Why Galaxies Care About AGB Stars:
A Continuing Challenge through Cosmic Time
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The loss of large amplitude pulsations at the end of AGB evolution

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Abstract. Since 2013, we are performing with the Nancay Radio Telescope (NRT) a monitoring program of >100 Galactic disk OH/IR stars, having bright 1612-MHz OH maser emission. The variations of the maser emission are used to probe the underlying stellar variability. We wish to understand how the large-amplitude variations are lost during the AGB – post-AGB transition. The fading out of pulsations with steadily declining amplitudes seems to be a viable process.

Keywords. stars: AGB and post-AGB, masers, stars: evolution

Stars evolving on the thermal-pulsing Asymptotic Giant Branch (AGB) are in general observed as large-amplitude variables, but are almost non-variable in the post-AGB phase. In models covering the AGB –post-AGB transition, the evolutionary timescales depend on the assumptions of the change of the mass-loss rates. They must drop on short timescales from late AGB values of 10^{-5}–10^{-4} to post-AGB values of 10^{-7}–10^{-8} $M_{\odot}$ yr^{-1}. While the mass loss rates are parametrized on the AGB as a function of pulsation period, they are completely unconstrained starting with the time after which the pulsation ceased until the time that a radiation driven wind as observed in Planetary Nebulae takes over (Miller Bertolami 2016; MB16 hereafter).

Towards the end of AGB evolution, stars can develop very high mass loss rates, which enshrouds them completely by dust and gas. Among them are the OH/IR stars, which encompass large-amplitude variables on the AGB (L-AGB stars) with periods ~ 700–2000 days and almost non-variable stars (S-pAGB: small amplitude post-AGB stars, including 'non-variable' stars), which are thought to evolve in the early post-AGB phase. In both phases, the stars are still deeply embedded in their dusty circumstellar shell. H_2O and OH maser emissions are present in both phases. The association of the S-pAGB stars with the post-AGB phase is supported by observations that some of them already have diluted dust shells (Engels 2007), which indicate a recent decrease of the mass loss rates, and that others show prominent bipolar outflows (f.e. OH17.7–2.0 = IRAS 18276–1431, Sánchez-Contreras *et al.* 2007; OH 53.6–0.2 = IRAS 19292+1806, Sahai *et al.* 2007) including "water fountains" (f.e. W43A = OH 31.0+0.0 = IRAS 18450–0148, Chong *et al.* 2015). It is during the obscured phase that (at least in the more massive stars) the AGB – post-AGB evolutionary transition takes place and the stars stop pulsating.

Monitoring the stars via their bright and relatively stable OH maser emission is needed, because especially the S-pAGB candidates have very red spectral energy distributions, and cannot be monitored in the optical or the near-infrared. As a basic sample to study the transformation of the variability characteristics, we use the full sample of OH/IR stars of Baud *et al.* (1981), updated by Engels & Jiménez-Esteban (2007). This "Bright

OH/IR star sample" comprises 115 stars, with almost all located at $10 < l < 150°$, $|b| < 4°$ along the Galactic plane. It is quite complete for bright 1612-MHz OH masers ($F_\nu > 4$ Jy). The brighter part of the sample has been monitored by Herman & Habing (1985)(herafter HH85), who reported several sub-groups with different amplitudes and periodicity among S-pAGB stars. Objects, which are currently transiting from L-AGB to S-pAGB variability may hide in the sample. To find them, we are monitoring, since 2013, the 1612-MHz OH masers with the NRT, to probe the underlying stellar variability.

In our sample, the L-AGB and S-pAGB stars are almost of equal number. Assuming similar OH maser luminosities, this implies that the "pulsating" phase connected to relatively high mass-loss rates ($\dot{M} > 10^{-5}\,M_\odot$/yr) is of similar duration as the early post-AGB phase (Engels 2002). OH/IR stars must have experienced hot bottom burning on the AGB to avoid being converted to carbon-rich stars, and as such they must have had massive progenitors on the main sequence $M \geqslant 3\,M_\odot$. According to MB16, the predicted transition times τ_{tr} during the early (and obscured) post-AGB phase until the optical reappearance of the central stars last only < 1000 years. In the later post-AGB phase, the dust shells are dispersed, and, in general, maser emission disappears. Assuming a minimum lifetime of the OH maser emission in the "Bright OH/IR stars sample" of 2000 years (Engels & Jiménez-Esteban 2007), the time for massive AGB stars to appear as obscured OH/IR stars can last only a few thousand years.

As of May 2018, we have the variability characterizations for 52 stars (34 L-AGB, 18 S-pAGB). Another 28 stars are currently (2018/2019) monitored to obtain a characterization, while the remaining stars are planned to be monitored in 2020/2021. Monitoring of newly recognized L-AGB stars is continued until the period is determined. S-pAGB stars are re-observed occasionally to search for long-term trends, such as found by Wolak *et al.* (2014). They reported that the OH maser of one of the S-pAGB stars, OH 17.7–2.0, is continuously fading since its discovery and predict that the maser will fall below the detection limit around 2030. While the L-AGB stars in HH85 are confirmed, some of their S-pAGB stars had to be reclassified as L-AGB variables with periods $P > 1000$ days. Among 15 OH/IR stars not monitored by HH85, we found 9 L-AGB stars (60%), while the reminder shows at most irregular fluctuations qualifying them as S-pAGB stars.

No stars with short-period, small amplitude pulsations have been found, as assumed to exist as transition objects by Blöcker (1995). However, we found a couple of stars, which show periodic variations with periods similar to those of L-AGB stars but with significantly smaller amplitude (Engels *et al.* 2018). We consider them as the best candidates for transition objects. While an instantaneous cessation of the pulsation (Vassiliadis & Wood 1994; MB16) cannot be ruled out, we consider the fading out of pulsations with steadily declining amplitudes (damped oscillator) as a viable process.

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