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Mass loss from an extreme OH/IR star: OH 26.5+0.6

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Abstract. Observations of H_2O isotopologues of the extreme OH/IR star OH 26.5+0.6 show that the star has an initial mass consistent with it being an intermediate-mass star. The *Herschel*-HIFI spectra show clear detection of $H_2^{16}O$ and $H_2^{17}O$ while $H_2^{18}O$ is missing, consistent with the prediction of hot bottom burning which occurs in stars with an initial mass ≥ 5 M$_\odot$. The star is currently losing mass at a high rate of a few 10^{-4} M$_\odot$ yr^{-1} which is thought to commence in the past ~ 200 years. We present new ALMA CO J=3-2 image which show that this high mass loss (superwind) region is compact, surrounded by extended shells of lower mass loss.

Key words. Stars: AGB and post-AGB – Stars: evolution – mass-loss – Circumstellar matter – Submillimeter: stars

1. Introduction

Low- and intermediate-mass stars lose most of their initial mass while they reside on the asymptotic giant branch (AGB) in order to evolve to become planetary nebulae (e.g., Habing 1996). Theoretical calculations by Vassiliadis & Wood (1993) suggested that the mass loss rate increased as a star evolved up the AGB and terminated this phase with a series of epochs when a star lost mass at a very high rate, superwind.

A subset of AGB stars shows strong OH 1612 MHz maser emission and due to the dusty circumstellar envelope as a result of mass loss, they are readily detected in the infrared and hence are called OH/IR stars. A number of these stars exhibit deep silicate absorption features at 9.7 and 18 μm indicating that the envelope is highly optically thick, i.e., the mass

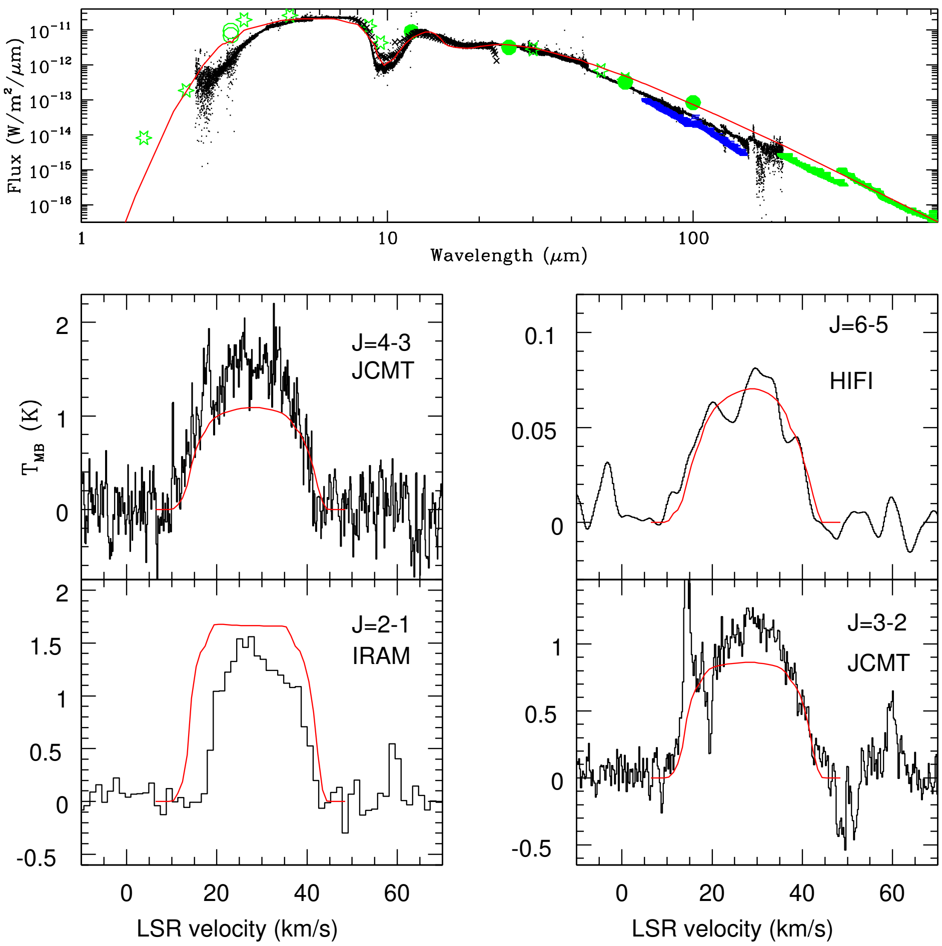

Fig. 1. Top : The SED fit of OH 26.5+0.6. The data are taken from the IRAS Point Source Catalogue, ISO-SWS and LWS as well as *Herschel*-PACS and SPIRE. Middle and lower panels show the CO observaions (black line) with the model fit (red line).

loss rate is very high – extreme OH/IR stars. However, CO observations of these objects are very weak, in some cases, the J=1-0 line is not detected (Heske et al. 1990).

2. A case study : OH 26.5+0.6

In this paper, we present observations and modelling of the mass loss from one extreme OH/IR star, OH 26.5+0.6.

2.1. Mass loss rates

We modelled the spectral energy distribution (SED) of OH 26.5+0.6 and derived a very high dust mass loss rate of $\sim 10^{-6}$ $M_{\odot}$ yr^{-1} (Justtanont et al. 1996). Assuming a dust-driven wind, we derive a dynamical mass loss rate (gas+dust) of $\sim 2 \times 10^{-4}$ $M_{\odot}$ yr^{-1}, i.e., a superwind. From this, we then modelled the CO observations taken from Heske et al. (1990), along with our own observations from the JCMT and the Herschel Space Observatory (hereafter, *Herschel*).

In order to explain the high mass loss rate derived from the warm dusty envelope and the low CO observations which come from farther out in the circumstellar envelope, we assume a two-density wind – a low past mass loss rate (*imdotM* $\sim 10^{-6}$ $M_\odot$ yr^{-1}) surrounding a recent superwind which occured ~ 200 years ago (Justtanont et al. 1996, see Fig. 1).

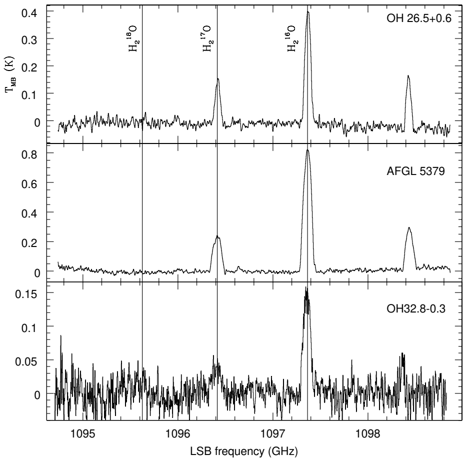

Fig. 2. *Herschel*-HIFI spectra of three extreme OH/IR stars showing the H_2O transition 3_{12}-3_{03} with positions of all three isotopologues marked with vertical lines. The emission line to the right is due the para-$H_2^{17}O$ ground state 1_{11}-0_{00} transition from the upper side-band.

2.2. H_2O isotopologues

Herschel observations of OH 26.5+0.6 and other extreme OH/IR stars show oxygen isotopes which are not commonly expected (Justtanont et al. 2013). The ratio of $^{18}O/^{17}O$ in the interstellar medium and the Sun varies between 3-5, respectively (Wilson & Rood 1994). The results from extreme OH/IR stars suggest a ratio of much lower than 1 as $H_2^{18}O$ is not detected (Fig. 2). However, this low ^{18}O is theoretically predicted when an AGB star undergoes hot bottom burning (HBB) which efficiently converts all ^{18}O to ^{15}N. This process occurs at the bottom of the convective layer when the temperature is 50 MK or higher and is attained for stars with an intial mass of at least 5 $M_\odot$ (Karakas & Lattanzio 2014); although the minimum mass for HBB activation is strongly model-dependent.

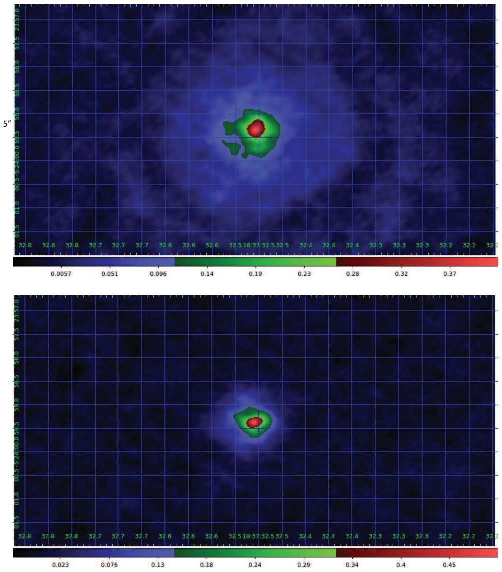

Fig. 3. ALMA images of CO J=3-2 (top) and SiO J=8-7 (bottom) showing that both have a compact core but CO shows extended envelop of past mass loss. The intensity scale is shown at the bottom of each figure and RA and Dec grid lines are 5″ apart.

2.3. Imaging the circumstellar envelope with ALMA

We recently obtained ALMA observations of OH 26.5+0.6. Using band 7, we obtained spctra which admitted ^{12}CO, ^{13}CO J=3-2 as well as SiO J=8-7. Due to the sensitivity of ALMA, we also detected a number of molecules such as NaCl, KCl and their isotopologues which has not been seen towards OH/IR stars before. With the ALMA baselines, we are able to filter out the interstellar contamination along the line of sight towards the object which hampers single-dish observations since the object lies in the galactic plane.

The size of the superwind (FWHM) is ≤ 0.4″ (Fig. 3) which is consistent with the IR observations of the superwind (Chesneau et al. 2005). Assuming the envelope is expanding at the CO terminal velocity of 15 km s^{-1}, and the star is 1.4 kpc away (Engels et al. 2015), the superwind size is ∼ 10^{16} cm, i.e., the superwind started ∼ 200 years ago.

3. Conclusions

Herschel observations of extreme OH/IR stars show that although the stars exhibit emission due to $H_2^{16}O$ and $H_2^{17}O$, the $H_2^{18}O$ lines are not detected which can be explained by the effect of hot bottom burning. This implies that extreme OH/IR stars are intermediate-mass star with a mass of ∼ 5 $M_\odot$ or higher. They also show evidence of a recent increase in the mass loss rate, a superwind. Modelling single-dish CO observations suggests that the superwind in these stars started recently – less than 10^3 years ago. Newly obtained ALMA observations of OH 26.5+0.6 confirm that almost all molecules show a compact emission region of ∼ 0.4″. Although with CO, we can trace past mass loss prior to the superwind.

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