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High-velocity Wind from IRS 1 in the NGC 2071IR

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Abstract. We present the results of 1.3 and 3.6 cm radio continuum emission toward the NGC 2071IR star-forming region, carried out with the VLA in its A configuration. We detect continuum emission toward the infrared sources IRS 1 and IRS 3 at both wavelengths. In particular, IRS 1 breaks up into three continuum peaks (IRS 1E, 1C, and 1W), aligned in the east-west direction, being IRS 1 the central source. The morphology of the condensation IRS 1W is very interesting, which has an elongated structure and shows a significant curvature towards the north. We suggest that this morphology could be explained as the impact of a high-velocity wind or jetlike outflow from IRS 1 on a close companion or other obstruction, which also explains the strong water maser emission observed toward IRS 1W.

Keywords. Stars: formation, ISM: jets and outflows,

1. Introduction

NGC2071, located at a distance of 390 pc, is a reflection nebula in the L1630 molecular cloud of Orion B (Anthony-Twarog 1982). Approximately 4′ north of NGC 2071 lies the infrared cluster NGC 2071IR (Persson *et al.* 1981), which has a total luminosity of 520 $L_\odot$ (Butner *et al.* 1990) and has been classified as an intermediate-mass star-forming region.

There is an energetic bipolar molecular outflow toward NGC2071 (Bally 1982). This powerful outflow, extending in the northeast-southwest direction and reaching $\sim 15'$ in length, is centered close to the infrared cluster NGC 2071IR and has been extensively studied in CO emission by several authors (e.g. Bally 1982, Chernin & Masson 1992). In addition, shock-excited molecular hydrogen emission has also been observed toward NGC2071IR, showing a spatial extent similar to the CO outflow and revealing several H_2 outflows in the field (Eisloffel 2000). In addition, many continuum sources at several wavelengths (centimeter, millimeter and infrared) have been detected toward NGC2071IR. In particular, three radio continuum sources are associated with infrared sources (Snell & Bally 1986), which are labeled as IRS 1, 2 and 3, where IRS 1 is the strongest one.

2. Observations

Interferometric observations were made with the VLA of the National Radio Astronomy Observatory (NRAO) in the A configuration during December 30, 2000. Continuum at 1.3 cm and H−2O maser emission were observed simultaneously. Two different bandwidths of 25 MHz (with seven channels) and 3.125 MHz (with 63 channels) were used for the continuum and line emission, respectively (see Trinidad *et al.* 2009 for details). In addition, observations of the continuum emission at 3.6 cm toward NGC 2071

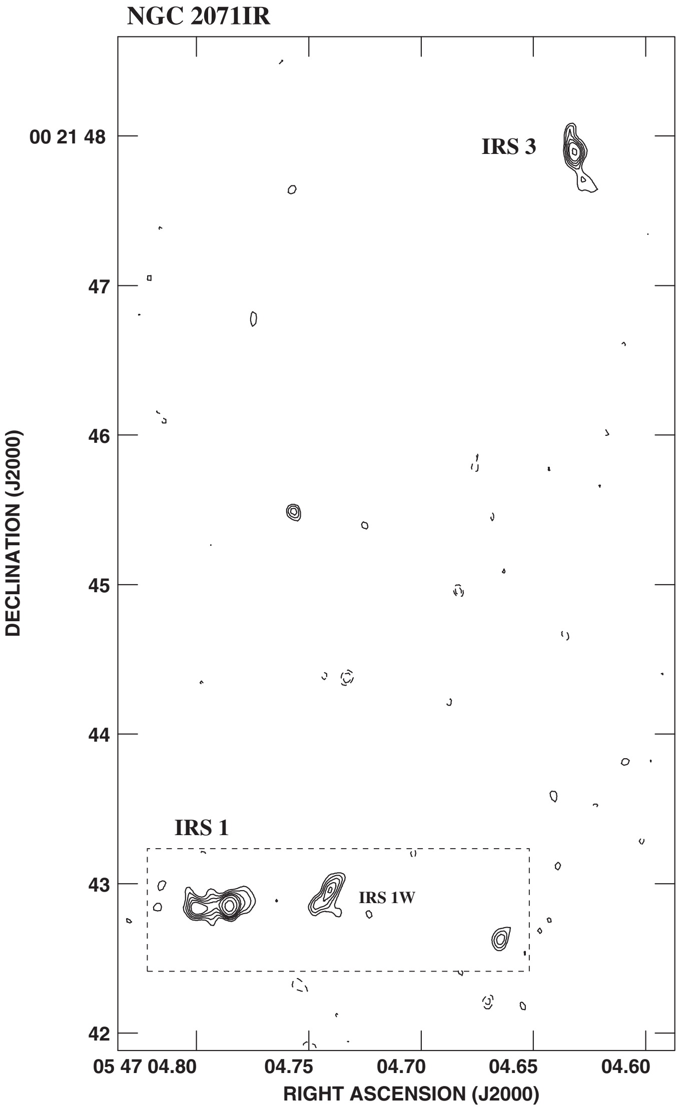

Figure 1. Three regions with radio continuum sources were detected in a field of $\sim 1600 \times 2300$ AU at 1.3 cm, which are spatially associated with the infrared sources IRS 1, IRS 3 and a new detection, VLA 1. Contours are -4, -3, 3, 4, 5, 6, 7, 9, and 12 times 160 μJy beam^{-1}, the rms noise of the map. The beam size is $0.12'' \times 0.09''$.

was also made with the VLA-A before the start of the 1.3 cm continuum and water maser observations, using an effective bandwidth of 100 MHz with two circular polarizations.

3. Results and Discussion

Figure 1 shows the radio continuum sources detected in the region, while Figure 2 shows the emission of the continuum source IRS 1 at 3.6 (gray scale) and 1.3 cm (contours).

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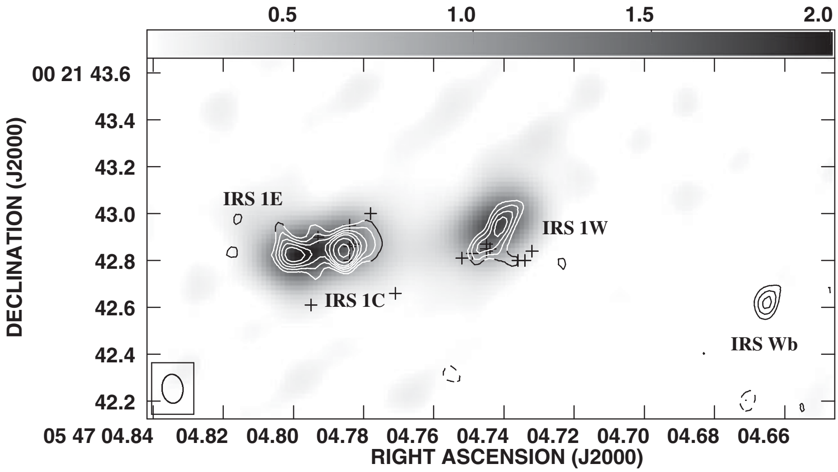

Figure 2. System IRS 1. Contours show 1.3 cm continuum emission, while gray scale shows the 3.6 cm continuum emission. IRS 1 is breaking up into three continuum peaks at 1.3 cm, which are aligned in the same direction as the two continuum peaks observed at 3.6 cm.

The observed morphology of the system IRS 1 at 1.3 cm is very similar to that of 3.6 cm, which is elongated in the east-west direction.

From Figures 2 and 3, we note that IRS 1 is breaking up into four continuum peaks aligned in the east-west direction (IRS 1E, 1C, 1W and 1Wb), being IRS 1 the main peak of the system. Based on the continuum flux densities at 1.3 and 3.6 cm, we found that IRS1C has an spectral index of 0.6, which could be consistent with IRS 1C being a thermal radio jet. In the same way, we found a similar spectral index for IRS 1W (0.5).

In particular, the morphology of the condensation IRS 1W is very interesting. Although this condensation seems to be ejected by IRS 1C along the western direction, its elongated structure shows a significant curvature towards the north. Moreover, the strongest water maser observed toward the NGC 2071IR is spatially associated with IRS 1W.

Models of water maser emission (e.g., Hollenbach 1997) suggest that the masers trace shocks produced by the interaction of the jet and the ambient material along the jet. In order to explain the curved morphology of IRS 1W, we suggest that this condensation is shocking a dense obstruction.

On the other hand, Skinner *et al.* (2007) found an unusual X-ray emission toward the young star IRS 1, which was explained by them as the impact of a high-velocity wind or jetlike outflow from IRS 1 on a close companion or other obstruction (only if IRS 1 is an embedded B-type star). Then, this collision could produce high-temperature X-ray plasma in a colliding-wind shock. In this case, the high-speed wind of the embedded star might actually be shocking on the dense surrounding material.

Interestingly, Seth *et al.* (2002) have suggested that the walls of the cavity surrounding IRS 1 might be the interface between outflowing and infalling material. These ideas could be consistent with our observational results, where IRS 1E and IRS 1W are condensations ejected by IRS 1C along its major axis and could explain the morphology of IRS 1W. Then, both the continuum and water maser emission support that IRS 1C is a radio jet, while IRS 1W and IRS 1E are condensations recently ejected by IRS 1C. However, new observations will be necessary to measure proper motions of the condensations.

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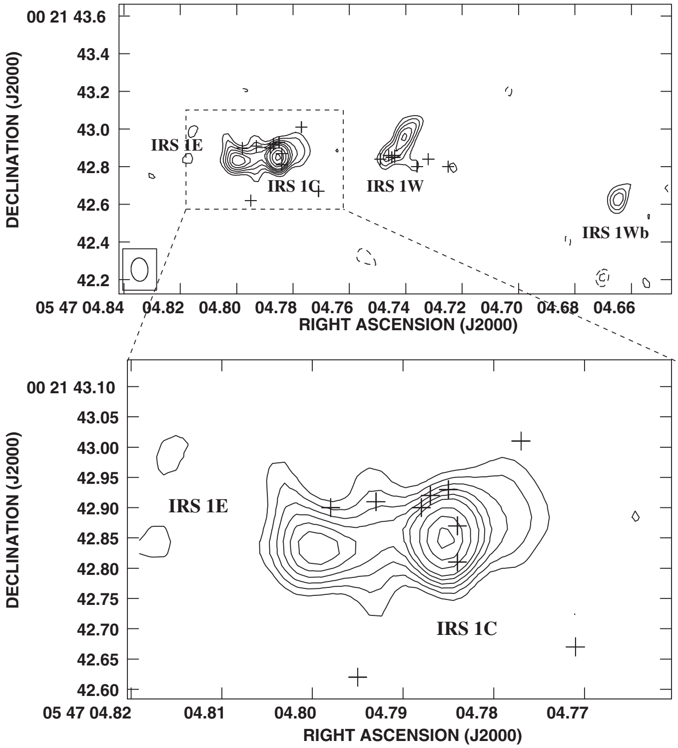

Figure 3. *Top panel:* 1.3 cm contour maps of the system IRS 1. *Bottom panel:* close-up of the central region of IRS 1. Contours are -4, -3, 3, 4, 5, 6, 7, 8, 10, 12, and 14 times 160 μJy beam^{-1}, the rms noise of the map. The beam size ($0.12'' \times 0.09''$). The crosses in the two panels show the position of the water masers observed toward IRS 1.

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