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RADIO OBSERVATIONS OF DISKS AND JETS IN YOUNG, CLOSE BINARY SYSTEMS

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RESUMEN

Presentamos los resultados obtenidos mediante observaciones de alta sensibilidad, llevadas a cabo con el VLA, las cuales revelan las características de la región cercana al origen de los flujos en SVS 13, NGC 1333 VLA 2 y L 723 con una resolución angular por debajo del segundo de arco. Estas observaciones sugieren que estas fuentes constituyen sistemas binarios compactos muy jóvenes. Discutimos la incidencia de discos y jets en el proceso de formación de dichos sistemas.

ABSTRACT

We present results from sensitive Very Large Array (VLA) observations revealing the characteristics of the region near the origin of the SVS 13, NGC 1333 VLA 2, and L 723 outflows with subarcsecond angular resolution. These observations suggest that these sources are young, close binary systems. We discuss the incidence of disks and jets in the formation of such systems.

Key Words: **BINARIES: CLOSE — ISM: JETS AND OUTFLOWS — RADIO CONTINUUM: ISM — STARS: FORMATION**

1. INTRODUCTION

It is now well established that disks and jets are intimately related, and that both phenomena are a natural consequence of the star-formation process (see e.g., Rodríguez 1994, 2002). However, despite the fact that most of the stars belong to binary systems, the binary star-formation process and, in particular, the development of disks and jets in such systems is still poorly known. Especially relevant is the study of the formation of close (< 100 AU separation) binary systems because they are the most frequent (e.g., Mathieu 1994) and also because it is in this kind of binaries where a significant interaction between the components of the system is expected, resulting in a larger difference with respect to the case of the formation of single stars. Detailed observational studies of disks and jets in such systems are difficult to carry out because they require very high angular resolution observations in order to be able to separate the emission of each component. As a result, at present the number of such systems with a good observational coverage is still scarce.

L 1551 IRS5, one of the best studied sources (see e.g., Osorio et al. 2003 and references therein), is considered a prototypical Class I object, driving a well defined bipolar outflow. However, this source is in fact a binary, with the two components of the system separated by 45 AU. As revealed by the 7 mm VLA observations of Rodríguez et al. (1998), each of the components of the L 1551 IRS5 binary system is associated with a disk of dust. Both components appear to be also associated with jets, as revealed by the two radio jets observed with the VLA by Rodríguez et al. (1998), and the two near-IR [Fe II] jets observed with the Subaru telescope by Itoh et al. (2000).

In this paper we present radio observations of other sources, showing that the two components of a binary system can present different properties regarding their association with disks and jets.

2. SVS 13

SVS 13, in the NGC 1331 region, was discovered as a 2.2 μm source by Strom, Vrba, & Strom (1976). Since the source is roughly aligned with the chain of Herbig-Haro objects 7–11, it was assumed to be the exciting source of this classical HH system. Later, Goodrich (1986) detected a faint visible counterpart of SVS 13. However, the star SVS 13 presents a number of peculiar properties. The source exhibited a large increase in its brightness in the optical and near-IR in 1988–1990 (e.g., Eislöffel et al. 1991), and since then the flux has remained almost steady. In addition, despite being optically visible, suggesting that it is a relatively evolved young object, SVS 13 is a strong millimetric source (e.g., Looney, Mundy, & Welch 2000), and presents other characteristics, such as an extremely high velocity CO outflow, that suggest it is in a much earlier evolutionary stage (a Class 0/I object; Bachiller et al. 2000).

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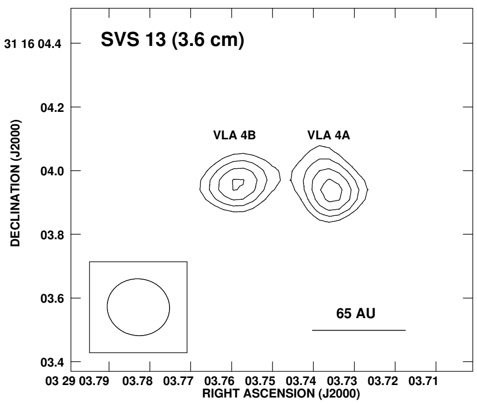

Fig. 1. VLA map at 3.6 cm of SVS 13, revealing that it is a binary radio source. Contour levels are −3, 3, 4, 5, and 6 times 14 μJy beam^{-1}. The half power contour of the synthesized beam is shown in the lower left corner. Adapted from Anglada et al. (2000).

Anglada, Rodríguez, & Torrelles (2000), through very sensitive VLA[7] observations, discovered that SVS 13 is, in fact, a close binary system, with the two components (VLA 4A and VLA 4B) separated by 0.″3 (65 AU at 220 pc), and with similar flux densities (see Figure 1). Since the optical position for SVS 13 was closer to VLA 4A, while the millimetric position appeared closer to VLA 4B, this result led Anglada et al. (2000) to suggest that the strong millimetric emission reported for SVS 13 could arise from only one of the components of the binary (VLA 4B), while the optical emission was coming from the other component (VLA 4A). Under this interpretation, one of the stars (VLA 4B) is surrounded by a dusty envelope or disk, while the other (VLA 4A, the visible star) is not. This scenario has been confirmed by our recent VLA observations at 7 mm (Anglada et al. 2003a), which reveal that VLA 4B presents strong 7 mm emission that can only be accounted for as due to dust, while VLA 4A has only marginally detectable 7 mm emission, which is most probably due to residual free-free emission, as revealed by the spectrum shown in Figure 2.

This result obtained for SVS 13 implies that the development of a protoplanetary disk may occur in only one of the components of a young binary system. In this respect, the case of the SVS 13 binary system appears to be opposite to the L 1551-IRS 5 case, where both components of the binary system are associated with disks (see Figure 3). These results are in agreement with theoretical simulations (e.g., Bate & Bonnell 1997), which show that, depending on the specific angular momentum of the system, the development of circumstellar disks can occur around one or both components of the binary.

[7]The VLA of the National Radio Astronomy Observatory is operated by Associated Universities, Inc., under cooperative agreement with the National Science Foundation.

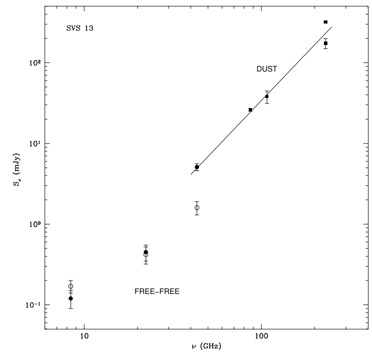

Fig. 2. Spectrum of SVS 13 from 3.6 cm to 1.3 mm. Open circles correspond to the emission of VLA 4A, while filled circles correspond to the emission of VLA 4B. The solid line is the best linear fit to the overall dust emission from 3.4 to 1.3 mm (filled squares). Note that the measured flux density of VLA 4B at 7 mm fits very well on the extrapolation of the millimeter dust emission, while the 7 mm flux density of VLA 4A appears to correspond to free-free emission, which dominates in the centimeter range. Adapted from Anglada et al. (2003a).

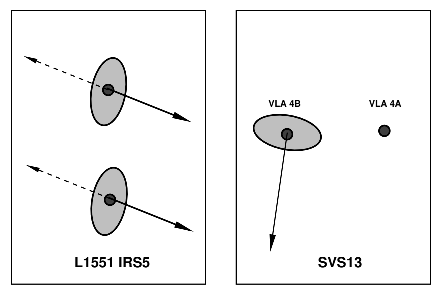

Fig. 3. Cartoon illustrating two possible scenarios in the formation of a binary system. In the L 1551-IRS 5 scenario (left) both protostars develop a disk-jet system, while in the SVS 13 scenario (right) only one protostar develops a disk-jet system.

3. NGC 1333 VLA 2

This centimeter radio continuum source (Rodríguez, Anglada, & Curiel 1997; Reipurth et al. 2002) is associated with the millimeter source MMS 3 in the NGC 1333 region (Chini et al. 1997). The VLA image obtained by Reipurth et al. (2002) at 3.6 cm, with an angular resolution of $\sim$ 0.″3 (see their Figure 5) shows that the source has a faint jet extended in the North-South direction. The bipolar thermal radio jet has an angular extent of about 1000 AU and shows evidence for a clear wiggling.

Simultaneous observations of the 1.3 cm continuum and water maser emission carried out with the VLA with an angular resolution of 0.″08 (Anglada et al. 2003b) reveal two groups of water masers separated by $\sim 0\rlap{.}''1$ (~ 25 AU) towards the core of the 3.6 cm source. The positions of the 1.3 cm and the 7 mm (Anglada et al. 2003b) continuum emission peaks coincide very well, but both are offset from the position of the 3.6 cm emission peak. Interestingly, one of the water maser groups is associated with the 1.3 cm and 7 mm peaks, while the other maser group is associated with the 3.6 cm peak. The case of NGC 1333 VLA 2 could be another example of a young, close binary system whose components exhibit different properties.

4. L 723

The outflow in L 723 is a prototypical example of a quadrupolar outflow, as can be seen in the CO map of Avery, Hayashi, & White (1990). The outflow presents two pairs of CO lobes: a larger pair aligned roughly in the NW-SE direction, and a smaller one, aligned roughtly in the NE-SW direction. VLA observations by Anglada et al. (1996) revealed that the source VLA 2 was elongated along the NW-SE direction, suggesting that it is a thermal radio jet responsible for the excitation of only the NW-SE pair of CO lobes. Additional VLA observations with higher angular resolution and sensitivity suggest that the core of the VLA 2 source splits into two sources separated by ~ 75 AU (Anglada et al. 2003c). One of the sources appears to be responsible for the excitation of the larger pair of CO lobes, while the second source appears to be responsible for the excitation of the smaller one.

5. CONCLUSION

Radio observations with an angular resolution high enough to separate the components of young, close binary systems reveal that the development and properties of disks and jets can be quite different for each component of the system. This is in agreement with the results obtained from theoretical simulations, which indicate that the accumulation of circumstellar material can proceed in a different way, depending on the relative masses of the components and the specific angular momentum of the system. These results suggest that the process of binary formation can be significantly more complex than that originating a single star.

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