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The ATCA/VLA OH 1612 MHz survey: Identification of post-AGB stars

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Abstract. The ATCA/VLA Galactic Plane survey detected OH 1612 MHz maser emission from a total of 766 sources. In most cases the detected sources have double-peaked spectral profiles which are characteristic of OH/IR stars. A small number of sources however have irregular spectra and uncertain classifications. We discuss the maser results for two sources with irregular OH spectra, D046 (OH 326.5−0.4) and B292 (OH009.1−0.4). For B292 we detected OH 1720 MHz emission – a transition previously unknown for evolved stars. D046 has exceptionally broad maser profiles and strong non-thermal radio continuum emission. Both are likely to be bipolar post-AGB sources.

Post-AGB sources can be identified from their MSX far-infrared properties. For the ATCA/VLA OH-selected sample, most of the likely post-AGB stars do *not* have unusual OH 1612 MHz spectra.

1. The ATCA/VLA OH survey

We report the completion of a survey with the Australia Telescope Compact Array and the Very Large Array for OH 1612 MHz maser emission from sources in the Galactic Plane (Sevenster et al. 1997a,b; 2001). This survey covers the region $|l| < 45°$, $|b| < 3°$ and velocities in the range $|v| \leq 350$ km s^{-1}. This region was fully covered using a total of 2414 pointing centres, separated by 30 arcmin. The survey is 95% complete for flux densities above 0.38 Jy. Positions of detected sources are determined to an accuracy of 0.5 arcsec.

The Galactic Plane survey detected OH 1612 MHz maser emission from a total of 766 sources. Of the detected sources, 661 (86%) have standard double-peaked spectral profiles which are characteristic of OH/IR stars on the asymptotic giant branch (AGB). Aperture synthesis observations have shown that for double-peaked sources, the strongest emission occurs along the line-of-sight through the stellar position, from the front and back of an expanding spherically-symmetric circumstellar envelope (e.g. Chapman & Cohen 1985; Welty, Fix & Mutel 1987). For 97 sources (13%), the OH 1612 MHz profiles have only a single (possibly broad) peak. It is likely that for most of these, the second peak is below the OH detection level. Eight sources (1%) were classified as 'irregular' with multiple emission peaks.

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2. OH/IR stars with irregular spectra

In general the evolutionary status of OH 1612 MHz maser sources with irregular or single-peaked spectral profiles is uncertain. In a follow-up study, we have obtained OH spectra for 18 objects selected from the Galactic Plane survey to have single-peaked or irregular profiles (Sevenster & Chapman in preparation). Observations were taken in all four of the ground-state OH-maser transitions at 1612, 1665, 1667 and 1720 MHz. We also searched these sources for centimetre radio continuum emission. Here we discuss two sources with irregular OH spectra; D046 (OH326.5−0.4) and B292 (OH009.1−0.4). Their OH maser spectra are shown in Figure 1.

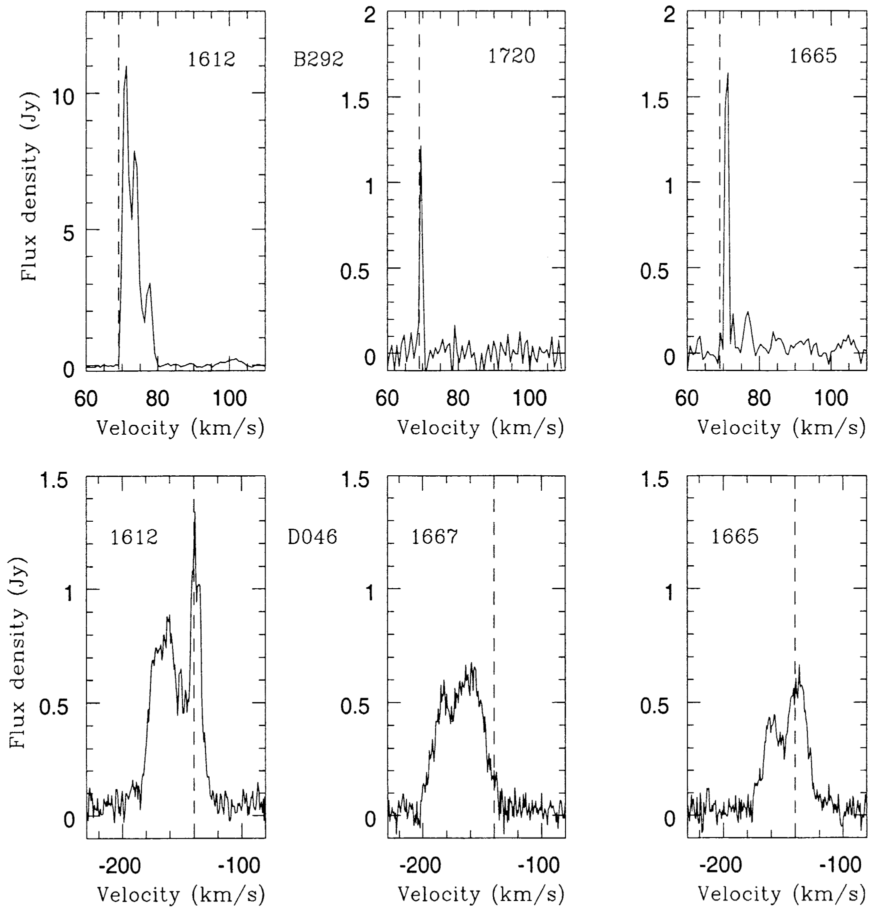

Figure 1. OH maser spectra for the sources B292 (top panels) and D046 (lower panels) obtained with the Australia Telescope Compact Array in November 1998 and September 1999. The channel separation is 0.73 km s^{-1}.

The OH 1612 MHz spectrum of B292 is 'one-sided' with a strong peak at 71 km s^{-1} and a much weaker feature at 101 km s^{-1}. A narrow 1665 MHz peak

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is evident at the same velocity as the outer 1612 MHz peak. No detection was made at 1667 MHz. However, the source was detected at 1720 MHz, a transition hitherto unknown for AGB or post-AGB objects. No continuum emission was found with a detection limit of a few mJy, making this source unlikely to be an ultra-compact HII region (Sevenster & Chapman 2001).

OH 1720 MHz maser emission occurs in star-forming regions, where it is radiatively pumped given a set of fairly strict conditions. It is also detected in some supernova remnants where the maser transition is pumped by collisional excitation. The IRAS and MSX far-infared colours of B292 are consistent with a classification as a young stellar object or post-AGB star while the OH spectra indicate that the star is young post-AGB star. The steep outer edge of the 1612 MHz emission peak is typical of AGB stars while the irregularity of the spectrum indicates that some disruption of the circumstellar envelope has occurred. At the end of the AGB evolutionary phase, stars undergo rapid changes as they evolve to become planetary nebulae. During the post-AGB phase, the stellar mass-loss rate decreases greatly and the star changes from losing mass in a cool dense wind, to losing mass in a much hotter and faster wind. Strong changes may also occur in the morphologies of the circumstellar envelopes. For B292, we suggest that the 1720 MHz maser emission is short-lived and collisionally excited in a region where shocks are present, at the interaction between the hotter post-AGB wind with the remnant AGB wind. Although the envelope structure is not known, the presence of both OH 1612 and 1720 MHz maser emission indicates that a bipolar geometry is likely.

D046 has a highly peculiar OH 1612 MHz spectrum that has changed little in shape between the survey detection in 1994 and the more recent detection in 1998. However the 1612 MHz flux density has increased by a factor of two during this interval. The OH 1612, 1665 and 1667 MHz spectral profiles are all exceptionally broad with velocity widths of $\sim$ 80 km s^{-1} but appear to be slightly shifted in velocity relative to each other (Figure 1). D046 is also highly unusual as a stellar source of non-thermal radio continuum emission. From the ATCA data taken in 1998, the radio continuum flux densities at 3, 6 and 13 cm are 11, 18 and 30 mJy respectively, corresponding to a spectral index of -0.8. The MSX far-infrared colours are very red and are consistent with a classification as a post-AGB star.

The OH maser properties of D046 are strikingly similar to several other sources with broad OH spectral profiles which have been identified, from infrared data and radio aperture synthesis observations, as post-AGB stars with bipolar outflows. Three examples of bipolar sources are OH231.8+4.2, HD101584 and IRAS 16342−3814. Zijlstra et al. (2001) have shown that for bipolar outflow sources, the OH masers may show two distinct kinematic components corresponding to an equatorial torus from the remnant AGB wind, and a bipolar outflow where the velocities of the masers increase linearly with distance from the central star. We suggest that D046 is likely to be a massive post-AGB star where both a bipolar outflow and remnant torus are present.

3. The identification of post-AGB stars from MSX and IRAS data

Of the 766 sources in the ATCA/VLA survey, 587 have IRAS identifications and 494 have MSX identifications. Sevenster (2001a,b) has recently compared the MSX and IRAS properties for sources with both OH and infrared identifications and has shown that MSX two-colour diagrams provide a powerful tool for classifying evolved stars. In particular, MSX colours provide a much clearer separation between AGB and post-AGB stars than given by IRAS colours. For low- and intermediate-mass stars with main-sequence masses below $\sim 4\ M_\odot$, the MSX 8–12 μm colour is given by $[8-12] < 0.9$ for AGB stars, and $[8-12] > 0.9$ for post-AGB stars. From a comparison of the far-infrared and OH 1612 MHz properties, a striking result is that the majority of sources identified from their MSX colours as post-AGB stars have standard double-peaked OH 1612 MHz spectral profiles with fairly low outflow velocities. Post-AGB stars with irregular OH 1612 MHz maser profiles probably represent only a small fraction of stars in this evolutionary stage.

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