New H$_2$O Masers associated with
Main-line OH Masers in the
Galactic Longitude Range 3° to 60°

J. L. Caswell, R. A. Batchelor, J. R. Forster and K. J. Wellington

Division of Radiophysics, CSIRO, P.O. Box 76, Epping, N.S.W. 2121.

Abstract

A search in the direction of OH masers emitting at 1665 or 1667 MHz has yielded 11 new H$_2$O masers. The new sources are discussed individually. The overall statistics of the search show that out of a total of 55 OH masers in the 3° to 60° galactic longitude range at least 36 have H$_2$O maser counterparts.

1. Introduction

Caswell and Haynes (1983, present issue p. 419) recently made a compilation of all known OH masers that emit predominantly on the main-line transitions (1665 or 1667 MHz) of the ground state and are located in the galactic plane between longitude 3° and 60°. In April 1982 we conducted a search for associated H$_2$O maser emission in the direction of those OH sources which are either new or now have greatly improved position estimates (Caswell and Haynes 1983). We used the Parkes 64 m radio telescope equipped with a new 22 GHz maser receiver and a 1024-channel correlator. The correlator was configured to give a total coverage of 24 MHz (320 km s$^{-1}$) with a resolution of 40 kHz (0.53 km s$^{-1}$) near the centre of the spectrum and 48 kHz near the edges. Five-minute integrations were used and our sensitivity (at the 3σ detection level) was between 1 and 2 Jy (1 Jy = 10$^{-26}$ W m$^{-2}$ Hz$^{-1}$) depending on weather conditions and telescope elevation angle. The OH maser r.m.s. position uncertainties are typically 20′ arc and a search was made only at the nominal positions. Our beam size at 22 GHz is 100′ arc. When an H$_2$O maser was detected we measured its position from a grid of observations to give an r.m.s. uncertainty of ~12′ arc in each coordinate. Further details of the equipment and observing procedure are given in Caswell et al. (1983, present issue p. 401), which describes a similar H$_2$O search in another region.

2. Results

Table 1 lists the newly discovered H$_2$O masers and Fig. 1 shows the spectra of most of the sources. The sources are discussed individually below. Note that where several H$_2$O maser features lie close together, the uncertainty in their relative positions is only a few seconds of arc, nearly an order of magnitude better than the absolute position; in contrast, the relative positions of H$_2$O and OH masers have r.m.s.
uncertainties of $\sim 30''$ arc and thus nominal separations of this amount are to be interpreted as coincidences within the errors. Remarks on nearby HII regions generally refer to maps at 5 GHz in the galactic plane surveys of Altenhoff et al. (1978) and Haynes et al. (1978), supplemented by hydrogen recombination-line data from Downes et al. (1980).

### Table 1. H$_2$O maser measurements, 1982 April

<table>
<thead>
<tr>
<th>H$_2$O maser ($l, b$)</th>
<th>Position (1950)$^A$</th>
<th>Radial velocity$^B$ (km s$^{-1}$)</th>
<th>Velocity width$^B$ (km s$^{-1}$)</th>
<th>Peak intensity (Jy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H$_2$O 3·91−0·01</td>
<td>17 51 35·6</td>
<td>+8</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>H$_2$O 8·68−0·36</td>
<td>18 03 21·5</td>
<td>+37</td>
<td>See Fig. 1</td>
<td>101</td>
</tr>
<tr>
<td>H$_2$O 11·90−0·14</td>
<td>18 09 15·2</td>
<td>+40</td>
<td>1</td>
<td>7·9</td>
</tr>
<tr>
<td>H$_2$O 16·58−0·05</td>
<td>18 18 17·1</td>
<td>+37</td>
<td>See Fig. 1</td>
<td>12</td>
</tr>
<tr>
<td>H$_2$O 16·61−0·05</td>
<td>18 18 21·3</td>
<td>+46</td>
<td>2</td>
<td>4·4</td>
</tr>
<tr>
<td>H$_2$O 23·01−0·41</td>
<td>18 31 56·2</td>
<td>+46</td>
<td>2</td>
<td>4·4</td>
</tr>
<tr>
<td>H$_2$O 23·44−0·18</td>
<td>18 31 55·6</td>
<td>+101</td>
<td>See Fig. 1</td>
<td>19</td>
</tr>
<tr>
<td>H$_2$O 31·25−0·11</td>
<td>18 46 10·5</td>
<td>+46</td>
<td>See Fig. 1</td>
<td>280</td>
</tr>
<tr>
<td>H$_2$O 32·75−0·08</td>
<td>18 48 48·3</td>
<td>+33</td>
<td>See Fig. 1</td>
<td>96</td>
</tr>
<tr>
<td>H$_2$O 35·03+0·35</td>
<td>18 51 29·5</td>
<td>+67</td>
<td>See Fig. 1</td>
<td>63</td>
</tr>
<tr>
<td>H$_2$O 45·46+0·05</td>
<td>19 12 02·6</td>
<td>+58</td>
<td>See Fig. 1</td>
<td>11·5</td>
</tr>
<tr>
<td>H$_2$O 45·44+0·07</td>
<td>19 11 56·8</td>
<td>+56</td>
<td>See Fig. 1</td>
<td>9·2</td>
</tr>
</tbody>
</table>

$^A$ The r.m.s. uncertainty is $\sim 12''$ arc, with the exception of H$_2$O 3·91−0·01 (r.m.s. error of $\sim 30''$ arc) and H$_2$O 45·44+0·07 (r.m.s. error of 10'' arc; position from Genzel and Downes 1977).

$^B$ The centre velocity and width of the strongest feature.

**H$_2$O 3·91−0·01**

The corresponding OH maser (OH 3·91−0·01) is readily detectable and has an r.m.s. position error of 18'' arc. The H$_2$O maser is weak and near the limit of our sensitivity and has a correspondingly larger position uncertainty of 30'' arc. In the direction of the masers there is no distinct peak in the 5 GHz radio continuum emission (Altenhoff et al. 1978). No reliable kinematic distance estimate can be made because the velocity is near zero and the source lies close to the direction of the galactic centre.

**H$_2$O 8·68−0·36**

An OH maser is at R.A. 18$^h$03$^m$24$^s$.1, Dec. $-21°37'34''$ (1950), with r.m.s. position uncertainty of $\sim 20''$ arc; the H$_2$O maser is quite strong and its position uncertainty is 12'' arc. The total positional discrepancy between the two masers is 37'' arc and is compatible with the true positions being coincident. Genzel and Downes (1979) reported a maser H$_2$O 8·67−0·36 at R.A. 18$^h$03$^m$18$^s$.6, Dec. $-21°37'59''$, with r.m.s. error of 5'' arc, which is separated by 44'' arc from our H$_2$O position and nearly 80'' arc from the nominal OH position. If the errors are realistic it appears to be a different source from the one which we have detected. Our spectrum of H$_2$O 8·68−0·36 taken 1982 April shows a peak approximately twice as strong as the Genzel and Downes (1979) maser (as measured in 1977 November) and no similarity in detailed velocity structure. At the Genzel and Downes position
New H$_2$O Masers

Fig. 1. Spectra of H$_2$O masers. The source names are shown within each frame and the observations were made in the period 1982 April 7–10. The velocity resolution is 0.53 km s$^{-1}$ (40 kHz). The velocity coverage of each spectrum was 320 km s$^{-1}$ but the outer regions where no emission was found are not shown.
in 1982 April we could detect only the source $\text{H}_2\text{O} \cdot 8\cdot 68 - 0\cdot 36$, with the intensity reduced by the amount expected from the offset relative to the beam centre. A weak HII region, G $\cdot 8\cdot 666 - 0\cdot 351$, is located at R.A. $18^h 03^m 17^s \cdot 2$, Dec. $-21^\circ 37' 55''$, and is likely to be associated with the masers.

$\text{H}_2\text{O} 11\cdot 90 - 0\cdot 14$

Nominal positions of the $\text{H}_2\text{O}$ and OH masers differ by a total of 41" arc, compatible with coincidence. The 5 GHz continuum map of Altenhoff et al. (1978) shows an HII region, G $11\cdot 944 - 0\cdot 037$, with its peak position displaced 7" arc from the masers but with a similar velocity of $+41\cdot 5$ km s$^{-1}$ (Downes et al. 1980). Any compact HII region precisely coinciding with the maser must be weaker than $\sim 0\cdot 1$ Jy at 5 GHz. Note that the nearby continuum source, G $12\cdot 0 - 0\cdot 1$, is non-thermal and believed to be a supernova remnant (Clark et al. 1975).

$\text{H}_2\text{O} 16\cdot 58 - 0\cdot 05$ and $\text{H}_2\text{O} 16\cdot 61 - 0\cdot 05$

These two sources are separated from each other by $86" \pm 5"$ arc and are also separated significantly in velocity. The nearby OH maser, OH $16\cdot 59 - 0\cdot 06$, is at R.A. $18^h 18^m 20\cdot 3$, Dec. $-14^\circ 33' 18''$, a nominal separation of 38" arc from $\text{H}_2\text{O} 16\cdot 58 - 0\cdot 05$ but compatible with a precise coincidence in view of the position uncertainties. By contrast, the weaker $\text{H}_2\text{O}$ maser, $\text{H}_2\text{O} 16\cdot 61 - 0\cdot 05$, is significantly displaced from the OH maser (by 68" arc) and its velocity is also offset from that of the OH maser; $\text{H}_2\text{O} 16\cdot 61 - 0\cdot 05$ has, in addition to the feature at $V = +46$ km s$^{-1}$ (see Table 1), a slightly weaker feature of 2.9 Jy at $V = -50\cdot 5$ km s$^{-1}$, with width of 1 km s$^{-1}$. Continuum emission in the vicinity of the masers is weak, being $\sim 0\cdot 1$ Jy at 5 GHz (Altenhoff et al. 1978).

$\text{H}_2\text{O} 23\cdot 01 - 0\cdot 41$

The maser OH $23\cdot 01 - 0\cdot 41$ is in good positional agreement with the $\text{H}_2\text{O}$ maser (nominal separation 16" arc). In the direction of the masers there is diffuse emission from an HII region with a recombination-line velocity of $+78$ km s$^{-1}$ (near that of the masers), but no compact HII component has been detected.

$\text{H}_2\text{O} 23\cdot 44 - 0\cdot 18$

The position of the maser OH $23\cdot 43 - 0\cdot 19$ agrees well with that of the $\text{H}_2\text{O}$ maser (nominal separation 23" arc). A nearby strong HII region, G $23\cdot 421 - 0\cdot 214$, has a velocity of $+101$ km s$^{-1}$, similar to that of the two masers, and is clearly associated with them. The velocity indicates a distance of nearly 10 kpc with no ambiguity, and the HII region, which is extended, may be comprised of several components not resolved with a beam size of several minutes of arc.

$\text{H}_2\text{O} 31\cdot 25 - 0\cdot 11$

The maser OH $31\cdot 24 - 0\cdot 11$ essentially coincides with the $\text{H}_2\text{O}$ maser (nominal separation 9" arc). The mean velocity of both the OH and $\text{H}_2\text{O}$ masers is $\sim 22$ km s$^{-1}$, leading to a kinematic distance estimate of either 1.6 or 15.5 kpc. The maser $\text{H}_2\text{O} 31\cdot 25 - 0\cdot 11$ has the largest received flux density of the sources reported here, and if it were at the far distance its luminosity would be an order of magnitude
greater than the median of all sources observed to date (Genzel and Downes 1977); however, if it were at the near distance it would be one of the lowest luminosity sources amongst those with complex spectra. On balance, we slightly favour the far distance estimate of 15·5 kpc. Outlying portions of the extensive HII region W43 lie in the same general direction as the masers but we assume W43 to be unrelated on account of its grossly different velocity, with components present near 50 and 100 km s\(^{-1}\). The W43 continuum emission hampers the detection of any weak HII region which might be related to the masers.

\( \text{H}_2\text{O}\ 32\cdot75-0\cdot08 \)

The nominal separation of \( \text{H}_2\text{O}\ 32\cdot75-0\cdot08 \) from \( \text{OH}\ 32\cdot74-0\cdot07 \) is 35° arc, not significantly greater than the uncertainty. The major continuum emission in this direction is from a supernova remnant, according to Caswell et al. (1975), at a distance estimated to be \( \sim 8 \) kpc from the surface-brightness/linear-diameter relationship of Caswell and Lerche (1979). The kinematic distance to the masers is either 2·5 or 14·3 kpc and the masers seem unlikely to be related to the supernova remnant. Any compact HII region in the direction of the masers appears to be weaker than \( \sim 0\cdot1 \) Jy at 5 GHz.

\( \text{H}_2\text{O}\ 35\cdot03+0\cdot35 \)

This \( \text{H}_2\text{O} \) maser is in good positional agreement with \( \text{OH}\ 35\cdot03+0\cdot35 \) (nominal separation 18° arc). A compact continuum source, G35·027+0·332, coincides to better than 1° arc and seems likely to be a compact HII region associated with the masers; unfortunately, since the source is quite weak, 0·4 Jy at 5 GHz, a recombination-line measurement has not been obtained. The velocity structure of the masers is quite extensive, with the strongest \( \text{H}_2\text{O} \) feature at \( V = +67 \) km s\(^{-1}\) and the OH emission extending from 40 to 50 km s\(^{-1}\). We adopt +50 km s\(^{-1}\) as our (rather uncertain) estimate of the systemic velocity; this is at one extremity of the OH emission and near the mid-range of the \( \text{H}_2\text{O} \) emission. The corresponding kinematic distance is either 3·4 or 12·9 kpc.

\( \text{H}_2\text{O}\ 45\cdot46+0\cdot05 \) and \( \text{H}_2\text{O}\ 45\cdot44+0\cdot07 \)

Spectra for both sources are shown in Fig. 1. The first source is a newly discovered \( \text{H}_2\text{O} \) maser displaying a single narrow feature at +58 km s\(^{-1}\); its position agrees well (nominal separation 27° arc) with the maser \( \text{OH}\ 45\cdot47+0\cdot05 \). The second source, \( \text{H}_2\text{O}\ 45\cdot44+0\cdot07 \), was reported (as 45·44+0·1) by Genzel and Downes (1977) and is 100° arc from \( \text{H}_2\text{O}\ 45\cdot46+0\cdot05 \); it can also be seen from our Fig. 1 that the peak intensity is at +56 km s\(^{-1}\), significantly displaced (by 2 km s\(^{-1}\)) from the velocity peak of \( \text{H}_2\text{O}\ 45\cdot46+0\cdot05 \). It is also worth noting, in order to minimize confusion between these sources in the future, that when Genzel and Downes measured their 1977 spectrum for \( \text{H}_2\text{O}\ 45\cdot44+0\cdot07 \) the peak was at +58 km s\(^{-1}\) (whereas it is now at +56 km s\(^{-1}\)), which is the velocity at which we now find the peak of the other source \( \text{H}_2\text{O}\ 45\cdot46+0\cdot05 \). A weak continuum ‘point’ source, G45·47+0·05, has been measured by Habing et al. (1974) with flux density at 5 GHz of 92 mJy; it coincides with the OH maser and is believed to be a compact HII region situated amongst more extended HII regions with larger flux densities.
### Table 2. H$_2$O masers associated with main-line OH masers between longitudes 3° and 60°

<table>
<thead>
<tr>
<th>$l$</th>
<th>$b$</th>
<th>OH maser Position (1950)</th>
<th>$l$</th>
<th>$b$</th>
<th>H$_2$O maser$^a$ Position (1950)</th>
<th>Peak intensity (Jy)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>R.A.</td>
<td></td>
<td></td>
<td>R.A.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.91</td>
<td>-0.01</td>
<td>17 51 35.6</td>
<td>3.91</td>
<td>-0.01</td>
<td>17 51 35.6</td>
<td>2</td>
<td>This paper</td>
</tr>
<tr>
<td>5.88</td>
<td>-0.39</td>
<td>17 57 26.7</td>
<td>5.89</td>
<td>-0.40</td>
<td>17 57 28.7</td>
<td>200</td>
<td>Batchelor et al. (1980)$^b$</td>
</tr>
<tr>
<td>8.68</td>
<td>-0.37</td>
<td>18 03 24.1</td>
<td>8.68</td>
<td>-0.36</td>
<td>18 03 21.4</td>
<td>101</td>
<td>This paper</td>
</tr>
<tr>
<td>9.62</td>
<td>+0.19</td>
<td>18 03 17.6</td>
<td>9.62</td>
<td>+0.19</td>
<td>18 03 16.0</td>
<td>90</td>
<td>Genzel and Downes (1979)</td>
</tr>
<tr>
<td>10.62</td>
<td>-0.38</td>
<td>18 07 30.4</td>
<td>10.62</td>
<td>-0.38</td>
<td>18 07 30.3</td>
<td>490</td>
<td>Genzel and Downes (1977)$^b$</td>
</tr>
<tr>
<td>11.03</td>
<td>+0.06</td>
<td>18 06 43.3</td>
<td>11.03</td>
<td>+0.06</td>
<td>18 06 42.2</td>
<td>27</td>
<td>Genzel and Downes (1979)</td>
</tr>
<tr>
<td>11.91</td>
<td>-0.15</td>
<td>18 09 18.1</td>
<td>11.90</td>
<td>-0.14</td>
<td>18 09 15.2</td>
<td>7.9</td>
<td>This paper</td>
</tr>
<tr>
<td>12.03</td>
<td>-0.04</td>
<td>18 09 07.4</td>
<td></td>
<td></td>
<td></td>
<td>&lt;2.4</td>
<td></td>
</tr>
<tr>
<td>12.22</td>
<td>-0.12</td>
<td>18 09 48.4</td>
<td>12.21</td>
<td>-0.12</td>
<td>18 09 48.6</td>
<td>85</td>
<td>Batchelor et al. (1980)$^b$</td>
</tr>
<tr>
<td>12.68</td>
<td>-0.18</td>
<td>18 10 59.6</td>
<td>12.68</td>
<td>-0.18</td>
<td>18 10 58.9</td>
<td>270</td>
<td>Johnston et al. (1973)</td>
</tr>
<tr>
<td>12.91</td>
<td>-0.26</td>
<td>18 11 44.3</td>
<td>12.91</td>
<td>-0.26</td>
<td>18 11 44.0</td>
<td>10</td>
<td>Genzel and Downes (1977)</td>
</tr>
<tr>
<td>14.17</td>
<td>-0.06</td>
<td>18 13 32.3</td>
<td>14.17</td>
<td>-0.06</td>
<td>18 13 32.9</td>
<td>15</td>
<td>Batchelor et al. (1980)</td>
</tr>
<tr>
<td>15.04</td>
<td>-0.68</td>
<td>18 17 31.9</td>
<td>15.04</td>
<td>-0.67</td>
<td>18 17 31.1</td>
<td>30</td>
<td>Batchelor et al. (1980)$^b$</td>
</tr>
<tr>
<td>16.59</td>
<td>-0.06</td>
<td>18 18 20.3</td>
<td>16.58</td>
<td>-0.05</td>
<td>18 18 17.7</td>
<td>32</td>
<td>This paper</td>
</tr>
<tr>
<td>18.46</td>
<td>-0.01</td>
<td>18 21 48.0</td>
<td></td>
<td></td>
<td></td>
<td>&lt;3</td>
<td></td>
</tr>
<tr>
<td>19.48</td>
<td>+0.16</td>
<td>18 23 10.3</td>
<td></td>
<td></td>
<td></td>
<td>&lt;20</td>
<td>Batchelor et al. (1980)$^b$</td>
</tr>
<tr>
<td>19.61</td>
<td>-0.23</td>
<td>18 24 49.9</td>
<td>19.61</td>
<td>-0.23</td>
<td>18 24 50.1</td>
<td>60</td>
<td>This paper</td>
</tr>
<tr>
<td>20.08</td>
<td>-0.13</td>
<td>18 25 22.7</td>
<td></td>
<td></td>
<td></td>
<td>&lt;20</td>
<td>This paper</td>
</tr>
<tr>
<td>20.24</td>
<td>+0.08</td>
<td>18 24 55.8</td>
<td></td>
<td></td>
<td></td>
<td>&lt;3</td>
<td></td>
</tr>
<tr>
<td>20.86</td>
<td>+0.48</td>
<td>18 24 39.8</td>
<td></td>
<td></td>
<td></td>
<td>&lt;20</td>
<td></td>
</tr>
<tr>
<td>22.44</td>
<td>-0.18</td>
<td>18 30 01.0</td>
<td></td>
<td></td>
<td></td>
<td>&lt;3</td>
<td></td>
</tr>
<tr>
<td>23.01</td>
<td>-0.41</td>
<td>18 31 56.7</td>
<td>23.01</td>
<td>-0.41</td>
<td>18 31 56.2</td>
<td>89</td>
<td>This paper</td>
</tr>
<tr>
<td>23.43</td>
<td>-0.19</td>
<td>18 31 55.8</td>
<td>23.44</td>
<td>-0.18</td>
<td>18 31 55.6</td>
<td>19</td>
<td>This paper</td>
</tr>
<tr>
<td>24.33</td>
<td>+0.11</td>
<td>18 32 32.3</td>
<td>24.33</td>
<td>+0.11</td>
<td>18 33 30.6</td>
<td>&lt;20</td>
<td>Batchelor et al. (1980)$^b$</td>
</tr>
<tr>
<td>24.78</td>
<td>+0.08</td>
<td>18 33 30.6</td>
<td>24.79</td>
<td>+0.08</td>
<td>18 33 30.3</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>ID</td>
<td>Reference</td>
<td>Comments</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----</td>
<td>-----------</td>
<td>----------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27·35 - 0·20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28·21 - 0·05</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28·83 - 0·25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28·87 + 0·06</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30·22 - 0·15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30·39 - 0·70</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30·60 - 0·06</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30·70 - 0·06</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30·79 - 0·06</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30·82 + 0·28</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31·21 - 0·18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31·24 - 0·11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31·29 + 0·06</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32·74 - 0·07</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33·13 - 0·09</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34·26 + 0·15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35·03 + 0·35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35·19 - 0·74</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35·20 - 1·73</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35·58 - 0·03</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40·62 - 0·14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>43·16 - 0·03</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>43·17 + 0·01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>43·80 - 0·13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45·07 + 0·13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45·10 + 0·12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45·47 + 0·13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45·47 + 0·05</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>48·61 - 0·02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>49·49 - 0·39</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In four cases (indicated by a ?) we are not aware of a sensitive H₂O search at the OH position.

* Other observations of the source are available in the literature, mostly cited in the reference given.
3. Statistics of OH/H$_2$O Maser Associations

In Table 2 we list the OH main-line masers in the galactic longitude range 3° to 60° (for more details see Caswell and Haynes 1983) and the corresponding H$_2$O data. This embodies the H$_2$O detections of Table 1 and some upper limits (of < 3 Jy) obtained in the present series of observations. For some of the sources we list previously unpublished null results from our earlier observations with a less sensitive receiver (Batchelor et al. 1980), the upper limits being typically 20 Jy if we take into account possible pointing errors.

![Graph](image)

**Fig. 2.** Distribution of the ratio of peak H$_2$O flux density to peak flux density of the associated OH maser. The hatched area corresponds to detected H$_2$O counterparts, and the unhatched area to H$_2$O upper limits.

Overall, H$_2$O detections have been made at 36 of the 55 (65%) maser sites; this high success rate is much better than that achieved when searching at the sites of HII regions and slightly better than when searching at the sites of far-infrared sources; thus Jaffe et al. (1981) cite a detection rate of about 12% at the positions of HII regions and 60% at the position of far-infrared sources. Caswell et al. (1983) achieved an even higher success rate at the positions of OH masers in the longitude range 340° to the galactic centre, where 38 out of 46 (80%) OH masers had H$_2$O counterparts. Following Caswell et al. (1983) we show a histogram (Fig. 2) of the distribution of the ratio of H$_2$O to OH intensity (using the peak flux density as the intensity measure). The median value is ~3 and the histogram is essentially identical to that for the longitude range 340° to the galactic centre, when we allow for the fact that some of the upper limits available for the present sample are rather cruder than those obtained in our other survey. When we look at the distribution of upper limits we see that an H$_2$O maser somewhat below our detection limit would still be well within the distribution defined by detected masers. Thus the histogram gives strong support for an intrinsic near one-to-one correspondence of H$_2$O masers with OH masers.

Most of the OH/H$_2$O maser pairs of Table 2 have positions coincident to within the uncertainty of typically 30° arc; higher precision measurements are needed to discover whether on a much smaller scale there are significant displacements of perhaps several seconds of arc, such as occur in a few well-investigated pairs (Forster
et al. 1978; Norris et al. 1982). If such displacements turn out to be common, then, as we suggested elsewhere (Caswell et al. 1983), this might be accounted for if in the process of star formation a dense molecular cloud fragments into two major portions, one forming a new star with a compact HII region and OH maser, and the other (not necessarily undergoing transformation to a star) becoming the site of the H$_2$O emission.

The ratio of H$_2$O to OH intensity may prove to be a useful parameter for investigating the evolution of the masing regions. The ratio may change systematically with age, with the onset of H$_2$O emission perhaps preceding that of the OH emission or possibly lasting for a longer period. Certainly our high detection rate of H$_2$O counterparts suggests that the OH maser phase does not last (much) longer than the H$_2$O maser phase. It may prove possible to use as a measure of age either the diameter of an associated compact HII region or even the separation of the OH and H$_2$O masers if these turn out to be in relative motion.

Finally we note that there is an urgent need for extensive unbiased surveys of H$_2$O masers, to be followed by searches for OH masers, compact HII regions and IR counterparts. The data of this type already available, although meagre (e.g. Caswell et al. 1977; Caswell et al. 1983), suggest that H$_2$O masers may be more prevalent than OH masers. The conditions required for the H$_2$O masers may be less stringent than those required for OH masers, and some support for this is given by the high-velocity ejecta which show H$_2$O maser emission but no OH emission. Thus, while it is generally accepted that the OH masers mark the sites of recently formed stars, the H$_2$O masers may merely mark the sites of compact molecular clouds which are not necessarily undergoing star formation—perhaps they are less massive. Jaffe et al. (1981) in their discovery of new H$_2$O masers associated with far-infrared sources were unable to reach a firm conclusion on the nature of the sources, and the issue is an important one requiring further investigation.

References

Manuscript received 23 November 1982, accepted 3 February 1983