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Letter to the Editor

A search for OH and H_2O maser emission from unidentified IRAS sources

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Summary. OH and H_2O maser emission has been searched for in 33 IRAS sources having far infrared colors approximating those of OH/IR stars. Eleven OH masers and six H_2O masers were found, with two sources common to both groups. Nine of the OH spectra are characteristic of OH/IR stars. One of the OH masers is circularly polarized and is possibly not a late-type star. One of the H_2O masers shows two groups of velocity components separated by 110 km s^{-1}.

Key words: OH/IR stars, H_2O masers, OH masers, IRAS sources

I. Introduction

The survey of the Infrared Astronomical Satellite (IRAS) has led to the discovery of many previously unknown objects. Some of these are presumably stars which are hidden by surrounding gas and dust preventing their optical detection. Such objects may be young stars embedded in the dust clouds from which they were formed, or late-type stars which form optically thick circumstellar shells during the latest stages of stellar evolution on the Asymptotic Giant Branch (AGB) (see e.g. Engels et al., 1983). From such shells is often observed intense 1612 MHz OH maser emission with a characteristic double-peaked velocity profile. These objects are called OH/IR stars and the detection of OH maser emission with such characteristics therefore permits an unambiguous identification. If only water maser emission is present, an identification is less certain but as water masers are frequently associated with star forming regions (e.g. Moorwood and Salinari, 1983), an identification with recently formed stars is more likely.

In this Letter we present the results of a search for OH and H_2O maser emission from all sources included in the IRAS circular 9. These sources were selected from the IRAS survey by searching for objects with flux ratios similar to those of the OH/IR stars discussed by Olnon et al. (1984). They do not form a statistically complete sample.

II. Observations

OH observations in the $^2\Pi_{3/2}$, J=3/2 main lines at 1665/1667 MHz and in the satellite line at 1612 MHz were made in January 1984 (J.D. 2445729) with the 100m Effelsberg dish. The half-power beamwidth was about 8' and the telescope sensitivity 1.7 K/Jy. We used a dual-channel FET receiver as front end, accepting left and right circular senses of polarization, and the signals were processed by two autocorrelation spectrometers in parallel. The 384 channel autocorrelator was split into two sections with central frequencies 1665 (LCP) and 1667 MHz (RCP). The same split was made for the 1024 channel autocorrelator but both halves were centered on 1612 MHz. Observations were made in total power mode and calibrated on the basis of continuum scans through 3C348 and NGC 7027 (Baars et al., 1977). Typical integration times were 3 min, and 6 min for the weaker masers. We first searched with a bandwidth of 1250 KHz in the main lines and 1562 KHz in the satellite line centered at a LSR velocity of 0 km s^{-1}. The resulting velocity coverage was ± 110 km s^{-1} at 1665/1667 MHz and ± 145 km s^{-1} at 1612 MHz. Detected OH masers were reobserved using a bandwidth of 312.5 KHz (main lines) and 390.6 KHz (satellite line), giving resolutions of 1.6 KHz (0.3 km s^{-1}) and 0.8 KHz (0.15 km s^{-1}) for uniform weighting. Our sensitivity limit (3σ) was 0.3 Jy at 1612 MHz and 0.6 Jy in the main lines.

Observations of the $6_{16} \rightarrow 5_{23}$ H_2O transition at 22 GHz were carried out in April 1984 (J.D. 2445801) using the 100m telescope with a half-power beamwidth of 42". The front end receiver was a K-band maser with an effective system temperature of approximately 60 K. Both autocorrelators were centered on v_{LSR} = 0 km s^{-1} and the unsplit mode was used. The bandwidths were 25 MHz (1024 channels) and 10 MHz (384 channels), resulting in a velocity coverage of ± 160 km s^{-1} and a velocity resolution of 0.4 km s^{-1}. The observations of the object H_2O 125.6+2.1 were made with a 12.5 MHz bandwidth. The sensitivity limit (3σ) was 0.5 Jy but because of the positional uncertainties of the IRAS sources, 2 Jy may be a more realistic limit.

III. Results

We detected 1612 MHz OH maser emission in 11 of the 33 sources in IRAS circular 9. Nine of these have spectra characteristic of OH/IR stars (Fig. 1). In two cases, the satellite line emission was accompanied by an OH maser in the main line at 1667 MHz. None of the sources had 1665 MHz emission above our sensitivity limit. Polarization was less than 10% in all but one case. Hence, the LCP and RCP 1612 MHz spectra were added to improve the signal-to-noise ratio. For OH 54.9-4.1, the LCP and RCP spectra are displayed separately because several features show pronounced polarization.

The results are listed in Table 1. The first column gives the OH masers, as identified by their galactic coordinates, together with the IRAS source identification. The galactic coordinates have a prefix "OH/IR" for OH-spectra typical of OH/IR stars, or

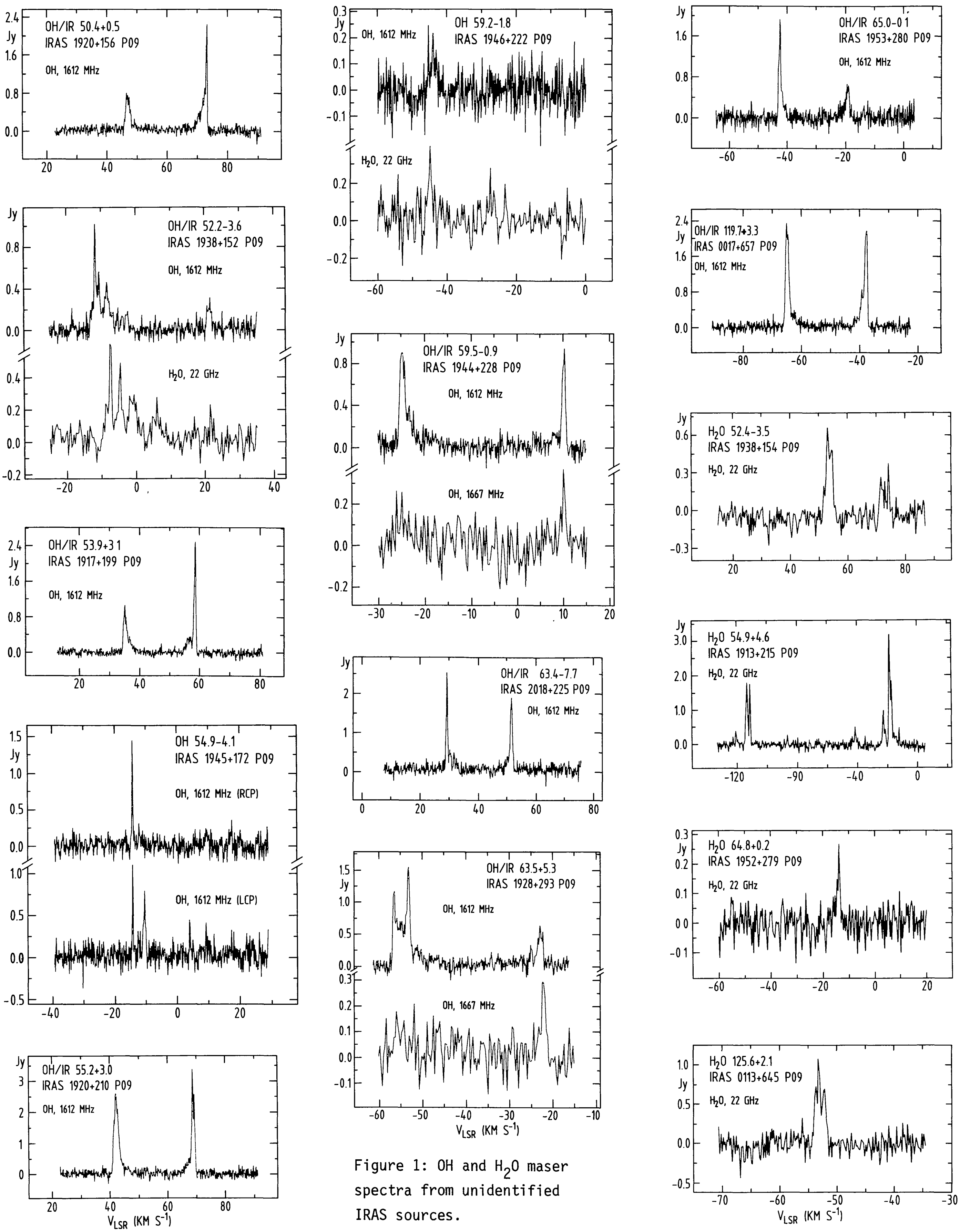

Figure 1: OH and H_2O maser spectra from unidentified IRAS sources.

Table 1. Results of the OH observations

Object	IRAS Ident.	Δv	v_{LSR}	v_{peak} (1612 MHz)	S_{peak}	v_{peak} (1667 MHz)	S_{peak}
		(km s^{-1})	(km s^{-1})	(km s^{-1})	(Jy)	(km s^{-1})	(Jy)
OH/IR 50.4+0.5	1920+156P09	27.5	59.5	46.7, 73.0	0.8,2.2	-	-
OH/IR 52.2-3.6	1938+152P09	34.6	4.6	-11.6, 21.6	1.0,0.3	-	-
OH/IR 53.9+3.1	1917+199P09	24.7	46.2	34.8, 58.3	1.1,2.5	-	-
OH 54.9-4.1	1945+172P09	-	-	-14.2,-10.4[1)] 4.1, 9.3	1.1,0.8 0.4,0.4	-	-
		-	-	-14.2[2)]	1.4	-	-
OH/IR 55.2+3.0	1920+210P09	28.6	55.2	42.0, 68.7	2.6,3.3	-	-
OH 59.2-1.8	1946+222P09	-	-	-45.7	0.3	-	-
OH/IR 59.5-0.9	1944+228P09	36.2	-7.5	-25.0, 10.2	0.9,0.9	-26.4,-25.2, 9.7	0.3:,0.3:,0.4
OH/IR 63.4-7.7	2018+225P09	23.6	40.8	29.4, 51.7	2.5,1.8	-	-
OH/IR 63.5+5.3	1928+293P09	34.8	-39.3	-56.2,-52.9,-22.8	1.2,1.5,0.6	-22.7	0.3
OH/IR 65.0-0.1	1953+280P09	24.4	-31.3	-42.7,-19.4	1.9,0.6	-	-
OH/IR 119.7+3.3	0017+657P09	28.7	-51.5	-65.1,-37.6	2.3,2.1	-	-

Notes: 1) Left circular polarized lines; 2) Right circular polarized line.

a prefix "OH" otherwise. The next columns give the total spread in velocity Δv of the maser emission, the radial velocity V_{LSR} of the stars (assumed to be the center of the velocity range Δv), velocities v_{peak} and flux densities S_{peak} of prominent peaks.

Water maser emission was detected in 6 sources (Fig. 1, Table 2), two of which have OH maser emission as well. In Table 2, v_c is the central velocity in the range Δv. The most unusual source is H_2O 54.9+4.6 which shows two groups of velocity components separated by about 110 km s^{-1}. In the case of this source, we determined the position of the H_2O maser using offset measurements. Our position agrees to within the errors with the IRAS position. We were able to check too that both velocity groups originate from the same position to within our errors and hence we do not believe that we are observing a chance superposition of sources. With the same method, we derived a position $\alpha(1950) = 01^h 13^m 16^s$ and $\delta = 64^o 34' 44''$ for H_2O 125.6+2.1 with 10" uncertainty. This is approximately 20" from the listed position. It is probable that the fluxes given in Table 2 for the remaining sources are underestimated because of the uncertainties of the IRAS coordinates which are of the order of 30".

We might possibly have missed some OH or H_2O masers due to our velocity limit of $\pm$ 150 km s^{-1}. However, in the longitude range covered by our observations no OH/IR stars have been previously found with velocities larger than $\pm$ 80 km s^{-1} (see e.g. Bowers 1978, Baud et al., 1979). Also, we note that the objects found by us all have central velocities less than 100 km s^{-1}. Hence we conclude that our non-detections are not due to insufficient velocity coverage.

IV. Discussion

We have identified 9 OH/IR stars on the basis of their double-peaked profiles. The single feature of OH 59.2-1.8 is unpolarized and hence we suggest that it may be an OH/IR star, whose second peak is below our detection limit. This is supported by the velocity spread of the water maser emission over 22 km s^{-1} (cf. Fig. 1). Thus about 30% of the sample are late-type stars hidden behind circumstellar shells. This is a lower limit, since oxygen-rich AGB stars with weaker or no OH maser emission, as well as carbon stars, might be present too. OH 54.9-4.1, having strongly polarized satellite maser features and no main lines emission, does not fit into any of the classification schemes for OH masers.

The location of the new OH/IR stars in the color-color plot of OH/IR stars given by Olnon et al. (1984) (their figure 2) is confined to the region of variable OH/IR stars, i.e. the sources found by us have color temperatures $T > 200$ K. No OH/IR star was detected among the cooler sources of circular 9, which have colors similar to the extremely red non-variable OH/IR stars.Thus the fraction of sources other than OH/IR stars increases with decreasing color temperature in the circular 9 sample.

According to the model of Elitzur et al. (1976) the 1612 OH masers are pumped by 35µm photons, with a pump efficiency $\eta < 0.25$. A rough estimate of η is given by the ratio of the mean OH peak flux density $<S_{peak}>$ to the 35µm flux density S_{35} (Evans and Beckwith, 1977). With $<S_{peak}> = (S_{peak}(blue) + S_{peak}(red))/2$ from Table 1 and $S_{35} = 0.5 * S_{25}$ * from IRAS circular 9 we find $0.04 < \eta > 0.25$ for 8 OH/IR stars and $\eta = 0.49$ for one (53.9+3.1). The mean pump efficiency is 0.17, in good agreement with the model prediction.

Of the sources which we do not detect, most are unlikely to be OH/IR stars. Taking $\eta_{min} = 0.04$ and a 3σ detection limit of 0.3 Jy at 1612 MHz, we would expect to see in OH any OH/IR star with $S_{25} > 15$ Jy. Seven sources are weaker than this and hence might be found in more sensitive measurements.

The OH/IR stars in the circular 9 sample have velocity spreads Δv between 23 and 37 km s^{-1}, similar

*) Adopting the ν^2 Rayleigh-Jeans limit for the corresponding frequencies.

Table 2. Results of the H_2O observations

Object (IRAS Ident.)	Δv (km s^{-1})	v_c (km s^{-1})	v_{peak} (km s^{-1})	S_{peak} (Jy)
OH/IR 52.2-3.6 (1938+152P09)	35	6.7	- 7.4 21.5	0.6 0.2
H_2O 52.4-3.5 (1938+154P09)	25	63.5	53.1 74.2	0.7 0.4
H_2O 54.9+4.6 (1913+215P09)	111	-66.1	-113.5 - 18.8	1.8 3.2
OH 59.2-1.8 (1946+222P09)	22	-36.0	- 45.0	0.4
H_2O 64.8+0.2 (1952+279P09)	8.5	-14.6	- 13.6	0.3
H_2O 125.6+2.1 (0113+645P09)	3.3	-53.0	- 53.2	1.1

to those of OH/IR stars known previously. We note, however, that several stars have high negative velocities, indicating perhaps large deviations from circular motions. An alternative would be that they are very distant (>10 kpc) from the Sun. At such distances, the bolometric magnitudes derived from the IRAS fluxes are between -4 and -7, consistent with luminosities of AGB stars. However a few stars (e.g. OH/IR 63.5+5.3) would in this case have to be more than 500 pc above the plane.

OH/IR 52.3-3.6 and the suspected OH/IR star 59.2-1.8 are the only OH masers in the circular 9 sample which show water maser emission. The identification of the four other H_2O sources is not evident. Two of them have the emission spread over two velocity groups. Whereas for H_2O 52.4-3.5 Δv is 25 km s^{-1}, similar to the spread seen in late-type stars, the spread over more than 110 km s^{-1} in H_2O 54.9+4.6 is peculiar. However all of these sources could be associated with regions of star formation and one test for this is to look for CO emission from the associated molecular cloud. In the particular case of H_2O 54.9+4.6, CO measurements in the J = 1→0 transition at 115 GHz carried out by Anders Winnberg using the Onsala 20m telescope proved negative ($T_A^* < 0.4$).

We note also that several of the circular 9 IRAS sources lie in regions covered by a recently completed 11 cm continuum survey (Reich et al., 1984). We found 1944+228P09 (= OH/IR 59.5-0.9), 1923+164P09 and 1923+167P09 to have point-like counterparts at 11cm, with peak flux densities of 0.31, 0.07 and 0.16 Jy respectively. We found no other 11cm counterparts to any known OH/IR star, many of which are much stronger both in OH and in the infrared than OH/IR 59.5-0.9. This suggests that the coincidences found with the IRAS sources may be accidental.

As might be expected from the selection criteria of IRAS circular 9, we found a relatively large number of OH/IR stars. All of them have at least one peak below the completeness limits of the radio surveys (cf. Baud et al., 1981). This implies that an extensive search for OH maser emission from IRAS sources will increase the number of known OH/IR stars substantially. Since the radial velocities of these stars can be obtained from their maser spectra, much more detailed studies of galactic structure and kinematics will be possible than previously (see Baud et al., 1981). It is also worth noting that the selection of unidentified IRAS sources likely to be OH/IR stars is facilitated when spectra of the 10μm silicate feature are available. A preliminary inspection of low resolution spectra between 6 and 23μm taken by IRAS shows that the presence of the 10μm feature in absorption makes it very likely that the star shows OH maser emission.

V. Conclusions

We found that 11 sources of IRAS circular 9 show OH maser emission, with one object displaying pronounced circular polarization. From the measured ratios of OH to FIR fluxes, we expect that at most one third of the remaining circular 9 sources might be OH masers too weak to exceed our sensitivity limit. Thus it appears that about 30% of the sample objects are OH/IR stars, with the total fraction of all late-type stars possibly higher. Our OH/IR stars are all located in the region of OH/IR variables in the IRAS color-color plot. Six IRAS sources show H_2O maser emission, with two of them being OH masers as well. Among the other four, there may be pre- or post-main-sequence objects; one is peculiar in its large velocity spread of more than 110 km s^{-1}.

Combining all results, we conclude that at least 50% of the circular 9 sources are galactic objects, with planetary nebulae, HII regions and carbon stars possibly making up a sizeable fraction of the remainder.

Further sensitive searches for OH emission from IRAS sources are a promising method of improving our knowledge of OH/IR star distribution and of galactic kinematics and structure.

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