Highlights of Astronomy, Volume 15
XXVIIth IAU General Assembly, August 2009
Ian F. Corbett, ed.

doi:10.1017/S1743921310009117

Radio and Millimeter Observations of YSOs

Luis F. Rodríguez

Centro de Radioastronomía y Astrofísica, UNAM, Apartado Postal 3-72 (Xangari), 58089 Morelia, Michoacán, México
email: l.rodriguez@crya.unam.mx

Abstract. The growth of a forming star takes place by accretion from the surrounding dense medium, facilitated by a circumstellar disk. But at the same time the forming system produces collimated outflows of gas that remove excess angular momentum and magnetic flux. A key question in the field is whether we can extend the disk/jet model to stars of the largest masses or if other ingredients are present. In this note, I review recent observations from the Very Large Array and the Submillimeter Array, of IRAS 16547-4247, a massive young stellar object that exhibits evidence for both a disk and an outflow.

Keywords. stars: formation, ISM: individual (IRAS 16547-4247)

1. Introduction

Our present understanding of star formation is primarily based on observations of the relatively abundant low-mass stars. The theoretical framework for star formation (Shu *et al.* 1987, see also McKee & Ostriker 2007) has been successful in explaining the processes that occur in the formation of these low mass stars, processes that are inferred from multiwavelength observations (e.g., Lada 1991, Evans 1999). Key ingredients in this scenario are the presence of a central protostar accreting from a circumstellar disk that is surrounded by an infalling envelope of dust and gas, as well as the presence of ionized jets and molecular outflows that carry out angular momentum and mechanical energy from the accretion disk into its surroundings.

The applicability of this paradigm to the formation of massive stars remains unproven. It is possible that massive stars are formed by processes that are radically different from those that produce low-mass stars, such as by the merging of lower mass protostars (Bonnell, Bate, & Zinnecker 1998). The role of the coalescence and accretion processes in the assembling of a massive star is still under debate. If massive O stars are formed by accretion we expect that disks and jets will be present in their earliest stages of evolution. On the other hand, if they are formed through coalescence of lower-mass stars then neither disks nor jets are expected since they would be disrupted during the merging process. For a recent review on the competing ideas to explain massive star formation see Zinnecker & Yorke (2007).

2. The case of IRAS 16547-4247

2.1. *SMA Observations*

The main result of these observations, described in detail in Franco-Hernández *et al.* (2009) is the detection of strong SO_2 emission that arises only from the brightest 1.3 mm dust continuum component. The line emission shows a velocity gradient (see Fig. 1) that, if modeled as a Keplerian ring, give a mass of $\sim$20 $M_\odot$, consistent with the mass derived from the VLA observations of H_2O maser. However, the data can also be fitted with a two-component model that gives a much smaller Keplerian mass.

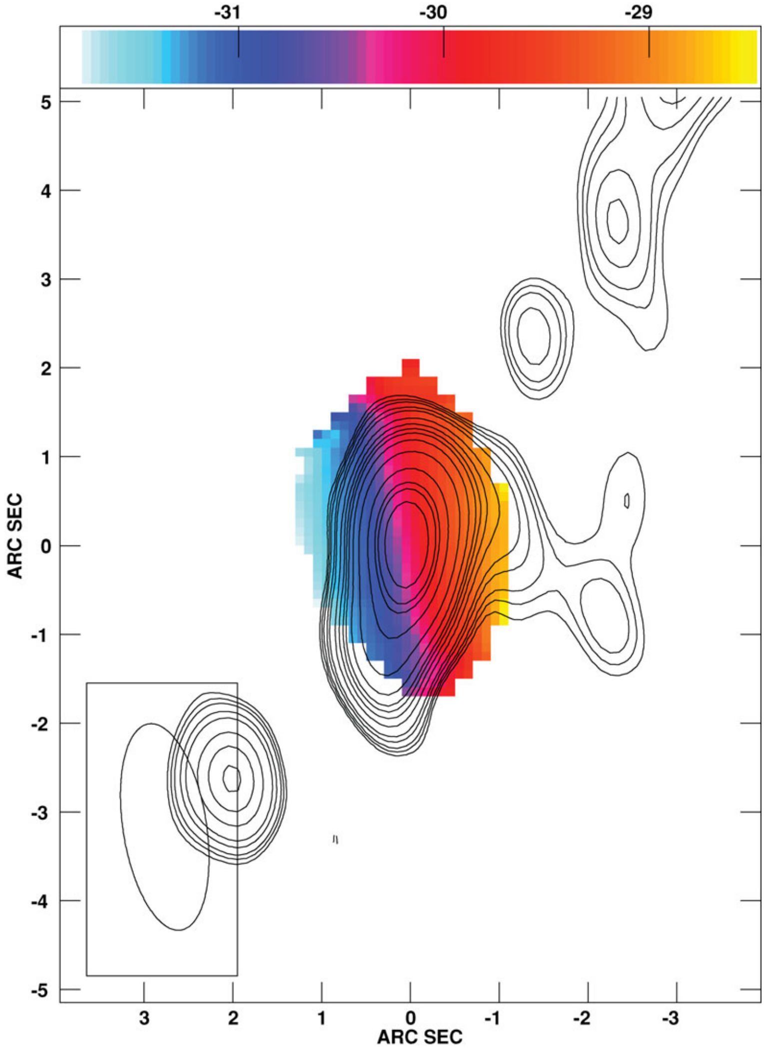

Figure 1. This image shows the first moment map of the 226.300 GHz SO_2 transition in color and the radio continuum emission at 3.6 cm with contours (Rodríguez *et al.* 2005). The color bar at the top shows the color coding for the LSR velocity of the gas in km s^{-1}. The synthesized beam for the 3.6 cm is shown in the bottom left corner of the panel. Contour levels for the 3.6 cm emission are -5, 5, 8, 10, 15, 20, 40, 60, 80, 100, 140, 180 times the rms noise level of 30 μJy beam^{-1}. The 3.6 cm source at the lower left corner of the image most probably traces an independent star and is not associated with the jet (Rodríguez *et al.* 2005). The synthesized beam for the 226.3 GHz data is $2\rlap{.}''3 \times 0\rlap{.}''8$; PA = 11°.

2.2. *VLA Observations*

In this case, the main results have been two. This first is the detailed imaging of the 3.6 cm emission from the associated thermal jet (Rodríguez *et al.* 2008), that indicate that the brightest components of the lobes show evidence of precession, at a rate of $0\rlap{.}^\circ 08$ yr^{-1} clockwise in the plane of the sky. The second result is the detection of a group of water masers that show a velocity gradient that, if interpreted as arising in a Keplerian ring, implies a mass of $\sim$30 $M_\odot$ for the central star(s) (Franco-Hernández *et al.* 2009). This mass is consistent with that determined at larger scales with the SO_2 emission.

https://doi.org/10.1017/S1743921310009117 Published online by Cambridge University Press

References

Bonnell, I. A., Bate, M. R., & Zinnecker, H. 1998, MNRAS, 298, 93
Evans, N. J., II 1999, ARA&A, 37, 311
Franco-Hernández, R., Moran, J. M., Rodríguez, L. F., & Garay, G. 2009, ApJ, 701, 974
Lada, C. J. 1991, NATO ASIC Proc. 342: The Physics of Star Formation and Early Stellar Evolution, 329
McKee, C. F. & Ostriker, E. C. 2007, ARA&A, 45, 565
Rodríguez, L. F., Garay, G., Brooks, K. J., & Mardones, D. 2005, ApJ, 626, 953
Rodríguez, L. F., *et al.* 2008, AJ, 135, 2370
Shu, F. H., Adams, F. C., & Lizano, S. 1987, ARA&A, 25, 23
Zinnecker, H. & Yorke, H. W. 2007, ARA&A, 45, 481