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Positions and 1665 MHz Line Profiles for 10 Northern OH Emission Sources

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Abstract

Positions with r.m.s. errors of about 20″ arc have been determined for the stronger OH emission sources discovered in two northern searches. Line profiles at 1665 MHz with 1 kHz resolution are presented for both senses of circular polarization.

1. Introduction

Three recent searches have more than doubled the number of known OH sources emitting predominantly on the 18 cm main lines. Six new emission sources at 1665 and/or 1667 MHz were discovered by Downes (1970), 11 by Turner (1970) and 17 by Robinson *et al.* (1971*b*). Positions accurate to 1′ or 2′ arc were determined for the sources found in the Parkes survey (with a 12′ arc beam) and the r.m.s. errors have been reduced in most cases to less than 30″ arc in later observations (Robinson *et al.* 1974, present issue pp. 575–96). No positioning observations were made in Turner's survey and the positioning accuracy in Downes's survey was limited by his 30′ arc beam.

Accurate positions for the northern sources are needed for a number of reasons:

(i) to compare the OH position with that of the associated HII region;

(ii) to ensure that the intensity of the source is not grossly underestimated owing to the source being at the edge of the search beam;

(iii) to enable measurements of the other OH transitions and searches for other molecules to be made at the precise position of the OH source;

(iv) to provide a good initial position for interferometric measurements of source structure and very precise positions;

(v) to provide homogeneous data for statistical investigations.

We have therefore used the Parkes 64 m telescope to determine the position of 10 of the stronger sources* in the lists of Downes (1970) and Turner (1970). Many features of the emission cannot be described adequately by a peak temperature and linewidth, and so for each source we present 1665 MHz profiles taken with 1 kHz resolution in both senses of circular polarization. Comparable profiles for sources discovered in the Parkes survey are presented in the companion paper (Robinson *et al.* 1974).

* Robinson *et al.* (1971*a*) presented improved positions for a further two sources of the OH/IR type discovered at 1612 MHz by Downes (1970) and Turner (1970).

Table 1. Improved positions of OH emission sources

OH source number	Final position (1950) R.A. h m s	Dec. ° ′	Features for positioning T_{peak} (K)	Pol'n sense	V_{lsr} (km s^{-1})	Nominal positions: Downes $l°$	Downes $b°$	Downes Δ* ′	Turner $l°$	Turner $b°$	Turner Δ* ′
OH 353·4−0·3	17 26 53	−34 39·0	3·5†	LH	−20				353·35	−0·4	3·2
OH 355·4+0·1	17 30 12	−32 45·7	20†	RH	+16				355·21	+0·1	8·6
OH 10·6−0·4	18 07 32	−19 56·5	28	RH	−2	10·6	−0·4	0·5	10·60	−0·4	1·25
OH 19·6−0·2	18 24 52	−11 58·6	4·5	RH	+42				19·60	−0·2	2·0
OH 20·1−0·1	18 25 24	−11 30·4	15	LH	+46	20·0	−0·2	5·8	20·00	−0·2	6·2
OH 33·1−0·1	18 49 37	+00 05·2	15	LH	+75, +79				33·18	−0·1	1·9
OH 35·6−0·0	18 53 53	+02 16·3	29	RH	+49	35·6	−0·0	0·7	35·58	−0·1	2·5
	19 11 05	+10 46·9	15†	RH	+54	45·1	+0·1	1·4			
OH 45·1+0·1	19 11 00	+10 45·6	32	RH	+56			2·9			
	19 11 00	+10 45·2	10	RH	+60			3·3			
OH 45·5+0·0	19 12 04	+11 04·2	22‡	LH	+65	45·5	+0·1	4·0			
OH 45·5+0·1	19 11 48	+11 07·2	32‡	LH	+59			1·0			
OH 48·6+0·0	19 18 14	+13 49·3	23	LH	+20				48·60	+0·0	2·3

* The position differences Δ are given in the sense of final relative to nominal position.

† The peak intensity in the other sense of circular polarization is slightly greater.

‡ The source intensity has been increased by a factor of 1·1 relative to the value indicated in Fig. 1*i* to allow for the 2′·4 arc displacement of the source from the centre of the beam.

2. Observations

The position for each source was determined from a grid of profiles taken with the sense of polarization of the most intense emission feature. The sources for which new positions were obtained are the 10 strongest listed by Downes (1970) and/or Turner (1970) in the galactic longitude range 353°–49°. The new positions are given in Table 1, in which each source is identified by the galactic coordinates of our more accurate position with the prefix OH, the prefix G being reserved for galactic continuum sources. For identification purposes, the galactic coordinates of both the Downes and Turner search positions are also given in the table, together with the displacements Δ of our final positions from their preliminary values.

The present observations were made in 12–16 June 1971. Measurements with the Owens Valley interferometer were made on half the sources after the completion of this work (Goss *et al.* 1973) and are discussed in Section 5 below. These measurements indicate that the present r.m.s. position errors are $\sim 20''$ arc. However, where intense features at slightly different velocities are present on the same profile, the r.m.s. error in the relative positions is smaller since for strong sources much of the position error is due to telescope pointing errors.

In Figs 1*a*–1*j* we show the 1665 MHz profiles of the 10 sources, observed in both senses of circular polarization with 1 kHz filter bandwidth. The ratio of flux density to antenna temperature is $1\cdot 59\times 10^{-26}\ \mathrm{W\,m^{-2}\,Hz^{-1}\,K^{-1}}$ for an unpolarized point source. The effective area of the Parkes 64 m telescope is 2·2 times that of the NRAO 43 m telescope used in Turner's (1970) search and 7·9 times that of the Agassiz 25 m telescope used by Downes (1970). Comparison of the present peak temperatures with those tabulated by both Downes and Turner show that considerably greater increases have resulted in most cases by optimizing the position, bandwidth and polarization.

Downes (1970) tabulated circular polarization measurements for the sources he discovered. The present results, with slightly better frequency resolution and an improved signal-to-noise ratio, confirm the Downes polarization values to within their quoted errors. Some circular polarization measurements made by Dickinson and Turner (1972) on five of the sources are not in good agreement with our results (see Section 3 below). The disagreement may partly arise from the poorer sensitivity of Dickinson and Turner's measurements (as indicated by their quoted errors) and in some instances from their poorer frequency resolution. In Section 4 below, we comment on the other sources listed by Downes (1970) and Turner (1970).

3. Newly Positioned OH Sources

OH353·4−0·3 (Fig. 1*a*). Observations at 2650 MHz with a 7′·4 arc beam (Beard *et al.* 1969) show the nearest continuum source to be G353·4−0·4 with flux density 7 f.u.* and half-power width 5′ arc, and separated 5′ arc from the OH position. The OH absorption feature noted by Turner (1970) is also visible in Fig. 1*a*, between -14 and $-18\ \mathrm{km\,s^{-1}}$. The low value of circular polarization quoted by Dickinson and Turner (1972), 4 ± 1% RH, is presumably an average over several features, since our profile shows that the individual features have much higher degrees of polarization but in opposite senses.

* 1 flux unit (f.u.) = $10^{-26}\ \mathrm{W\,m^{-2}\,Hz^{-1}}$.

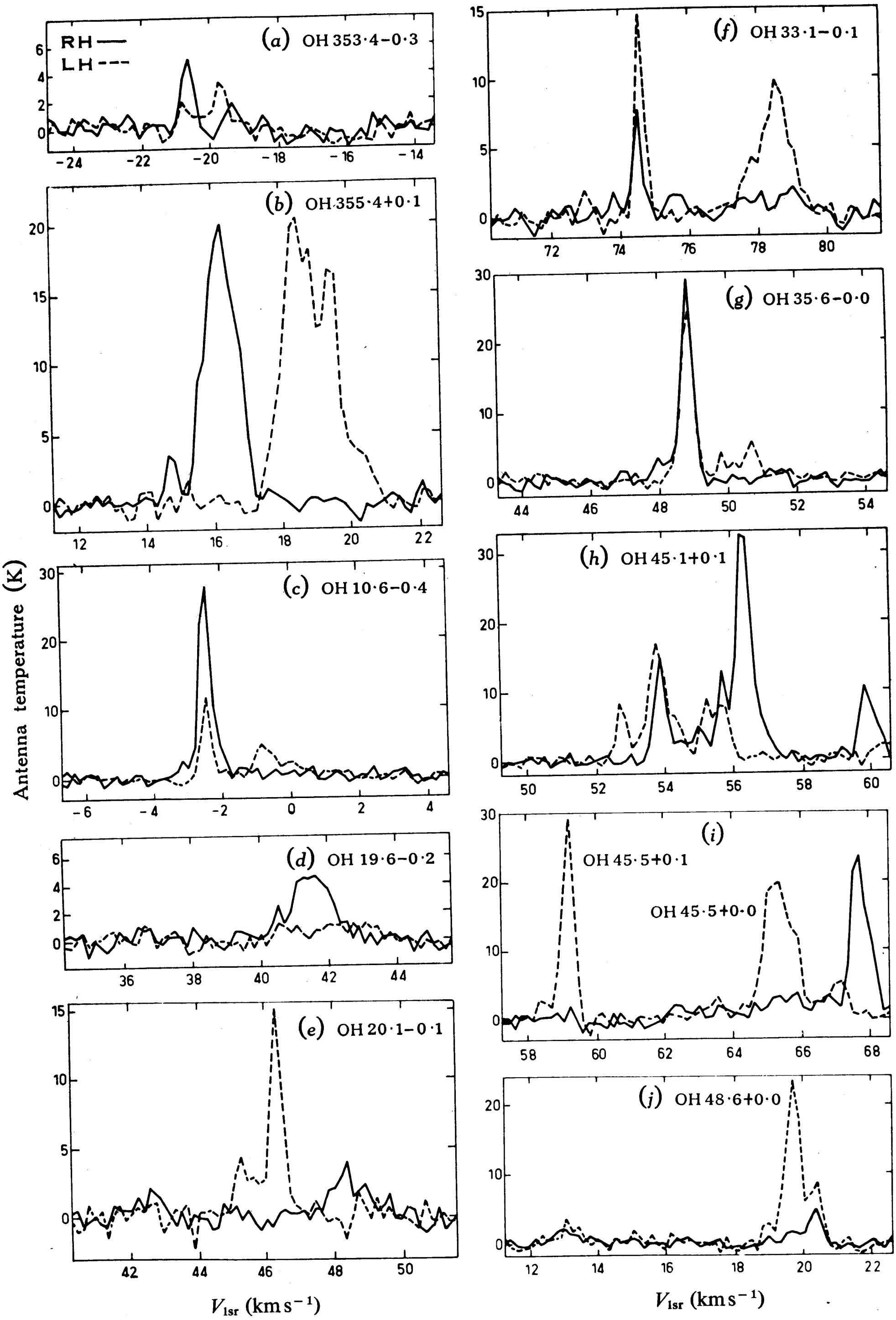

Fig. 1. Profiles of 1665 MHz OH emission for the indicated sources showing RH (full curves) and LH (dashed curves) circular polarization. The filter bandwidth is 1 kHz and the radial velocities are given relative to the local standard of rest.

OH355·4+0·1 (Fig. 1*b*). The nearest continuum source is G355·2+0·1 with flux density 20 f.u. and separated 8′ arc from the OH position (Beard *et al.* 1969). An extended HII region, RCW 132 (NGC 6383), covers the area. The present profile shows two oppositely polarized features of comparable intensity separated ~2·7 $\mathrm{km\,s^{-1}}$. The similar basic pattern observed in NGC 6334A (separation of 3·4 $\mathrm{km\,s^{-1}}$ for the 1665 MHz transition) has been interpreted by Gardner *et al.* (1970) as possibly due to Zeeman splitting (in a field of 5·7 mG). It appears to be worth investigating OH 355·4+0·1 also as a possible example of Zeeman splitting (the inferred longitudinal component of the magnetic field being 4·5 mG). We note that Dickinson and Turner (1972) also measure 100% RH polarization for the +16 $\mathrm{km\,s^{-1}}$ feature but their value of only 16±25% LH polarization for the +19 $\mathrm{km\,s^{-1}}$ feature disagrees with our value of 100% LH by an amount larger than expected from their quoted errors.

OH10·6−0·4 (Fig. 1*c*). As noted by Downes (1970), the nearest continuum source is G10·6−0·4, a compact HII region observed with high resolution by Shaver and Goss (1970). The continuum source is within 1′ arc of the OH position. The polarization measurement given by Dickinson and Turner (1972) of 65% RH at $V = -1\cdot0\,\mathrm{km\,s^{-1}}$ does not satisfactorily describe the featues as seen in the present profile. In contrast, Downes's summary of the polarization characteristics agrees quite well with our profile.

OH19·6−0·2 (Fig. 1*d*). The nearest continuum source is G19·6−0·2, with a flux density at 2700 MHz of 13 f.u. (Goss and Day 1970). Its half-intensity width is 8′×7′ arc whereas the separation of the OH and the continuum peak is only 3′ arc.

OH20·1−0·1 (Fig. 1*e*). The OH position is nearly 8′ arc from the peak of G20·0−0·1, which has a flux density at 2700 MHz of 14 f.u. and a half-intensity width of ~6′×10′ arc (Goss and Day 1970).

OH33·1−0·1 (Fig. 1*f*). The positions of the two OH features were not significantly different and the average position has been given in Table 1. This position is only 3′ arc from G33·1−0·1 (Beard and Kerr 1969), which has a flux density of 5·5 f.u. at 2650 MHz and a half-power width of 7′ arc. Dickinson and Turner (1972) list OH polarization parameters with very large quoted errors. The polarization characteristics can be seen with a good signal-to-noise ratio on the present profile. Also, from this general direction, 1612 MHz emission of the double-peaked (in velocity) variety associated with OH/IR objects has been reported (Dickinson and Turner 1972), but Winnberg *et al.* (1973) show that the 1612 MHz position is clearly separated from the 1665 MHz source OH 33·1−0·1.

OH35·6−0·0 (Fig. 1*g*). The OH position is less that 3′ arc from the peak of G35·6−0·0 (Beard and Kerr 1969), which has a flux density at 2650 MHz of 15 f.u. and a half-power width of 9′ arc.

OH45·1+0·1 (Fig. 1*h*). On the RH profile, positions for each of the three peaks were obtained. The positional accuracy for *relative* positions on the same profile is better than 20″ arc, and thus the position of the +54 $\mathrm{km\,s^{-1}}$ feature is significantly different from that of the +56 and +60 $\mathrm{km\,s^{-1}}$ features. The small-diameter HII region G45·1+0·1 observed with high resolution at 408 MHz by Shaver and Goss (1970) is ≤3′ arc from the OH positions. A very weak compact feature within this HII region has been detected by Wynn-Williams *et al.* (1971) at 2700 MHz and its position is nearest to the +54 $\mathrm{km\,s^{-1}}$ OH feature.

OH 45·5+0·0 and 45·5+0·1 (Fig. 1*i*). The separation of these OH sources is 4′·8 arc, and the present profile is taken at the mean position so that the intensity of each feature is reduced to 0·9 of its true value. We have not positioned the single RH feature at +67·7 km s^{-1} but it is probably associated with OH 45·5+0·0. The OH sources were not separable with Downes's (1970) 30′ arc beam. Continuum maps by Schraml and Mezger (1969), Shaver and Goss (1970), and Wynn-Williams *et al.* (1971) show that, in addition to the compact HII region G45·5+0·0 almost coincident with OH 45·5+0·0, there is a weaker continuum source near OH 45·5+0·1.

OH 48·6+0·0 (Fig. 1*j*). The OH position is approximately 1′·5 arc from the compact HII region G48·6+0·0 (see high-resolution maps by MacLeod and Doherty (1968) and Shaver (1969)).

4. Comments on Remaining Sources of Downes and Turner

Of the remaining 11 OH sources reported by Downes (1970) and Turner (1970) as emitting at 1665 and 1667 MHz, nine are within the declination range of the Parkes 64 m telescope, and for these we note as follows.

G345·58−0·1 was independently discovered and positioned in the Parkes survey (as OH 345·7−0·1). Our final position was 8′·5 arc from Turner's (1970) discovery position.

G348·20+0·5 was searched for only in the general survey (Robinson *et al.* 1971*b*) using 10 kHz filters and a linearly polarized feed. No source was evident (peak-to-peak noise ~1·2 K), but this does not conflict with the intensity reported by Turner (1970) as the source is one of the weakest in his list.

G349·15+0·0 although detected in the RH sense of polarization in our observations, was too weak to be readily positioned. Dickinson and Turner (1972) also reported that the 1665 emission is RH polarized.

G357·63−0·1 could not be detected at Turner's (1970) nominal position (peak-to-peak noise ~2·5 K in 1 kHz bandwidth) but, from Turner's listed intensity at 1665 MHz, it was expected to be near our sensitivity limit. However, Dickinson and Turner (1972) list 'absorption' from this direction, and apparently its original listing as a 1665 MHz *emission* source was erroneous (D. F. Dickinson, personal communication).

G14·20−0·2 is a very weak source detected by Turner (1970) at 1667 MHz only. It was not searched for at Parkes. The further observations of Dickinson and Turner (1972) show it to emit at 1665 MHz also.

G19·02−0·3 could not be detected at Turner's (1970) nominal position. Dickinson and Turner (1972) noted that Turner's original report of emission from this direction is erroneous.

G25·35−0·2, like G19·02−0·3, is actually an absorption feature rather than an emission source (Dickinson and Turner 1972).

G32·85+0·1: we note that Turner's galactic coordinates correspond to equatorial coordinates (1950·0) of R.A. $18^h 49^m 05^s$, Dec. −00° 10′·8, and not to $18^h 48^m 54^s$, +00° 09′ 22″ as listed by Turner (1970). The galactic coordinates are near a continuum source separated 20′ arc from OH 33·1−0·1, and we found no OH source at the

The average spectrum for 30 Doradus from three separate observing sessions is shown in Fig. 1. The curve is the resultant of three Gausians fitted to the observed points. The He 109α line is relatively close to the noise level. The ratio by number $N(\mathrm{He}^+)/N(\mathrm{H}^+) = 0 \cdot 08$ (less than half the value reported by Mezger *et al.* 1970). It is equal to the average ratio obtained from 17 southern Milky Way objects observed in H, He 90α lines (McGee *et al.* 1974). The intensity of the H 137β line is such that the temperature ratio $T_{\mathrm{H}137\beta}/T_{\mathrm{H}109\alpha}$ is $0 \cdot 25$.

The source MC 77 was the only other one where a line other than Hα lines was detected. The H 137β line in MC 77 gives a ratio $T_{\mathrm{H}137\beta}/T_{\mathrm{H}109\alpha} = 0 \cdot 23$; for conditions at local thermodynamic equilibrium the expected ratio is $0 \cdot 28$. The only result we can give for helium in MC 77 is $N(\mathrm{He}^+)/N(\mathrm{H}) < 0 \cdot 1$.

Non-detection of H 109α

No recombination line was detected in the thermal source MC 13. The inference from these observations is $T_{\mathrm{L}}/T_{\mathrm{C}} < 1 \cdot 6\%$. Since MC 39, 43 and 63 are well-established supernova remnants, it was not expected that any lines would be detected in them.

Conclusions

The recombination lines in the Large Magellanic Cloud appear to be similar in form to those in our Galaxy with respect to their half-widths and to the ratio of hydrogen α to hydrogen β and of ionized helium to ionized hydrogen. However, the $T_{\mathrm{L}}/T_{\mathrm{C}}$ ratios are much lower than in the Galaxy, possibly because the large area intercepted by the telescope beam at the Large Magellanic Cloud includes, in addition to the thermal source of the recombination line, other components which increase the value of T_{C}. The observations of 30 Doradus confirm the results from optical spectroscopy that the ratio of helium to hydrogen in this nebula is normal.

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