# Chemical diversity of post-AGB stars in the LMC

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**Summary.** We report on the chemical analysis of an exploratory sample of five post-AGB stars in the Large Magellanic Cloud, based on UVES-VLT spectra. The sample reveals a wide chemical diversity, similar to the diversity seen in *Galactic* post-AGB stars. One object is a post-3rd dredge-up object, heavily enhanced in carbon and s-process elements; one object is carbon enhanced, but does not show s-process enhancements, and its chemistry is therefore not understood. The other three objects show some degree of *depletion* in their photosphere: the refractory elements are underabundant with respect to the non-refractories. This depletion pattern is understood as the result of a chemical process in which a gas-dust separation in the circumstellar environment is followed by a photospheric accretion of only the gas. In the Galaxy, the efficiency of this process is dependent on the initial metallicity. Here we show that at LMC metallicities, the depletion process can be very efficient. The most favorable circumstance for this process to occur is, if the circumstellar dust is trapped in a disk. The presence of a disk in evolved objects is likely related to binarity (see contributions of Gielen and Deroo in these proceedings).

**Key words:** Stars: AGB and post-AGB – Stars: abundances – Stars: carbon – Magellanic Clouds

## 1 Chemical diversity of *Galactic* post-AGB stars

During the past decennia, it has been realized that post-AGB stars are chemically much more diverse than previously thought, with only a fraction of them showing the expected signature of a 3rd dredge-up. Binary objects have a totally different chemical signature than single objects, and both subgroups are, in their turn, also not chemically homogeneous. In this first section, we will give a small overview of the results on galactic post-AGB objects (for an extensive review, see [12]).

*Binary objects* tend to have a totally different photospheric composition than single objects. Most binary post-AGB stars show some degree of *depletion* of refractory elements in their photosphere: elements with a high dust condensation temperature

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are underabundant, e.g. [6, 8]. A self-consistent evolutionary scenario for the depletion phenomenon is not yet developed, but a rough sketch is as follows [14]: When the AGB star evolves into an orbit which is too small to accommodate its increase in radius, a phase of strong binary interaction will occur which results in the creation of a stable circumstellar disk [4, 5]. In this disk, dust formation will lead to a chemical fractionation in which elements with a high condensation temperature will preferentially condense on dust grains, while elements with a low condensation temperature will stay in the gas phase. The cleaned gas separates from the dust and re-accretes onto the star, making the photosphere devoid of refractory elements. Remarkably, depletion patterns are often observed, but in almost all objects there is observational evidence that a stable and probably circumbinary disk is present indeed [13].

RV Tauri stars are a subclass of the Pop. II Cepheids, probably in the post-AGB stage of evolution, as first argued by [7]. Many of the RV Tauri stars show an infrared excess, which is caused by the circumstellar dust that was likely formed by heavy mass loss during the preceding AGB phase. All members of the RVB spectroscopic subgroup of the RV Tauri stars show also some degree of depletion in their photosphere. Our radial velocity monitoring of these RV Tauri that is still ongoing, proves that the binary fraction is indeed very high [8]. Note that depletion does not seem to occur in globular cluster RV Tauri stars, or in field RV Tauri stars of low metallicity ($[Fe/H] < -1$).

Other post-AGB objects with a spectral energy distribution (SED) indicative of a cooling and expanding detached shell, but without radial velocity information and hence presumably *single*, are also far from chemically homogeneous. Some objects are the most s-process enriched objects known to date (e.g. [11], and references therein) while others are not enriched at all. This dichotomy is very strict, in the sense that mildly enhanced objects do not exist, except for a few rather atypical objects. Furthermore, the s-process enriched sub-group exhibits a large spread in s-process efficiency, as these stars do not obey the expected anti-correlation between metallicity and s-process efficiency. In other words, examples exist of post-AGB stars with a very similar metallicity, but with a totally different s-process neutron irradiation.

## 2 The LMC sample

In this contribution, we report on the abundance results of an exploratory sample consisting of the five brightest RV Tauri stars in the LMC found by the MACHO experiment [2]. This LMC sample of RV Tauri stars with their known luminosity is a unique sample to study the nature of these stars and of the post-AGB evolution in general. Moreover, abundance analyses of post-3rd dredge-up stars in the LMC should make it possible to study the yields of the AGB nucleosynthesis in a more metal deficient environment than the Galaxy. High resolution, high signal-to-noise optical spectra of our exploratory LMC sample were taken with the UVES spectrograph mounted on the VLT-UT2 (Kueyen) telescope. More details on the observations and the reduction can be found in [9].

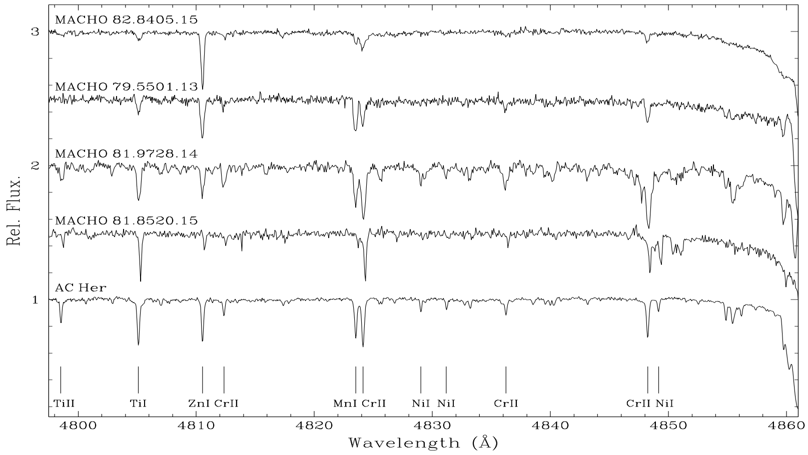


**Fig. 1.** Sample spectra of objects in our exploratory LMC sample (except MACHO 47.2496.8, see Section 3), together with the spectrum of AC Her, a galactic depleted post-AGB star. [Zn/Fe-peak] and [S/Ti] ratios are diagnostics for depletion, since they are elements with the same chemical history, but with different condensation temperatures. Note the strong Zn line compared to other lines of e.g. Ti of Cr, in the spectra of MACHO 82.8405.15 and MACHO 79.5501.13.

## 3 MACHO 47.2496.8: a post-3rd dredge-up object

One object of our sample, MACHO 47.2496.8, is a true post-3rd dredge-up object displaying strong carbon and s-process enrichments. Its results are extensively discussed in a dedicated paper [9], and the abundance pattern has been recently modeled in a letter [3]. Here, we only note its remarkably low intrinsic metallicity of [Fe/H] $= -1.4$, and an overall enrichment of 1.2 and 2.1 dex for the light (Zr-peak) and heavy (Ba-peak) s-process elements respectively.

## 4 Three depleted objects

In three out of five objects, we found a clear anti-correlation in the abundance results between the abundances of the elements and their condensation temperature (Fig. 2), indicating that the depletion phenomenon has taken place. MACHO 82.8405.15 is the most heavily depleted source of the three, with [Fe/H]$=-2.6$, in combination with [Zn/Fe] $= +2.3$ and [S/Ti] $= +2.5$. This degree of the depletion is comparable to the strongest depletions seen in field Galactic RV Tauri stars. The results of this star are therefore published in a dedicated letter [10]. MACHO 79.5501.13 is also quite strongly depleted, with [Fe/H] $= -1.9$ and [Zn/Fe] $= +1.3$. The third object, MACHO 81.9728.14, is only marginally depleted, but still the elements with the highest condensation temperature ($> 1500$ K) are underabundant by $\sim$0.8 dex. If the Zn abundance is interpreted as the initial metallicity of the object, then it seems

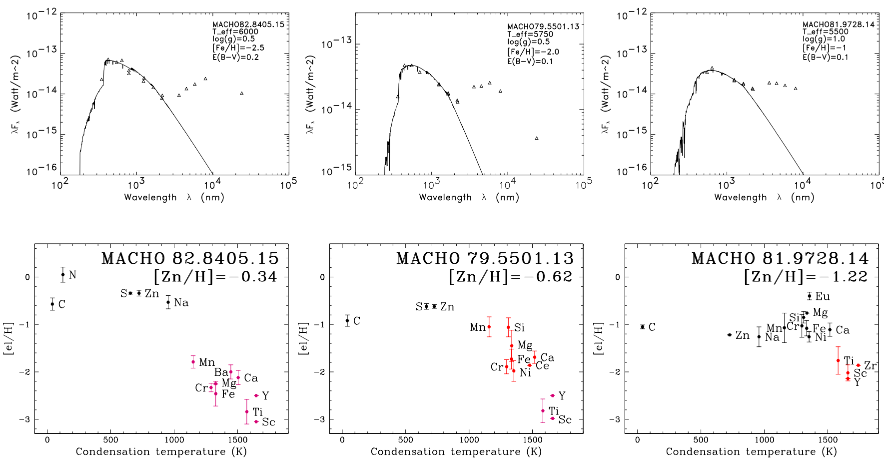


**Fig. 2.** The SEDs (*upper row*) and the abundance pattern (*lower row*) of the three depleted objects in our sample.

that the depletion process is less efficient for more metal deficient objects. This effect is also seen in Galactic depleted objects, although initial metallicity is clearly not the only parameter that determines the depletion efficiency. The SEDs of the three depleted objects (Fig. 2) have the typical shape of a *disk* object. They consist of two components: an optical one from the photosphere, and a hot dust excess in the infrared, indicative for the presence of dust near the star likely in a stable disk.

## 5 MACHO 81.8520.15: not understood

The abundance pattern of MACHO 81.8520.15 (Fig. 3) is not easily understood. At least two possible interpretations can be put forward: either all elements (including Zn) are depleted, except carbon, or the star is of low initial metallicity and has enhanced its carbon, but not its s-process elements. The scenario in which all elements, except C, are depleted, is less plausible, since in the SED there is no strong indication for the presence of a disk. Nevertheless, a very small but significant IR-excess is present at 8 $\mu$m. Moreover, carbon stars without s-process enrichment do exist in the Galaxy [1], and may be related to this object. We have not yet found a possible evolutionary channel leading to this abundance pattern.

## 6 Conclusions

This exploratory sample of five post-AGB stars in the Large Magellanic Cloud reveals the same chemical diversity already seen in their Galactic counterparts. One object, MACHO 47.2496.8, is a true post-3rd dredge-up object, heavily enriched in carbon and s-process elements. MACHO 81.8520.15 is C-rich, but not s-process enriched, and is therefore not understood with the current nucleosynthetic AGB models. The other three objects are depleted, showing a stronger depletion for higher

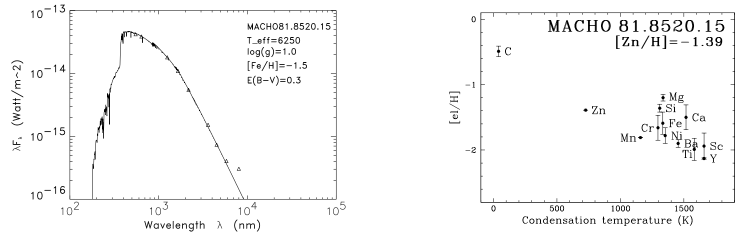


**Fig. 3.** The SED (*left panel*) and the abundance pattern (*right panel*) of MACHO 81.8520.15.

initial metallicities. The three depleted objects possess a near IR-excess indicating a stable dust reservoir, probably a disk.

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