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22 GHz Observations of Southern H_2O Sources

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Abstract

The discovery of three new H_2O sources associated with HII regions is reported. Observations of other southern H_2O sources show, in several instances, considerable intensity changes over a 20-month interval.

Introduction

We report here the results of a search for H_2O emission at the positions of 1665 MHz OH emission sources associated with HII regions. A previous search (Johnston *et al.* 1972; subsequently referred to as JRCB) covered all of these positions in August 1971, but in view of the extreme variability of H_2O emitters it is desirable to periodically repeat searches for H_2O emission in directions which previously have yielded null results. In the present work several improvements have been made relative to the 1971 observations. The resurfacing of the Parkes 64 m dish has been extended to a larger diameter; a new, more sensitive receiver was used, and the availability of the new Parkes digital autocorrelation spectrometer enabled us to search over a larger radial velocity range with increased resolution. In addition, the OH positions at which we searched are known with greater precision than at the time of the JRCB investigation.

Equipment

The resurfaced portion of the Parkes 64 m radio telescope provides a reflector that is now sufficiently accurate for use at 22 GHz. Measurements on Jupiter indicate an efficiency of $\sim 13\%$ for the 37 m diameter now resurfaced, yielding a flux density to antenna temperature ratio of $19 \times 10^{-26}\ \mathrm{W\,m^{-2}\,Hz^{-1}\,K^{-1}}$. This may be compared with $\sim 14\%$ and $25 \times 10^{-26}\ \mathrm{W\,m^{-2}\,Hz^{-1}\,K^{-1}}$ for the 32 m diameter portion illuminated in the observations by JRCB. Scans through the W49 H_2O source yielded a telescope beamwidth to half-power of 86″ arc.

The receiver consisted of a single-sideband mixer followed by a room-temperature parametric amplifier, and the total system noise temperature was 1700 K. The receiver could be used in either a total power or a switched-beam mode, the switching in the latter case being effected between the main beam (*E* vector vertical) and a reference beam (*E* vector horizontal) displaced 7′ arc in elevation. The amplified signal was fed into a 256-channel quadrant of the digital autocorrelator operating in the 1-bit mode. For most observations a radial velocity coverage of $66\ \mathrm{km\,s^{-1}}$ (5 MHz) was used which yielded a resolution of $0\cdot32\ \mathrm{km\,s^{-1}}$ ($23\cdot7$ kHz) per channel for a uniformly weighted autocorrelation function; where Hanning weighting (windowing) was used to reduce side lobes the resolution was $0 \cdot 53$ km s^{-1} (39 kHz) per channel. Two strong sources were observed using a higher resolution of $0 \cdot 21$ km s^{-1} ($15 \cdot 6$ kHz) per channel.

Observations

Measurements of the continuum emission from Jupiter were made to establish our flux density calibration. We assumed that the brightness temperature of Jupiter is 140 K, uniform over the optical disc, and we adopted an atmospheric transmission coefficient of 90%. Since the zenith-angle range used was generally restricted to between 10° and 45° and observations were made only in clear or light-cloud conditions, both the dish efficiency and the atmospheric transmission were assumed constant, in accordance with the findings of the 1971 measurements. The telescope pointing was investigated using the continuum source Jupiter and the two water vapour sources VY CMa and W49. After applying corrections, we believe the pointing to be accurate to about 20″ arc (r.m.s.), and this is the accuracy of our positions for the stronger sources.

Total power observations were used in the search, with integration times varying between 2 and 8 min on source, combined with similar or longer integrations at a reference position. The typical r.m.s. noise on the profiles was $1 \cdot 5$ K. A small 5-point grid (points displaced from the centre by $0' \cdot 7$ arc north, south, east and west) was searched at each position to allow for telescope pointing uncertainties and OH positional errors.

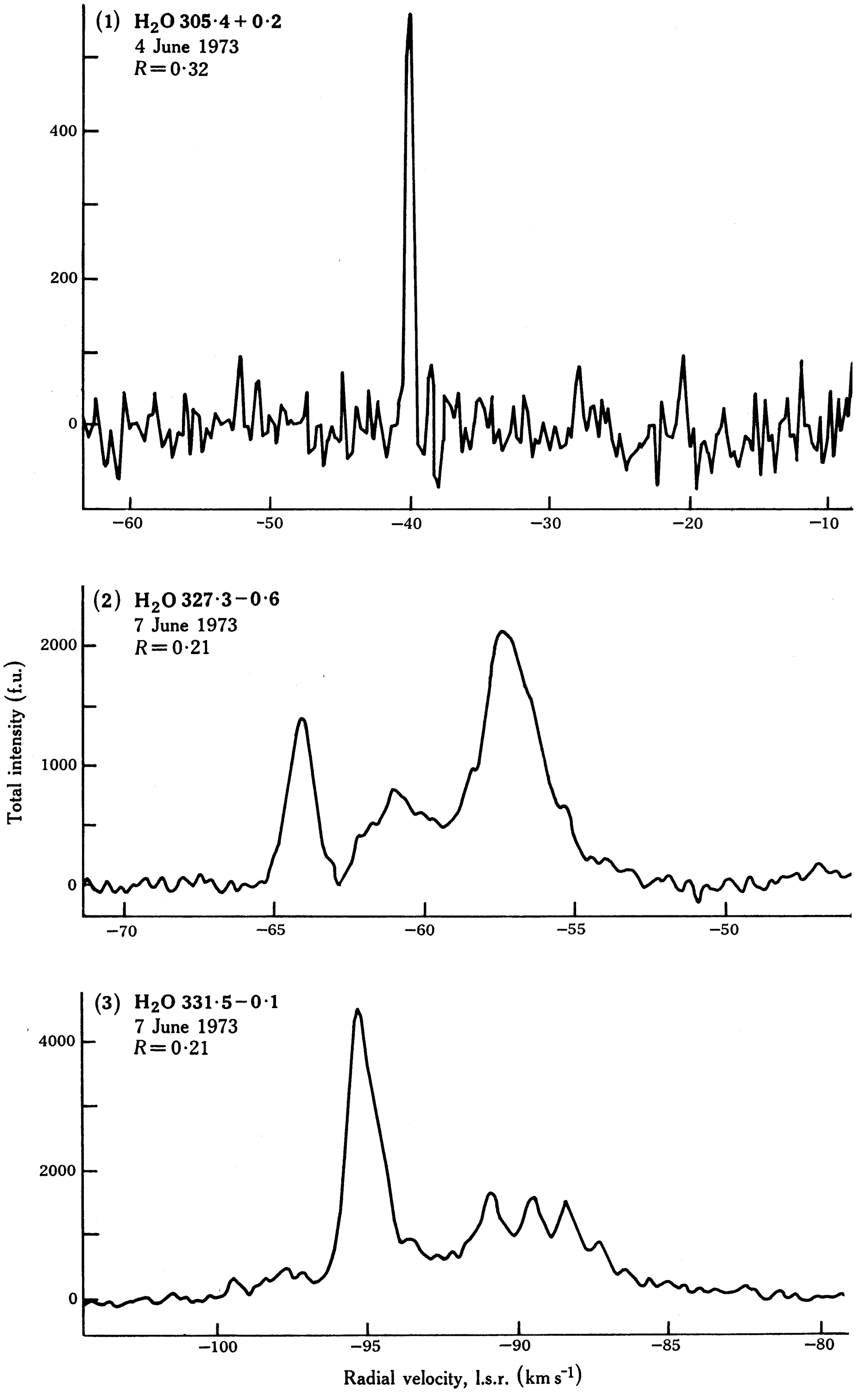
Beam-switching was used to obtain final profiles of known sources, since this technique generally yields a flatter baseline.

Results

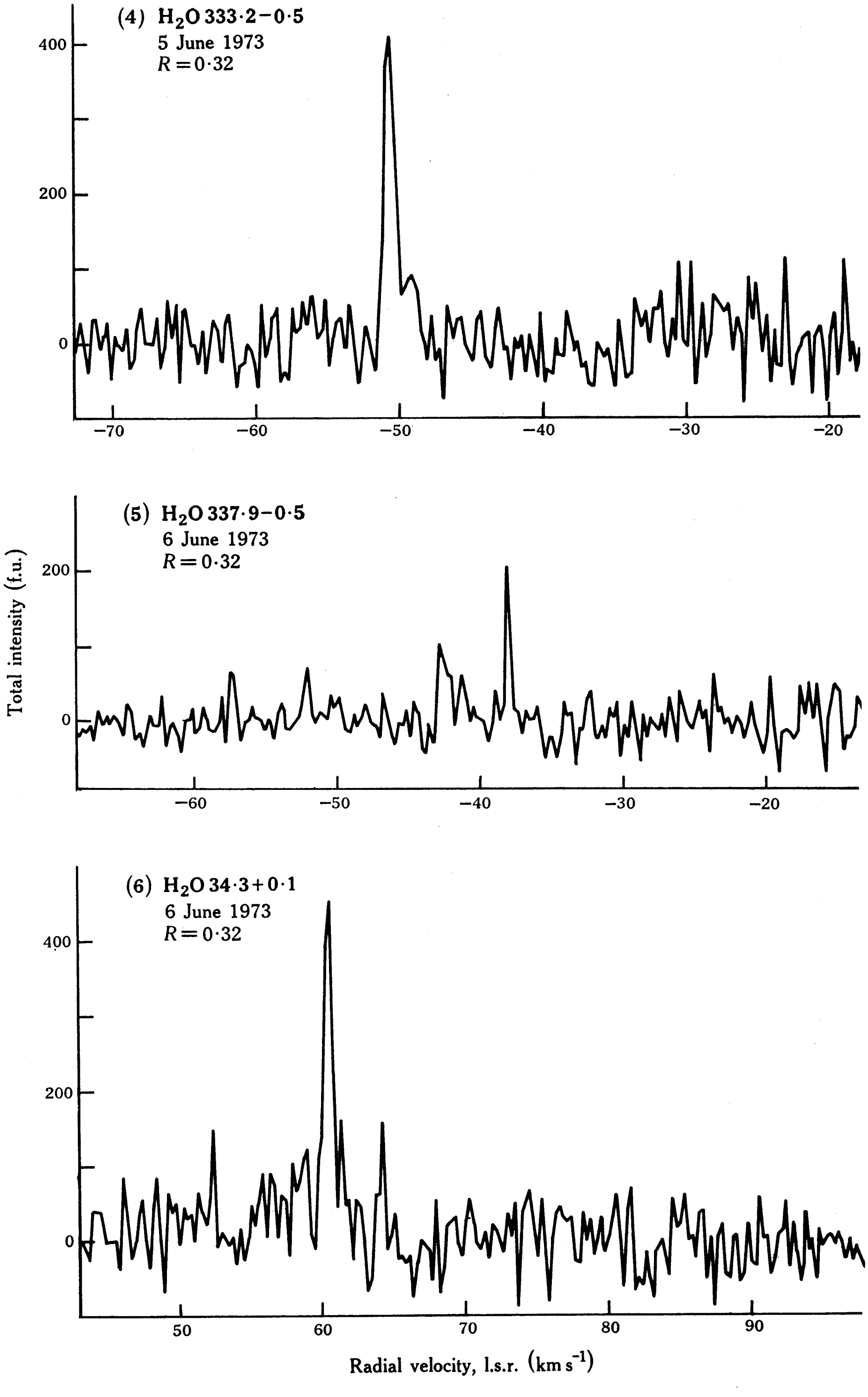
Three new sources were discovered associated with OH $305 \cdot 4 + 0 \cdot 2$, OH $333 \cdot 2 - 0 \cdot 5$ and OH $337 \cdot 9 - 0 \cdot 5$ and profiles are shown in Figs 1, 4 and 5. Peak intensities together with positions measured in these observations (4–8 June 1973) are listed in Table 1 for the new sources and also for 11 previously known sources. Profiles for known sources of particular interest are shown in Figs 2, 3, 6 and 7. The intensity scale incorporates the same correction for atmospheric absorption as used in the Jupiter calibration observations (made each day). The scale assumes furthermore that the H_2O emission is not substantially polarized. Published polarization measurements on other sources tend to justify this assumption; in the particular case of H_2O $331 \cdot 5 - 0 \cdot 1$, our own measurements confirm that the emission is less than 10% linearly polarized.

The positions derived in the present observations are generally more accurate than those measured earlier by JRCB and they show closer correspondence with the OH positions. The most accurate OH positions available, chiefly from Robinson *et al.* (1974), are included in Table 1 to indicate this close agreement. Table 2 lists the positions of OH emission at which we unsuccessfully searched for H_2O emission.

Figs 1–7. Profiles of seven H_2O sources observed in June 1973. Uniformly weighted autocorrelation functions were used except for Figs 2, 3 and 7, where Hanning weighting (windowing) was employed. The source name, date of observation and resolution R (in km s^{-1}) are specified for each profile. (1 flux unit (f.u.) = 10^{-26} W m^{-2} Hz^{-1}.)



(1) H₂O 305·4+0·2
4 June 1973
R=0·32
400
200
0
−60
−50
−40
−30
−20
−10
(2) H₂O 327·3−0·6
7 June 1973
R=0·21
2000
1000
0
−70
−65
−60
−55
−50
(3) H₂O 331·5−0·1
7 June 1973
R=0·21
4000
2000
0
−100
−95
−90
−85
−80
Total intensity (f.u.)
Radial velocity, l.s.r. (km s⁻¹)


(4) H2O 333·2−0·5
5 June 1973
R = 0·32
400
200
0
−70
−60
−50
−40
−30
−20
(5) H2O 337·9−0·5
6 June 1973
R = 0·32
Total intensity (f.u.)
200
0
−60
−50
−40
−30
−20
(6) H2O 34·3+0·1
6 June 1973
R = 0·32
400
200
0
50
60
70
80
90
Radial velocity, l.s.r. (km s-1)

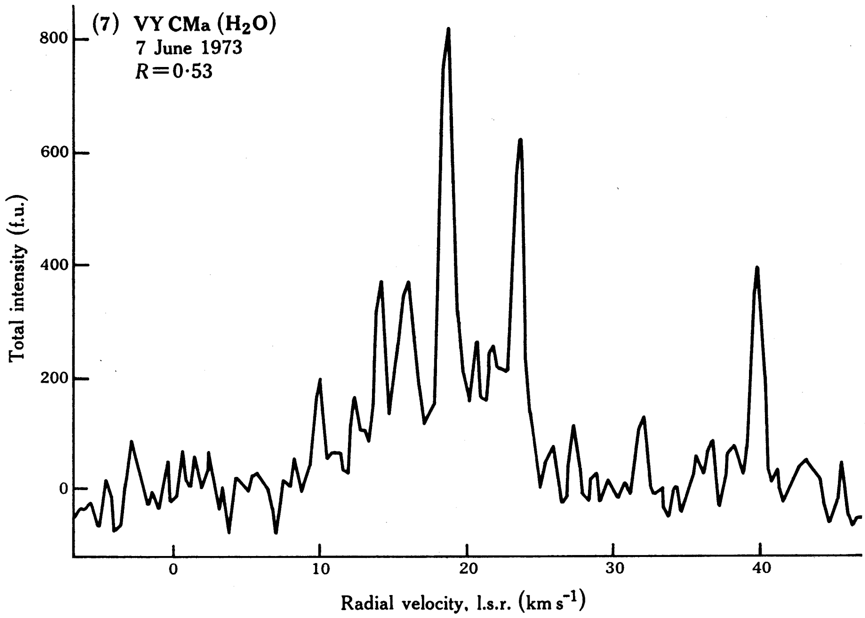


Table 1. H_2O sources observed in June 1973

The data for the three newly discovered sources are printed in italic

Galactic coordinates (or source name)	H_2O position (1950·0) R.A. h m s	H_2O position (1950·0) Dec. ° ′ ″	H_2O peak intensity (f.u.)	OH position (1950·0) R.A. h m s s	OH position (1950·0) Dec. ° ′ ″ ″	OH ref.*
285·3−0·1	10 29 32·9	−57 46 58	661	10 29 35·5±2·5	−57 46 27±20	1
291·6−0·4	11 12 53·0	−60 53 13	264	11 12 54·1±2·7	−60 53 08±20	1
305·4+0·2	*13 09 21·2*	*−62 21 26*	*559*	*13 09 22·7±2·3*	*−62 21 15±16*	*1*
327·3−0·6	15 49 14·1	−54 28 29	2129	15 49 12·8±4·0	−54 28 29±35	1
331·0−0·2	16 06 02·2	−51 47 30	373	16 06 05·0±1·7	−51 47 02±16	1
331·5−0·1	16 08 19·8	−51 21 02	4354	16 08 23·2±1·7	−51 20 45±16	1
333·2−0·5	*16 17 11·6*	*−50 28 22*	*405*	*16 17 16·7±1·8*	*−50 27 45±17*	*1*
333·6−0·2	16 18 25·3	−49 59 01	234	16 18 27·1±2·1	−49 59 01±20	1
337·9−0·5	*16 37 27·4*	*−47 02 10*	*201*	*16 37 29·5±1·8*	*−47 02 02±18*	*1*
345·7−0·1	17 03 17·5	−40 47 22	259	17 03 22·8±1·3	−40 47 06±16	1
10·6−0·4	18 07 30·3	−19 56 31	567	18 07 30·6±0·7	−19 56 27±6	2,3
M17 (15·0−0·7)	18 17 29	−16 13 42	<150	—	—	T
34·3+0·1	18 50 48·5	+01 11 12	453	18 50 48 ±2·0	+01 11 06±30	4
VY CMa	07 20 54·9	−25 40 13	871	07 20 55·0±0·6	−25 40 11±5	5

* References: 1, Robinson *et al.* (1974); 2, Goss *et al.* (1973); 3, Caswell and Robinson (1974); T, see text; 4, Caswell and Robinson (unpublished data); 5, Eliasson and Bartlett (1969).

Notes on Individual Sources

H_2O 285·3−0·1. The accurate OH position agrees somewhat more closely with our new H_2O position than with that of JRCB. The two H_2O features observed by JRCB are both present still, and have shown only small changes (<20%) in intensity.

H_2O 291·6−0·4. Our H_2O position differs by 30″ arc from that of JRCB and is in excellent agreement with the OH position. Two H_2O features were seen by JRCB but the one with radial velocity (l.s.r.) of $+2\ \mathrm{km\,s^{-1}}$ has now decreased in intensity to below our detection limit.

Table 2. OH positions where no H_2O was detected

OH source	Position (1950·0) R.A. h	m	s	Dec. °	′	″	Central search radial velocity* ($\mathrm{km\,s^{-1}}$)	Upper limit on H_2O peak intensity (f.u.)
301·0+1·1	12	32	00·0	−61	22	39	−46	115
308·9+0·1	13	39	37·0	−61	53	44	−50	115
309·9+0·5	13	47	12·5	−61	19	58	−60	115
320·2−0·3	15	06	00·3	−58	13	35	−76	115
324·2+0·1	15	29	01·8	−55	45	22	−90	115
328·2−0·5	15	54	04·9	−53	50	09	−34	115
330·9−0·4	16	06	29·8	−51	57	38	−66	190
331·4−0·3	16	08	35·8	−51	38	16	−76	155
337·7−0·1	16	34	49·8	−46	54	48	−44	155
338·9−0·1	16	39	29·4	−46	03	05	−34	115
338·9+0·6	16	36	56·4	−45	35	53	−66	125
340·1−0·2	16	44	39·0	−45	16	26	−50	190
345·5+0·3	17	00	56·9	−40	39	38	−20	115
347·6+0·2	17	08	20	−39	05	00	−100	190
20·1−0·1	18	25	24	−11	30	24	+50	190

* Relative to the local standard of rest.

H_2O 305·4+0·2. We regard this source (see Fig. 1) as a new one, since it differs significantly in both position and velocity from the source reported by JRCB at approximately these galactic coordinates. Our new source agrees well with the accurately measured OH position; a preliminary detection of the H_2O emission was made in October 1972 during unpublished test observations. In the present observations we did not detect the source listed by JRCB, but our sensitivity might not have allowed its recognition if it had been even slightly weaker than when first reported. The position of the source found by JRCB differed significantly from the OH position but agreed well with the peak of an intense HII region optically thick at 408 MHz (Shaver and Goss 1970).

H_2O 327·3−0·6. The major features now seen in this source (Fig. 2) have increased in intensity by an order of magnitude relative to the observations of JRCB. Our position agrees well with the new OH position whereas the position given by JRCB differs by about 90″ arc. It is possible that the JRCB position refers to an adjacent but separate source, but more probably its position was in error by 90″ arc.

H_2O 331·0−0·2. The H_2O emission does not differ significantly from that observed by JRCB, although our position is in slightly better agreement with the accurate OH position.

H_2O 331·5−0·1. The feature with radial velocity (l.s.r.) of -95 km s^{-1} (see Fig. 3) has increased in intensity by a factor of about three relative to the observations of JRCB. Our position is in better agreement with the accurate OH position.

H_2O 333·2−0·5. This new source (see Fig. 4) differs in position from the OH source by 50″ arc in right ascension and 37″ arc in declination. Our H_2O position may have a larger error than usual, since it was determined at the large zenith angle of 46°. The associated HII region complex contains two intense components optically thick at 408 MHz (Shaver and Goss 1970). We note that the less accurate OH position at which JRCB searched is in error by $\gtrsim$80″ arc in right ascension (130″ arc from our H_2O position), and this fact (rather than variability in the H_2O intensity) may account for JRCB's failure to detect the H_2O source.

H_2O 333·6−0·2. Our position is in good agreement with both the OH position and the compact HII region whereas the JRCB position differs by about 60″ arc. Our observation of this source has a low signal-to-noise ratio but shows that a feature at $v = -57$ km s^{-1} seen in August 1971 has decreased significantly in intensity to below our detection limit.

H_2O 337·9−0·5. The position of this new H_2O source (see Fig. 5) agrees well with that of the OH emission and with a small-diameter HII region which is optically thick at 408 MHz (Shaver and Goss 1970).

H_2O 345·7−0·1. The OH position lies between the H_2O positions determined in these observations and in those of JRCB. The H_2O emission peak seen by JRCB at $v = -8·7$ km s^{-1} has weakened and the maximum intensity now occurs at $v = -8·0$ km s^{-1}.

H_2O 10·6−0·4. Our H_2O position is in excellent agreement with the OH position whereas the JRCB position differs by 60″ arc. No significant intensity changes have occurred.

M17 (H_2O 15·0−0·7). Johnston *et al.* (1973) reported H_2O emission with a peak intensity of 3160 f.u. from this source on 8 February 1972 whereas none (<200 f.u.) was detected in October 1971. Their position has an uncertainty of 1′ arc and we made observations centred at this position and covering a grid of ±1′ arc in declination and ±4 s in right ascension. We did not detect any emission (<150 f.u.) and thus the source has apparently decreased in intensity by at least an order of magnitude. We also searched for OH emission from M17 on 31 July 1973 over the velocity range -50 to $+30$ km s^{-1} but detected none on either the 1665 or the 1612 MHz transition, the upper limits being 3 f.u. in a 3·9 kHz bandwidth in either of two orthogonal linear polarizations.

H_2O 34·3+0·1. This source was first detected by Turner and Rubin (1971). Our position agrees well with the OH position and our spectrum (Fig. 6) is of higher resolution than that of Turner and Rubin. The different spectral resolutions make velocity and intensity comparisons difficult, but within these limitations the source does not appear to have changed significantly since first detected.

VY CMa. A comparison of profiles taken in 1969 and 1970 (e.g. Sullivan 1973) with the present observations (Fig. 7) and those of JRCB shows that the features near $+14·5$ and $+18$ km s^{-1}, which were formerly the most intense, have decreased by an order of magnitude over the past three years. Sullivan (1973) reported that a feature near $+35\ \mathrm{km\,s^{-1}}$ had apparently shifted in velocity from $+34\cdot8$ to $+35\cdot4\ \mathrm{km\,s^{-1}}$ between August 1969 and August 1970. However, Moran *et al.* (1973) found that by February 1971 this interesting feature had decreased in intensity by an order of magnitude to below their sensitivity limit. We made observations on 23 March 1972 in which no feature could be detected (<100 f.u.) in the velocity range $+30$ to $+50\ \mathrm{km\,s^{-1}}$ but we now (7 June 1973) observe a feature at $+40\ \mathrm{km\,s^{-1}}$ (Fig. 7) which we have again detected in more recent observations (30 September 1973).

Conclusions

The pattern of erratic intensity variability which has been noted earlier for other water vapour sources is repeated here. The reasons why the three new sources were not detected in the earlier observations of JRCB probably include variability and also the lower accuracy of the OH positions then available. Two of the new sources are near intense small-diameter HII regions optically thick at 408 MHz, as were a number of the H_2O sources discovered by JRCB. Our positions for both new and known H_2O sources confirm that in most cases no significant separation from the associated OH source is detectable with the present accuracy of about 20″ arc (r.m.s.).

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