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VLA DETECTION OF THE EXCITING SOURCES OF THE MOLECULAR OUTFLOWS ASSOCIATED WITH L1448 IRS2, IRAS 05327+3404, L43, IRAS 22142+5206, L1211, AND IRAS 23545+6508

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RESUMEN

Presentamos observaciones sensitivas hechas con el "Very Large Array" a 3.6 cm hacia nueve campos conteniendo flujos moleculares. Detectamos candidatos para las fuentes excitadoras de flujos moleculares en seis de los campos: L1448 IRS2, IRAS 05327+3404, L43, IRAS 22142+5206, L1211, e IRAS 23545+6508. Discutimos los parámetros de estas fuentes, así como su relación con fuentes detectadas a otras longitudes de onda.

ABSTRACT

We present sensitive Very Large Array observations at 3.6 cm of nine fields containing molecular outflows. We detected candidates for the exciting sources of the molecular outflows in six of the fields: L1448 IRS2, IRAS 05327+3404, L43, IRAS 22142+5206, L1211, and IRAS 23545+6508. We discuss the parameters of these sources, as well as their relation with sources detected at other wavelengths.

Key Words: **ISM: JETS AND OUTFLOWS — STARS: FORMATION — STARS: MASS LOSS — RADIO CONTINUUM: STARS**

1. INTRODUCTION

The presence of powerful outflows seems to characterize the early life of most stars. Molecular observations of high velocity gas at the 0.1 pc scale trace the time-integrated effect of the outflow over the last 10^2–10^5 years (e.g., Fukui et al. 1993). In contrast, subarcsecond observations of the outflow exciting sources in the centimeter radio continuum reveal the presence of ionized gas that has left the star within the last several months or years (e.g., Anglada 1996; Rodríguez 1997).

Usually, the exciting sources of molecular outflows are heavily obscured (e.g., Anglada, Sepúlveda, & Gómez 1997; Sepúlveda 2001) and their detection and study has to be undertaken at wavelengths longer than several microns. In particular, sensitive observations at cm wavelengths made with interferometers provide accurate positions and flux densities of these sources and allow future, more refined studies. In order to update the sample of molecular outflows studied at cm wavelengths, in this paper we present a search for radio continuum sources, made at 3.6 cm, toward nine fields with recently reported molecular outflows that had not been previously observed at high sensitivity (that is, reaching rms levels of about 20 μJy) with the Very Large Array (VLA). Our observations detect candidates for the exciting sources in six of the fields.

2. OBSERVATIONS

Sensitive continuum observations of the nine fields containing outflows were made during 2000 August 17 using the VLA of the NRAO[2] in the D con-

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[2] NRAO is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

figuration. On-source integration times of about one hour were obtained for the observed fields. The absolute amplitude calibrator was 0137+331 (J2000 coordinates), with an adopted flux density of 3.23 Jy. The regions and the positions of the phase centers observed, the phase calibrators used and their bootstrapped flux densities are given in Table 1. The observations were made in both circular polarizations with an effective bandwidth of 100 MHz. The data were edited and calibrated following the standard VLA procedures and using the software package AIPS. We made cleaned, natural-weight maps of the regions. The rms noise at the center of the fields and synthesized beam dimensions of these maps are given in Table 1. The positions and flux densities of the sources detected are given in Table 2. We considered as detections only those signals above 5σ. In this table we also give proposed counterparts to the centimeter sources.

3. COMMENTS ON INDIVIDUAL REGIONS

In this section we discuss individually the regions studied. Several of the radio sources listed in Table 2 have no reported counterparts and are not further discussed by us.

3.1. *L1448 IRS2*

L1448 IRS2 (= IRAS 03222+3034) is a Class 0 object (O'Linger et al. 1999) that is embedded in a high density ammonia core (e.g., Anglada et al. 1989), in the L1448 dark cloud. L1448 IRS2 powers a large, bipolar CO and H_2 outflow (O'Linger et al. 1999; Eislöffel 2000), whose blue lobe is associated with HH 195 (Bally et al. 1997). Wolf-Chase, Barsony, & O'Linger (2000) suggest that two distinct outflows, with the orientation of their axes differing by $\sim 14°$, may be present, and that L1448 IRS2 may be a compact binary system (unresolved at their angular resolution of $\sim 7''$).

The source VLA 4, first detected by us at radio wavelengths, falls inside the error ellipsoid of IRAS 03222+3034 (L1448 IRS2). Our position coincides within $\sim 1''$ with the SCUBA 450 and 850 μm position given by O'Linger et al. (1999). We then identify this radio object with the exciting source of the outflow. In Figure 1 we show this source. Our data lack the angular resolution required to test the suggestion of Wolf-Chase et al. (2000) for a binary system, but this can be easily done with future observations using a more extended VLA configuration.

The source VLA 6 (see Table 2) was first detected by Anglada et al. (1989) at 6 cm, and coincides with L1448 IRS3. Curiel et al. (1990) showed it actually

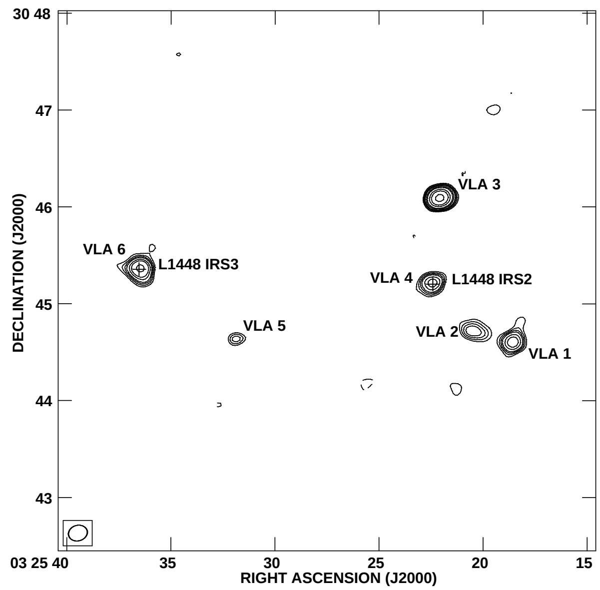

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Fig. 1. VLA map of the 3.6 cm continuum emission from the central region of the molecular outflows in L1448 IRS2 and L1448 IRS3. Contour levels are −3, 3, 4, 5, 6, 8, 10, 15, 20, and 30 times 25 μJy beam^{-1}. In this and the following maps the half-power contour of the synthesized beam is shown in the bottom left corner of the map. The positions of sources at other wavelengths are indicated with a cross and a label.

to be a double source at 6 and 2 cm. The components, with separation of about $6''$ approximately in the N-S direction, were named L1448N(A) and (B) by them. Both of these sources are Class 0 objects and drive outflows (Wolf-Chase et al. 2000 and references therein). Our data do not resolve the source into its two components. However, the total flux density measured by us at 3.6 cm agrees well with the interpolation from the Curiel et al. (1990) flux densities at 6 and 2 cm. This result suggests that the source has not varied significantly over a timescale of about 10 years.

The sources VLA 1 and 3 are detected at 20 cm in the NRAO VLA Sky Survey (NVSS; Condon et al. 1998). If we assume that the sources have no time variation in their flux densities, spectral indices of -1.2 ± 0.1 (VLA 1) and -0.6 ± 0.1 (VLA 3) are obtained, suggesting they are synchrotron background sources.

3.2. *AFGL 490-iki*

The AFGL 490-iki object (IRAS 03234+5843) is the driving source of a CO outflow with a clear bipolar morphology (see Lyder, Belton, & Gower 1998 and references therein), located $\sim 7'$ south of the energetic AFGL 490 outflow, in the Cam OB1 region.

TABLE 1

REGIONS OBSERVED AT 3.6 CM

Region	Phase Center[a] α(J2000)	δ(J2000)	Phase Calibrator	Bootstrapped Flux Density (Jy)	rms noise (μJy)	Synthesized Beam Size (arcsec)	PA (deg)
L1448 IRS2	03 25 22.5	+30 45 06	0336+323	1.601±0.003	25	11.8×9.6	−74
AFGL 490-iki	03 27 28.3	+58 54 10	0244+624	0.669±0.002	23	11.7×8.6	+52
IRAS 05327+3404	05 36 05.5	+34 06 11	0555+398	5.837±0.018	24	13.5×9.5	−77
NGC 2023 mm1	05 41 24.9	−02 18 09	0552+032	0.663±0.002	33	16.5×8.4	−43
L43	16 34 29.3	−15 47 01	1558−141	0.348±0.001	23	16.6×8.6	+22
IRAS 22103+5828	22 12 02.5	+58 42 57	2148+611	0.895±0.002	20	10.9×8.6	+36
IRAS 22142+5206	22 16 10.4	+52 21 25	2148+611	0.895±0.002	20	10.4×8.7	+33
L1211	22 47 12.2	+62 01 51	2148+611	0.895±0.002	21	11.3×8.6	+39
IRAS 23545+6508	23 57 05.2	+65 25 11	0019+734	0.579±0.001	22	11.1×8.0	+22

[a]Units of right ascension are hours, minutes, and seconds; units of declination are degrees, arcminutes, and arcseconds.

Lyder et al. (1998) classify this source as a pre-main-sequence B3–B4 star with a mass of $\sim 7 M_\odot$. We did not detect a counterpart to AFGL 490-iki at a 5-σ level of 0.1 mJy.

The source VLA 2 is detected in the NVSS and we estimate a spectral index of -0.9 ± 0.1 for it, consistent with a synchrotron background source.

3.3. *IRAS 05327+3404*

The source VLA 2, first detected by us at radio wavelengths, falls inside the error ellipsoid of IRAS 05327+3404 (see Figure 2). The radio position coincides within $\sim 1''$ with the optical position given by Magnier et al. (1996) for the source, proposed by these authors to be the driver of the optical and molecular outflow. This source has a peculiar morphology in the optical images, appearing as a star with a "tail" extending to the north. Magnier et al. (1996; 1999) propose that this is a bipolar CO outflow roughly in the direction of the tail. However, neither the bipolarity, nor the axis direction are clearly visible in their data.

3.4. *NGC 2023 mm1*

NGC 2023 mm1 is a Class 0 source, that drives a CO bipolar outflow (Sandell et al. 1999). We will assume that it is located at a distance of 400 pc (Anthony-Twarog 1982). We did not detect a centimeter counterpart to NGC 2023 mm1 at a 5-σ level of 0.17 mJy.

The source VLA 2 was originally detected by Rodríguez & Reipurth (1994) with a 3.6 cm flux density of 4.1 ± 0.5 mJy, very similar to that measured by us nine years later.

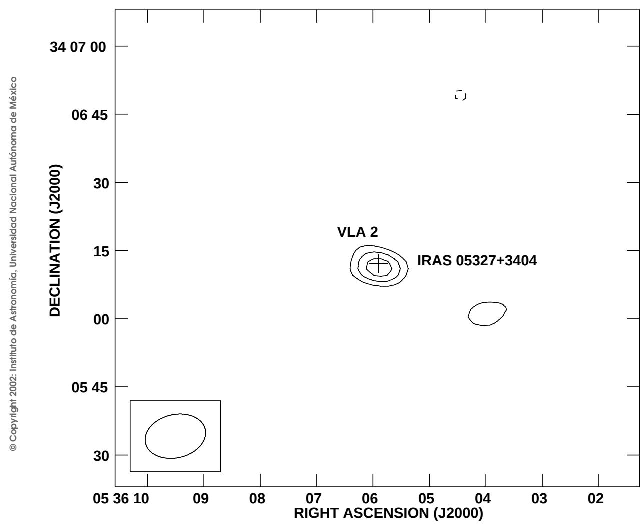

Fig. 2. VLA map of the 3.6 cm continuum emission from the central region of the molecular outflow near IRAS 05327+3404. Contour levels are −3, 3, 4, and 5 times 24 μJy beam^{-1}.

3.5. *L43*

The L43 outflow, in the northern part of the Ophiuchus complex is a highly asymmetrical outflow, with the blueshifted lobe much stronger than the redshifted one (see Mathieu et al. 1988; Bence et al. 1998). The CO outflow is associated with RNO91, which is also identified as IRAS 16316−1540. The source VLA 2 coincides to within $\sim 1''$ of the refined position for IRAS 16316−1540 (Myers et al. 1988), and we associate it with the exciting source of this outflow (see Figure 3). A detailed discussion of this source, a Class II protostar, is given by Bence et al. (1998). A recent study of the CO out-

TABLE 2

SOURCES DETECTED AT 3.6 CM

Region	VLA Source	Position[a] α(J2000)	δ(J2000)	Flux Density (mJy)	Counterpart	References
L1448 IRS2	1	03 25 18.56	+30 44 36.2	0.45 ± 0.03	20 cm	1
	2	03 25 20.50	+30 44 43.2	0.30 ± 0.03		
	3	03 25 22.09	+30 46 05.6	0.89 ± 0.03	20 cm	1
	4	03 25 22.43	+30 45 13.0	0.34 ± 0.03	IRS2/sub-mm	2
	5	03 25 31.88	+30 44 38.2	0.22 ± 0.03		
	6	03 25 36.49	+30 45 22.0	1.55 ± 0.08	IRS3/6 cm/2 cm	2, 3, 4
AFGL 490-iki	1	03 27 07.13	+58 51 39.5	0.90 ± 0.09		
	2	03 27 48.86	+58 51 12.1	9.8 ± 0.5[b]	20 cm	1
IRAS 05327+3404	1	05 36 04.20	+34 04 53.5	0.22 ± 0.03		
	2	05 36 05.89	+34 06 11.3	0.15 ± 0.03	IRAS	5
NGC 2023 mm1	1	05 41 38.11	−02 15 42.4	5.4 ± 1.1[c]		
	2	05 41 41.39	−02 19 48.0	4.0 ± 0.7	3.6 cm	6
L43	1	16 34 24.13	−15 44 55.2	0.34 ± 0.04		
	2	16 34 29.30	−15 47 01.7	0.36 ± 0.02	IRAS	7
	3	16 34 39.64	−15 45 37.3	0.30 ± 0.06		
	4	16 34 41.89	−15 49 17.5	4.5 ± 0.5		
IRAS 22103+5828	1	22 11 31.07	+58 44 30.0	4.5 ± 0.9	20 cm	1
	2	22 12 04.40	+58 42 06.7	0.12 ± 0.02		
	3	22 12 23.13	+58 46 06.8	2.5 ± 0.5	20 cm	1
IRAS 22142+5206	1	22 16 10.18	+52 21 22.3	0.21 ± 0.03	IRAS	
	2	22 16 10.47	+52 21 35.4	0.32 ± 0.03	Mid-IR?	8
L1211	1	22 47 01.41	+62 01 35.2	0.16 ± 0.03	MMS1	9
	2	22 47 07.61	+62 03 20.5	0.17 ± 0.03		
	3	22 47 11.33	+62 01 21.8	0.26 ± 0.04		
	4	22 47 16.46	+62 02 50.1	0.16 ± 0.04		
	5	22 47 17.00	+62 02 37.4	0.18 ± 0.04	MMS4	9
IRAS 23545+6508	1	23 57 02.89	+65 24 39.9	0.79 ± 0.03	6 cm	10
	2	23 57 04.10	+65 28 23.2	1.25 ± 0.10	20 cm	1
	3	23 57 06.20	+65 25 17.1	2.44 ± 0.03	IRAS/opt./6 cm	10
	4	23 57 06.81	+65 24 52.7	0.14 ± 0.02	6 cm	10
	5	23 57 12.95	+65 25 47.5	1.27 ± 0.03	20 cm	1
	6	23 57 15.56	+65 25 08.7	0.54 ± 0.02		
	7	23 57 16.52	+65 26 36.1	0.36 ± 0.04	6 cm	10

[a]Units of right ascension are hours, minutes, and seconds; units of declination are degrees, arcminutes, and arcseconds.
[b]Extended source. [c]Double source.

References.—(1) NVSS: Condon et al. 1998; (2) O'Linger et al. 1999; (3) Anglada et al. 1989; (4) Curiel et al. 1990; (5) Magnier et al. 1996; (6) Rodríguez & Reipurth 1994; (7) Myers et al. 1988; (8) Meixner et al 1999; (9) Tafalla et al. 1999; (10) Dewdney et al. 1991.

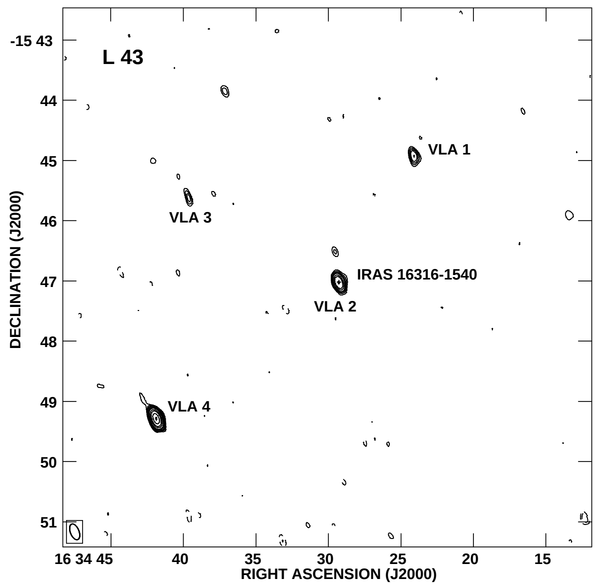

Fig. 3. VLA map of the 3.6 cm continuum emission from the central region of the molecular outflow in L43. Contour levels are −3, 3, 4, 5, 6, 8, 10, 15, 20, 30, and 40 times 23 μJy beam^{-1}.

flow is presented by Lee et al. (2000), while Kumar et al. (1999) detected and studied the outflow in the 2.122 μm line of H_2.

3.6. *IRAS 22103+5828*

We did not detect a centimeter counterpart to IRAS 22103+5828, the proposed exciting source of this molecular outflow (Yonekura et al. 1998), at a 5-σ level of 0.1 mJy. Source VLA 2 (Figure 4) falls inside a $C^{18}O$ core, but outside the lobes of the mapped outflow.

The sources VLA 1 and 3 are detected in the NVSS and we estimate spectral indices of -0.7 ± 0.1 (VLA 1) and -0.5 ± 0.1 (VLA 3), suggesting that they are synchrotron background sources.

3.7. *IRAS 22142+5206*

Both radio sources detected are close to the center of the molecular outflow reported by Dobashi et al. (1998). The source VLA 1 falls inside the error ellipsoid of IRAS 22142+5206 (see Figure 5). This IRAS source has been associated in the literature with both young and evolved objects.

Comoretto et al. (1988) reported strong water maser emission toward this source. Its IRAS spectrum (with flux densities of 21, 92, 172, and 140 Jy at 12, 25, 60, and 100 μm, respectively) peaks at 60 μm, suggesting an AGB star or a proto-planetary nebula candidate. However, Dobashi et al. (1998)

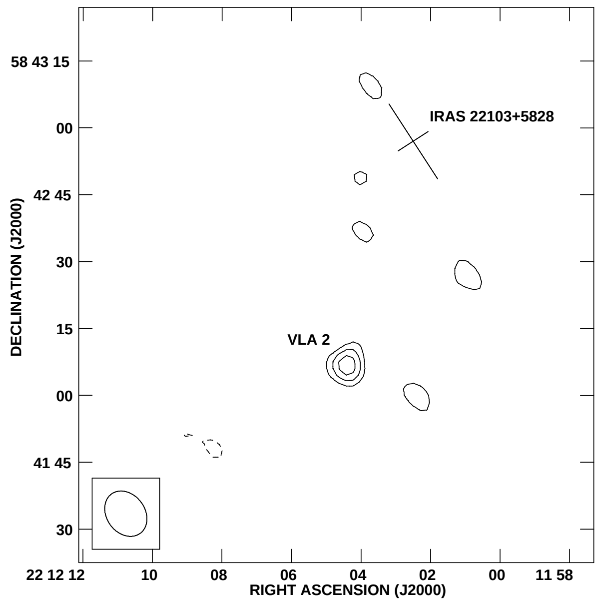

Fig. 4. VLA map of the 3.6 cm continuum emission from the central region of the molecular outflow near IRAS 22103+5828. Contour levels are −3, 3, 4, and 5 times 20 μJy beam^{-1}.

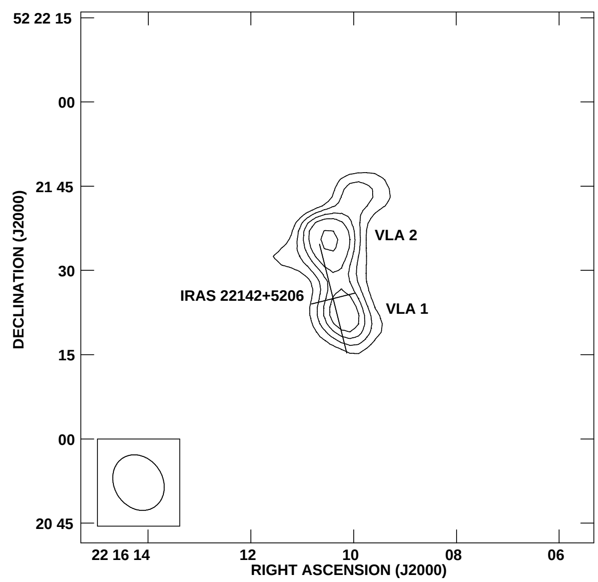

Fig. 5. VLA map of the 3.6 cm continuum emission from the central region of the molecular outflow near IRAS 22142+5206. Contour levels are −3, 3, 4, 5, 6, and 8 times 20 μJy beam^{-1}.

find extensive CO emission and a massive molecular outflow associated with IRAS 22142+5206, strongly favoring a protostellar nature. The *HST* survey of Ueta, Meixner, & Bobrowsky (2000) failed to show indications of optical nebulosity associated

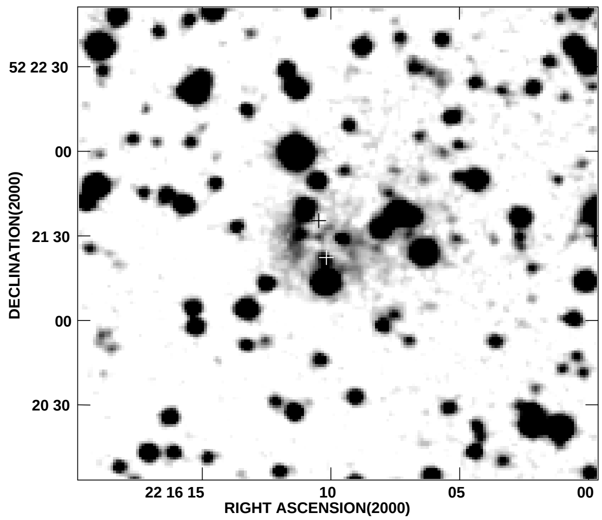

Fig. 6. Red image of the IRAS 22142+5206 region from the POSS-II (greyscale). The positions of the two VLA sources are shown with crosses. Note the presence of faint nebulosity.

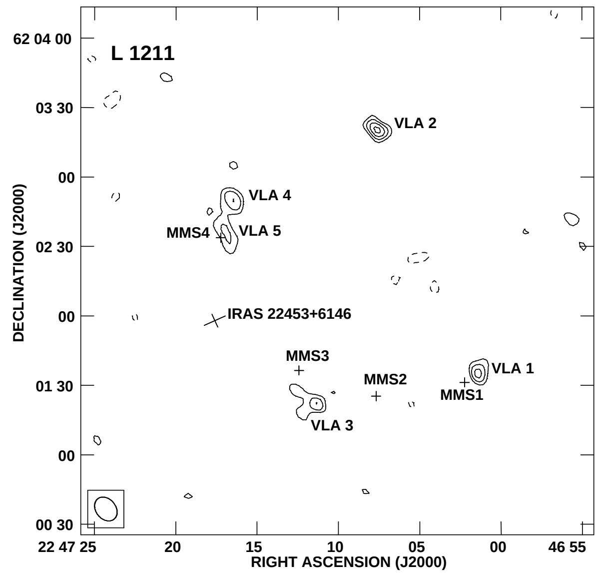

Fig. 7. VLA map of the 3.6 cm continuum emission from the central region of the molecular outflow in L1211. Contour levels are -3, 3, 4, 5, and 6 times 21 μJy beam^{-1}.

with IRAS 22142+5206. However, we clearly find evidence of associated nebulosity in the red image of the Second Palomar Observatory Sky Survey (POSS-II), as shown in Figure 6. This nebulosity is very faint and extended and may have been missed in the relatively small field used by Ueta et al. (2000). This discrepancy requires further investigation. From the Fig. 6 image we also find that VLA 1 appears to be associated with an optical object. Ueta et al. (2000) reported a second, weaker star $\sim 2''$ east of the main source, although they did not discuss the nature of the object.

Meixner et al. (1999) report a mid-IR source located $7''$ north of the nominal IRAS position. We believe that this source could be associated with VLA 2. So, there are at least three different objects (VLA 1, VLA 2, and Ueta et al.'s weak source $\sim 2''$ to the east of their main source) inside a region of a few arcsec in size around the position of the IRAS source. The possibility that the sources VLA 1 and VLA 2 correspond to two different objects, located near in the sky but physically unrelated, should be studied with additional observations.

3.8. *L1211*

This is a very crowded region, with several mm and cm sources present. As can be seen in Fig. 6, the sources VLA 1 and VLA 5 appear to be spatially associated with the sources MMS1 and MMS4 (Tafalla et al. 1999), respectively. It is interesting that the two molecular outflows in the region are attributed by Tafalla et al. (1999) to these two mm sources. We thus propose that VLA 1 and VLA 5 are associated with the exciting sources of these two outflows.

3.9. *IRAS 23545+6508*

The brightest source in our field, VLA 3, falls very close to the IRAS 23545+6508 error ellipsoid (see Figure 8), that was proposed as the exciting source of the CO outflow mapped by Yang & Wu (1998). Source VLA 3 is clearly extended, with a deconvolved angular size of $\sim 12'' \times 10''$. Dewdney et al. (1991) detect a star in the R band that seems to fall at the center of VLA 3 (see Figure 7). These authors also report a 6 cm flux density of 0.97 mJy for this source, while we find a 3.6 cm flux density of 2.44 mJy. This result appears to suggest an optically thick H II region. However, the source has a brightness temperature of a few K at cm wavelengths, while a brightness temperature of 10^4 K is expected for an optically thick H II region. Further observations are needed to understand this discrepancy. The sources VLA 1, 5, and 6 were detected also by Dewdney et al. (1991) at 6 cm, but no flux densities are given for them.

There is also a fainter, compact source, VLA 4, located close to the IRAS 23545+6508 error ellipsoid (see Fig. 8). Because of its compact size, we suggest that VLA 4 may be the true exciting source of the outflow.

The outflow morphology, as mapped by Yang & Wu (1998), is complex and it appears to continue

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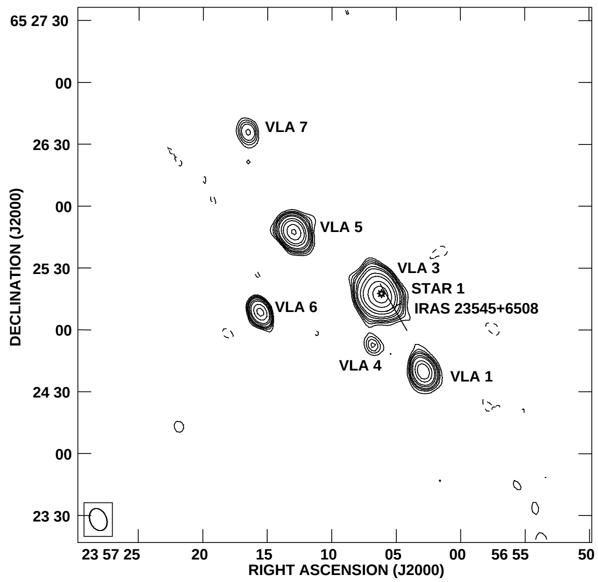

Fig. 8. VLA map of the 3.6 cm continuum emission from the central region of the molecular outflow near IRAS 23545+6508. Contour levels are −3, 3, 4, 5, 6, 8, 10, 15, 20, 30, and 40 times 22 μJy beam^{-1}. The star marks the position of the R-band object detected by Dewdney et al. (1991).

outside the region mapped by them. We think that the presence of several, partially overlapping outflows that could be excited by the observed VLA sources is a possibility that cannot be excluded. In fact, source VLA 1 is the source that appears to be closer to the center of symmetry of the main outflow lobes; so, this source is also a valid candidate, alternative to IRAS 23545+6508, to drive the main outflow. A region of blueshifted emission is seen near the position of VLA 7; so, this source could be associated with another, partially mapped CO outflow. A more detailed mapping of this outflow region, with better angular resolution and sensitivity, is required.

The sources VLA 2 and VLA 5 are detected in the NVSS and we estimate spectral indices of -0.8 ± 0.1 (VLA 2) and -0.8 ± 0.1 (VLA 5), suggesting they are synchrotron background sources.

4. DISCUSSION

In the nine fields mapped, we have detected a total of 33 sources inside the FWHM of the primary beam ($5\farcm4$ at 3.6 cm) above a 5-σ level, which was typically 0.12 mJy at the center of the field. Using equation (A11) of Anglada et al. (1998), the expected number of background sources in the nine fields is 7 ± 3. Thus, most of the sources appear to be related to the star-forming regions studied.

We have detected new VLA continuum sources toward the center of symmetry of seven of the 10 outflows studied (in addition to L1448 IRS3 that was previously detected with the VLA), and we propose that these radio sources are tracing the driving sources of these outflows. Our observations provide a position for these sources with an accuracy of $\sim 0\farcs5$, which, in general, results in an improvement with respect to those of previous determinations. The number of expected background objects suggests that, in addition to the proposed outflow exciting sources, a large fraction of the remaining detected radio sources should also be associated with the star-forming regions.

In Table 3 we list the parameters of the associated molecular outflows and their exciting sources (we do not include L1448 IRS3 in our discussion since this cm source was already known and was included in the previous studies quoted below). The momentum rate in the outflow, $\dot{P}$, is estimated from CO observations. From a sample of 33 outflow exciting sources of low bolometric luminosity, Anglada (1996) obtains that the momentum rate in the outflow is correlated with the radio luminosity of the exciting source at 3.6 cm, according to $(\dot{P}/M_\odot\,\mathrm{yr}^{-1}\,\mathrm{km\,s}^{-1}) = 10^{-2.5}(S_\nu d^2/\mathrm{mJy\,kpc}^2)^{1.1}$. For low luminosity sources it is expected that the contribution from photoionization is negligible and the proposed mechanism invoked to account for the observed radio emission is shock ionization. Then, a correlation between the observed radio luminosity and the momentum rate in the outflow is expected (see Anglada et al. 1998 and references therein). The observed correlation is consistent with the shock models of Curiel et al. (1987; 1989) and an efficiency for the shock ionization of $\sim 10\%$.

Unfortunately, only for a few of the sources discussed here can we test whether or not they follow the correlation. For the sources IRAS 22142+5206, IRAS 23545+6508 and AFGL490-iki (this last one has not been detected) the bolometric luminosity of the associated object is high enough to produce detectable radio emission by photoionization. In fact, for these three sources the expected radio continuum luminosity obtained assuming optically thin emission, and the rate of ionizing UV photons predicted by Thompson (1984) for the corresponding bolometric luminosities, exceeds the values observed (in the case of AFGL490-iki, the upper limit obtained). This has been found in other young stellar objects of relatively high luminosity. Carral et al. (1999) propose that if these sources contain multiple systems, this situation can account for the observed discrep-

TABLE 3

PROPERTIES OF THE CENTRAL SOURCES AND OUTFLOWS

Region	VLA Source	d (kpc)	$L_{\rm bol}$ ($L_\odot$)	$S_\nu d^2$ (mJy kpc^2)	$\dot{P}$ ($M_\odot\,{\rm yr}^{-1}\,{\rm km\,s}^{-1}$)	References
L1448 IRS2	4	0.3	5.2	0.031	2.4×10^{-4}	1
AFGL 490-iki	···	0.975	1100	< 0.11	2.5×10^{-3}	2, 3
IRAS 05327+3404	2	1.2	41–82	0.22	2.8×10^{-6}	3, 4, 5
NGC 2023 mm1	···	0.4	7	< 0.026	1.4×10^{-3}	6
L43	2	0.16	4.3	0.0092	5.0×10^{-7}	7, 8
IRAS 22103+5828	···	0.9	67	< 0.081	5.3×10^{-4}	9
IRAS 22142+5206	1/2	4.5	16100	4.25/6.48	1.0×10^{-3}	10
L1211	1	0.725	< 12	0.084	5.1×10^{-5}	3, 11
L1211	5	0.725	35	0.095	1.3×10^{-4}	3, 11
IRAS 23545+6508	3	1.4	4000	4.78	2.5×10^{-4}	12

References.—(1) O'Linger et al. 1999; (2) Lyder et al. 1998; (3) This paper; (4) Magnier et al. 1996; (5) Magnier et al. 1999; (6) Sandell et al. 1999; (7) Myers et al. 1988; (8) Bence et al. 1998; (9) Yonekura et al. 1998; (10) Dobashi et al. 1998; (11) Tafalla et al. 1999; (12) Yang & Wu 1998.

ancies. This could be the case for IRAS 22142+5206, where at least three different objects are found inside a region of a few arcsec in size. Alternatively, a high mass accretion rate can quench the development of an observable ionized region and has also been proposed as an explanation to account for the lack of radio continuum emission in high luminosity objects (e.g., Osorio, Lizano, & D'Alessio 1999). Of the remaining objects, the radio sources detected in L1448-IRS2 and L1211 do fall very close to the observational correlation between the outflow momentum rate and the radio continuum luminosity (Anglada 1996). The source with the largest discrepancy is IRAS 05327+3404. However, it should be noted that the outflow momentum rates can have considerable uncertainties. This is particularly true for the case of the possible CO outflow associated with the source IRAS 05327+3404 because of the poor quality of the data available (Magnier et al. 1999), and perhaps for the outflow near NGC2023 mm1 (Sandell et al. 1999).

Future observations with higher sensitivity, such as those that could be performed with the Expanded Very Large Array (EVLA), will allow a more complete census of the incidence, distribution of flux densities, and spectral indices of the centimeter radio continuum sources associated with molecular outflows. Also, the EVLA will allow sensitive, subarcsecond angular resolution observations to be carried out routinely, so that a survey of outflow sources at centimeter wavelengths with both high sensitivity and high angular resolution will become feasible. If these observations are combined with millimeter and far-IR data with an angular resolution high enough to separate the contributions of the components in binary and multiple systems, it would become possible to more reliably relate the properties of the radio continuum emission to the luminosity of the embedded objects.

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REFERENCES

Anthony-Twarog, B. J. 1982, AJ, 87, 1213

Anglada, G. 1996, in Radio Emission from the Stars and the Sun, ed. A.R. Taylor & J.M. Paredes, ASP Conf. Ser., 93, 3

Anglada, G., Rodríguez, L. F., Torrelles, J. M., Estalella, R., Ho, P. T. P., Cantó, J., López, R., & Verdes-Montenegro, L. 1989, ApJ, 341, 208.
Anglada, G., Sepúlveda, I., & Gómez, J. F. 1997, A&AS, 121, 255
Anglada, G., Villuendas, E., Estalella, R., Beltrán, M. T., Rodríguez, L. F., Torrelles, J. M., & Curiel, S. 1998, AJ, 116, 2953
Bally, J., Devine, D., Alten, V., & Sutherland, R. S. 1997, ApJ, 478, 603
Bence, S. J., Padman, R., Isaak, K. G., Wiedner, M. C., Wright, G. S. 1998, MNRAS, 299, 965
Carral, P., Kurtz, S., Rodríguez, L. F., Martí, J. Lizano, S., & Osorio, M. 1999, RexMexAA, 35, 97
Comoretto, G. et al. 1988, A&AS, 84, 179
Condon, J. J., Cotton, W. D., Greisen, E. W., Yin, Q. F., Perley, R. A., Taylor, G. B., & Broderick, J. J. 1998, AJ, 115, 1693.
Curiel, S., Cantó, J., & Rodríguez, L. F. 1987, RevMexAA, 14, 595
Curiel, S., Raymond, J. C., Moran, J. M., Rodríguez, L. F., & Cantó, J. 1990, ApJ, 365, L85
Curiel, S., Rodríguez, L. F., Cantó, J., Bohigas, J., Roth, M., & Torrelles, J. M. 1989, Ap. Lett. Comm., 27, 299
Dewdney, P. E., Roger, R. S., Purton, C. R., & McCutcheon, W. H. 1991, ApJ, 370, 243
Dobashi, K. Yonekura, Y., Hayashi, Y., Sato, F., & Ogawa, H. 1998, ApJ, 115, 777
Eislöffel, J. 2000, A&A, 354, 236
Fukui, Y., Iwata, T., Mizuno, A., Bally, J., Lane, A. P. 1993, in Protostars and Planets III, eds. E. H. Lay & J. I. Lunine (Tucson: U. of Arizona Press), 603
Kumar, M. S. N., Anandarao, B. G., & Davis, C. J. 1999, A&A, 344, L9
Lee, C. F., Mundy, L. G., Reipurth, B., Ostriker, E. C., & Stone, J. M. 2000, ApJ, 542, 925
Lyder, D. A., Belton, D. S., Gower, A. C. 1998, ApJ, 116, 840
Magnier, E. A., Waters, L. B. F. M., Kuan, Y. J., Chu, Y. H., Taylor, A. R., Matthews, H. E., & Martín, E. L. 1996, A&A, 305, 936
Magnier, E. A., Waters, L. B. F. M., Groot, P. J., van den Ancker, M. E., Kuan, Y.-J., & Martín, E. L. 1999, A&A, 346, 441
Mathieu, R. D., Myers, P. C., Schild, R. E., Benson, P. J., Fuller, G. A. 1988, ApJ, 330, 385
Meixner, M., Ueta, T., Dayal, A., Hora, J. L., Fazio, G., Hrivnak, B. J., Skinner, C. J., Hoffmann, W. F., & Deutsch, L. K. 1999, ApJS, 122, 221
Myers, P. C., Heyer, M. L., Snell, R. L., & Goldsmith, P. F. 1988, ApJ, 324, 907
O'Linger, J., Wolf-Chase, G., Barsony, M., & Ward-Thompson, D. 1999, ApJ, 515, 696
Osorio, M., Lizano, S., & D'Alessio, P. 1999, ApJ, 525, 808
Rodríguez, L. F. 1997 in IAU Symp. 182, Herbig-Haro Flows and the Birth of Stars, eds. B. Reipurth & C. Bertout (Dordrecht: Kluwer), 83
Rodríguez, L. F., & Reipurth, B. 1994, A&A, 281, 882
Sepúlveda, I. 2001, Ph.D. Thesis, University of Barcelona
Sandell, G., et al. 1999, ApJ, 519, 236
Tafalla, M., Myers, P. C., Mardones, D., & Bachiller, R. 1999, A&A, 348, 479
Thompson, R. I. 1984, ApJ, 283, 165
Ueta, T., Meixner, M., & Bobrowsky, M. 2000, ApJ, 528, 861
Wolf-Chase, G.A., Barsony, M., & O'Linger, J. 2000, ApJ, 120, 1467
Yang, C., & Wu, Y. 1998, Chin. Astron. Astrophys., 22, 451
Yonekura, Y. Dobashi, K., Hayashi, Y., Sato, F., Ogawa, H., & Fukui, Y. 1998, ApJ, 115, 2009

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