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VLA 6 cm continuum observations of OH/IR stars

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Summary. A number of OH/IR stars with accurately known positions was searched for radio continuum emission at a wavelength of 6 cm (5 GHz). None were detected at a level of ~0.1 mJy. The lack of detections in this and previous searches implies either that the transition time between the tip of the asymptotic giant branch, the locus of the OH/IR stars, and the planetary nebula stage is much shorter than the duration of the "superwind" phase, or that there is a noticeable difference between the OH/IR stars on the one hand and Vy 2–2, the only known example of an object in the transition stage, on the other.

Key words: stars – long period variables – OH/IR – circumstellar shells – interferometry – 6 cm continuum – OH masers

1. Introduction

OH/IR stars are evolved M-type giants, or supergiants with masses ranging from 2 to 5 $M_\odot$ (see for numbers quoted in this section Herman and Habing, 1984b). Many lose mass at a very high rate, $-\dot{M} > 10^{-5}\, M_\odot\, \mathrm{yr}^{-1}$, and consequently are in a short-lived, but dramatic phase of their evolution. In a few 10^4 yr the star can shed its entire envelope and the OH/IR stars may be the precursors of population I planetary nebulae. Their extreme mass loss rate, which occurs in the last 1000 yr of the asymptotic giant branch (AGB) evolution (see Baud and Habing, 1983), suggests that some might be in an intermediate stage with OH maser emission in the outer parts of the shell and radio continuum emission from a hot, ionized region close to the star. Depending on mass, mass loss, and dust content of the nebula, Spergel et al. (1983) deduce transition times from the tip of the AGB to the PN stage, t_{TR}, of 10^2–10^4 yr. For the present sample $t_{TR} \simeq 10^3$ yr (cf. Renzini, 1983), of the same order as the length of the "superwind' phase" Objects with the highest shell expansion velocities ($v_e > 15\, \mathrm{km\, s^{-1}}$), that are thought to be the youngest, the most massive ($> 3\, M_\odot$), and the most luminous ($> 2.5\, 10^4\, L_\odot$) stars, could have a stellar wind energetic enough to create a small H II region. Such a scenario has been proposed (see Kwok, 1981) for the OH emitting PN Vy2–2 (see Davis et al., 1979). Recent VLA observations (Seaquist and Davis, 1983) have confirmed the positional coincidence between the OH maser and the radio continuum source associated with Vy 2–2.

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2. Observations

We have used the VLA[1] to search for 6 cm continuum emission from a sample of twelve OH/IR stars with accurately ($\pm 1''$) known positions (see Baud et al., 1984). The sources were selected in such a manner that they covered a range in expansion velocity and OH luminosity, leading to an inferred range in mass loss rate from $2\, 10^{-5}$ to $2\, 10^{-4}\, M_\odot\, \mathrm{yr}^{-1}$ (see next section and Table 1). The observations were made by Perley in the "remote observing mode" on July 16, 1982 when the VLA was in a hybrid configuration between *A* and *B* array (see for a general description of the VLA: Thompson et al., 1980). All 27 telescopes were used at $\lambda = 6$ cm with a bandwidth of 50 MHz. All sources were observed in three snapshots of ten minutes each, yielding a 3σ sensitivity of 180 μJy.

Calibrations were done every 20 min on the continuum source 1741 – 038, and on 3C286 at the beginning and the end of the run. Maps of $10'' \times 10''$ were made in Leiden with the VLA reduction package.

3. Results

None of the OH/IR stars were detected. In Table 1 the names of the objects are listed and the phase in the light curve, ϕ, at which they were observed. The phases ($\phi = 0$ corresponds to maximum light) were calculated using the periods and phase zeropoints found by Herman and Habing (1984a). The distances, *D*, have been taken from Herman and Habing (1984b) based on the phase delay between the two OH emission peaks, or, when the star was not included in their program, the near kinematic distance is given, using a distance to the Galactic Centre of 9.2 kpc (see Herman et al., 1984). The expansion velocity, v_e, and the absolute (at $D = 1$ kpc) OH peak flux density, L_{OH} ($= D\sqrt{S_{\mathrm{LV}} S_{\mathrm{HV}}}$, the harmonic mean of the two strongest peaks), are tabulated. When the star was included in the program of Herman and Habing (1984a), L_{OH} is the averaged value over the light curve, otherwise it has been taken from Baud et al. (1981).

The mass loss rates were inferred from v_e and L_{OH} (see Baud and Habing, 1983). Generally, these compare well with mass loss rates as found from infrared or CO observations (see Herman, 1984). In the last column the *measured* rms-values are given. At the,

[1] The Very Large Array of the National Radio Astronomy Observatory (NRAO). The NRAO is operated by Associated Universities, Inc., under contract with the National Science Foundation

Table 1

Name OH—	ϕ	D (kpc)	v_e ($km\,s^{-1}$)	$\langle L_{OH} \rangle$ ($Jy\,kpc^2$)	$\dot{M}$ ($10^{-5} M_\odot yr^{-1}$)	F_{6cm} (μJy) 1σ	Remarks
18.5+1.4	0.037	4.50 (1)	10.85	139.5	2.27	95	Slightly variable
20.7+0.1	0.122	8.31 (1)	18.21	598.7	7.88	90	
21.5+0.5	0.616	11.63 (1)	18.76	2813.0	17.59	91	
25.1−0.3	0.405:	4.69 (1)	12.14	159.7	2.71	114	Slightly variable
27.0−0.4		6.76 (2)	14.50	138.9	3.02	90	Not in monitor program
27.5−0.9		7.35 (2)	13.50	170.1	3.11	82	Not in monitor program
28.5−0.0	0.353	2.45 (1)	13.12	63.95	1.86	195	
29.4−0.8		8.02 (2)	11.75	240.7	3.22	95	Not in monitor program
30.1−0.7	0.921	1.77 (1)	20.51	196.8	5.09	94	
31.0−0.2	0.276:	6.50 (1)	14.27	273.4	4.17	213	Non variable
32.0−0.5	0.090	9.30 (1)	20.58	678.4	9.48	80	
39.9−0.0	0.009	3.07 (1)	14.71	63.14	2.07	110	

Notes: (1) See Herman and Habing (1984b). (2) Kinematic distance; $D_0 = 9.2$ kpc. Monitor program: see Herman and Habing (1984a)

accurately known, stellar positions even more stringent upper limits can be set to the continuum flux received.

4. Discussions and conclusions

Vy 2–2 remains the only known object in the transition stage. Its distance is unknown, but its optical visibility suggests $D = 1$ kpc. The 6 cm continuum flux is 19 mJy (see Seaquist and Davis, 1983), and the spectrum bends over around 20 GHz (1.5 cm). The radius of the circumstellar shell is $3\,10^{15}\,(D/\text{kpc})$ cm.

The mean distance of the OH/IR stars in this program is 6.2 kpc, the individual values ranging from 2 kpc to 11 kpc. With our sensitivity, an object like Vy 2–2 remains detectable at the 5σ level out to 6 kpc, but none of our stars show continuum emission.

Maybe, the OH/IR stars are, on the average, not as far in their evolution as Vy 2–2. In that case, an eventually present ionized region should best be searched for at even higher frequencies. Also, t_{TR} might be considerably shorter than the "superwind" phase. In both cases a much larger sample of OH/IR stars should be observed.

Finally, it is possible that Vy 2–2 is fundamentally different from the "normal" OH/IR stars; its radius is a factor ten smaller than the mean value for OH/IR stars (see Herman and Habing, 1984a) and it has only a very weak OH maser; $L_{OH} = 5(D/\text{kpc})^2$ Jy kpc^2 (see Seaquist and Davies, 1983), compared to $L_{OH} \gg 100$ Jy kpc^2 for the selected OH stars. If these differences are fundamental, rather than an evolutionary effect, then the selection of our candidates was clearly not appropriate.

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