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Letter to the Editor

The surroundings of the superluminal source GRS 1915+105

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Abstract. We have carried out radio studies of the surroundings of the superluminal microquasar GRS 1915+105. Our main goal was to understand the possible relation of GRS 1915+105 with two infrared/radio sources that appear symmetrically located with respect to GRS 1915+105 and aligned with the position angle of the relativistic ejecta. We have also studied a nearby supernova remnant to test if the event that created the remnant could have been the progenitor of this hard X-ray binary.

Key words: ISM: HII regions – ISM: individual objects: IRAS 19124+1106, IRAS 19132+1035, SNR 45.7-0.4 – ISM: supernova remnants – X-rays:stars

1. Introduction

Great advances have been made at radio, infrared, and X-ray wavelengths in the study of the microquasar GRS 1915+105 (Mirabel & Rodríguez 1994; 1998), the first superluminal source found in our Galaxy. Much less attention has been paid to its surroundings, in particular trying to search for nearby supernova remnants that could be associated to the formation of this hard X-ray binary, and also to understand where in the interstellar medium is the large kinetic energy of the relativistic ejecta (reaching 10^{43} ergs; Rodríguez & Mirabel 1999) being dissipated.

In this paper we present a large-scale mosaic image at 20-cm continuum of the environment of GRS 1915+105 searching for nearby supernova remnants and other extended objects. We also report on extensive radio continuum and recombination line studies of two infrared/radio sources, IRAS 19124+1106 and IRAS 19132+1035, that appear symmetrically located with respect to GRS 1915+105 and aligned with the position angle of the relativistic ejecta. All the observations were made with the Very Large Array of NRAO[1].

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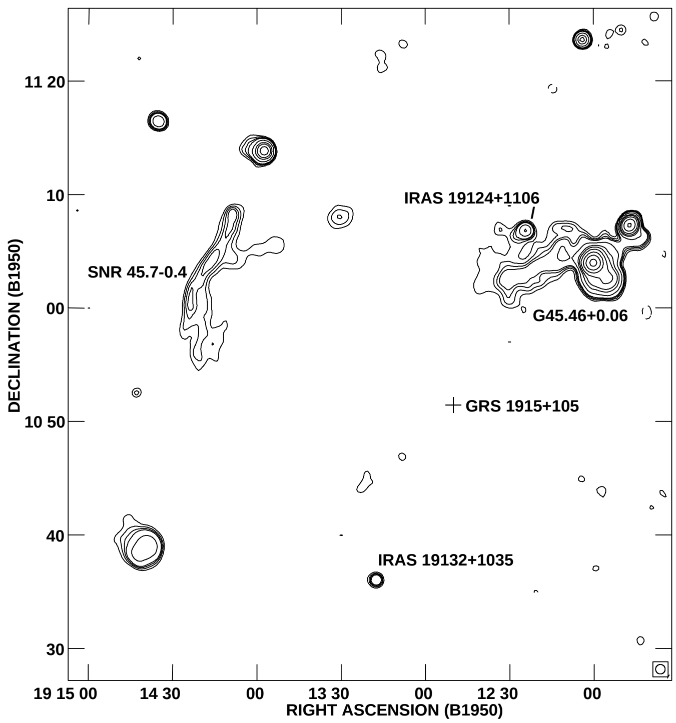

Fig. 1. VLA mosaic at 20-cm of the surroundings of GRS 1915+105. Contours are -4, 4, 6, 8, 10, 20, 40, 60, 100, 200, 400, and 800 times 3 mJy beam^{-1}. The half power contour of the beam is shown in the bottom right corner. The arrows indicate the position angle of the relativistic ejecta.

2. Large scale 20-cm continuum map

During 1997 December 14 we did a 3×3 mosaic of the surroundings of GRS 1915+105 at 20-cm continuum using the VLA in the D configuration. The resulting image is shown in Fig. 1. The most important objects in the region are identified in this Figure. GRS 1915+105 was undetectable at the epoch of the observations and its position is marked with a cross. To its NW and SE we can see the two IRAS sources, IRAS 19124+1106 and IRAS 19132+1035, that will be dis-

Table 1. Flux densities of IRAS 19124+1106 and IRAS 19132+1035

IRAS	S_ν(20-cm) (mJy)	S_ν(6-cm) (mJy)	S_ν(2-cm) (mJy)
19124+1106	114±4	130±4	114±6
19132+1035	60±4	63±4	52±6

cussed below. IRAS 19124+1106 appears projected in close association with a complex of H II regions that includes well-studied sources as G45.46+0.06.

To the NE of GRS 1915+105 we can see the supernova remnant SNR 45.7-0.4. This remnant was first observed at 30.9 MHz by Kassim (1988) with the Clark Lake telescope. It was later observed by Fürst et al. (1987) at 1.4, 2.7, 4.7, and 10.6 GHz with the Bonn telescope. The Bonn observations show spectral indices in the range of -0.3 to -0.5, and at 4.75 GHz 21% polarization in the arc-shaped structure shown in Fig. 1.

Are SNR 45.7-0.4 and GRS 1915+105 related? In the sky, and assuming a distance of 12.5 kpc, GRS 1915 appears displaced by about 40 pc from the centroid of SNR 45.7-0.4. The proper motion study of GRS 1915+105 by Dhawan, Mirabel, & Rodríguez (1998) sets an upper limit of 100 km s^{-1} for the velocity of the source with respect to its galactic position. Then, if GRS 1915+105 is a binary ejected during the supernova event that produced SNR 45.7-0.4, it required about 400,000 years to get to its present position. This time interval seems to be much larger that typical lifetimes for detectable supernovae (∼100,000 years) and we consider unlikely a common origin for both objects.

3. IRAS 19124+1106 and IRAS 19132+1035

These two bright IRAS sources are also relatively bright radio continuum sources and appear symmetrically located with respect to GRS 1915+105 (see Fig. 1). Furthermore, their position angle with respect to GRS 1915+105 is very similar to that of the relativistic ejecta (∼150°). IRAS 19124+1106 has PSC IRAS flux densities at 12, 25, 60, and 100 μm of 3.9, 19.6, 260.6, and 581.5 Jy, while IRAS 19132+1035 has PSC IRAS flux densities at 12, 25, 60, and 100 μm of 6.9, 34.0, 277.4, and 488.8 Jy. The IRAS colors are characteristic of embedded H II regions.

3.1. Matching-beam continuum

We carried out matching-beam (∼4″) observations of the two IRAS sources by observing at 20-cm (B configuration; 1997 February 24), 6-cm (C configuration; 1996 April 22), and 2-cm (D configuration; 1996 September 29). In all cases 1923+210 was the phase calibrator and either 1328+307 or 0134+329 the amplitude calibrator. Both sources show the flat spectra characteristic of optically-thin H II regions (see Table 1).

In Figs. 2 and 3 we show the matching-beam maps of IRAS 19124+1106 and IRAS 19132+1035, respectively, at 20, 6, and 2-cm. IRAS 19124+1106 appears to be a classical cometary H II region. There is, however, a remarkable feature

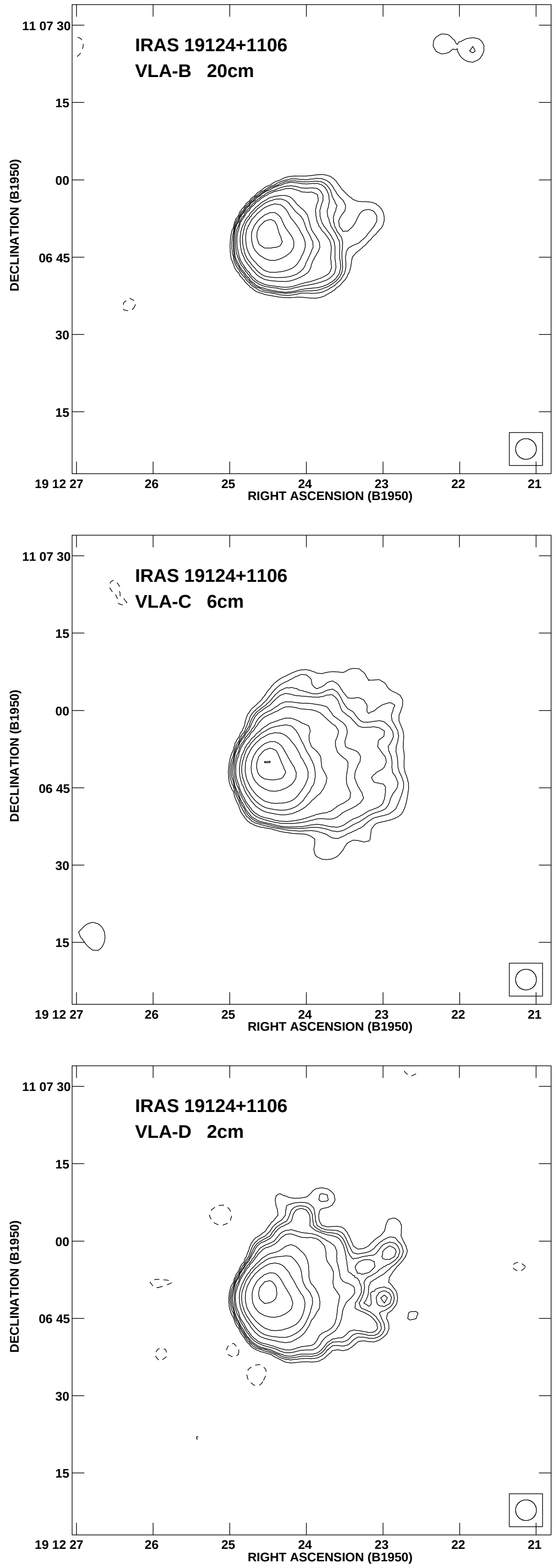

Fig. 2. VLA maps at 20 (*top*), 6 (*middle*), and 2 cm (*bottom*) of IRAS 19124+1106. The half power contour of the beam, with diameter of 4″, is shown in the bottom right corner. Contours are -4, 4, 6, 8, 10, 15, 20, 40, 60, 100, 200, 300, and 400 times 0.05 mJy beam^{-1}.

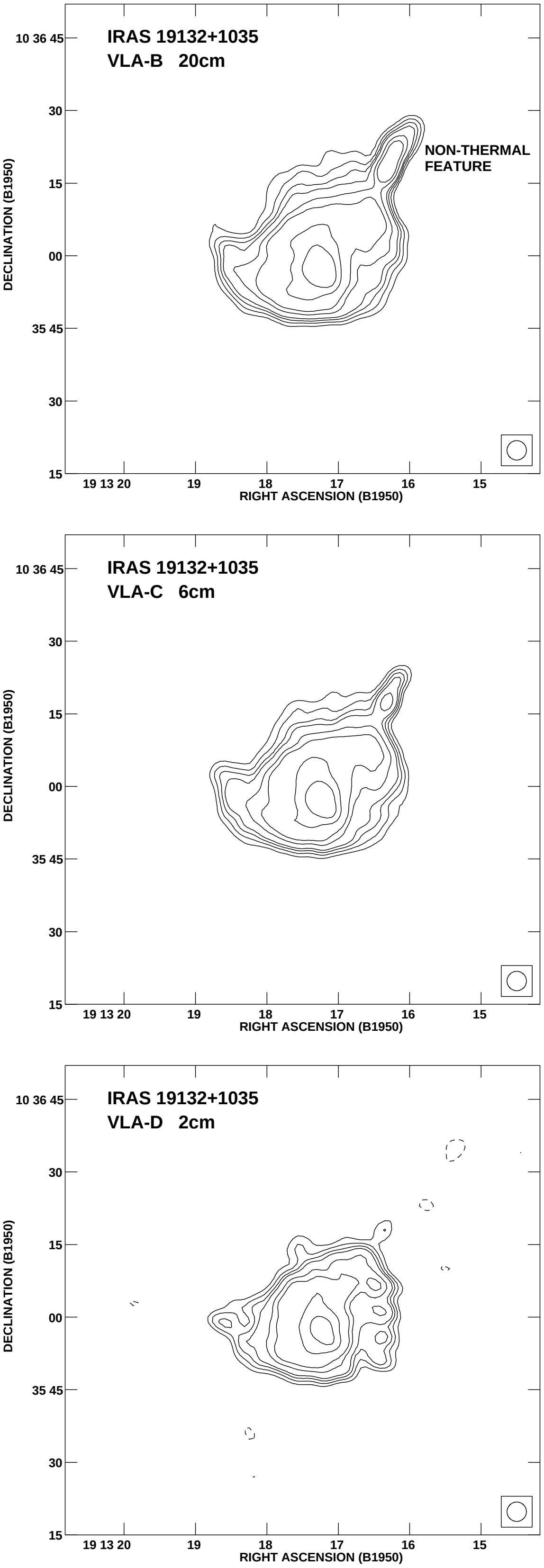

Fig. 3. VLA maps at 20 (*top*), 6 (*middle*), and 2 cm (*bottom*) of IRAS 19132+1035. The half power contour of the beam, with diameter of 4″, is shown in the bottom right corner. Contours are -4, 4, 6, 8, 10, 15, 20, 40, 60, 100, 200, 300, and 400 times 0.05 mJy beam^{-1}.

in IRAS 19132+1035. To its northwest edge a linear feature of non-thermal spectrum is clearly observable. The approximate flux densities for this feature at 20, 6, and 2-cm are 5, 2, and $\leq$1 mJy, respectively, for a spectral index of -0.8. This feature points back approximately to GRS 1915+105. There are several possible explanations for this non-thermal feature.

1) It could be a non-thermal jet produced by the interaction of the ejecta from GRS 1915+105 with the H II region. Furthermore, it can be speculated that the interaction of the relativistic ejecta with the molecular cloud at this position (Chaty et al. 1998) could have induced star formation.

2) It could be a background source that happens to lie along the line of sight. This possibility seems unlikely, given that the lineal feature is relatively bright ($\sim$5 mJy at 20-cm) and that it is aligned toward GRS 1915+105.

3) The feature could be a non-thermal jet emanating from the star that ionizes the H II region or even from one of the lower-mass stars that probably formed in this region, since stars tend to form in groups. Radio continuum jets have been observed to emanate from many young stars. However, the majority are of thermal (i. e. free-free) nature (Rodríguez 1997), although a few appear to be non-thermal (i. e. synchrotron) emitters (Wilner et al. 1997).

3.2. H92α radio recombination line

In addition to the continuum study, we observed the H92α recombination line during 1998 January 15. At that epoch the array was in its lowest angular resolution D configuration. The observations were made using 0134+329 as absolute amplitude calibrator, 1226+023 as bandpass calibrator, and 1923+210 as phase calibrator.

The spatially-integrated continuum and H92α line parameters are given in Table 2 and the H92α spectra are shown in Fig. 4. The observed recombination line parameters are also typical of H II regions. We have used the measured v_{LSR} velocities and the galactic rotation curve of Brand & Blitz (1993) to estimate distances of 7.4 and 6.0 kpc for IRAS 19124+1106 and IRAS 19132+1035, respectively. For IRAS 19124+1106 we have a near/far ambiguity in the kinematic distance and we adopted the far distance because of its probable association with the G45.46+0.06 H II region complex that is known to be located behind the tangencial point (Downes et al. 1980). Given its relatively high v_{LSR}, we assumed that IRAS 19132+1035 is located close to the tangencial point. The derived parameters from the the H92α and 3.6-cm continuum observations are given in Table 3.

The derived IRAS luminosities are 3.3$\times$10^4 $L_\odot$ and 2.4$\times$10^4 $L_\odot$, for IRAS 19124+1106 and IRAS 19132+1035, respectively. These luminosities correspond to an O9.5 ZAMS star and a B0 ZAMS star, and agree well with the stellar classes inferred from the ionized gas (see Table 3).

We conclude that the parameters of IRAS 19124+1106 and IRAS 19132+1035 are perfectly consistent with those of compact H II regions that seem to be closer than GRS 1915+105 (7.4 kpc and 6.0 kpc, instead of 12.5 kpc). The only anomaly remains

Table 2. H92α Radio Recombination Line Observations

IRAS	S_C (mJy)	S_L (mJy)	Δv (km s^{-1})	v$_{LSR}$ (km s^{-1})	Angular Size ($''$)
19124+1106	131.7±0.9	14.9±1.0	25.4±1.9	57.3±0.9	15±2
19132+1035	61.0±0.3	8.9±1.1	23.4±3.2	75.7±1.6	20±3

Table 3. Derived Parameters from the H92α and 3.6-cm Continuum Observations

Source	Distance (kpc)	T_e^* (K)	Physical Size (pc)	$\dot{N}_i$ (phot s^{-1})	ZAMS Star Required	n_e (cm^{-3})	M$_{HII}$ (M$_\odot$)	τ_c (nepers)
IRAS 19124+1106	7.4	6800±600	0.54	6.0×10^{47}	O9	5.4×10^{2}	3.5	0.002
IRAS 19132+1035	6.0	5900±1000	0.59	1.7×10^{47}	B0	2.6×10^{2}	2.1	0.001

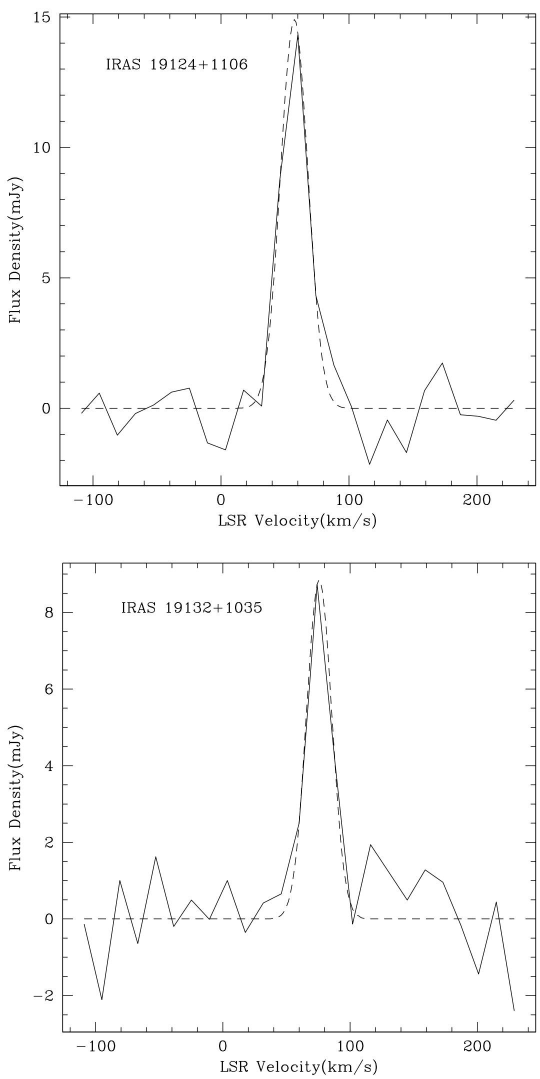

Fig. 4. H92α spectra of IRAS 10124+1106 (*top*) and IRAS 19132+1035 (*bottom*). The dashed line is the least-squares Gaussian fit to the data.

the linear non-thermal feature observed in IRAS 19132+1035. It should also be noted that IRAS 19132+1035 has a sharp edge towards the south, that could be related to either a bow shock or an ionization front.

4. Conclusions

1. We find that the supernova SNR 45.7-0.4 is too far from GRS 1915+105 too ascribe a common origin to both objects.
2. The bright IRAS/radio sources IRAS 19124+1106 and IRAS 19132+1035 appear to be H II regions ionized by late O or early B stars. We find that a peculiar non thermal feature is associated with IRAS 19132+1035, but cannot reach a firm conclusion on its nature.

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