SF2A 2008
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AGB MASS LOSS AND CARBON STARS IN THE GALACTIC HALO

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Abstract. The mass loss of stars on the asymptotic giant branch (AGB) is a critical phenomenon for stellar evolution, but the AGB superwinds are not fully understood and physically modelled. One of the important characteristics that we would like to know is how mass loss depends on metallicity. At low metallicity, evolved AGB stars are carbon stars. From a systematic survey for cool carbon stars in the Galactic halo, we have identified 16 very dusty objects located far (> 2 kpc) from the Galactic plane and at distances of 2 to 20 kpc (Mauron 2008). One of these objects had been detected in CO by Groenewegen et al. (1997), its circumstellar expansion velocity is very small (3 km/s), and it is deficient in oxygen. We suggest that detection of CO from these 16 halo very dusty C stars might yield key information on mass loss at low metallicity.

1 Introduction

The AGB stars play an important role in stellar and galactic evolution. Stars with initial masses of ~ 1 to ~ 7 solar masses evolve to white dwarfs and lose a large fraction of their initial mass. The strength of this high mass loss (superwinds) determines the lifetimes of stars on the AGB and their populations. Another crucial aspect of the AGB is the return of matter into the interstellar medium. The AGB superwinds contribute to the ISM enrichment with fresh nuclear products and with grains. However, despite the key role of the AGB superwind, its mechanism remains difficult to explain.

A large number of observations of AGB winds close to the Sun have been done in the last years. The winds have been observed thanks to their CO millimeter emission and their infrared excess due to dust, and we have a rich sample for which mass-loss rates, the dust abundance and the expansion velocity have been measured. These observations have been used to explain mass loss (see, e.g. Habing & Olofsson 2004). The generally accepted mass-loss scenario is levitation of matter by pulsation and shocks, followed by dust condensation. Then, radiation pressure on grains leads to the outflow. However, the detailed physics and chemistry of these phenomena are not well established. For example, it appeared recently that silicate grains cannot drive outflows (Woitke 2006, Hofner & Andersen 2007). We also ignore why mass loss is modulated with a characteristic time of ~ 500 years. The best example of this modulation is the incomplete concentric shells of IRC+10216 (Mauron & Huggins 1999) and similar shells can also be seen in the AGB remnant halos of many post-AGB stars. This time interval is neither the pulsation period nor the interval between thermal pulses. Therefore, some important characteristics of the mass-loss mechanism are not explained.

Another important question about these AGB superwinds is whether they depend on the metallicity of the stars. At low metallicity, AGB stars are mainly carbon (C) stars because only a small amount of dredge-up carbon is needed to make the photosphere C-rich. Consequently, AGB stars in metal-poor galaxies like the Magellanic Clouds or Fornax are in large majority C stars. It is not clear whether mass-loss could depend on metallicity (Mattsson et al. 2008, Matsuura et al. 2007). The AGB stars in these external galaxies and particularly their infrared emission have been observed for many years and especially recently with *Spitzer*, and this permits to quantify the amount of dust in their circumstellar envelopes. However, these stars are too distant (~ 50 kpc or more) for their CO millimeter emission to be detected. Consequently, one ignores two important quantities which are the dust-to-gas ratio and the wind expansion velocity. It is therefore of great interest to search and find metal-poor C star closer to us than the Magellanic Clouds. For this reason, it is interesting to examine the population of AGB C stars in the Galactic halo.

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2 The C stars in the Galactic halo

The AGB C stars located in the halo have been found with very different methods. Among a sample of C stars discovered with objective-prism plates, Bothun et al. (1991) noted that several of them were very red and were probably AGB stars. Because AGB C stars have a large $B-R$ color index, Totten & Irwin (1998) selected very red point sources on the digitized APM Schmidt plates taken at high galactic latitude. Follow-up spectroscopy allowed them to discover 36 cool halo C stars. Forty-one were known previously, so that Totten and Irwin (1998) could list a sample of 77 halo C stars, with some of them being CH-type stars. Because cool C stars are bright at near-infrared wavelengths, the publication of the 2MASS catalog offered the opportunity to select candidate stars with 2MASS JHK colors typical of AGB C stars and verify these candidates by follow-up spectroscopy. With this method, 100 new AGB C stars at $|b| > 20$ deg. could be discovered (Mauron et al. 2004, Mauron 2008 and references therein).

Among the ~ 150 cool halo C stars, several have an important infrared excess. While the J-K color is between 1.4 and 2 for most AGB C stars, there are 16 C stars with J-K>3. These 16 dusty C stars are unusual because they are at large distances from the galactic plane, between ~ 2 and 10 kpc. Therefore, they do not belong to the usual population of AGB C stars close to the Sun which have a scale height of 200 pc. In addition, one of these stars was detected in CO emission and the expansion velocity is only 3 km/s (Groenewegen et al. 1997). Comparing the CO and the dust loss-rate, these authors found that the star is deficient in oxygen, so that the low expansion velocity may be a sign of low metallicity. We have obtained an estimate of mass loss rates for the 16 halo C stars by using the K-[12] color, and we have found that the $\dot{M}$ values are between 1.0 and 12×10^{-6} $M_{\odot}\,yr^{-1}$ (Mauron 2008). Taking into account their distances, between 2 and 20 kpc, their winds should be detectable in the CO millimeter lines. This will inform us on the frequency of wind velocities as low as 3 km/s and on the possible link between a low metallicity and a low wind velocity.

3 Conclusions

The AGB phase is important for stellar and galactic evolution, but one of the important phenomena, mass loss, is not completely understood. How mass loss depends on metallicity is not clear, and we propose that a detailed study of 16 dusty halo C stars might give some crucial information. These stars are well above the galactic plane, in contrast with usual AGB stars of the solar neighbourhood, and their mass loss rates are strong, of the order of 4 10^{-6} $M_{\odot}\,yr^{-1}$. It should be possible to detect most of these objects in CO, and to see if any low expansion velocity is correlated with low metallicity.

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