Why Galaxies Care About AGB Stars:
A Continuing Challenge through Cosmic Time
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OH/IR stars versus YSOs in infrared photometric surveys

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Abstract. AGB stars play a major role in the chemical evolution of the galaxies. It thus is important to establish reliable photometric selection criteria to count them, especially AGB stars at the last stages of AGB evolution like OH/IR stars. Here, we have identified about 1500 OH/IR stars and 500 YSOs with methanol masers, in all major mid– and far–infrared surveys (IRAS, MSX, AKARI, WISE, GLIMPSE, and Hi–Gal). We show that AGB stars with high mass-loss rates cannot be disentagled from YSOs with only mid–infrared photometry; far–infrared photometry is essential. In the region observed by GLIMPSE, we show that the proportion of AGB stars has been severely underestimated in previous works: about 70% of "intrinsically" red objects in GLIMPSE are AGB stars rather than YSOs.

Keywords. stars: AGB and post-AGB, stars: pre–main-sequence

1. Samples and identifications

There are about 2000 OH/IR stars known in the Galaxy. They are characterised by a double-peaked OH profile, where the distance between the peaks is a direct measurement of the expansion velocity of the circumstellar envelope. OH/IR stars have been observed in various ways with different astrometric accuracies: in single-dish surveys (2 to 30 arcmin accuracy), colour-selected IRAS samples (10 to 90 arcsec accuracy), or in interferometric surveys (1 to 6 arcsec accuracy). Their identification in modern infrared surveys, and in crowded regions like the galactic plane, has thus been challenging. Mid–infrared IRAS sources were first identified in the AKARI and WISE surveys, taking into account the resolutions, the consistency between fluxes, and blending. This program has actually been applied to all IRAS sources in order to improve their identifications in the SIMBAD database. OH observations were cross-identified between themselves on the basis of the velocity profile. Finally, about 1500 OH/IR stars have a secure identification in MSX, AKARI, WISE, GLIMPSE, MIPSGAL (Gutermuth & Heyer 2015) or/and Hi–Gal (Molinari *et al.* 2016). The sample of YSOs contains some well known OH masers, but mostly methanol masers from the MMB survey (Caswell *et al.* 2010, astrometric accuracy 0.4"). About 500 could be identified in infrared surveys (MSX, AKARI, WISE, GLIMPSE, MIPSGAL, or/and Hi–Gal).

2. Results and comparison with previous works

Figure 1 shows the newly defined samples of OH/IR stars and YSOs on mid- and far-infrared colour-colour diagrams. At first view, it seems that YSOs are "redder" than

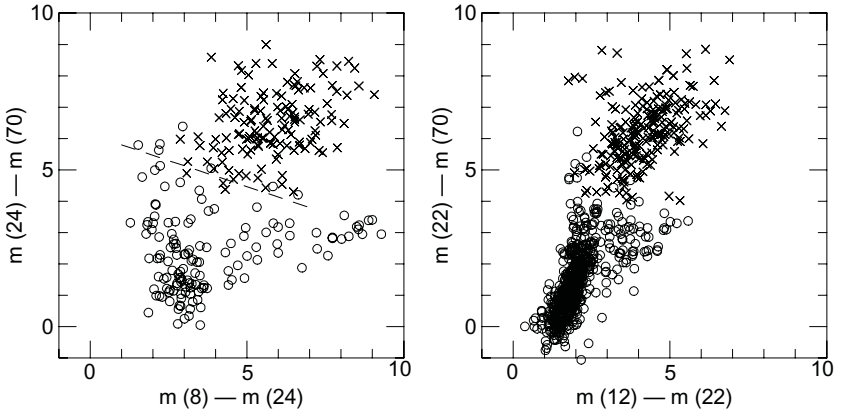

Figure 1. Infrared colour-colour diagrams of OH/IR stars (open circles) and YSOs (crosses). Left: GLIMPSE + MIPSGAL + Hi–Gal; the dashed line shows the separation between OH/IR stars and YSOs. Right: WISE + Hi-Gal.

OH/IR stars. This, however, is only true with the colours combining mid– and far-infrared. For mid–infrared colours, OH/IR stars can be as red as YSOs, up to $m(8) - m(24) = 10$ based on Spitzer data, or up to $m(12) - m(22) = 5$ using WISE photometry.

In the past years, the lack of available far–infrared photometric catalogues led many authors to set up selection criteria based on mid–infrared observations only. For instance, Robitaille *et al.* (2008) selected 16500 intrinsically red sources in the GLIMPSE and MIPSGAL surveys. Their selection criteria were based on a colour–magnitude diagram combining $m(4.5)$ and $m(8) - m(24)$. They concluded that their sample contained over 11000 YSOs and about 7000 AGB stars. Using combined mid– and far–infrared colour-colour diagrams we reach the opposite conclusion: 11300 sources are expected to be AGB stars, 3100 cannot be classified, and only 2100 are very likely YSOs.

3. Conclusions

AGB stars with optically thick circumstellar envelopes cannot be disentangled from YSOs with mid–infrared photometric observations only. Far–infrared observations are needed to separate them. Checking the environment on infrared images can also help as YSOs are usually located in star–forming regions. We have established reliable selection criteria to separate OH/IR stars and YSOs in combined mid– and far–infrared colour–colour diagrams. We conclude that the intrinsically red sources selected by Robitaille *et al.* (2008) towards the galactic plane are mostly AGB stars – about 70% – rather than YSOs.

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