

A chemically peculiar post-AGB star in the Small Magellanic Cloud

D. Kamath¹, H. Van Winckel¹, K. De Smedt¹ and P.R.Wood²

¹ Instituut voor Sterrenkunde, K.U.Leuven, Celestijnenlaan 200D bus 2401, B-3001 Leuven, Belgium

² Research School of Astronomy and Astrophysics, Mount Stromlo Observatory, Weston Creek, ACT 2611, Australia

E-mail: ¹ devika.kamath@ster.kuleuven.be

Abstract. Post-Asymptotic Giant Branch (post-AGB) stars bear signatures of the entire chemical and morphological changes that occur prior to and during the AGB phase of evolution. These objects also provide vital clues on the ultimate fate of the star. Detailed chemical abundance studies of some of these objects have shown that they are chemically much more diverse than anticipated. As expected, some are the most *s*-process enriched objects known to date while others are not *s*-process enriched. Our recent study has revealed a star in the Small Magellanic Cloud, J005252.87-722842.9, which displays a peculiar chemical signature that does not correspond to the expected chemical diversity observed in these objects. This unique object reveals the possibility of a new stellar evolutionary channel where the star evolves without any third dredge-up episodes or during its evolution becomes devoid of its nucleosynthetic history.

1. Introduction

Post-AGB stars are low- to intermediate-mass stars that have evolved off the AGB because a strong dusty mass loss removed almost the whole stellar envelope. This mass loss occurs either by binary interaction or, for single stars, by a phase of very high mass-loss rate called the superwind [1]. Their atmospheres hence contain signatures of the chemical enrichment from internal nucleosynthesis that has occurred prior to and during their entire AGB lifetime. During the post-AGB phase, the warm stellar photosphere makes it possible to quantify the chemical abundances in post-AGB stars for a very wide range of elements from CNO up to the most heavy *s*-process elements, well beyond the Ba peak [2], that are brought to the stellar surface during the AGB phase [3].

The observationally well-studied Galactic sample of post-AGB stars resulted in some interesting discoveries. Firstly, the Galactic post-AGB stars have been found to be chemically much more diverse than anticipated: 21 micron sources, *s*-process enriched single stars, non *s*-process enriched objects, and binaries that display photospheric depletion. Secondly, Galactic post-AGB can be classified into two groups based on their spectral energy distributions (SEDs). The first group of objects (shell-sources), display a double peaked SED. This type of SED is most likely characteristic of single post-AGB stars. The second group of objects (disc-sources) display SEDs with an onset in the near-IR, indicating the presence of hot-dust which represents a stable compact circumbinary disc, characteristic of binary post-AGB stars. See [4] for a review on post-AGB stars.



Though the Galactic sample is observationally well studied the poorly known distances (and hence luminosities and masses) of the Galactic post-AGB sample, hamper the interpretation of their abundances in the broader theoretical context of stellar (chemical) evolution. Due to the known distances to the Magellanic Cloud (MC) post-AGB stars, these objects provide excellent constraints and offer unprecedented tests for AGB theoretical models of low- and intermediate-mass stars, as a function of initial mass and metallicity. Our recent search for MC post-AGB stars [5, 6], in the SMC and LMC, respectively, yielded a spectroscopically verified catalogue of optically visible post-AGB stars.

We are currently studying the MC post-AGB objects in detail. Our studies so far have revealed that the MC objects also display a chemical and morphological diversity similar to the Galactic post-AGB stars [7] and references therein. Our recent study revealed a peculiar object, J005252.87-722842.9, a SMC post-AGB star, that does not follow any of the observed chemical diversity trends mentioned above and does not conform to the standard single or binary evolution and nucleosynthesis scenarios.

2. Data and Observations

J005252.87-722842.9 is a SMC post-AGB star first discovered in our extensive low-resolution spectroscopic survey of optically bright post-AGB stars in the SMC [5]. The photometry covering the optical, near-IR and mid-IR bands are presented in [5]. Based on the visual inspection of the position of the peak of the dust excess in the SED of this object (see Figure 1), it is likely that it is a shell-type source with an expanding dusty circumstellar shell.

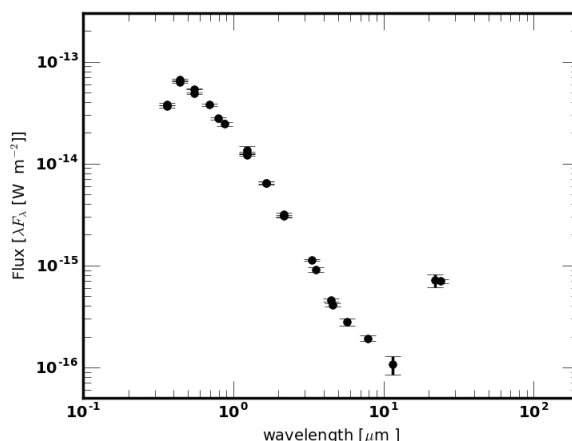


Figure 1. Spectral energy distribution of J005252. The black symbols indicate the broadband photometry corrected for foreground extinction.

We obtained high-resolution spectra using the UVES echelle spectrograph, mounted on the 8m UT2 Kueyen Telescope of the VLT array at the Paranal Observatory of ESO in Chili. Full details of the spectra will be presented Kamath et al., 2016, in prep. We note that the data reduction procedure is presented in [7].

3. Spectral analysis

To study the photospheric composition of J005252, we performed a systematic spectral analysis for this object. Using the UVES spectra, we first determined accurate atmospheric parameters for this object and then we carried out a detailed abundance analysis study. The atmospheric

parameter determination and the detailed abundance analysis of J005252 will be presented in Kamath et al., 2016, in prep. The determined stellar parameters of J050221 are listed in Table 1.

Table 1. Spectroscopically determined atmospheric parameters of J005252. N_{FeI} and N_{FeII} show the number of lines used for Fe I and Fe II respectively. Note: Assumed solar $[\text{Fe}/\text{H}] = 7.50$ dex [8]. L_{ph}/L_{\odot} represents the photospheric luminosity of J005252 and M/M_{\odot} is the derived mass of J00525.

Stellar Parameters	J05252 _{UVES}
T_{eff} (K)	8500 ± 125
$\log g$ (dex)	1.50 ± 0.25
ξ_t (kms^{-1})	2.0 ± 0.25
$[\text{FeI}/\text{H}]$	-1.11 ± 0.01
$[\text{FeII}/\text{H}]$	-1.02 ± 0.07
$[\text{Fe}/\text{H}]$	-1.20 ± 0.15
N_{FeI}	34
N_{FeII}	39
$E(B-V)$	0.05
L_{ph}/L_{\odot}	9000
M/M_{\odot}	0.65

Our detailed abundance analyses showed that J005252 has rather intriguing abundances. It is relatively metal poor (with $[\text{Fe}/\text{H}] = -1.2 \pm \text{dex}$) with $[\text{O}/\text{Fe}] = 0.6 \pm \text{dex}$. It shows no signs of Carbon (including the strong C I line at 6587 \AA , see Figure 2). It also shows no signs of s -process enrichments. All post-AGB stars that are s -process enriched shows the presence of Barium (see [7] and references therein). However no traces of Ba was found in the spectra of J005252 (see Figure 2). Furthermore, we also find that the photosphere of J005252 does not show any signs of photospheric depletion (see [9] and references therein).

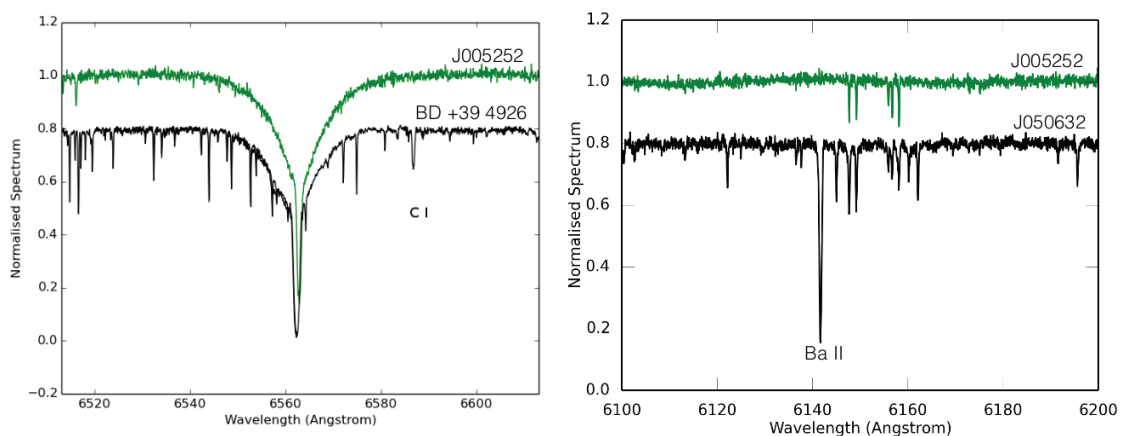


Figure 2. Right Panel: Normalised spectra of J005252 (in green) and of BD +39 4926, a carbon-enhanced Galactic object (in black), covering the region that contains a strong C I line at 6587 \AA . Left Panel: Normalised spectra of J005252 (in green) and of J050632, a s -process rich LMC object (in black), covering the region that contains a strong BaII line at 6142 \AA .

4. Understanding the photospheric chemistry of J005252

Assuming, that J005252 is a single star (due to its non-depleted photospheric chemistry and also based on the shell-type SED of the object), stellar evolution and nucleosynthesis models [10, 11] that are appropriate for J005252 (based on its luminosity, initial mass and metallicity) predict this object to have undergone TDU events and therefore be C-rich and likely to be *s*-process enhanced. Synthetic models of TP-AGB stars that are calculated to fit the SMC CSLF also predict a star with the luminosity and metallicity of J005252 to be C-rich. We consider the possibilities of nucleosynthetic process, such as hot bottom burning (HBB) [12, 13] that can prevent the formation of high-luminosity carbon stars. However, HBB is only active in stars with $M \gtrsim 4 - 5 M_{\odot}$. Since J005252 is star with $M \approx 1.5 - 2 M_{\odot}$ and $Z = 0.001$, it is likely that the temperature at the base of the convective envelope during the interpulse period is not high enough to activate HBB.

Therefore, the only way to explain the intriguing chemistry of J005252 is via some mechanism that restricts the third dredge-up, possibly a mass-loss mechanism that results in an AGB life without dredge-up episodes. Alternatively, this object could be a product of a merger scenario wherein it is not easy to trace the merger process and therefore understand the nucleosynthetic history of the end-product.

5. Conclusions

In this paper, we present the discovery of J005252, a chemically peculiar star in the SMC. This object is luminous ($9000 L_{\odot}$), metal-poor ($[Fe/H] = -1.2 \pm 0.08 \text{ dex}$) and has a shell-type SED. This object shows no traces of carbon, indicating that it has not undergone any third-dredge up episode during its entire AGB phase. This is contradictory to what is expected from a object with low-metallicity, low initial mass (1.5 to $2.0 M_{\odot}$) and a shell-type SED (which indicates that it is likely to be a single star). Furthermore, J005252 shows neither signs of an *s*-process enrichment, which is characteristic of single post-AGB stars, nor a depleted photospheric chemistry which is characteristic of binary post-AGB stars. Therefore, this object provides the first observational evidence for a star that fails the third dredge-up.

Acknowledgments

DK and HVW acknowledge the support of the KU Leuven contract GOA/13/012. PRW has received support from the Australian Research Council Discovery Project DP120103337.

References

- [1] Nie J D, Wood P R and Nicholls C P 2012 *Mon. Not. R. Astrophys. Soc.* **423** 2764
- [2] Reyniers M and Van Winckel H 2003 *Astron. Astrophys* **408** 33
- [3] Karakas A I and Lattanzio J C 2007 *Publ. Astron. Soc. Australia* **24** 103
- [4] Van Winckel H 2003 *Astron. Astrophys. Rev.* **41** 391
- [5] Kamath D, Wood P R and Van Winckel H 2014 *Mon. Not. R. Astrophys. Soc.* **439** 2211
- [6] Kamath D, Wood P R and Van Winckel H 2015 *Mon. Not. R. Astrophys. Soc.* **454** 1468
- [7] De Smedt K, Van Winckel H, Kamath D and Wood P R 2015 *Astron. Astrophys* **583** 56
- [8] Asplund M, Grevesse N, Sauval A J and Scott P 2009 *Astron. Astrophys. Rev.* **47** 481
- [9] Maas T, Van Winckel H and Lloyd Evans T 2005 *Astron. Astrophys* **429** 297
- [10] Karakas A I 2010 *Mon. Not. R. Astrophys. Soc.* **403** 1413
- [11] Fishlock C K, Karakas A I, Lugaro M and Yong D 2014 *Astrophys. J.* **797** 44
- [12] Boothroyd A I, Sackmann I J and Ahern S C 1993 *Astrophys. J.* **416** 762
- [13] Lattanzio J, Frost C, Cannon R and Wood P R 1996 *Mem. Soc. Astron. Italiana* **67** 729