The Post-AGB cores in 'non-variable' OH/IR stars

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Summary. Almost since their discovery more than 20 years ago 'non-variable OH/IR stars' were suspected to be stars beginning their Post-AGB phase. Due to the extreme optical thickness of their circumstellar shells not much information except far-infrared fluxes and maser observations were available. Using the new Spitzer/GLIMPSE and the 2MASS surveys the faint near-infrared counterparts can now be identified beyond doubt. Several counterparts are unusually bright. They generate a near-infrared excess in the spectral energy distributions. These counterparts are considered as the central stars (the Post-AGB core) emerging from the steadily diluting shells. These stars will develop on short timescales into post-AGB stars with prominent double-peaked spectral energy distributions.

Key words: post-AGB stars – non-variable OH/IR stars

1 Introduction

The observed diversity in morphologies of Planetary Nebulae seemingly is determined at the end of AGB evolution when the mode of mass loss changes on short timescales [1]. It is commonly assumed that the end of AGB evolution is reached when the star has lost most of its mass and only a tiny amount ($\sim 10^{-3}$ M$_\odot$) of the envelope above the degenerate C-O core remains. At this moment, the pulsation thought to drive the heavy mass loss on the AGB [10] stops and the mass loss rate decreases in a couple of centuries from $> 10^{-5}$ M$_\odot$/yr to $> 10^{-8}$ M$_\odot$/yr. This departure from the AGB is accompanied by a drastic change of the overall spectral energy distribution (SED): An heavy obscured OH/IR star, which is optically invisible on the AGB, converts into an optically visible post-AGB star with a strong infrared excess [8].

OH/IR stars, which have stopped pulsating ('non-variable OH/IR stars'), are considered to be in this transition phase ([9], [3]). They may already have detached shells, and their H_2O masers already witness the changes of the mass loss process, while the OH masers located farther out are still undisturbed. The number of 'non-variable OH/IR stars' found by the monitoring program of Herman & Habing [6] is however surprisingly high. Out of 45 stars monitored 13 (28%) did not show any large-amplitude variability, although they are as strongly obscured as the variable OH/IR stars. A first order guess implies then that the time a star spends as a 'non-variable OH/IR star' is about one third of the lifetime as regular OH/IR star, and assuming that the transition process lasts a few hundred years yields an uncomfortably short lifetime for regular OH/IR stars of only ∼1000 years. This would mean that OH masers appear only after the very last thermal pulse.

I readdress here the nature of the 'non-variable OH/IR stars' using an analysis of the infrared properties of their parent sample on the base of new near-infrared photometry from GLIMPSE and 2MASS.

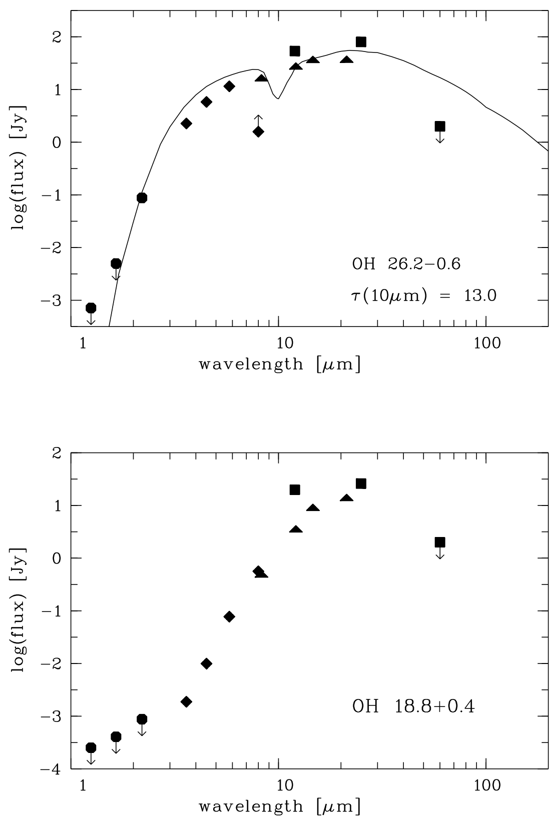

Fig. 1. Spectral energy distributions of OH 26.2-0.6 (top) and OH 18.8+0.4 (bottom). OH 26.2-0.6 is a classical large-amplitude variable OH/IR star, showing no near-infrared excess. A model SED with optical depth $\tau(10\mu m) = 13$ obtained with DUSTY is overplotted. OH 18.8+0.4 is a 'non-variable OH/IR star' with an extreme red SED and no near-infrared excess. 2MASS data (1–3 μm) are labeled as circles, GLIMPSE data (3–9 μm) as diamonds, MSX data (8–22 μm) as triangles, and IRAS data (12–60 μm) as squares.

2 1–60 μm spectral energy distributions

The parent sample is a compilation of several blind 1612 MHz OH maser surveys along the galactic plane with a completeness limit of $\approx$5 Jy [2] . The sample contains N=114 OH/IR stars, of which Herman & Habing [6] monitored the N=45 strongest. They found no differences in the distance distributions for the two groups of variable and non-variable OH/IR stars.

For all OH/IR stars in the sample, except three, IRAS and/or MSX counterparts were identified. At the positions of the MSX sources near-infrared counterparts were searched for in the ground-based 2MASS infrared survey (J, H, and K filters) and in the space-based Spitzer/GLIMPSE survey at 3.6, 4.5, 5.8 and 8.0 μm. For all objects spectral energy distributions were constructed and model distributions calculated with the DUSTY radiation transfer program [7] were fitted. Examples of the SEDs obtained are given in Fig. 1 and 2.

The counterparts for regular variable OH/IR stars are usually very red. Their (coarse) SEDs can be fitted adequately with a central star of temperature 2500 K, a dust condensation temperature of 800 K, a dust density distribution $\rho \propto r^{-2}$, standard optical constants for silicate dust, and a standard grain size distribution. The only parameter varied was the optical depth. As example, SED and model fit of OH 26.2-0.6 is shown in Fig.1.

Among the 'non-variable OH/IR stars' and those with unknown variability status several rather blue counterparts were found. The best examples are OH 53.6-0.2 and OH 23.8+0.2 (Fig.2). Generally, before the availability of GLIMPSE data it was difficult to verify the blue 2MASS counterparts detected, because of the high probability of chance coincidences with field stars in the galactic plane. A number of stars show a steep decrease shortwards of 20 μm (see OH 18.8+0.4 in Fig. 1). Such SEDs are intermediate between those of regular variable OH/IR stars and 'non-variable OH/IR stars' with blue excess. They may represent the first stage of post-AGB SEDs, before the near-infrared excess develops. Adequate fits of the post-AGB SEDs, assuming a simple abrupt stop of the heavy mass loss, leading to a hollow expanding dust shell, could not be obtained so far.

The differences in the SEDs of variable and non-variable OH/IR stars are systematic. None of the variable OH/IR stars shows a near-infrared excess, while among ten 'non-variable OH/IR stars' having GLIMPSE photometry three show a near-infrared excess and the rest the steep intermediate SED. Of three 'non-variable OH/IR stars' located outside the GLIMPSE area two have blue 2MASS counterparts. The presence of a near-infrared excess in several 'non-variable OH/IR stars' corroborates their classification as early post-AGB stars recently departed from the AGB.

3 Discussion

The near-infrared excess is due to the dilution of the circumstellar shell after the end of the strong AGB mass loss. These stars will develop into the better known optical

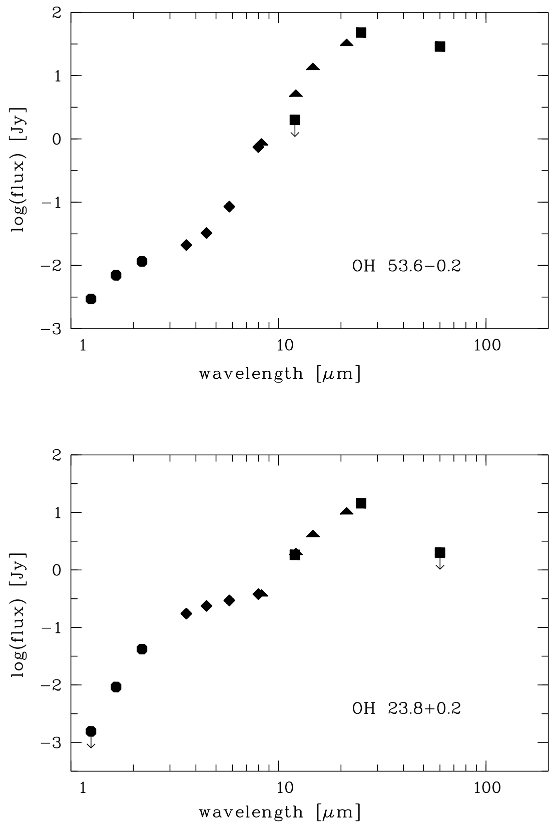

Fig. 2. Spectral energy distributions of OH 53.6–0.2 (top) and OH 23.8+0.2 (bottom). OH 53.6–0.2 is a 'non-variable OH/IR star' with a weak near-infrared excess. The variability status of OH 23.8+0.2 is unknown. The star shows the strongest near-infrared excess in the sample. The symbols are as in Fig. 1.

visible post-AGB stars with strong far-infrared excesses. Attempts to reproduce the post-AGB SEDs by simple models assuming an abrupt drop of the mass loss rates failed so far. Possibly, changes of the dust properties as observed by García-Hernández et al. [5] in Spitzer/IRS spectra of such stars have to be taken into account. Furthermore, the assumption of a rapid decline of the mass loss rates at the very end of AGB evolution might be wrong [4] and the assumption of a radially symmetric distribution of the circumstellar dust have to be given up even in this early stage of post-AGB evolution.

The strong OH masers allow to pinpoint optically obscured post-AGB stars throughout the Galaxy. Their rather high frequency among OH/IR stars remain however a puzzle, if the short transition times predicted by theory are considered.

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