SHOCK-EXCITED MASER EMISSION FROM SUPERNOVA REMNANTS: G32.8—0.1, G337.8—0.1, G346.6—0.2, AND THE HB 3/W3 COMPLEX

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ABSTRACT

We present the results of VLA observations in the ground-state hydroxyl (OH) transition at 1720 MHz toward 20 supernova remnants (SNRs). We detect compact emission from four objects. For three of these objects (G32.8—0.1, G337.8—0.1, and G346.6—0.2), we argue that the emission results from masers that are shock-excited due to the interaction of the SNR and an adjacent molecular cloud. We observe a characteristic Zeeman profile in the Stokes V spectrum, which allows us to derive a magnetic field of 1.5 and 1.7 mG for G32.8—0.1 and G346.6—0.2, respectively. The velocity of the masers also allows us to determine a kinematic distance to the supernova remnants (SNRs). Our criteria for a maser to be associated with an SNR along the line of sight are that the position and velocity of the maser and SNR must agree and the OH (1720) emission must be unaccompanied by other OH lines.

Key words: ISM: clouds — ISM: magnetic fields — ISM: molecules — supernova remnants

1. INTRODUCTION

Supernova remnants (SNRs) are a primary source of energy and heavy elements in the interstellar medium (ISM). While this is well accepted, it is difficult to demonstrate specific instances of interaction between the SNR and cold dense gas in the ISM. Massive stars evolve quickly and are thought to influence the molecular clouds (MCs) from which they formed (see Elmegreen 1998 for a review). Circumstantial evidence, such as morphological signatures, has been the primary evidence of this interaction (e.g., Routledge et al. 1991; Landecker et al. 1987). Interpretation of such observations is inconclusive because of confusion due to projections along the line of sight. Thus there is a need for an indicator of SNR-MC interaction.

In a series of recent papers, we have utilized the 1720 MHz line of the hydroxyl molecule (OH) as a diagnostic for such an interaction. The ground state of the OH molecule has four transitions: the main lines at 1665.4018 and 1667.3590 MHz and the satellite lines at 1612.231 and 1720.530 MHz. Main-line OH masers are commonly found near compact H II regions, while 1612 MHz OH masers are found in the circumstellar shells of evolved stars. Goss & Robinson (1968) first detected the satellite 1720 MHz OH maser emission toward the SNRs W28 and W44. They found strong narrow-line 1720 MHz emission and a broad line 1612, 1665, and 1667 MHz absorption, which distinguished the 1720 MHz masers from those found in other environments.

The remnants W28 and W44 later became prototypes for SNRs interacting with molecular clouds. Frail, Goss, & Slysh (1994) reobserved W28, discovering 26 maser spots, and argued that the 1720 MHz radiation is maser emission due to a strong inversion of the line from collisional excitation by H2 behind the SNR shock. The location of the maser spots and the physical characteristics of the SNR and MC are consistent with the shock excitation model of Elitzur (1976).

In addition to being an unambiguous sign of SNR-MC interaction, OH masers can tell us more about the host SNR and its physical characteristics. In systems in which the velocity has been measured by other means, there is strong agreement between the velocity of the masers and the systemic velocity of the remnant. This allows a kinematic distance to be derived. Polarimetric observations reveal Zeeman profiles in the Stokes V signal that allow us to measure the magnetic field in several of the maser spots (Claussen et al. 1997). We can already loosely constrain the temperature and density of the environment of the maser via Elitzur’s (1976) theory. Furthermore, in the future it may be possible to use maser theory to infer accurate physical parameters of the postshock gas from the OH masers.

The initial success with W28 prompted Frail et al. (1996) to perform a survey for 1720 MHz OH maser emission toward 66 SNRs, using the Green Bank and Parkes telescopes. A total of 19 detections were made. Follow-up observations with an interferometer were made to distinguish between compact maser emission (θ < 1") and spatially extended thermal line emission. This resulted in the detection of OH (1720 MHz) masers toward five new SNRs. This survey work has continued toward the Galactic Center (e.g., Yusef-Zadeh et al. 1996) and in the Galactic plane (Green et al. 1997).

Green et al. (1997) reported that of the ~160 SNRs searched for OH emission, 17 have yielded maser emission, or 10% of the sample. However, they report higher detection rates for remnants within the “molecular ring” of the Galaxy. Many of these individual SNRs have several maser spots. For instance, W28, W44, and IC 443 have 41, 25, and 6 masers, respectively (Claussen et al. 1997). The 10% detection rate in a random sample of Galactic SNRs suggests
that more SNR-MC interactions have yet to be discovered in the remaining systems.

In the Green et al. survey of 75 SNRs, there were 33 detections of OH. However, 16 were not reobserved with an interferometer to determine whether the detections result from compact maser emission or extended Galactic thermal emission. The goal of the present study was to determine which of the remaining detections visible from the VLA\(^1\) were due to shock-excited OH maser emission. In addition, we also observed several other sources that had not been sampled by the Green et al. survey but were likely cases for SNR-MC interaction. Two of these were Cas A and CTB 109. Also, we have noticed a strong correlation between OH maser detections and members of Rho’s (1996) thermal composite SNRs. This may suggest molecular cloud interactions as an origin for this class of SNRs. Therefore, we observed three SNRs from this category (3C 396, CTB 104A, and HB 3).

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### Table 1

**Summary of 1997 December and DnC Configuration 1720 MHz Observations**

| Name       | R.A. (B1950.0) | Decl. (B1950.0) | \(V_{LSR}\) (km s\(^{-1}\)) | Common Name | Notes |
|------------|----------------|----------------|----------------------------|-------------|-------|
| G13.3–1.3A | 18 14 39.0     | −18 09 30.0    | +30                        | D           |       |
| G13.3–1.3B | 18 13 38.5     | −18 35 48.0    | +30                        | D           |       |
| G32.8–0.1  | 18 48 50.0     | −00 12 00.0    | +90                        | Kes 78      | D     |
| G33.6–0.1  | 18 50 15.0     | +00 37 00.0    | +90                        | Kes 79      | D     |
| G39.2–0.3  | 19 01 40.0     | +05 23 00.0    | +70                        | 3C3 96      | R     |
| G93.7–0.2A | 21 29 00.0     | +51 05 00.0    | −45                        | CTB 104A    | R     |
| G93.7–0.2B | 21 25 00.0     | +50 55 00.0    | −45                        | R           |       |
| G109–1.1   | 22 59 00.0     | +58 45 00.0    | −50                        | CTB 109     |       |
| G111–2.1   | 23 21 10.0     | +38 32 00.0    | −40                        | Cas A       |       |
| G132.7+1.3A| 02 16 00.0     | +61 45 00.0    | −40                        | HB 3        | R     |
| G132.7+1.3B| 02 19 00.0     | +61 50 00.0    | −40                        | R           |       |
| G189.1+3.0 | 06 14 04.0     | +22 22 40.0    | 0                          | IC 443      | D     |
| G340.6+0.3 | 16 44 05.0     | −44 29 00.0    | −100                       | D           |       |
| G342–0.2   | 16 51 15.0     | −43 48 00.0    | 0                          | D           |       |
| G341–0.3   | 16 51 25.0     | −43 56 00.0    | 0                          | D           |       |
| G343.1–0.7A| 16 55 23.65    | −42 54 35.0    | −70                        | D           |       |
| G343.1–0.7B| 16 56 45.9     | −43 24 35.0    | −70                        | D           |       |
| G346.6–0.2 | 17 06 50.0     | −40 07 00.0    | −70                        | D           |       |
| G348.5–0.0 | 17 12 00.0     | −38 25 00.0    | −100                       | D           |       |
| G352.7–0.1 | 17 24 20.0     | −35 05 00.0    | 0                          | D           |       |
| G354.8–0.8 | 17 32 41.0     | −33 40 00.0    | −70                        | D           |       |

Note.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.

### Table 2

**Summary of Spectral Line Fits for 1720 MHz Masers**

| Name       | R.A. (B1950.0) | Decl. (B1950.0) | \(S\) (mJy) | \(\sigma_{rms}\) (mJy beam\(^{-1}\)) | \(V_{LSR}\) (km s\(^{-1}\)) | \(\Delta V\) (km s\(^{-1}\)) | Notes |
|------------|----------------|----------------|-------------|-------------------------------|-----------------|------------------------|-------|
| G32.8–0.1  | 18 49 14.02    | −00 14 14.2    | 494         | 4.5                           | −86.1           | 0.97                   |       |
| G337.8–0.1 | 16 38 32.15    | −46 56 16.1    | 143         | ...                           | −45             | ...                    |       |
| G346.6–0.2 | 17 06 42.23    | −40 11 08.6    | 1240        | 11                            | −74.0           | 1.28                   |       |
|            | 17 06 35.53    | −40 10 22.2    | 320         | ...                           | −76.2           | 1.74                   |       |
|            | 17 06 56.03    | −40 09 38.3    | 183         | ...                           | −76.2           | 1.75                   |       |

Note.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.

2. Observations

The observations were made at the VLA on 1997 October 25 and December 19 in the DnC and D configurations, respectively. A bandwidth of 780 kHz was used, divided into 127 spectral channels using the on-line Hanning smoothing. This yielded both L and R hands of circular polarization with a velocity resolution of 1.1 km s\(^{-1}\) (6.1 kHz per channel) and a velocity coverage of 120 km s\(^{-1}\). The band was centered at 1720.53 MHz, offset by the single-dish line-emission velocity or the systemic velocity of the remnant (when known). Table 1 lists the pointing centers for all observations along with the central velocities for the observations, and Table 2 summarizes the spectral line fits for 1720 MHz masers.

Follow-up observations were made on 1998 February 5, 6, and 13 during the move time between D and A configurations. For the first two days, we had 24 antennas in the D configuration, and we observed G32.8–0.1 and G346.6–0.2. For the third day, we used 13 antennas, which were in the A configuration, and HB 3 was observed. A bandwidth of 195 kHz was used, divided into 127 spectral
FIG. 1.—Radio continuum image of G32.8 – 0.1 at 1.7 GHz from the current data. The position of the maser is marked as a cross on the image and the velocity is noted. The size and position angle of the cross are those of the Gaussian fit. Continuum contour levels are 3, 6, 12, 24, and 48 mJy beam$^{-1}$, and the beam size is $59" \times 39"$, as shown in the bottom left.

### TABLE 3

| Name          | R.A. (B1950.0) | Decl. (B1950.0) | $S$ (mJy) | $\sigma_{\text{rms}}$ (mJy beam$^{-1}$) | $V_{\text{LSR}}$ (km s$^{-1}$) | Notes        |
|---------------|----------------|-----------------|-----------|----------------------------------------|-------------------------------|--------------|
| W3 northwest  | 02 21 39.85    | +61 54 33.8     | 2215      | 25                                     | –38.6                         |              |
| W3 H/D        | 02 21 41.12    | +61 53 30.4     | 749       | 25                                     | –60.6                         |              |
|               | 02 21 41.11    | +61 53 30.4     | 550       | 25                                     | –63.3                         | Second peak  |
| W3 G          | 02 21 46.89    | +61 52 16.0     | 263       | 25                                     | –44.7                         |              |
| W3OH          | 02 23 16.58    | +61 38 58.4     | 1916      | 11                                     | –44.7                         |              |

Note.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.
The magnetic field strength is shown plotted with the derivative of $I$ with respect to frequency (dashed line) scaled by the magnetic field strength is shown plotted with the $V$ spectrum.

channels using on-line Hanning smoothing. This yielded parallel-handed circular polarizations with a velocity resolution of 0.53 km s$^{-1}$ (1.5 kHz per channel) and a velocity coverage of 34 km s$^{-1}$. During these observations, we also observed in the main-line transitions at 1665 and 1667 MHz with the same spectral resolution. We centered, both spatially and spectrally, on the masers detected during our 1997 observations.

After the VLA observations, we became aware of an Australia Telescope Compact Array (ATCA) observation of one of the southern SNRs detected in OH (1720 MHz) by Frail et al. (1996). In a survey of star-forming regions in both satellite lines of OH, Caswell et al. (1998) serendipitously observed the SNR G337.8–0.1 in one field. This data was acquired on 1997 November 27 in the 6C configuration with a 4 MHz bandwidth and 2048 channels, yielding 0.68 km s$^{-1}$ velocity resolution in the orthogonal terms of linear polarization.

All image processing was done using NRAO’s AIPS package. The continuum data was fitted via a least-squares method and subtracted. Three-dimensional image cubes were generated for all pointings in Stokes $I$, then CLEANed using the AIPS task IMAGR. This resulted in average rms noise levels of 5–10 mJy beam$^{-1}$. Stokes $V$ cubes were made for pointings where masers were detected.

Positional errors are roughly 0.1–0.2, or perhaps worse in accordance with the usual formula for a positional error $\Delta\theta = \pm (\theta/2)(S/N)^{-1}$. The sizes of the beams are also represented by the size of the crosses in Figures 1, 3, 4, and 5 below.

3. RESULTS

With the completion of the present work, all of the northern SNRs ($\delta > -45^\circ$) detected by Green et al. (1997) with single-dish detections of the 1720 MHz line have been followed up with the VLA. Several southern SNRs await confirmation. We observed 17 SNRs, detecting compact maser emission toward two of them. This confirmation rate of 10% is similar to previous surveys (Frail et al. 1996; Green et al. 1997; Yusef-Zadeh et al. 1996). There are now a total of 19 SNRs toward which we have detected OH (1720 MHz) masers. Below we discuss each of our recent detections, reviewing what is known about the individual SNR and whether our maser detections imply a physical association between the maser and the remnant.

3.1. G32.8–0.1 (Kes 78)

Kes 78 is an elongated shell-type SNR approximately 20' (north-south) × 10' (east-west). Although the quality of our 1.7 GHz continuum image in Figure 1 has limited sensitivity, the remnant does resemble that of earlier lower resolution images (see Kassim 1992 and references therein). We detected a single maser spot at $V_{\text{LSR}} = +86.1$ km s$^{-1}$ along the eastern edge of the SNR. Caswell et al. (1983) identified an H$_2$O maser near the center of Kes 78 coincident with main-line OH maser emission in this direction. This maser likely originates in an unrelated compact H II region along the line of sight, since it is 7' away (18464''10''5, -00°15'36'' [B1950.0]) from our OH (1720 MHz) detection and has $V_{\text{LSR}} = +33$ km s$^{-1}$.

We also detected a significant signal in Stokes $V$, with the classical antisymmetric S-shaped profile about the peak in the Stokes $I$. Such a profile is characteristic of Zeeman splitting in the presence of a magnetic field (Heiles et al. 1993). As we have done for earlier efforts (Yusef-Zadeh et al. 1996; Claussen et al. 1997), we fitted the derivative of the Stokes $I$ to the Stokes $V$ profile for this maser source and derived a line-of-sight measurement of the magnetic field. The result of this fit is shown in Figure 2. Good agreement can be obtained with the $V$ profile for $B_{\text{los}} = +1.5 \pm 0.3$ mG. This value lies nearly centered between those which we measured earlier for the SNRs W44 and W28 ($B_{\text{los}} \approx 0.2$ mG) and Sgr A East ($B_{\text{los}} \approx 3$ mG).

| Galactic Name | Common Name | SNR Type | No. Masers | $V_{\text{LSR}}$ (km s$^{-1}$) | $D$ near, far (kpc) | Stokes $V$ | B Field (mG) |
|---------------|-------------|----------|------------|----------------------------|-------------------|-----------|-------------|
| G32.8–0.1……..| Kes 78      | Shell    | 1          | -86.1                     | 5.5, 8.8*         | Y         | 1.45        |
| G337.8–0.1….. | Kes 41      | Shell    | 1          | -45                      | 12.3              | N*        | …          |
| G346.6–0.2……..|             | Shell    | 5          | -76.0                    | 5.5, 11*          | Y         | 1.70        |

* Near and far values.

b Observations for this remnant were not taken in Stokes $V$. 

![Figure 2](image-url)
If we make the assumption that the shock is transverse to the line of sight, then the velocity of the masers represents the LSR velocity of the SNR (Frail et al. 1996; Claussen et al. 1997), we can use the rotation curve of the Galaxy (Fich, Blitz, & Stark 1997) to derive the kinematic distance to the remnant. Without any other distance discriminator, \(+86.1 \text{ km s}^{-1}\) corresponds to either a near distance of 5.5 kpc or a far distance of 8.8 kpc. The tangent point in this direction (assuming a distance to the Galactic center of 8.5 kpc) is at 7.1 kpc with \(V_{\text{LSR}} \approx +100 \text{ km s}^{-1}\).

### 3.2. The HB 3/W3 Complex

The SNR HB 3 is a large, evolved remnant embedded in a star-forming region that contains the W3 H II complex. Routledge et al. (1991) found W3 and HB 3 to lie at \(-43 \text{ km s}^{-1}\) and estimate HB 3 to be \(60 \times 80 \text{ pc}\) in diameter. Routledge et al. made a case that HB 3 and W3 lie at the same distance due to their discovery of a bright region of CO emission associated with W3 that is partially surrounded by continuum emission from HB 3, all occurring at the systemic velocity. While it appears that HB 3 is interacting with molecular gas in which W3 is embedded, there is no evidence for a direct interaction of W3 and HB 3. W3 lies to the southeast of HB 3, and their centers are separated by about 1", or about 40 pc at the distance of the system (Landecker et al. 1987; Normandeau, Taylor, & Dewdney 1997).

We found six 1720 MHz masers (see Table 3) without corresponding 1665/7 main-line emission in the direction of HB 3 and W3. We also reduced archival VLA data, taken on 1989 January 20 and 23 when the array was in the A configuration. The pointing center was toward the W3 Main complex of H II regions, and all four ground-state OH transitions were observed. We were able to map the 1720 MHz OH masers toward W3(OH), the main part of W3, and toward the southeast part of HB 3. The velocity coverage was from \(-80\) to \(-10 \text{ km s}^{-1}\) with respect to the local standard of rest. These earlier observations confirmed four out of the six 1720 MHz masers reported in Table 3. Also, none of the four had associated main line emission to the level of about 50 mJy/beam (3 \(\sigma\)).

All but one of these can be immediately ruled out as being due to the HB 3-W3 interaction because of position (see Figure 3). The remaining northernmost maser is close to the...
interaction region in the southeast quadrant of HB 3. Spatially, it is near the peak in the \(^1\)\(^2\)CO and, at \(-38.6\ \text{km s}^{-1}\), it coincides with the velocity of the bulk of the molecular material between \(-36\) to \(-45.9\ \text{km s}^{-1}\). However, comparing with Routledge et al., we found the maser lies outside of the 408 MHz continuum emission of HB 3. This led us to conclude that none of the masers seen in this direction are collisionally excited by the shock of HB 3, and, instead, they are most likely associated with the compact H II regions of W3.

3.3. G337.8 \(-0.1\) (Kes 41)

A single maser was detected toward Kes 41, shown superposed on the 843 MHz continuum image from Whiteoak & Green (1996) in Figure 4. It lies on the northwestern edge between the twin “caps” of enhanced radio emission that define the distorted \(6' \times 4'\) shell of this SNR. Caswell et al. (1975) have measured H I absorption toward this SNR and see evidence for absorption by gas up to the tangent point at 7.9 kpc (for \(R_\odot = 8.5\ \text{kpc}\)) at \(V_{\text{LSR}} \approx -130\ \text{km s}^{-1}\). If we accept this (the quality of the H I spectrum is not high), then it implies that Kes 41 lies beyond the tangent point. In this case, the velocity of the maser \((-45\ \text{km s}^{-1}\)) gives a kinematic distance of 12.3 kpc, making Kes 41 a modest-sized remnant with a diameter of 20 \(\times\) 15 pc.

3.4. G346.6 \(-0.2\)

G346.6 \(-0.2\) is a little-studied remnant. The image we show in Figure 5 is from the 843 MHz Molonglo Observatory Synthesis Telescope survey of Whiteoak & Green (1996) and, although it is well characterized as a circular shell of 8' diameter, there is pronounced flattening along the northwestern side. This prompted Dubner et al. (1993) to suggest that the SNR is interacting with the surrounding medium. A total of five masers were detected toward this SNR. They are all located along the southern edge of the SNR and scatter within a few km s\(^{-1}\) about a mean \(V_{\text{LSR}} \approx -76.0\ \text{km s}^{-1}\). At this velocity, the kinematic distance to the masers (and hence the SNR) yields a near value of 5.5 kpc and a far value of 11 kpc. The tangent point in this direction is at 8.3 kpc with \(V_{\text{LSR}} \approx -170\ \text{km s}^{-1}\).

In Figure 6 we show the Stokes \(I\) and \(V\) for the brightest maser line toward G346.6 \(-0.2\). The second component that can be seen in this figure is the weak line at \(-76.2\ \text{km s}^{-1}\).
s^{-1}. Significant V flux is only detected toward the strong maser. Following the same procedure as used for Kes 78, we derived $B_{\text{los}} = 1.7 \pm 0.1$ mG.

4. DISCUSSION

As in previous surveys of this kind (Frail et al. 1996; Green et al. 1997), we will argue below that the OH (1720 MHz) masers that we have detected in G346.6 $-0.2$ and G32.8 $-0.1$ are directly associated with the SNRs themselves. From continued work of this kind it has become clear that these SNR OH (1720 MHz) masers represent a distinct class of OH masers in our Galaxy, separate from OH masers in star-forming regions and evolved stars. Moreover, evidence is steadily accumulating that the SNR OH (1720 MHz) masers are collisionally excited by H$_2$ molecules and are therefore a good tracer of SNR interactions with molecular clouds.

Observationally there are several important signatures that we look for in establishing whether a particular maser detection is associated with a SNR along the line of sight. First, we require close agreement in both position and velocity for the OH (1720 MHz) masers and the SNR. The masers should be found interior to, or along the radio continuum edges of, the SNR. For the three associations we have advocated here (Kes 78, Kes 41, and G346.6 $-0.2$) this is certainly the case (for a summary of maser detections in this work, see Table 4). Other potential associations like HB 3 and G27.4 $+0.0$ (Green et al. 1997) are rejected on this basis. Velocity information can also be extremely useful but it is often difficult to obtain. For example, in this work an H I absorption spectrum was available only toward Kes 41, yielding just a lower limit to the LSR velocity of the SNR. It has been noted in several instances where the LSR velocity of the SNR is known, that the maser velocities lie within a few km s$^{-1}$ of this value (Claussen et al. 1997; Green et al. 1997; Frail et al. 1996). Such close agreement is taken to imply that the masers originate in shocks transverse to the line of sight, and we have used this fact to derive kinematic
A second important observational constraint is that we require that any OH (1720 MHz) maser detection be accompanied by main-line emission or a 1612 MHz detection. More specifically, Goss & Robinson noted that for Goss (1968), the integrated line strength of [O I] at 63 μm that peaks toward the masers in W44 and 3C 391 (Reach & Rho 1996), and broad lines (∆v ~ 10–50 km s⁻¹) of CO and other millimeter/submillimeter lines at the location of masers toward W28, W44, W51C, and 3C 391 (Wootten 1977, 1981; Koo & Moon 1997; Frail & Mitchell 1998). Although no published searches have been made for any sign of molecular shocks from Kes 78, Kes 41, or G346.6-0.2, the inference can be drawn that SNRs with OH (1720 MHz) masers are prime candidates for such studies.

It should be stressed that while the detection of a OH (1720 MHz) maser spot in an SNR is strong evidence of a shock interaction with a molecular cloud, the converse is not true. According to Elitzur (1976), a strong inversion of the OH molecule at 1720 MHz works under a limited range of kinetic temperatures (25 ≤ T_k ≤ 200 K) and H₂ gas densities (10³ cm⁻³ ≤ n ≤ 10⁵ cm⁻³). Moreover, the maser process requires large column densities of OH with low velocity dispersion in order to produce coherent amplification. Thus, the absence of OH (1720 MHz) masers toward an SNR is not proof against an interaction, only that the conditions in the remnant are not favorable for their formation. For example, in this work we obtained null detections of OH (1720 MHz) toward Cas A and G109.1–1.0, both of which have some evidence of an interaction with an adjacent molecular cloud (Tatematsu et al. 1990; Keohane, Rudnick, & Anderson 1996; Koralesky & Rudnick 1998). Likewise, it is worth noting that OH (1720 MHz) masers are not the sole province of SNRs. Although 1720 MHz masers are less common in H II regions than are their main-line counterparts (Gaume & Mutel 1987), they do exist, and in some cases they have no accompanying main line or 1612 MHz emission. The isolated 1720 MHz detections that we made in W3 (§ 3) are one such example. Another is the bipolar outflow H II region S 106 with the main lines detected in absorption and bright OH (1720 MHz) maser emission (Loushin 1989). More recent modeling of the excitation of the OH molecule by Pavlakis & Kylafis (1996a, 1996b) demonstrates that strong inversions at 1720 MHz are possible with radiative pumping at the densities and strong infrared radiation associated with compact H II regions. Elitzur & de Jong (1978) further showed that OH masers can arise in the interface zone between the shock and ionization front driven by the H II region. This underscores the need to apply the selection criteria outlined above in order to determine whether a maser detection belongs to the class of H II regions or SNRs.

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