VLA observations of 6-cm excited OH

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ABSTRACT
The VLA was used to determine precise positions for 4765-MHz OH maser emission sources toward star-forming regions which had been observed about seven months earlier with the Effelsberg 100-meter telescope. The observations were successful for K3-50, DR21EX, W75N, and W49A. No line was detected toward S255: this line had decreased to less than 5 per cent of the flux density observed only seven months earlier. The time-variability of the observed features during the past 30 years is summarised. In addition, to compare with the Effelsberg observations, the 4750-MHz and 4660-MHz lines were observed in W49A. These lines were found to originate primarily from an extended region which is distinguished as an exceptional collection of compact continuum components as well as by being the dynamical centre of the very powerful H2O outflow.

Key words: masers – ISM:molecules – ISM:individual(K3-50, DR21EX, W75N, W49A) – radio lines:ISM

1 INTRODUCTION
The low lying 2Π1/2, J = 1/2 rotationally excited state of OH has three hyperfine transitions in the 6-cm band: the F=0→1 at 4660.242 MHz, the F=1→1 at 4750.656 MHz, and the F=1→0 at 4765.562 MHz (Lovas, Johnson, & Snyder 1979). We have previously reported observations conducted with the Very Large Array (VLA) of the National Radio Astronomy Observatory1 of these lines in three sources: W3 (Gardner, Whiteoak, & Palmer 1983), NGC 7538(IRS1) (Palmer, Gardner, & Whiteoak 1984), and Sgr B2 (Gardner, Whiteoak, & Palmer 1987). Here we report observations of additional sources conducted in 1984 March–April. Observations of the 6-cm OH lines have established that they are closely associated with star formation, and that in many sources they are the most highly variable of the OH maser lines. Our primary interest in this paper is in the accurate positions of the observed lines and the variability of line intensities. Subsequent papers in this series will report a detailed study of both ground state and excited state OH and H2O maser emission in one region and a VLBA study of 4765-MHz emission in several regions.

2 OBSERVATIONS
Observations were made with 25 antennas of the VLA. For the 1984 March observations, the VLA was in the CnB hybrid array; in April, the C-array. These configurations provided beamwidths ~4 arcsec. For the 4765-MHz observations, a correlator bandwidth of 0.781 MHz was divided into 512 spectral channels. For the 4660- and 4750-MHz observations, a bandwidth of 3.125 MHz was used in conjunction with 256 channels. On-line Hanning smoothing of the resulting spectra and retention of every other channel yielded 256- and 128-channel spectra with resolution of 3.0 kHz and 24 kHz respectively. Because of restricted data-taking rates at the VLA at that time, observations were conducted in only one sense of polarisation (right circular) and only the central 31 of the Hanning smoothed spectral channels were recorded. Both previous observations and theory had established that these lines are unpolarised (Zuckerman et al. 1968; Zuckerman & Palmer 1970). The only exception to date is MonR2, and in this case, it is argued that the polarisation may arise from amplification of a polarised background source (Smits, Cohen, & Hutawarakorn 1998). Because the 4765-MHz line is the most commonly detected of the three OH transitions, we observed only this line, except for W49A in which we observed all three OH lines. The velocity resolution for all 4765-MHz observations was 0.19 km s−1 yielding a total velocity coverage of ±2.88 km s−1. For the other two lines observed in W49A, at 4750 MHz the resolution was 1.54 km s−1 yielding a velocity coverage of ±23.1 km s−1 and at 4660 MHz, 1.57 km s−1 yielding a velocity coverage of ±23.6 km s−1. While the small velocity coverage at 4765 MHz was disappointing, we had access to then recent unpublished observations of these lines with the 100-m tele-
scope at Effelsberg by Gardner (private communication, hereafter FFG) to use to plan our observations. The FWHM of the Effelsberg telescope at this wavelength is \(~\sim 3\) arcmin, while the FWHM of the primary beam of the VLA antennas at this wavelength is \(~\sim 10\) arcmin. Therefore, any source detected by FFG would also be detected by the VLA. However, any unexpected features outside the narrow velocity range that we were able to cover were not recorded. Other details for each source are provided in Table 1. All images produced from the observations extended well beyond the FWHM of the primary beam because some positions were not well known and to allow for serendipity.

In addition to data for each line channel, a pseudo-continuum “channel 0” was recorded. These data consist of an average over the central 3/4 of the spectral band. For the 4765-MHz observations, channel 0 contained data from 192 of the 3.0 kHz channels in the original (mostly unrecorded) Hanning smoothed data set. For the 4750- and 4660-MHz observations, the pseudo-continuum was an average over 96 of the 24 kHz channels. We checked carefully that the resulting continuum images were not contaminated by line emission by comparing them with images made from averages of known line-free channels. For DR21, channel 0 was not used. Rather, a normal VLA continuum observation was made (50-MHz bandwidth), so line contamination is not an issue.

The results for the 4765-MHz line observations are summarised in Table 2. To facilitate comparisons with recent work, both B1950 and J2000 positions are given. The position uncertainties are caused by errors in positions of the phase calibrators, errors in array baselines, and thermal noise. Phase calibrator positions were adjusted to modern values (uncertainties <0.01 arcsec) and led to a sensible shift only for W49 (0.1 arcsec in declination). The errors quoted are 4-σ and are dominated by thermal noise except for the highest signal-to-noise source, DR21EX. No attempt was made to de-convolve the line widths for instrumental broadening because in most cases the widths are close to our resolution. In the following subsections, a brief discussion is given for each source. Because the 4765-MHz emission is very variable, in Table 2, we summarise all flux density measurements since these lines were discovered for the four detected sources. In order to compare our results with those obtained at different epochs by other observers when there was a significant difference in pointing position, we have corrected their measurements for the pointing offset from the VLA-determined positions by assuming Gaussian antenna beams. In a few cases the offsets are rather large so that the Gaussian approximation is crude. The flux densities quoted are the corrected values, and this is indicated by a (C) following the value in Table 2. Note that in some cases, exact dates of observations were not published. We estimate that the errors in flux densities in Table 2 are dominated by the absolute calibration uncertainties of the observations and are therefore about 10 per cent.

### 2.1 S255

This field is complex in the radio continuum; but, because the VLA in the C-array resolves out structures larger than \(~\sim 30\) arcsec, our continuum image shows only the compact source G192.58-0.04 (Turner & Terzian 1985). This source is located approximately between the optical nebulae S255 and S256, and about 1 arcmin north of the cometary nebula PP56 which is associated with a near-IR source, both H$_2$O and 1665-MHz ground state OH masers, and IRAS 06099+1800. Although FFG had detected a maser feature of amplitude 1.2 Jy at $V_{L,SR}$= 6.61 km s$^{-1}$ on September 15, 1983, approximately seven months later we detected no emission exceeding 50 mJy (5σ). This line has not been detected subsequently: 1σ upper limits of 230 mJy and 780 mJy were obtained in 1989 June/July (Cohen, Masheder, & Walker 1991, hereafter CMW) and in 1998 September 7 (Szymczak, Kus, & Hrynky 2000, hereafter SKH). For a maser at the position found by FFG, these upper limits should be increased by 16 per cent and 5 per cent, respectively. At the adopted distance to S255 and S256 (1.2 kpc; Israel 1976), the projected separation between the 4765-MHz maser and PP56 corresponds to \(~\sim 0.35\) pc – that is, the source of the 4765-MHz maser is well separated from the other known masers in this field.

### 2.2 K3-50

The spectrum at the position of maximum maser intensity is shown in Fig. 1, the location of the maser on the continuum image made from our data is shown in Fig. 2. The position given in Table 2 is the position of the feature in the central channel ($V_{L,SR}$=20.45 km s$^{-1}$). The maser is located on the edge of the dominant compact HII region which was identified as the centre of an ionised bipolar flow by De Pree et al. (1994). [Our C-array data does not contain the short spacings necessary to accurately image the extended flux density in this region which leads to the negative bowl around the bright compact sources; a better image of all of the radio continuum from this region at 6 cm is found in Roelfsema, Goss, & Geballe (1988).] In Table 2 it can be seen that for most of the 20 years since its discovery (Gardner & Martin-Pintado 1983, hereafter GMP), the flux density, while variable, has stayed within a factor of two of 1 Jy – except for the flaring episode observed by SKH.

K3-50 is part of the W58 complex of ionised and molecular gas (Dickel, Goss, & De Pree 2001). Ground state OH is seen only in absorption in the immediate vicinity of K3-50. The nearest maser feature seems to be the well known 1720-MHz source ON-3 which is 2.25 arcmin to the northeast which corresponds to \(~\sim 5\) pc projected separation at the 7.4 kpc distance of the complex (Harris 1975, scaled to an 8.5 kpc distance to the Galactic centre). A more sensitive high resolution search for 18-cm masers would be worthwhile.

### 2.3 DR21EX

DR21EX is located \(~\sim 2\) arcmin north of the well known ground-state OH source DR21(OH) which is located \(~\sim 3\) arcmin north of the compact HII region DR21 which dominates the continuum in this field. The spectrum at the maser intensity maximum is shown in Fig. 3; the location of the maser with respect to continuum is shown in Fig. 4. The most striking thing about this maser is its large separation from detectable continuum sources. Table traces the evolution of the feature near 5 km s$^{-1}$ from 1968 to 2002. In 1968, no feature was detected to a limit of \(< 2\) Jy (4-σ); in 1982 a single feature was discovered which reached an intensity of 12.8 Jy in 1984. Since then, the intensity has decreased irregularly so that in 2001, the flux density was \(< 1\) Jy and velocity features at \(~\sim 5\) km s$^{-1}$ were no longer the dominant features in the spectrum.

The flux densities in Table 3 refer to components with $V_{L,SR}$ = 5.1–5.3 km s$^{-1}$. Features at other velocities (outside the range observed in this paper) have been detected as noted in Table 3. Most of the features are located very close to the position of the \(~\sim 5\) km s$^{-1}$ feature. A notable exception is that while Cohen, Masheder, & Caswell (1995, hereafter CMC) found that the position of the 4.0 km s$^{-1}$ feature was the same as that of the 5 km s$^{-1}$ feature;
Palmer & Goss (in preparation, hereafter PG) found a feature at $V_{LSR} = -3.70$ km s$^{-1}$ which was offset $\sim$15 arcsec north of the 5 km s$^{-1}$ position on 2001 March 02.

PG have detected a 1720-MHz maser within 1 arcsec of the 4765-MHz 5-km s$^{-1}$ position; this is the only ground state OH maser from this position in the literature (although many are reported near DR21(OH) and DR21). Genzel & Downes (1977) report groups of H$_2$O-maser features both at the DR21(OH) position and $\sim$1 arcmin north of the 4765-MHz feature. PG have detected another group of H$_2$O-maser features at the 4765-MHz 5-km s$^{-1}$ position.

### 2.4 W75N

Ground state 1665-, 1667-, and 1720-MHz OH masers (as well as other masers) are located very near this 4765-MHz maser. The spectrum at the maser maximum is shown in Fig. 1; the maser location with respect to the continuum sources in the field is shown in Fig. 2. There were two velocity components which have slightly different positions (see Table 2). The masers fall on the edge of a small HII region, $\sim$1 arcsec from its centre. This offset corresponds to 2000 AU at the accepted distance to this source, 2 kpc.

The ground state masers are scattered over a region about 5 arcsec in diameter, but most are tightly clustered in a V-shaped region with sides about 1.5 arcsec long (Hutawarakorn, Cohen, & Brebner 2002). A Zeeman pair of 1720-MHz features was identified by those authors close to the “point” of the V. The 4765-MHz feature is offset $\sim$1.6 arcsec west of this pair (outside of the V).

The summary in Table 3 shows that during the 20 years that this source has been observed, its peak flux density has varied by more than two orders of magnitude.

### 2.5 W49A

This is a complex region located at $\sim$11.4 kpc distant (Gwinn, Moran, & Reid 1992). The continuum shows at least 45 distinct HII regions (De Pree, Mehringer, & Goss 1997, hereafter DMG). Many ground state OH masers in all four lines have been detected in this complex region as well as numerous H$_2$O masers. All three 6-cm lines were observed, and they revealed three principal sites of maser activity separated by $\geq$ 1 arcmin. One site shows only point-like 4765-MHz emission; another, only point-like 4660-MHz emission; and the third, spatially extended 4750- and 4660-MHz emission with a broad velocity range as well as point-like 4765-MHz emission. Comparisons of 18-cm OH masers in W49A with the 6-cm masers are difficult for two reasons. First, W49A contains many powerful ground state masers in all four lines so that fainter features may be confused. Second, because W49A is $\geq$5 times further away than DR21 and W75N for which we have noted closely spaced 4765-MHz and 1720-MHz features, neither linear resolution nor sensitivity to intrinsically faint features is comparable to those in the these sources. The continuum image from our data with the sites of 6-cm maser activity identified is shown in Fig. 2. Note that our observations resolve out a significant amount of the extended flux density. We refer to the continuum components shown in multi-configuration images of DMG both because they show the extended flux density more accurately and because they have higher spatial resolution.

#### 2.5.1 4765 MHz

The spectrum at the position of maximum intensity is shown in Fig. 3. This position is at the edge of the HII region called R3 by DMG. Table 3 summarises the observations of the 8.2 and 8.6 km s$^{-1}$ features since 1968. Because the positions of the two agree, and because before 1994.8 only the former was detected and since 1994.8 only the latter (except for the report by SKH in 1998), they are treated as one in the table. More than 6 years of closely spaced monitoring data is provided by Smits (1997, 2003, hereafter S1, S2). The 4765-MHz masers in W49A showed no dramatic flaring episodes, but a maser in the 8.2 – 8.6 km s$^{-1}$ velocity range has been present with an intensity varying on both long and short timescales (but within a factor of four of 1 Jy) for more than 30 years.

The presence of features at other velocities is noted in Table 3. The principal ones are those at $\sim$2.2 and $\sim$11.9 km s$^{-1}$. Using the ATCA, Dodson & Ellingsen (2002) determined that the positions of both the 8.6 km s$^{-1}$ and the 11.9 km s$^{-1}$ features are the same (and the same as that we determined for the feature shown in Fig. 3b), while the position of the 2.2 km s$^{-1}$ is offset by 65 arcsec, north and east (into the Source G region, see below). However, the ATCA positions for features in W49 have relatively large errors in declination (2 – 5 arcsec). PG have improved the positions of these features and strengthened these conclusions.

The 4765-MHz maser at 8.2/8.6 km s$^{-1}$ is located within $\sim$0.1 arcsec of several 1665-MHz and 1720-MHz features (Gaume & Mutel 1987). The 2.2 km s$^{-1}$ position is in a very complex region with many ground state masers. The nearest are a collection of 1667-MHz masers offset by $\sim$1 arcsec; the nearest 1720-MHz masers are $\sim$5 arcsec distant.

#### 2.5.2 4660- and 4750-MHz Emission

The 4750- and 4660-MHz lines are detected in a spatially extended source located at the position of continuum source G (see Fig. 2). The 4660-MHz line is the more extended: covering Source G and extending to the west across source B to approximately the position of source A (see fig. 2 of DMG). The 4750-MHz line has measurable intensity only in the Source G region. The 4660-MHz line also has a narrow velocity component $\sim$3.5 arcmin away (projected separation: $\sim$11 pc) between the main component of W49 South and the compact component W49 South-1 (source names follow DMG).

#### 2.5.2.1 Extended Component

The spectra of the extended components integrated over a box 25 arcsec x 12 arcsec are shown in Fig. 3 and b. The integrated profiles of the two lines are strikingly similar. For both lines, the spatial extent of the emission is at least 17 arcsec(RA) by 6 arcsec(dec). However, when inspected on a pixel-by-pixel basis, there are significant differences. The 4660-MHz line clearly has two velocity maxima in much of this region. The spectra toward individual positions are broad in velocity. The FWHM of the line ranges from $\sim$4 km s$^{-1}$ to $\sim$17 km s$^{-1}$. In contrast, the 4750-MHz line is dominated by a single velocity maximum throughout the region. The FWHM ranges from $\sim$4 km s$^{-1}$ to $\sim$18 km s$^{-1}$. The general agreement in profile shape and spatial distribution of the two lines together with the differences on a pixel-by-pixel basis, argue for excitation in the same volume of gas with minor differences in excitation from point to point.

The positions of the peaks as a function of velocity is shown in Fig. 4. For the 4660-MHz line, the position of the eastern component (near source G) moves rather smoothly westward to the edge...
of source B as the velocity increases from $V_{LSR}=4.32$ km s$^{-1}$ to $V_{LSR}=19.25$ km s$^{-1}$. The errors at each point depend on the signal to noise; they are $<0.05$ arcsec near the line maximum and $\sim0.2$ arcsec at each end. The western component (near Source A) is not visible at all velocities and is $<0.6$ arcsec. Similarly, for the 4750-MHz line, the position of maximum intensity moves rather smoothly as a function of velocity (mostly in RA) over about 4 arcsec. The emission in each channel is also slightly extended for both lines.

Note that these lines have much lower peak intensities than do the 4765-MHz lines reported above and that they have much greater FWHM’s (compare Fig.'s 1 and 3). Most of the published values must be read from plots and are therefore not precise; but, including re-observations of these lines with the VLA in 2001 August and November (PG), it seems that neither of these lines has varied in the $\sim$30 years since they were discovered. The only difference between the VLA measurements and single dish measurements is that single dish measurements of the 4660-MHz line include varying amounts of the narrow feature near W49 South (discussed in the next paragraph) which would add about 70 mJy at $V_{LSR}$~$\sim$14 km s$^{-1}$ if observed with a large single dish beam. With the present angular resolution, it is not possible to determine whether the emission is actually extended on this scale, or if it consists of a clump of unresolved features. However, PG have observed both lines with the VLA with 0.4 arcsec resolution, and find that they do not break up into collections of narrow features.

The region of the extended 4750- and 4660-MHz emission is the location of many ground state masers in all four transitions [see fig. 7 of Gaume & Mutel (1987) which shows the positions superposed on a contour image of Sources B, G, and A.]

2.5.2.2 Point-like component The spectrum at the maximum near W49 South is shown in Fig. 13. The B1950 position is $19^h07^m58.03^s, 09^\circ00'03.4''$. This source resembles the 4765-MHz masers: it is point-like (diameter $<1.2$ arcsec), and has a velocity FWHM $<$2.5 km s$^{-1}$ (it may well be much narrower because our resolution is only 1.5 km s$^{-1}$ for this line). The velocity is $\sim$14.4 km s$^{-1}$. We have much less information about variability of this component because it is not separated in the single dish measurements; on 2001 Aug 27, the 4660-MHz peak flux density was essentially the same as reported here (PG). We have searched the entire 10 arcmin primary beam and no other sources were detected at 4660 MHz.

At the position of the 4660-MHz maser, the upper limit for any 4750-MHz emission is $\sim$12 mJy ($<20$ per cent of the 4660-MHz emission). The 4660-MHz maser is located $\sim$0.3 arcsec from several 1612-MHz masers and within 0.5 arcsec of several 1667-MHz masers. The nearest 1720-MHz masers are $\sim$1.1 arcsec away. A possible association of 4660-MHz emission with 1612-MHz maser has been noted by Whiteoak et al. (1987) in SgrB2.

3 DISCUSSION Our primary goal was to determine precise positions for the 4765-MHz masers. The principal limitation is that our velocity coverage did not allow us to include all now known velocity components. As shown in Table 2, our position determinations are more than adequate to guide VLBI observations. We note that in cases where features at several velocities are present, their separations are frequently not at the arc second scale (like separations of 18-cm OH or H$_2$O maser spots) but by 10’s of arc second to arc minutes (more similar to the separations of clumps of 18-cm OH or H$_2$O maser spots). A byproduct of this work was a study of the time-variability of these masers. We have examined all published data, two unpublished studies (FFG and RPZ), and some of our work in progress (PG). As most other observers have discovered, the 4765-MHz masers are highly time-variable. Powerful flares such as reported for DR21EX by FFG and this paper and, most spectacularly, in Mon R2 reported by Smits et al. (1998) are relatively rare. Nevertheless, it is striking that over 20 – 30 year periods, three of the four maser sources detected in this paper have exceeded 6 Jy at some time. That is, although usually rather faint, these masers occasionally reach flux density levels so that they could be detected in an observation of a few minutes duration with a typical 25-meter telescope. All known 4765-MHz features vary at some level, some at the 10 per cent level and others by more than 100 per cent.

The region from which the spatially extended 4660-MHz and 4750-MHz emission is detected in W49A is exceptional in several ways. This region contains a partial ring of HII regions (called source G by De Pree et al. (1984)) and several other compact continuum components (see De Pree et al. (2004) and Wilner et al. (2001)). This region also contains the dynamical centre of an exceptionally powerful H$_2$O maser outflow. Morris (1976) found that the velocity range exceeded 500 km s$^{-1}$. From a five epoch proper motion VLBI study, Gwinn et al. (1992) located the dynamical centre of the outflow within source G. The dynamical center did not correspond to any of the sub-components G1 – G5 resolved by DMG with 0.8 arcsec resolution. Subsequently G2, the source nearest the dynamical centre was resolved into three sources: G2a – G2c by De Pree et al. (2000) with 0.04 arcsec resolution. Recently, Wilner et al. (2001) in a study at 1.4 mm (~0.2 arcsec resolution) identified an extension of G2b which corresponds to the dynamical center of the H$_2$O outflow. A possible solution to the “life-time problem” for the large number of closely spaced compact HII regions (Dreher & Welch 1983; Wood & Churchwell 1988) is that they may be confined by surrounding molecular clouds with densities $n_H \sim 10^6 – 10^7$ cm$^{-3}$ (De Pree, Rodriguez & Goss 1995). A density range of $\sim 10^7$ – $10^8$ cm$^{-3}$ is required to collisionally excite the $\tilde{2}P_{1/2}$, $J = 1/2$ lines and it is above the range of density required for excitation of the 1.4-mm methyl cyanide emission observed by Wilner et al. (2001). Therefore, the scenario of De Pree et al. (1995) would provide a natural explanation for excitation of the observed OH and methyl cyanide lines. In summary, the entire region seems filled with dense gas in either a neutral or an ionised state.

An important question is whether the spatially extended 4660-MHz and 4750-MHz emission is maser or thermal emission. The peak flux density at 4750-MHz is 97 mJy/beam in a 4.11 arcsec x 1.72 arcsec beam, corresponding to a brightness temperature $\sim$700 K. For the 4660-MHz line, the peak brightness is 168 mJy/beam in a 4.33 arcsec x 1.70 arcsec beam corresponding to $\sim$1200 K. Therefore it is hard to escape the conclusion that the spatially extended 4660-MHz and 4750-MHz emission with broad velocity widths near W49A source G is maser emission.

A picture that is compatible with the considerations above is that the 6-cm OH lines are usually weakly inverted in the dense gas surrounding star-forming regions. Spatially extended, broad velocity, non-variable 4660-MHz and 4750-MHz lines are detectable whenever $||r||$ in the dense regions is large enough. Because the 4765-MHz lines are more frequently found, conditions for large inversions must be reached occasionally for these lines, although the column density and velocity coherence reach high enough values
to produce the narrow, intense lines at 4765-MHz along any line of sight only for relatively transient periods.

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Table 1. Observing Log

| Source | Line (F→F) | Pointing Position (RA(B1950), Dec(B1950)) | Date of Observation | \(V_{lsr}\) (km s\(^{-1}\)) | Synthesised Beam (arcsec x arcsec, \(^{\circ}\)) |
|--------|------------|------------------------------------------|---------------------|-----------------|---------------------------------|
| S255  1→0 | 06 09 58.000, 01 01 60.000 | 1984 Apr 29 | 6.61 | 6.24x4.22, PA=-66.2 |
| W49A  1→0 | 19 07 52.000, 09 01 15.000 | 1984 Mar 23 | 8.25 | 4.26x1.83, PA=-79.6 |
|    1→1 | "          | "            | "      | 4.11x1.72, PA=-77.2 |
|    0→1 | "          | "            | "      | 4.33x1.70, PA=-76.2 |
| K3-50 1→0 | 19 59 48.000, 33 24 00.000 | 1984 Apr 29 | -20.45 | 4.49x3.78, PA=-60.4 |
| DR21EX 1→0 | 20 37 14.000, 42 12 00.000 | 1984 Apr 29 | 5.24 | 4.25x4.13, PA=-51.1 |
| W75N 1→0 | 20 36 50.000, 42 26 55.600 | 1984 Apr 29 | 11.90 | 5.19x3.96, PA=-79.8 |

Table 2. Results for 4765-MHz Line Observations

| Source | RMS (mJy) | RA(1950) | Dec(B1950) | RA(J2000) | Dec(J2000) | Peak Flux (mJy) | Velocity \((\text{km s}^{-1})\) | FWHM \((\text{km s}^{-1})\) |
|--------|-----------|----------|------------|-----------|------------|----------------|-----------------|----------------|
| S255   | 10        | -        | -          | -         | -          | -              | -               | -              |
| W49A   | 15        | 09 00 20.6±0.1 | 19 10 10.95±0.01 | 09 05 17.7±0.1 | 1440±60 | 8.23±.01 | 0.35±.1 |
| K3-50  | 13        | 33 24 21.4±0.4 | 20 01 45.78±0.03 | 33 32 45.4±0.4 | 600±40 | -20.43±.02 | 0.46±.1 |
| DR21EX | 17        | 42 14 01.7±0.1 | 20 39 00.42±0.01 | 42 24 38.9±0.1 | 12830±200 | 5.23±.01 | 0.37±.1 |
| W75N   | 8.5       | 42 26 58.7±0.6 | 20 38 36.45±0.05 | 42 37 35.1±0.6 | 280±30 | 13.90±.05 | 0.42±.1 |
|        | 20 36 49.99±0.08 | 42 26 58.3±0.9 | 20 38 36.43±0.08 | 42 37 34.7±0.9 | 170±30 | 9.37±.10 | 0.23±.1 |
Table 3. Summary of 4765-MHz Emission Variability

| Source | Date       | $S_{\text{max}}$ (Jy) | Reference | Comments |
|--------|------------|------------------------|-----------|----------|
| K3-50  | 1982 (early) | 0.6                    | GMP       |          |
|        | 1983 Aug 23 | 0.6                    | FFG       |          |
|        | 1984 Apr 29 | 0.6                    | (this paper) |          |
|        | 1991        | 1.0                    | CMC       |          |
|        | 1998 Jun 30 | 6.8                    | SKH       |          |
|        | 1998 Oct 20 | 2.4                    | SKH       |          |
|        | 1998 Dec 1  | 2.2                    | SKH       |          |
|        | 2001 Aug 9  | 1.9                    | PG        |          |
|        | 2002 Jan 10 | 2.3                    | PG        |          |
| DR21EX | 1968 Feb    | <2.0 (C)               | Zuckerman et al. (1968) |          |
|        | 1982 (early) | 4.9 (C)                | GMP       |          |
|        | 1983 Aug 03 | 10.9                   | FFG       |          |
|        | 1984 Apr 29 | 12.8                   | (this paper) |          |
|        | 1989 Jun/Jul| 7.3 (C)                | CMW       | observed 27 times in interval |
|        | 1991        | 3.8                    | CMC       | also $V_{\text{lsr}}$ = 4.0 km s$^{-1}$ |
|        | (1994.8 – 1996.4) | ~2.0 | S1; S2 | also $V_{\text{lsr}}$ = 3.2 km s$^{-1}$ (no -4.0 km s$^{-1}$) |
|        | 1998 Jun 30 | 6.4 (C)                | SKH       |          |
|        | 2001 Mar 02 | 1.0                    | PG        | also $V_{\text{lsr}}$ = 3.7 km s$^{-1}$ |
|        | 2001 Jun 12 | 1.1                    | PG        |          |
|        | 2001 Nov 15 | 0.8                    | PG        | $V_{\text{lsr}}$=$\sim$5 km s$^{-1}$ no longer dominant feature |
|        |            |                        |           | at least four features: $V_{\text{lsr}}$=2.28 – 5.71 km s$^{-1}$ |
| W75N   | 1983 Sep 15 | 0.1, 0.2               | FFG       | $V_{\text{lsr}}$= 13.90, 9.37 km s$^{-1}$ |
|        | 1984 Apr 29 | 0.3, 0.2               | (this paper) | $V_{\text{lsr}}$= 13.90, 9.37 km s$^{-1}$ |
|        | 1989 Jun/Jul| <0.3 (C)               | CMW       |          |
|        | 1998 Aug 14 | 2.9                    | SKH       | $V_{\text{lsr}}$=10.4 km s$^{-1}$ |
|        | 1998 Nov 20 | 4.3                    | SKH       | $V_{\text{lsr}}$=10.3 km s$^{-1}$ |
|        | 1998 Dec 2  | 6.1                    | SKH       | $V_{\text{lsr}}$=10.4 km s$^{-1}$ |
|        | 1998 Dec 19 | 10.0                   | SKH       | $V_{\text{lsr}}$=10.3 km s$^{-1}$ |
|        | 2001 Mar 02 | 0.04                   | PG        | $V_{\text{lsr}}$=10.49 km s$^{-1}$ |
| W49    | 1968 Feb    | 1.0                    | Zuckerman et al. (1968) | probably inadequately resolved |
|        | 1969 (early) | 2.0                    | Zuckerman & Palmer (1970) |          |
|        | 1974 Feb    | 2.5 (C)                | RPZ$^a$   |          |
|        | 1980 Sep    | 2.0                    | JSS$^b$   |          |
|        | 1981 Aug    | 1.6                    | JSS       |          |
|        | 1982 (early) | 1.3                    | GMP       |          |
|        | 1982 May    | 1.6                    | JSS       |          |
|        | 1983 Aug 23 | 1.4                    | FFG       |          |
|        | 1984 Mar 23 | 1.4                    | (this paper) |          |
|        | 1989 Jun/Jul| 1.6 (C)                | CMW       | observed 80 times in this interval, $V_{\text{lsr}}$= 8.6 km s$^{-1}$ |
|        | (1994.8 – 1998.3) | ~2.0 | S1; S2 | also $V_{\text{lsr}}$ = 2.2, 3.62, and 8.36 km s$^{-1}$ |
|        | 1998 Jul 05 | 3.5                    | SKH       | $V_{\text{lsr}}$=8.2 km s$^{-1}$ |
|        | 2000 Sep 15/16 | 0.2 | Dodson & Ellingsen (2002) | $V_{\text{lsr}}$=8.6 km s$^{-1}$ |
|        | 2001 Aug 09 | 0.3                    | PG        | $V_{\text{lsr}}$=8.61 km s$^{-1}$ |
|        |            |                        |           | also $V_{\text{lsr}}$ = 2.2 and 11.9 km s$^{-1}$ |

$^a$ RPZ=Rickard, Palmer, & Zuckerman (unpublished manuscript)

$^b$ JSS=Jewell, Schenewerk, & Snyder 1985
Figure 1. The 4765-MHz OH maser spectra obtained with the VLA. The velocity resolutions are $0.19 \text{ km s}^{-1}$. (a) The spectrum toward K3-50. (b) The spectrum toward DR21EX. (c) The spectrum toward W75N. (d) The spectrum toward W49A. Spectra (a) – (c) were obtained 1984 April 29; while (d) was obtained 1984 March 23. The rms noise levels and the synthesised beams for each are given in Table 2.
Figure 2. The 6-cm continuum emission observed with the VLA in this experiment. The contours are in units of the rms noise, beginning with ±3; dashed contours are negative. For (a) – (c), the synthesised beams are ∼5 arcsec by ∼4 arcsec and crosses indicate the 4765-MHz maser position in each source. (a) K3-50, showing significant negative contours because of missing short spacings; (b) DR21 is the strong source at the bottom, well separated from the maser (this observation was made in the normal VLA continuum mode); (c) W75N; (d) The continuum emission from the W49A region observed with the VLA on 1984 March 23. Positions are indicated with crosses for the unresolved 4660-MHz maser near W49 South and for the unresolved 4765-MHz maser near source R3. The extent of 4660- and 4750-MHz emission near source G is indicated (see also figure 4). The synthesised beam is 4.2 arcsec by 1.7 arcsec.
Figure 3. The spectra of W49A at 4660-MHz and 4750-MHz observed with the VLA on 1984 March 23. The velocity resolution is $\sim$1.5 km s$^{-1}$, about eight times broader than for the 4765-MHz masers in Figure 1. The synthesised beams are $\sim$4.2 arcsec by $\sim$1.7 arcsec, and the rms noise per channel is 3 mJy per synthesised beam. (a) The spectrum of 4660-MHz emission integrated over 25 arcsec by 12 arcsec box including sources G, B and A. (b) The spectrum of 4750-MHz emission in W49 integrated over the same box as (a). (c) The spectrum toward the 4660-MHz source near W49 South.
Figure 4. The locations of 4660- and 4750-MHz emission peaks in the source G region of W49A. The points are connected in order by velocity. For the 4660-MHz line the positions plotted show both maxima where two Gaussians could be fitted to the line. Note that the velocity changes systematically with position for the eastern peak. The 4750-MHz data is plotted 2.5 arcsec south of the actual declination. The velocity of the peak at 4750-MHz is derived from fits to single Gaussians. Again, the positional variation with velocity is rather systematic.