We compared the observed elemental abundances with theoretical nucleosynthesis model predictions for single stars and binaries with $Z = 10^{-4}$. The observed elemental abundances except for N could be explained either by a 1.5 $M_\odot$ single star model or a binary model composed of 0.75 $M_\odot$ + 1.5 $M_\odot$ stars. Using theoretical evolutionary tracks for post-AGB stars, we found that the progenitor of the central star was perhaps a 1–1.5 $M_\odot$ star and evolved into a system of a white dwarf with a core mass of ~0.62 $M_\odot$ and an ~0.09 $M_\odot$ ionized nebula. We estimated the dust mass of 5.8×10^{-6} $M_\odot$ in the nebula, which composes of amorphous carbon and PAHs. The presence of carbon dust indicates that BoBn 1 has experienced the third dredge up (TDU) during the thermal pulse AGB phase.

The progenitor might have been initially quite N-rich. The He-flash-driven deep mixing might be responsible for the over-abundance of N. From careful consideration of observational results and a comparison between BoBn 1 and K 648 in M 15, we propose that the progenitor was a binary and had experienced coalescence during its evolution to become a C- and N-rich PN. The similar evolutionary scenario would be also applicable to K 648 [3].

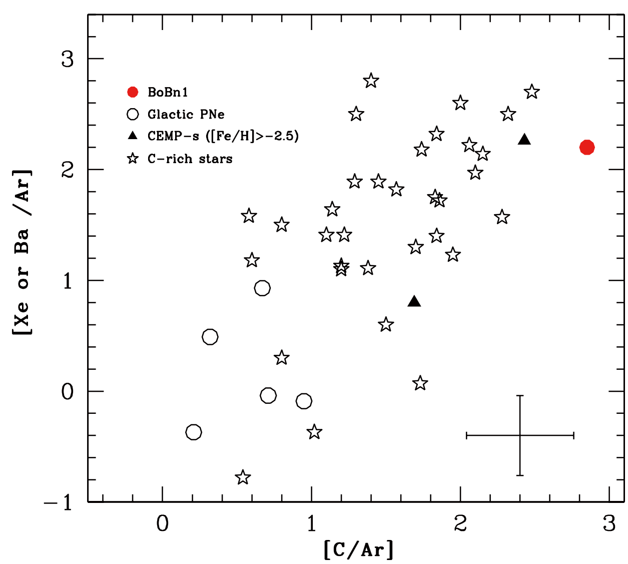

Figure 1: [Xe or Ba/Ar]-[C/Ar] diagram. The [Xe/Ar] value of BoBn 1 is upper limit. The diagram indicates that the C and *s*-process elements are certainly synthesized in the same layer and brought up to the stellar surface by the TDU.

References

[1] Otsuka, M., et al.: 2010, *ApJ*, **723**, 658.
[2] Aoki, W., et al.: 2007, *ApJ*, **655**, 492.
[3] Alves, D. R., et al.: 2000, *AJ*, **120**, 2044.