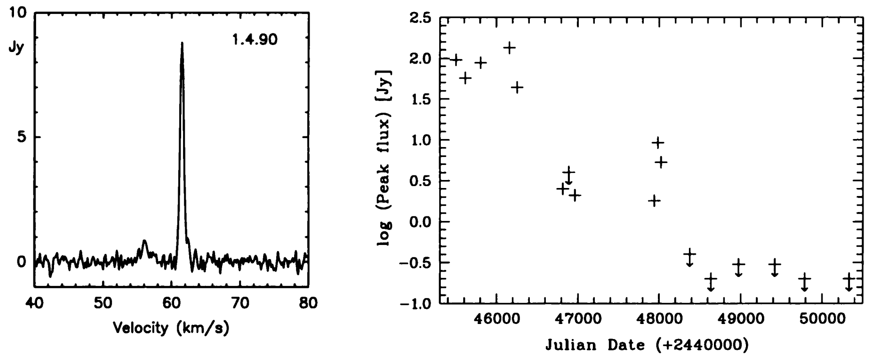
Masers: Probing the Mass Loss Process in PPN

Dieter Engels

Hamburger Sternwarte, Gojenbergsweg 112, D–21029 Hamburg

With the advent of the IRAS All-Sky Survey a sizeable number of transition objects between the AGB and the PN-phase were found – the Proto Planetary Nebulae (PPN). Oxygen-rich AGB stars often show prominent masers of SiO, H_2O, and OH, which are lost during the transition process. The heavy mass loss on the AGB however does not stop abruptly and a new axisymmetric wind develops during the PPN phase. These winds both may host new masers and they can be used to study the changes of the mass loss process after that the stars have stopped their large-amplitude variations on the AGB. Several PPN are known to have OH masers, and at least in one case, HD 101584, the presence of a bipolar outflow could be proven (te Lintel Hekkert et al. 1992). Lewis (1989) found that main-line OH masers become prominent again. I will discuss here conclusions, which can be drawn from observations of H_2O masers in PPN.



(a) Representative H_2O maser spectrum of OH 17.7-2.0. The emission occurs close to the center of the OH velocity range between 47 and 75 km s^{-1} (Type A spectrum).
(b) Lightcurve of the maser between 1983 and 1996. For each epoch the peak flux of the strongest line was taken. Data are from Nyman et al. (1986), Engels et al. (1986), Likkel (1989) and Engels (in preparation).

I monitored the 1.3cm H_2O maser emission of four "non-variable" OH/IR stars using the 100m-radiotelescope in Effelsberg. The stars were selected because of their peculiar maser spectra, and their maser lightcurves cover now more than 10 years. "Non-variable" OH/IR stars are considered as PPN because the large-amplitude pulsation has stopped and evidence was gathered from infrared measurements that they have detached circumstellar shells. Two stars, OH 15.7+0.8 and OH 17.7-2.0, show Type A maser spectra, e.g. the emission is concentrated at the radial velocity of the star (Figure 1a). This is unusual, because the FIR dust emission measured by IRAS and the OH maser emission infer mass loss rates of $>10^{-5}$ $M_\odot$ yr^{-1} and Type A maser profiles occur on the AGB only in stars with lower mass loss rates ($<10^{-6}$ $M_\odot$ yr^{-1}). At higher mass loss rates the maser consists of two line complexes close to the velocities of the OH maser peaks (Type B spectra) (Engels et al. 1986). I suggest that these masers trace the Post-AGB wind with a mass loss rate of $\approx 10^{-7}$ $M_\odot$ yr^{-1}, which is in this case simply the final phase of the decaying AGB wind. Given typical shell sizes of OH masers, the start of the decay of the mass loss rate occured less than 200-2000 years ago. In addition to the peculiar spectral shapes, the time evolution of their maser spectra is absolutely remarkable. The H_2O maser of OH 17.7-2.0 has undergone a dramatic decrease in intensity since its discovery in 1983. After 1990 the maser disappeared completely (Figure 1b). From observations of semiregular and blue Mira variables we know that a threshold mass loss rate somewhere between 10^{-8} and 10^{-7} $M_\odot$ yr^{-1} exists, below which H_2O masers are not observed anymore. One is therefore tempted to attribute the decrease of H_2O maser luminosity to a rapid decrease of the mass loss rate in OH 17.7-2.0 by a factor ≈ 10 well below a level of 10^{-7} $M_\odot$ yr^{-1}. By accident we may have witnessed the very short period of H_2O maser emission from the AGB wind, dying out on the extremely short time scales of 20-30 years proposed by Bedijn (1987). OH 15.7+0.8 shows a similar light curve and disappeared three years ago. These H_2O masers give further evidence for a smooth transition of the mass loss process at the end of the AGB evolution, a conclusion already reached before by Bedijn from modelling of the infrared energy distributions of these stars.

The two other "non-variable" OH/IR stars monitored are OH 12.8-0.9 and OH 37.1-0.8, which show water masers outside the OH maser velocity range. Their intensities remained constant over the time although individual maser lines appeared and disappeared with lifetimes of 1-3 years. Their inferred H_2O outflow velocities are ≈ 11 and ≈ 12 km s^{-1} higher than their OH outflow velocities, which is incompatible with the standard model of AGB circumstellar shells, in which the expansion velocity increases outwards. I share the opinion of Gomez et al. (1994) that these masers trace a new Post-AGB wind, possibly with bipolar geometry. These stars might be linked to the "water fountain" sources with H_2O and OH outflow velocities of 40–130 km s^{-1} (Likkel et al. 1992). For OH 12.8-0.9 an increase of the H_2O maser outflow velocity was observed during the monitoring program, indicating that the outflow traced by this maser is still accelerated. We may witness a star, which is currently developing the high ouflow velocities seen presently in "water fountain" sources.

The search for peculiar masers in cool IRAS sources provides a powerful tool to discover very young PPN, before they have left the main strip in the IRAS color-color diagram populated by ordinary OH/IR stars.

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