H$_2$O MASERS ASSOCIATED WITH COMPACT H II REGIONS IN SGR B2

R. Genzel, D. Downes and J. Bieging

Max-Planck-Institut für Radioastronomie, Auf dem Hugel 69, 53 Bonn,
Federal Republic of Germany

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SUMMARY

The H$_2$O lines at positive velocities in Sgr B2 come from only four distinct centres of maser emission. Three of these maser centres coincide with compact H II regions in Sgr B2. The H$_2$O emission probably arises in the shells of dense neutral gas surrounding the compact H II regions, as in other H$_2$O maser sources throughout the Galaxy.

The water vapour emission at 22·2 GHz from Sgr B2 was found by Waak & Mayer (1974) to come from a source region which was extended in declination. The map by Goss et al. (1976) shows 14 separate H$_2$O condensations which appear to be spread over an area of $0·3' 	imes 1·6'$ (RA x Dec.). The map made by Morris (1976) has 22 H$_2$O features, and Morris suggested that features with similar velocities tended to cluster spatially. In order to investigate this region with higher spatial resolution and greater positional accuracy, we have observed Sgr Br with the 100-m telescope at Effelsberg, which at 22 GHz has a half-power beamwidth of $40'' 	imes 43''$. We find that the H$_2$O features at positive velocities come from only four distinct positions, three of which coincide with the strongest compact H II regions in Sgr B2.

The observations were made on 1976 May 1 and 2, with the same equipment and observing technique described in our earlier paper on NGC 7538 (Genzel & Downes 1976). The telescope pointing was determined by continuum scans through various quasars and Sgr B2 itself. The strongest continuum peak in Sgr B2 was a point source which we assumed to be component 5 of Martin & Downes (1972). The position adopted for this component was a mean of interferometric measurements (Martin & Downes 1972; Balick & Sanders 1974; Rogstad, Lockhart & Whiteoak 1974).

Sgr B2 was mapped in the H$_2$O line with a grid of 50 points separated by 20". The integration time was 5 min per point, the system temperature was 1000 K, the resolution of the 384-channel autocorrelation spectrometer was 32 kHz ($0·43$ km s$^{-1}$), and the rms noise was 0·5 K (which corresponded to 3 Jy at the elevation of Sgr B2).

Computer-drawn contour maps of integrated line antenna temperature were prepared for about fifty line features in the observed spectra. The widths of the features ranged between 0·6 and 1·2 km s$^{-1}$. The maps show the following results.

(a) None of the 50 features broadens the telescope beam.
Fig. 1. Location of H$_2$O and OH maser sources and compact continuum sources in Sgr B2. The positional uncertainties are given by crosses for the H$_2$O centres, by ellipses for the continuum sources (designated by their numbers in the list of Martin & Downes), and by rectangles for the OH sources (Bieging 1976; Goss et al. 1976).

(b) Each feature comes from one of four positions in Sgr B2.
(c) The group of lines which we designate H$_2$O(1) (velocities between 90 and 105 km s$^{-1}$) and the group H$_2$O(2) (velocities 0–65 km s$^{-1}$) come from two positions near the continuum component 4 of Martin & Downes. This continuum source has a half-power width of $\approx 12''$, and the two H$_2$O sources seem to lie on its periphery.
(d) The group H$_2$O(3) (velocities 70–90 km s$^{-1}$) coincides with the intense,
compact continuum source 5 of Martin & Downes and with an OH source (Raimond & Eliasson 1969; Goss et al. 1976; Bieging 1976), which we label OH(1). This position is also close to the centroid of radiation at 3 mm, 1 mm, and 350 μm (Westbrook et al. 1976; Righini, Simon & Joyce 1976).

(c) The group H$_2$O(4) (velocities between 50 and 70 km s$^{-1}$) coincides with a second OH maser (Raimond & Eliasson 1969; Harvey et al. 1974; Goss et al 1976; Bieging 1976), for which no radio continuum component has yet been found. A more sensitive search for a continuum source might now be worth while.

Table I lists the positions of the H$_2$O, OH and radio continuum sources, and Fig. 1 is a schematic diagram of the region mapped. We have indicated the velocity ranges of the different H$_2$O centres on the spectra in Fig. 2. Our spectra did not
TABLE I

<table>
<thead>
<tr>
<th>Identification</th>
<th>RA (1950)</th>
<th>Dec. (1950)</th>
<th>Velocity range (km s(^{-1}))</th>
<th>Number of features</th>
</tr>
</thead>
<tbody>
<tr>
<td>H(_2)O (1)</td>
<td>17 44 10(^\prime).1 ± 0(^\prime).2</td>
<td>−28 21 11 ± 4</td>
<td>90 − 105</td>
<td>3</td>
</tr>
<tr>
<td>H(_2)O (2)</td>
<td>17 44 10(^\prime).4 ± 0(^\prime).2</td>
<td>−28 21 21 ± 3</td>
<td>0 − 65</td>
<td>26</td>
</tr>
<tr>
<td>Continuum source 4</td>
<td>17 44 10(^\prime).5 ± 0(^\prime).1</td>
<td>−28 21 15 ± 5</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>H(_2)O (3)</td>
<td>17 44 10(^\prime).5 ± 0(^\prime).2</td>
<td>−28 22 01 ± 3</td>
<td>70 − 90</td>
<td>8</td>
</tr>
<tr>
<td>OH (1)</td>
<td>17 44 10(^\prime).7 ± 0(^\prime).4</td>
<td>−28 22 01 ± 6</td>
<td>51 − 56</td>
<td>—</td>
</tr>
<tr>
<td>Continuum source 5</td>
<td>17 44 10(^\prime).7 ± 0(^\prime).1</td>
<td>−28 22 04 ± 5</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>H(_2)O (4)</td>
<td>17 44 10(^\prime).7 ± 0(^\prime).2</td>
<td>−28 22 44 ± 3</td>
<td>50 − 70</td>
<td>15</td>
</tr>
<tr>
<td>OH (2)</td>
<td>17 44 10(^\prime).6 ± 0(^\prime).06</td>
<td>−28 22 43 ± 0(^\prime).8</td>
<td>67 − 69</td>
<td>—</td>
</tr>
<tr>
<td>Continuum source 3</td>
<td>17 44 09(^\prime).0 ± 0(^\prime).2</td>
<td>−28 21 55 ± 15</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

include the group of features at −30 km s\(^{-1}\). These features may constitute a fifth H\(_2\)O maser centre in Sgr B2, although the data of Goss et al. and Morris suggest that the −30 km s\(^{-1}\) features come from a position very close to that of our source H\(_2\)O(4). Some of the weak features in Fig. 2 in H\(_2\)O(4) (for example, the spike at +30 km s\(^{-1}\)) actually come from H\(_2\)O(2) and are caused by a 6 per cent sidelobe located 1.5′ north of the main beam.

From these data we draw the following conclusions.

1. Our new H\(_2\)O map, showing the coincidence of H\(_2\)O and OH masers and compact H\(\text{II}\) regions, now confirms the idea of separate sites of star formation, as opposed to a model of H\(_2\)O emission along an elongated ionization front.

2. In particular, the present map rules out a global source model for Sgr B2 (see the discussion of Kwan & Thuan 1974), at least on a scale of 10\(^\prime\)−40\(^\prime\) (0.5−2.0 pc), in which a hypothetical common pump source excites a large region of relatively uniform density and temperature.

3. Unlike W49, the H\(_2\)O emission in Sgr B2 can be resolved with a single-dish telescope into spatially distinct centres. The present data show that the entire wide-velocity spectrum, with an apparent width of over 100 km s\(^{-1}\), is split up into at least four velocity groups. Each of these spatially distinct groups has a velocity dispersion of only ∼30 km s\(^{-1}\), making it unnecessary to invoke Raman scattering to explain the 100 km s\(^{-1}\) width of the emission.

4. As in the case of NGC 7538 (Genzel & Downes 1976), H\(_2\)O maser sources are closely associated with compact H\(\text{II}\) regions. The best example for this in Sgr B2 is the coincidence between H\(_2\)O(3) and the continuum source MD5. Like NGC 7538–IRS1, the continuum source MD5 in Sgr B2 has a turnover frequency >10 GHz. It must therefore be a very compact H\(\text{II}\) region with an electron number density greater than 10\(^5\) cm\(^{-3}\) and an age less than 10\(^4\) yr.

5. The virial theorem probably cannot be applied to the velocity dispersion of the H\(_2\)O features to estimate an associated mass, since the H\(_2\)O maser cloudlets may not be gravitationally bound (Strelbitskii & Syunyaev 1972). However, the velocity dispersion is of the expected order of magnitude for the opposite sides of shock and ionization fronts expanding into the neutral matter surrounding a compact H\(\text{II}\) region. The mean velocities of the various H\(_2\)O groups are probably those of the compact H\(\text{II}\) regions and their exciting stars. This model implies
that the H$_2$O features in Sgr B2 would have proper motions of $\sim 4 \times 10^{-4}$ arcsec yr$^{-1}$, which might be detectable in the future with VLBI methods.

REFERENCES


