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NEW RESULTS ON THE HH 80-81 JET

C. Carrasco-González,[1,2] L. F. Rodríguez,[3] M. Osorio,[2] G. Anglada,[2] J. Martí,[4] J. M. Torrelles,[5]
R. Galván-Madrid,[3,6,7] and P. D'Alessio[3]

RESUMEN

Presentamos nuevas resultados en el chorro HH 80-81 obtenidos por medio de observaciones con el SMA y el VLA. Estas observaciones nos han permitido resolver un disco circunestelar compacto alrededor de la protoestrella masiva, y descubrir emisión sincrotrón linealmente polarizada en el chorro.

ABSTRACT

We present new results on the HH 80-81 jet obtained from SMA and VLA observations. These observations allowed us to resolve a compact circumstellar disk around the massive protostar, and to discover linearly polarized synchrotron emission from the jet.

Key Words: ISM: jets and outflows

1. RESOLVING A CIRCUMSTELLAR DISK AROUND A MASSIVE PROTOSTAR

It is well known that the formation of low-mass stars takes place with the assistance of an accretion disk that transports gas and dust from the envelope of the system to the protostar, and a jet that removes angular momentum from the system, allowing the accretion to proceed. However, in high-mass stars it has been difficult to establish the presence of accretion disks. Only a few accretion disks around B-type protostars have been tentatively reported (e.g., Cepheus A HW2; Patel et al. 2005). However, most of these candidates are still controversial, and even, it has been proposed that high-mass protostars could not be associated with circumstellar disks.

The HH 80-81 system consists of a highly collimated radio jet with a total projected extent of 5.3 pc at an adopted distance of 1.7 kpc (Martí et al. 1993). The jet is driven by the IRAS 18162−2048 protostar, whose luminosity ($\sim 2\times10^4$ $L_\odot$) is equivalent to that of a B0 zero-age main sequence (ZAMS) star. Since HH 80-81 possesses an extraordinarily well-collimated jet, it seems reasonable to propose that it should be originating from an accretion disk. Some studies have reported the presence of large structures of dense molecular gas with elongated morphologies perpendicular to the axis of the outflow (e.g. Torrelles et al. 1986; Yamashita et al. 1989). Thermal dust continuum emission at mm and sub-mm wavelenghts has also been detected towards the protostar (Gómez et al. 2003; Fernández-López et al. 2011; Qiu & Zhang 2008). However, all those observations lack angular resolution to resolve the structure of a compact disk, and the existence of such a disk is still unclear.

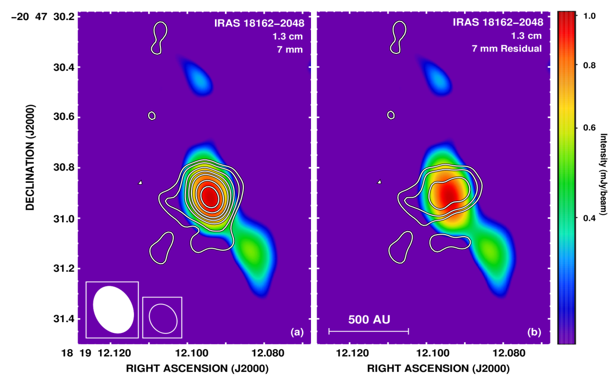

Fig. 1. (a) Superposition of the 7 mm VLA contour map over the 1.3 cm VLA map (colors). Contours are 3, 4, 6, 8, 10, 14 and 18 times the rms of the map, 120 μJy beam^{-1}. (b) Same as (a), but after substraction of the free-free contribution at 7 mm.

Through Submillimeter Array (SMA) observations at 860 μm, we detected emission from the SO molecular line associated with the protostar. This emission shows a velocity gradient ($\sim$3 km s^{-1} over $\sim$1700 AU), roughly perpendicular to the radio jet, with the protostar located at its center. We interpret this gradient as due to rotational motions gravitationally bounded by the central protostar, and we estimated a central mass of $\sim$17 $M_\odot$.

[1]Max-Planck Institute für Radioastronomie, Germany.
[2]Instituto de Astrofísica de Andalucía, CSIC, Spain.
[3]Centro de Radioastronomía y Astrofísica, Universidad Nacional Autónoma de México, Mexico.
[4]Departamento de Física, EPSJ, Universidad de Jaén, Spain.
[5]Instituto de Ciencias del Espacio (CSIC/IEEC), Spain.
[6]Harvard-Smithsonian Center for Astrophysics, USA.
[7]Academia Sinica, Inst. Astron. and Astrophys., Taiwan.

We also performed high-angular resolution ($\simeq 0.1''$) observations at 1.3 cm and 7 m with the Very Large Array (VLA). At 1.3 cm, the emission seems to be tracing the innermost part of the large scale radio jet, while at 7 mm, the emission shows a quadrupolar morphology (see Figure 1). A similar morphology has been observed in other radio jets of low-mass stars at wavelengths where comparable contributions of free-free emission from the radio jet and thermal dust emission from a perpendicular disk are present (e.g., HL Tau: Carrasco-González et al. 2009). Therefore, we interpret the morphology of the 7 mm emission as the result of a combination of free-free emission from an ionized jet (in the N-S direction) and thermal dust emission from a perpendicular circumstellar disk (in the E-W direction).

We modeled the 7 mm emission, using physically self-consistent α-disk models (D'Alessio et al. 2006). We found that, in order to simultaneously reproduce the size and flux density of the 7 mm emission, a central protostar with a minimum mass of 10 $M_{\odot}$ is required. From the modeling, we also estimated an accretion rate of 5–10$\times 10^{-5}$ $M_{\odot}$ yr^{-1}.

2. DISCOVERY OF SYNCHROTRON EMISSION FROM THE PROTOSTELLAR JET

Supersonic jets are observed to emerge from a wide variety of astrophysical systems, from young stellar objects to active galactic nuclei (AGNs). Observation of linearly polarized synchrotron emission from relativistic electrons of AGN jets reveal the properties of the magnetic field in these jets, showing that it plays an important role in their origin, collimation, and propagation at large distances (e.g., Lyutikov et al. 2005). Theoretical models of jets from YSOs also require a magnetic field as a key ingredient in the jet formation (e.g., Shu et al. 1994). However, YSO jets are dominated by emission from thermal electrons (e.g, Anglada 1996), which is not sensitive to the magnetic field. Interestingly, negative spectral indices have been reported in a few jets from YSOs, suggesting that a non-thermal synchrotron emission component from relativistic electrons could be present. In this case, the acceleration of particles would be most likely produced where the fast thermal jet impacts on the surrounding medium and a strong shock wave is formed by a Fermi mechanism.

We performed high-sensitive VLA observations at 6 cm of the HH 80-81 jet where negative spectral indices in some of the knots of the radio jet have been previously reported (Martí et al. 1993). We found that the emission of the knots located

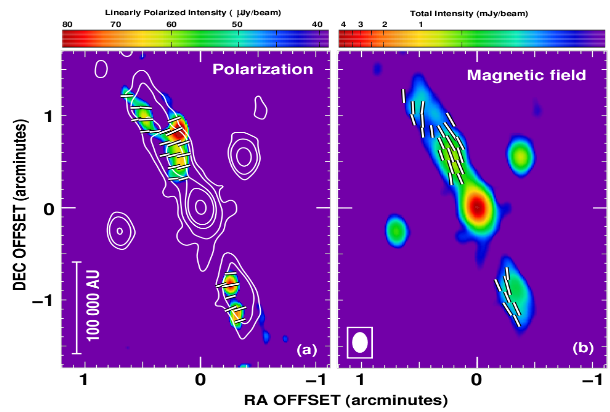

Fig. 2. (a) Superposition of the 6 cm VLA contour map over the linearly polarized continuum intensity image. Polarization direction is shown as white bars. Contour levels are 40, 100, 400, 850, and 3300 μJy beam^{-1}. (b) The apparent magnetic field direction (white bars) is superposed with the total continuum intensity image (color scale). Adapted from Carrasco-González et al. (2010).

$\sim$0.5 pc from the driving source is linearly polarized (see Figure 2a), clearly indicating the presence of non-thermal synchrotron emission in this jet, and implying the presence of relativistic electrons and a magnetic field.

The direction of the apparent magnetic field (perpendicular to the polarization vectors) is very well aligned with the direction of the HH 80-81 radio jet (see Figure 2b). The degree of linear polarization increases as a function of the distance from the jet axis. These characteristics of the synchrotron emission are very similar to those observed in AGN jets, and are indicative of a large-scale helical magnetic field.

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